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EXPERIMENTAL INVESTIGATIONS

BY THE

STATE BOARD OF HEALTH

OF MASSACHUSETTS,

UPON THE

PURIFICATION OF SEWAGE

BY FILTRATION AND BY CHEMICAL PRECIPITATION,
AND UPON THE

INTERMITTENT FILTRATION OF WATER.

MADE AT LAWRENCE, MASS.,

1888–1890.

Part II.

OF

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FILTRATION OF SEWAGE AND OF WATER,

AND

CHEMICAL PRECIPITATION OF SEWAGE

At the Experiment Station of the State Board of Health of Massachusetts in 1888 and 1889.

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The results of preliminary experiments upon the filtration of water and a general description of the Experiment Station at Lawrence, together with a summary of results previously obtained in Europe upon filtration of sewage, are given in the nineteenth annual report of the Board. To render intelligible the operations at the Experiment Station during the past two years, the description of the Station and of materials used for filtering are again given, with a plan and sections of the premises.

The filtering grounds are situated in the easterly part of the city of Lawrence, on the north bank of the Merrimack River, and comprise about two-thirds of an acre, with their surface from fifteen to twenty feet above the river in summer. This surface is in extreme freshets entirely submerged, and has, in the past forty years, been built up about eight feet by the deposition, when overflowed, of very fine river silt.

On the northerly side of the grounds is a building (shown in plan and sections A A), three hundred feet long and about ten feet wide and ten feet high. It is nearly all below the surface of the ground, with which it slopes about one foot in one hundred feet. It is lighted by windows in the roof. Running lengthwise through this building is a drain (*d d*), and above this was an open wooden conduit (*b b*), about two feet wide and one foot high, resting on piles and sloping with the building. This conduit is now divided at each twenty-five feet of its length by a tight partition. Each section thus formed is used as a measuring basin, — being twenty-five feet long, about two feet wide and one foot high, and holding between two and three hundred gallons, — and has an outlet by which its contents may be turned into the drain beneath.

Outside of the building, in the field, where the surface of the ground is seven and one-half feet above the top of the measuring basins, are ten large wooden tanks, sunk their full depth into the ground, one opposite each of the measuring basins.

These tanks, numbered 1 to 10 in the drawings, were made of cypress, circular in plan, sixteen feet eight inches in diameter inside, at the bottom, seventeen feet four inches at the top, and six feet deep inside. They were set with the bottom sloping four inches towards the building, and the tops of the staves were cut level with the low side. They rest upon mudsills and a bed of puddle; and, before the sides were puddled in, the tanks were proved to be completely water-tight.

In each tank an underdrain fifteen feet in length, of horse-shoe section of about two square inches in area, is set with open part downwards and half an inch above the bottom, resting on blocks six inches apart, and the floor is covered with one layer of coarse gravel stones about one inch by two inches, this by another layer of smaller size, upon which follow layer after layer of gravel, decreasing in size to one-eighth of an inch in diameter, and making a thickness of three and a half inches. This fine gravel is covered with very coarse mortar sand, with top surface level, three and one-half inches deep in the middle of the tank. Above this substratum, which is the same in all of the tanks, the several tanks are filled as follows: —

Tank No. 1. — Filled five feet in depth with very coarse, clean, mortar sand.

Tank No. 2. — Filled five feet in depth with very fine, nearly white sand.

Tank No. 3. — Filled with peat from a cultivated field, four feet in depth, with the previously undisturbed lower layers, and covered one foot in depth with the original top layer.

Tank No. 4. — Filled five feet in depth with river silt, being mostly a very fine sand from the excavation made in setting Tank No. 5.

Tank No. 5. — Filled five feet in depth with a good quality of brown soil, taken in the fall from a garden which had been manured and cultivated that season.

TANK No. 6. — Filled three feet and eight inches in depth with coarse and fine sand and fine gravel.

TANK No. 7. — Filled three feet and eight inches in depth with the same as No. 6; above which are ten inches of yellow, sandy loam, and six inches of brown soil.

TANK No. 8. — Filled three feet and eight inches with the same as No. 6; above which is a depth of eight inches of yellow, sandy loam like that in No. 7; and this is covered with eight inches of sand and gravel, like that beneath the loam.

TANK No. 9. — Filled four feet three inches in depth with a very compact, sandy hard pan of clay, sand and gravel, covered with nine inches of brown soil.

In each case the filtering material was thrown from the shovel, scattering into water which partly filled the tank. After filling each tank to the height given, which was generally three inches below the top of the tank, a little sloping bank one foot wide was filled around the inside of each tank, of the same material as the upper layer of the filter, to prevent the liquid applied reaching the side of the tank too freely. The area of the surface to which sewage is applied and the effective area of the filtering material is regarded as being one two-hundredth of an acre.

TANK No. 10 has been used for the measurement of the rain-fall and the evaporation.

From the end of the underdrain at the lowest point in the bottom of each tank, extends through the bottom a short brass pipe two inches in diameter, to which, by a quarter-turn, is connected a two-inch iron pipe, which, passing through the ground and into the building, conveys drainage from within the tank to its measuring basin, where the quantity is read from a scale indicating gallons.

During November and December, 1887, water from the city mains was applied to the several tanks, with results given in the report for that year.

Sewage has been brought to the building in a two and a half inch pipe of galvanized iron, from a point in the main sewer of the city about one thousand feet above its outlet, and above the entrance of streams from the manufacturing establishments. This sewage from stores and from the dwellings of perhaps ten thousand people may reasonably be regarded as ordinary city sewage, similar during very dry weather to sewage separate from storm water, but during wet weather very much diluted by surface drainage.

The iron pipe follows the sewer to its outlet, and then rests upon the bed of the river for three thousand feet, then extends three hundred feet within the filtering grounds, entering the building and running along by the side of the drain. The sewage is raised by two pumps (*p. p.*) into two measuring basins (*m. b.*), (*m. b.*), within the building at a higher level than the top of the filtering tanks, where the quantity to be put upon any tank is noted by a scale of heights indicating gallons, and is distributed, by movable hose, to either of five tanks from one measuring basin, and to the other five tanks from the other measuring basin.

Besides these large filtering tanks, there have been placed within the building ten galvanized iron tanks having about the same depth, but a diameter of only twenty inches, giving an area of surface one-hundredth of that of the large tanks, or one twenty-thousandth of an acre. These tanks are numbered from eleven to twenty. Each has a sloping bottom and a faucet placed low enough to completely drain the bottom. On the bottom of each is placed coarse gravel, covered with finer gravel and coarse sand to a depth of five inches, as in the larger tanks.

Upon these layers, common to all, there was put into No. 11 three feet and eight inches of material like that in No. 6. Tanks numbered 12, 13, 14 and 20 were filled to a depth of five feet with coarse sand like that of No. 1; and tanks numbered 15, 16, 17 and 18 were filled with sand and peat, taken from the Saugus Marshes.

In the field beyond the filter tanks the area of about one-third of an acre is sloped in the direction from the line of tanks about one foot in ten feet, and in the direction parallel with them about one foot in one hundred feet. This area is laid out in shallow drains to receive sewage for filtration, underdrains being placed sixty feet apart, to catch samples of the effluent.

These underdrains are put at the depth of four feet, and slope like the surface,—one foot in ten feet,—being about fifty feet in length, opposite tanks Nos. 3 and 8, and opposite the space between Nos. 5 and 6.

Trenches were cut two feet wide and the bottom coated with two inches of puddling clay, plastered on, a little lower in the middle, where the two-inch drain tile was laid with open joints, and surrounded with six inches in depth of gravel.

The surface drains are in the material of the field, which for several feet in depth is a fine river silt, which freezes about as readily and compactly as clay. To guard against the interference of this hard freezing, shallow trenches, which follow the surface of the field in slopes, one foot in thirty feet, one foot in fifty feet, and one foot in one hundred feet, were dug out one foot wide, with the bottom level of the same width, and of the following depths: No. 1, six inches deep; No. 2, one foot deep; No. 5, three feet deep; No. 6, two and one-half feet deep; and filled in to these depths with coarse mortar sand similar to Tank No. 1.

Trench No. 7 was dug out one and one-half feet wide and two feet deep; and Trench No. 8, two feet wide and one and one-half feet deep, and filled with the same sand. These trenches are filled with coarse sand of the different depths and widths, to determine how much of such material is necessary to prevent trenches in river silt from freezing and preventing filtration in the coldest weather. These trenches have the surface of the sand about four inches below the level of the ground adjacent, except near their lower end, where in fifty feet it increases to ten inches below.

They are about five feet apart, and in length as follows: No. 1, 113 feet; No. 2, 152 feet; No. 3, 195 feet; No. 4, 221 feet; No. 5, 176 feet; No. 6, 218 feet; No. 7, 203 feet; No. 8, 177 feet.

As no water appeared at the outlets of the underdrains for several months, wells were bored, as shown upon the plan, between two of these outlets and the river, to a depth of eight feet below the drains, before reaching water, which stood nearly at the level of water in the river at the time.

All of the large tanks and the trenches were exposed to snow and rain through the first winter and summer, and until Nov. 20, 1888, when tanks numbered 1, 2, 4, 5, 6 and 7 were covered with canvas, and trenches numbered 5, 6, 7 and 8 were covered with boards, to keep out the snow. The canvas coverings were removed March 13, 1889.

Object of the Work.

The conditions and results at each tank will soon be given in detail; but first let the object of the work be clearly presented. The object is to learn how to purify sewage. Sewage varies much in the amount of impurity it carries, depending upon the amount of water used. It is much more dilute in American than in European cities. Here a sewage stronger than ordinary would contain, say, 998 parts of pure water, one part of mineral matter and one part of animal and vegetable matter. The animal and vegetable matter are, for convenience, classed together and called organic matter.

Sewage would become entirely purified if we should take out the two parts of mineral and organic matter and leave the 998 parts of pure water; but, as the mineral matter is not generally objectionable, we are satisfied to call it purified if we succeed in taking out the one part of organic matter.

Of the two parts of mineral and organic matter in one thousand parts of sewage, about one-half is in suspension, and can be strained out by the finest strainer that water will pass through; the other half is dissolved in the water, and cannot be thus strained out.

If a way can be devised by which the impurity of sewage can be completely oxidized or burned, so that inorganic or mineral matter only remains in the otherwise pure water, the result will evidently be satisfactory. To learn how to do this is the main object of our work.

The experience of others as well as our own has proved — what common sense would suggest — that, if as much sewage as will flow through a body of sand be continually applied to it, some of the impurity of the sewage will be retained in the sand, and will, for a time, be removed from the outflowing water; but the sand will grow to be more and more filthy, until finally the effluent will become as impure as the sewage that is applied. Under these conditions, no process of burning can go on within the sand, because no air is present to support combustion.

If, however, we change the conditions, and apply, to-day, to the surface of a body of open sand, an inch in depth of sewage, and to-morrow apply another inch in depth, and on following days a like quantity, and after a time watch what is taking place, we shall find that the sewage which covered the whole surface an inch deep yesterday shortly settled below the surface, the bottom particles going down about nine inches and the top particles remaining just below the surface. In this nine inches about two-thirds of the space is occupied by sand, one-ninth of the space is water, and about one-quarter is air. The sewage is suspended here in extremely thin layers, covering the particles of sand and stretching between some of the nearest particles, and intimately mingled with more than twice its volume of air.

Upon covering the surface with sewage to-day, the sewage of yesterday and most of the air which is associated with it are pushed down, with more or less mixture, by the incoming sewage, to the nine inches next below; the same quantity of water is pushed down through each of the lower layers of the sand, and the same amount goes out at the bottom. Fresh air is brought into the upper nine inches with the incoming sewage; and, if this open sand be five feet in depth to underdrains, the sewage applied on any day will, in very thin laminæ, be slowly moving for a week over particles of sand intermingled with twice its volume of air.

These conditions are found to be favorable for processes to go on within the sand, which have an effect similar to that of burning up the organic matter and leaving only a mineral residue in the otherwise nearly pure water.

This method of filtration is known as "intermittent filtration," in distinction from the first-described "continuous filtration."

The process of purification in intermittent filtration has been called an oxidizing process, or, more familiarly, a burning; but the chemical products of burning, or rapid dry oxidation by means of heat, are not the same as the products of wet oxidation occurring in the thin laminæ of the liquid, covering the particles of sand, in contact with air within the filter. Here nitrification occurs, that is, nitric acid is formed from the nitrogen of the organic matter and the oxygen of the air; and this strong acid immediately combines with the potash or soda or lime or other base in the sewage, forming nitrate of potash or of soda or other salt; but when the same liquid is evaporated, and the organic residue is burned by the application of heat, no nitric acid is formed, and no nitrification results.

When these investigations were commenced, it was known that nitrification sometimes took place in a liquid when acted upon by a current of electricity; beyond this, the experiments of Schlœsing and Muntz in France and of Warington in England tended to prove that nitrification in a liquid never takes place but with the aid of organisms introducing into the process the conditions of organic life. As nitrification takes the leading place in the process of purification of sewage, we must then regard as essential to the process the conditions most favorable to the action of the organisms which produce nitrification. Among these conditions experiments had already shown that the presence of oxygen was essential; so was the presence of organic matter, of moisture, and of some alkali; and the temperature should be nearly that which is favorable for plant life. Such organisms had been known to exist either in sewage or in the material of which some filters were composed, and, when existing with the other conditions favorable for producing nitrification, large quantities of organic matter could be converted into inorganic and mineral matter.

The relations of space occupied by sand, liquid and air, in the example just given of intermittent filtration, obtain only in a coarse sand of quite even grain. In such a sand air may be found, in nearly the quantity indicated, many feet below the surface; and sometimes the application of sewage over the whole surface will force air out through the underdrains at the depth of five or six feet; and a few hours after the application air may move freely through the sand from the underdrains to the surface.

These relations differ widely in sands of finer grain and with mixed sands. In some, though completely underdrained, liquid will be held in the lower two feet of a five-feet layer, filling all of the space between the particles of sand, keeping this depth entirely saturated, while the upper three feet in depth may contain from one to two times as much air as water.

Still finer material may remain saturated throughout its whole depth, and give space for air only near the surface, after standing long enough for the liquid there to be evaporated.

A few careful series of experiments have been made in laboratories abroad, giving varying and sometimes astonishing results of the purification of sewage by filtration.* But previous to the investigations here presented very little was definitely known anywhere of the conditions most favorable for the purification of sewage by any given material. Whether it would purify at all, and, if at all, how much sewage could be applied, and what periods of intermission were necessary for obtaining a desired quality of effluent, and whether and under what conditions disease-producing germs could be removed, were questions which, at the beginning of these investigations, could be determined only by the resulting purification obtained by experiment; that is, by applying sewage through the different seasons of the year, in varying quantities, and with varying periods of intermission, to considerable areas of the various classes of material found in our valleys.

The Experiment Station at Lawrence has been arranged, and the experiments have been conducted, for the purpose of determining

* For a more detailed account of those experiments, and a general statement of the results of irrigation and of intermittent filtration in purifying sewage up to the time of beginning these investigations, see nineteenth annual report of the State Board of Health of Massachusetts, pp. 37-41.

the fundamental principles of filtration not previously established, and to learn what can practically be accomplished by filters made of some of the widely varying materials found in suitable localities for filtration areas, that there may be deduced from these results, together with the quality and physical characteristics of the materials used, the probable efficiency of other materials to be found throughout the State.

About four thousand chemical analyses of the sewage applied to the tanks and of the filtered effluent have been made in twenty-two months, the results of which are given in accompanying tables. These analyses have been made under the direction and careful superintendence of Prof. T. M. Drown, — in part at the laboratory of the Board at the Massachusetts Institute of Technology in Boston, and in part at the laboratory of the Board in Lawrence.

The experiments upon the filtration of water and of sewage, and upon chemical precipitation of sewage, have been organized and carried on under the direction of the writer, who has been most ably supported by Professor Drown and by Mr. Allen Hazen, chemist in charge of the laboratory in Lawrence, both of whom have devoted their scientific ability, not only to the technical work of obtaining the results of analyses, but to the interpretation of results, and to the establishment of series of experiments upon the filtration of chemical substances analogous to different elements of sewage, that they might have more definite data to aid in the interpretation of the results obtained with sewage. These experiments are described, together with the methods of analysis when differing from those usually practised, in the reports of these chemists, appended.

Observations upon the number of bacteria, living in the sewage and in the various effluents, have been made during the two years by different observers, as follows: From November, 1887, to June, 1888, by Dr. E. K. Dunham; from June to August, by Mr. H. L. Grant; through September and October, 1888, by Mr. G. R. Tucker. In November, 1888, this department was reorganized and placed under the superintendence of Prof. Wm. T. Sedgwick, who has been ably supported by Mr. E. O. Jordan.

The examination of microscopic organisms was, during the first year, under the care of Mr. G. H. Parker, Mr. C. B. Davenport, observer; and during the second year, under the care of Professor Sedgwick, Mr. G. L. West, observer.

Method of Recording and the Meaning of the Results of Analyses.

The qualities of the sewage applied to these filters, and of the more or less purified effluent flowing from their underdrains, are herein expressed in the usual form of results of chemical analyses. That these may be understood by the general reader, some explanation of the terms used and the significance of the results will be given.

One method of determining the amount of organic matter in a liquid is to heat a certain weight of it until it all evaporates, leaving a solid residue. This residue is made up of mineral matter and of organic matter. If a vessel containing this residue be carefully weighed and then heated to a low red heat, the mineral matter will be changed but little, if any, while the organic matter will be nearly all burned up, and pass off as gases. If, now, the vessel be again weighed, the loss in weight will be approximately the amount of organic matter burned up, which is nearly the same as the actual amount of organic matter in the original quantity of water.

In the tables which follow, the part of the residue upon evaporation, in the samples of sewage and of effluent from the filters, which is burned up, is called "loss on ignition," and the part that is not burned is called "fixed residue." The former has been regarded by chemists as expressing, in two samples, the relative amount of organic matter, and the latter the amount of mineral matter. Some deviations from thus comparing the organic matter, in samples widely differing in composition, will be explained later.

The principal constituents of animal and vegetable matter are carbon, oxygen, nitrogen and hydrogen; and when such matter decays, much of the carbon unites with oxygen, forming carbonic acid, which passes off as a gas; and much of the nitrogen and hydrogen unite, forming ammonia.

The organic matter in water, as it decays, gives off carbonic acid, which in part remains in solution, and in part escapes. The ammonia resulting from the decay remains in solution. Other organic matter, about ready to decay, gives up ammonia when the water is boiled. The ammonia in solution, and the ammonia thus set free from the organic matter in the water, pass off in the steam in a short boiling; and, if this steam be again condensed, the ammonia is all held in solution, and its quantity can be readily determined. This is the quantity of ammonia which in the following tables is called "free ammonia," and, being the product of decay, is the most characteristic ingredient of sewage.

There is still a quantity of combined nitrogen in the remaining organic matter; a part of which — one-half, more or less — can be made to pass off as ammonia, by putting into the water an alkaline solution of permanganate of potash, — a strong oxidizing agent, — and again boiling. The ammonia thus obtained is placed in the tables under the name of "albuminoid ammonia."

In sewage generally the free ammonia is a much larger quantity than the albuminoid ammonia; and, as putrefaction goes on, the albuminoid ammonia becomes more and more free ammonia; but in the purified effluent we find the free ammonia has been in large part changed by oxidation and combined with bases forming nitrates; a part has disappeared, — possibly escaped as ammonia and as nitrogen gas; and the albuminoid ammonia, much reduced in amount, forms the larger quantity.

For convenience in plotting diagrams and in expressing percentages, the sums of the free and albuminoid ammonias are given in the table of results under the heading "sum of ammonias."

In the oxidizing process of purification in the sand, nitric acid is formed from the nitrogen of the ammonia and of the organic matter, and the oxygen of the air. This strong acid immediately combines with the potash or soda or lime or other base in the sewage, forming nitrate of potash or of soda or other salt, or what is commonly known as saltpetre or Chili saltpetre, — salts which, in the small quantities in which they exist in the water coming from the filters, are regarded as entirely harmless. The nitrogen contained in these salts in the sewage, or in the water, is given in the tables under the heading "nitrogen as nitrates," and is generally referred to as "the nitrates."

The nitrogen in the salts in which the oxidation is not carried so far, either from too little air in the sand or from other cause, being nitrous acid salts, is given in the tables under "nitrogen as nitrites."

The chlorine of the table expresses in general the relative amount of common salt in samples. It may come in part from chloride of calcium or of potassium or of magnesium; but these salts are generally in small quantity in sewage, while chloride of sodium or common salt is a characteristic ingredient.

In all of the tables of analyses of sewage and of effluent, the numbers given express so many parts or such fraction of one part in one hundred thousand parts; that is, in one hundred thousand pounds of the sewage or effluent there is found to be the number of pounds or the fraction of a pound of the material expressed in each of the columns.

In making comparisons of the organic impurity of the effluent from the filter with that of the applied sewage, we meet with some indeterminate points which render the comparisons inexact.

The method of determining the "loss on ignition," practised here in the past fifteen months, has removed many of the uncertainties of ordinary results; but the fact that a part of the organic matter — and a larger part where there is decaying matter, as in sewage, than in the purified effluent — is removed by the process of evaporation, causes the comparison of the "loss on ignition" of the sewage with that of the effluent to indicate a less purification than has actually taken place. An indication in the same direction is given by the further fact presented in the annexed report of the chemists, that if the mineral salts usually found in the effluents of our nitrifying filters were in solution in distilled water with no organic matter, and were subjected to the same process of evaporation and ignition, the loss on ignition would be a quite large fraction of one part in one hundred thousand, varying with the salts from 0.3 part to 0.7 part (which may be held in mind in a general view as 0.6 part), which, not being organic matter, should be deducted from the observed loss on ignition, to give the amount of organic matter. Still another condition affects the meaning of the result. All organic matter contains carbon, but all does not contain nitrogen. That containing nitrogen is in general the more liable to putrefy, and is regarded as the more objectionable.

When comparing by the resulting ammonias, we have to consider that free ammonia is, to a considerable degree, the result of a decomposition of organic matter previously existing, and not an expression of the organic impurity at present existing. There is, in sewage, a much larger part of the total ammonia of this character than in a purified effluent; and when we compare the organic impurity of the effluent with that of the sewage, by saying, the sum of the free and albuminoid ammonia of the former is such a percentage of that of the latter, we give, when the free ammonia has nearly all been removed, an expression of more complete purification than actually took place. If, on the other hand, we compare only the albuminoid ammonia of each, we obtain a result which indicates, when nearly all the free ammonia has been removed, a less purification than actually took place.

When purification is carried to a good degree of completeness, its true expression would generally be between that indicated by comparing the sum of the ammonias, and that indicated by comparing the albuminoid ammonias. In the varying stages of purification this result would be sometimes greater and sometimes less than that shown by comparison of the sum of ammonias; but for simplicity of statement the sum of ammonias of both sewage and effluent are presented on the diagrams and in the description of results. All of the data are, however, given in the tables of analyses, so that other comparisons can be made if desired.

It will be found that the percentage which the organic matter in the effluent from the filters is of that in the sewage, when shown by the loss on ignition, — even when the process is conducted with great care, and the correction that has been mentioned is applied, — is two times, more or less, the percentage which the albuminoid ammonia of the effluent is of that of the sewage. One reason for this is, that the former process, as far as it can be depended upon, presents the relation of all of the organic matter in the effluent to all of the organic matter in the sewage, while the latter process presents nearly the relation of the nitrogenous organic matter in the effluent to that in the sewage; and, as the nitrogenous matter is the more objectionable kind of organic matter, the latter comparison indicates more nearly the degree of purification from the more objectionable parts of organic matter.

The purifying ability of a filter is indicated, not only by the smallness of the quantity of ammonia in the effluent, but by the greatness of the amount of nitrates. The nearer the nitrogen of the nitrates in the effluent is to the whole amount of nitrogen in the sewage, the more completely has the nitrogenous organic matter of the sewage been destroyed, and its objectionable part been used to form part of an unobjectionable mineral matter.

FILTER TANK No. 1.

Physical Characteristics.

This tank contains, above the gravel and underdrains, about 9,000 gallons of coarse mortar sand, unusually clean and of quite even size of grain. A physical analysis of a sample gives the following result, in which the number of the sieve expresses the number of meshes in an inch in length and width.

	Approximate Diameter of Grains, in Inches.	Percentage of the Whole Quantity.
Between sieve No. 2 and No. 4, ...	–	3
Between sieve No. 4 and No. 10, ...	–	12
Between sieve No. 10 and No. 20, ...	–	32
Between sieve No. 20 and No. 40, ...	0.020 to 0.040	46
Between sieve No. 40 and No. 55, ...	0.012 to 0.020	4.5
Between sieve No. 55 and No. 70, ...	0.010 to 0.012	1.0
Between sieve No. 70 and No. 100, ...	0.008 to 0.010	1.0
Between sieve No. 100 and No. 140, ...	0.005 to 0.008	0.4
	0.003 to 0.005	0.07
	0.000 to 0.003	0.03

By heating this sand to redness there is lost 0.42 of one per cent., from which we should conclude that the organic matter it contains is somewhat less than this amount. Treated with strong sulphuric acid at a boiling temperature for two hours, there remains in this sand 98.28 per cent. of silica and other insoluble material. The soluble portion contained alumina to the equivalent of 0.45 of one per cent. of the whole, and 0.53 of one per cent. of oxide of iron and manganese.

The specific gravity of the solid particles is 2.64, and when closely packed dry the specific gravity of the mass is 1.64; and the air space includes 38 per cent. of the whole. As the sand has been packed in the tank, the open space appears to be about 36 per cent.

The tank contained 9,000 gallons of sand, which, when saturated, contained 3,240 gallons of water; and when drained there remained about 1,040 gallons of water and 2,200 gallons of air.

The quantity of water remaining in this sand, when drained so that no more will readily run from it, is probably a little greater near the bottom than in the upper layers; but the sand is so open that, when so drained, air can pass quite freely up through a depth of five feet of it; and when the surface is covered with water, air within the sand will be forced down and out through the underdrains. With finer sands this is not the case: they may be entirely saturated in the lower foot or more of their depth, while the upper layers contain much air; and, the free motion of air through the mass being cut off by the saturated portion, the conditions affecting nitrification and the life of organisms passing through are materially changed.

A sample of open sand like this of Tank No. 1, having a depth of five and a half feet, allowed water to pass through it at the rate of three hundred million gallons per acre per day, when covered to the depth of six inches.

First Application of Sewage. External Circumstances. Frost and Snow.

Sewage was first applied to Tank No. 1 on the 10th of January, 1888. Previous to this time water at the temperature of 45° F. had been filtering at the rate of 1,000 gallons a day. No frost was seen upon the surface, and it is quite certain that none was in the sand on January 9, after the last 1,000 gallons were applied. On the morning of the 10th the temperature of the air was 16°. At noon it rose to 26°, and the next morning was 7°. On the two following mornings it fell to 1° below zero. Four hundred and eight gallons of sewage were applied on the afternoon of January 10; and in half an hour from the beginning of the application an increased flow began at the outlet; and in the next two hours 200 gallons had flowed out, indicating that there was little or no obstruction from frost at this time. On the next day the same amount was applied, with a similar result. Following this, for ten days 300 gallons were applied daily.

On January 14 the surface of the tank was covered with two inches of snow and ice; and it is probable that from this time sewage was obstructed in entering the tank, and, instead of flowing down freely through all parts of the area, went through small sections where there was the least obstruction. On January 17 the temperature of the air was 2° below zero, and three-eighths of an inch of ice covered the surface. On this and the three following days the rate of flow indicated decided obstruction by frost.

During the remainder of the month, with the daily minimum temperature of the air averaging 5° below zero, but little more than three-quarters of the quantity applied went through; some accumulated on the surface with the snow, and a part remained frozen in the sand, so that on February 1 nearly all the sewage entered the lower part of the tank by a single opening through the frost, which the sewage had to this time kept open, although its temperature when applied was but 36°. This temperature, being some eight degrees lower than that of the sewage in the sewer, was due to the sewage being brought to the station through an iron pipe, which, for more than a half mile of its length, lay upon the bed of the river in water at about 32°.

To distribute the sewage through a larger part of the tank, two holes were cut through the frost on February 2, and there was found to be a depth of snow and ice of one foot above the sand, and of ten inches of frost within the sand.

While, in this tank of very open sand, 150 gallons of sewage at 36° — applied daily during the extremely cold weather of the last ten days of January — maintained an open passage at one place through the frost, it was found that in other tanks, of closer material, holes cut through the frost would grow smaller by an interior lining of ice.

Finding the sewage applied at so low a temperature as 36°, during such cold weather, would not keep the tanks open, a hot-water pipe was run through the measuring tanks, into which all of the sewage was pumped; and for the first two weeks in February the temperature of the sewage applied to this tank was from 36° to 44°, — averaging 40°; being still 4° degrees lower than the temperature of sewage in the sewer. On the 7th and 14th of February new holes were cut through the frost, and the quantity of effluent increased to ninety per cent. of the applied sewage; still, the accumulated snow and ice were allowed to remain, to see the effect of applying 150 gallons of sewage daily at the low temperature of 40° to a level surface of very open material.

After a trial of two weeks with this temperature of sewage, when the morning temperature of the air averaged 8°, the snow and ice on the surface did not decrease; and, the holes cut in the ice and frost being all within a diameter of ten feet, it was evident that the filtration was effected by a small fraction of the material of the tank.

To render the filtration more effective, the snow and ice were, on the 17th of February, all removed from the surface of the tank; and a ring, one and a half feet wide, with outer edge one foot from the outside of the tank, was cut two inches into the sand. This ring, which was not connected with the former holes at any point, was filled with sewage at 37°, which settled one inch in fifteen minutes; indicating — as many other incidents have during the winter — that this sand, when frozen to a considerable depth, so that no opening can be found for a fine steel point, will nevertheless allow liquid to pass through it.

From this time the temperature of the sewage was increased to 52°; and the quantity of effluent was greater than the quantity of sewage applied, — including some melted frost from the sand and some of the rain and snow which fell upon the surface, — and the filter became very much more efficient in purifying the sewage. For the three weeks after removing the snow and ice from the surface, the morning temperature of the air was from 3° to 33°, — averaging 16°; and the temperature of the sewage averaged 52°; the effluent from the tank remained at 36°; the frost within the tank grew less, disappearing over the whole surface, but to be found a few inches below by sounding.

On March 8, the upper surface of the frost was about eight inches below the surface of the sand; and, by examination with a steel rod, the frost appeared to cover more than ninety per cent. of the area of the tank; still, the sewage disappeared freely, and, at many places, within the area of frost. Upon applying about 80 gallons of sewage at 63° at one place, and pressing the nozzle of the hose vertically against the frost, a hole would be cut through to the bottom of the frost, which was about two feet below the surface of the sand.

To thaw the frost more effectually, the outlet of the tank was closed on the 8th of March, and about 2,200 gallons of sewage, heated to 59°, were applied during this and the two following days, filling the tank to a little above the sand; after which, about 200 gallons were drawn off daily, and the same amount applied, keeping the tank about full until the 16th of the month, when about 2,000 gallons were drawn off; and the quantity applied was afterwards continued at 150 gallons per day.

Between the 8th and 17th of March, 3,300 gallons of sewage, at an average temperature of 63° F., were applied, and the same amount drawn off at 37°, — the reduction in temperature being nearly all due to the thawing of frozen sand in the tank; and there still remained some frost to be thawed, the top of which was about sixteen inches below the top of the sand, and appeared to include about one-ninth of the horizontal area of the tank.

For the remainder of March and through the month of April, the 150 gallons of sewage, which were applied in about eight minutes of each day, disappeared as rapidly as applied; and the effluent exceeded the amount applied by about five-eighths of the rainfall.

From the 22d of January to the end of April the quantity of sewage applied daily was 150 gallons, except from March 8 to 17, when more was applied, and excepting three days when none was applied.

The temperature of the effluent was very constantly at 36°; until, when applying large quantities of heated sewage to thaw the frost in the tank, it was irregular, ranging from 36° to 42°; after which it was quite steady at 38° and 39°, until the 1st of April, when it reached 40°, and, during this month, gradually increased to 46°.

Beginning of Nitrification.

The nitrates of the sewage were very constantly a little less than 0.01 part in 100,000 parts. The nitrates of the effluent rose, in the first week, to 0.10 parts; but fell, by the 1st of February, to 0.02 parts; and averaged less than 0.02 parts until the 28th of March, when they rose to 0.03 parts; followed by 0.05, 0.08, 0.10 parts, and, by a continued rise through the month of April, to 1.00 part per 100,000. The time of the change when the increase in nitrification began was when the temperature of the effluent was 39°.

The nitrates continued rising till the 7th of May, when they reached 3.00 parts; at which time the temperature of the effluent was 50°. They fell before the end of the month to 0.70 parts, and averaged for May 1.97 parts per 100,000.

Progress of Sewage through Sand indicated by its Chlorine.

The saltness of a liquid is not removed by filtering through sand. Hence, the time when any salt liquid applied to a filter reaches the outlet may be determined by the chlorine in the effluent. Previous to the application of sewage large quantities of water had been filtered through this tank, whose chlorine amounted to 0.24 parts in 100,000. The quantity of water held by the sand at the time of the application of sewage was probably about 1,000 gallons. When this quantity of water is held on the surface of the sand particles, and hanging between them on the sides that are most nearly in contact, there is still air space amounting to about 2,000 gallons between these thin walls of water. Upon applying water sufficient to cover the surface of the tank, the upper layer of the sand will become saturated. The air space there will become filled with water, and the newly arrived water will evidently pass by some of the water held between the particles of sand. If the depth of water applied over the surface of the tank be small, say one inch, it would fill the air space then in the sand to the depth of four inches, if it went down in a body; but before going far the forward particles mix with the particles previously in the sand, to some extent, and push some before them. Some of the applied water lags behind, and the new water mingled with that previously in the sand is distributed over a greater depth. The newly arrived water moves on less rapidly, and more completely replaces the water previously held, and pushes this on before it; and in the lower part of the tank the water moving downward is at first entirely water that had previously been held by adhesion and capillary attraction.

The distance below the surface which any of the newly applied water reaches, before another application is made, will depend upon the amount applied and upon the size of the grains of sand. The larger and more even the grains of sand, the larger will be the air spaces and the smaller will be the amount of water held in the sand after it has drained for a day, and the more freely can the new water pass by the old. If the new water is applied in large quantity, it will pass by more of the old and reach the outlet by pushing before it less of the old than if applied in small quantity.

In the case of Tank No. 1, with about 1,000 gallons of water, with chlorine at 0.24 parts, held within the sand, 408 gallons (or sufficient to cover the surface to a depth of three inches) of sewage, having 3.48 parts of chlorine per 100,000, were applied in forty-three minutes. Half an hour after the beginning of the application, water with chlorine at 0.24 parts began to flow out, and in the next two hours half as much as had been applied flowed out. On the next day, after another application of 408 gallons had been made, and 510 gallons had flowed out after the first sewage had been applied, the chlorine of the effluent amounted to 2.76 parts, or 79 per cent. of that of the sewage. Hence liquid from the first sewage, put on in this large quantity, had passed by much of the water previously held in the sand. Later experiments with this open sand, in this and other tanks, have given the following results: After the sand had been draining a day or two sewage was applied, within an hour, to a depth of three inches over the surface. The most forward particles of the sewage passed by nearly all of the liquid held in the smaller interstices of the sand, and, within an hour from the time they entered the sand at the top, reached the bottom, having pushed before them not more than two per cent. of the liquid previously held in the sand. The particles first coming through were few, mixed with many of the liquid previously held, taken on from point to point all the way down from the top. About one-tenth of the 1,000 gallons previously held had come out when the applied sewage formed one-quarter of the effluent; and when one-half of the 1,000 gallons had come out, the effluent was about one-half from sewage.

An experiment with the same depth of finer sand, like Tank No. 2, upon which was put a depth of one and a quarter inches of water containing a known quantity of salt, and this followed by daily applications of like quantities of water without salt, showed that five-sixths of the contained water was pushed out before any of the applied water came through, and that half of the salt had come through when a quantity of liquid equal to that previously held had passed out. The first of the applied salt water reached the outlet on the eleventh day after it was applied; and all of it had flowed out on the seventeenth day. On the day when it was strongest the salt water came through diluted, by a little more than half, with water previously held.

In this finer sand the whole mass was much more nearly saturated with held water, and the space in which the new water could pass by was very small, so that the first particles of the new water did not reach the bottom till five-sixths of the water previously in the tank had been pushed out. But with the coarse sand of Tank No. 1 we find the effluent to be from one-half to three-quarters sewage when half the quantity of original water had passed out.

Tables of Analyses.

The daily observations upon this tank, together with the results of two hundred and three chemical analyses of the effluent made during the twenty-two months when sewage has been applied, are given in tables at the end of this section.

A table of four hundred and seventy-four analyses of sewage applied to this and to other tanks will also be found there, and a second table giving analyses of the same sewage after passing through filter paper in the laboratory.

Effects of Frost upon the Effluent.

Although the chlorine of the effluent attained 79 per cent. of that of the sewage when 510 gallons of effluent had passed the outlet, it did not equal that of the sewage till January 18, when 2,500 gallons had passed out. In the time from January 11 to 18, the effluent was partly from sewage and partly from water previously in the tank.

From the preceding account of the frost, it is probable that in the first four days the sewage entered the tank over its whole area; but that from January 14 to February 17 the sewage applied went down through the tank in a varying area, — a part of the time through a small fraction of the whole area; in which case the result of the filtration would be similar to that which would have existed if many times as much sewage had flowed through the whole area of the tank.

In this time the ammonias of the effluent rose in the first week, while replacing the water, to 1.1470 parts in 100,000. This was the highest they have ever attained, due no doubt to obstruction on the surface, caused by a morning temperature of 2° below zero and six inches of snow of the previous day. From this time to February 17 the sum of the ammonias decreased to 0.3400 parts and averaged 0.6553 parts, which was 46 per cent. of the ammonias of the sewage. The quantity of effluent averaged 141 gallons per day.

From February 17 to March 7 the quantity of effluent averaged 174 gallons per day, and the ammonias averaged 0.2670 parts, or 18 per cent. of those of the sewage.

From March 8 to 16, when the tank was filled and filtration was made "continuous," about 200 gallons were put on and drawn off daily; the ammonias increased from 0.2640 parts to 0.4650 parts, but fell again, upon drawing the sewage out of the tank and continuing the intermittent application of 150 gallons daily; when, to the end of the month, they averaged 0.3544 parts, which was 31 per cent. of that of the sewage.

First Effects of Nitrification.

During the first three and a half weeks after the nitrates began to increase the ammonias did not decrease, but continued nearly the same, averaging 0.3940 parts, and were 23 per cent. of those of the sewage.

During the latter half of April and in the month of May, the nitrates increased rapidly from 0.300 parts on April 16 to 3.000 parts on May 7, and fell to 2.000 parts May 12, and to 0.700 parts on May 30; and the ammonias decreased from 0.3800 parts on April 16 to 0.0460 parts on May 12, and to 0.0102 parts on May 30. They decreased, during this time of rapid nitrification, from 31 per cent. of those of the sewage to one-half of one per cent. The free ammonia decreased from 0.3600 parts to 0.0012 parts, and the albuminoid ammonia from 0.0200 parts to 0.0090 parts.

General Results of Filtration through the First Winter, and of the Beginning of Nitrification.

The nitrates and ammonias of the effluent have been traced through the cold months to and through a very marked change in both, which occurred in the month of May. By the figures in the tables at the end of this section and the aid of the accompanying diagram we will briefly review this important stage of filtration, occurring at a season when some writers upon filtration have said no purification occurs.

The nitrates of the effluent were, during January, February and March, but little greater than those of the sewage. It was a period of no nitrification within the tank.

The ammonias of the effluent were, from January 18 to February 17, 46 per cent.; from February 17 to March 7, 18 per cent.; and from March 16 to March 31, 31 per cent., or a mean of 32 per cent. of those of the sewage, when the average daily quantity flowing through the tank was 153 gallons, which is at the rate of 30,600 gallons per acre per day.

From experiments, to be reported, upon other tanks of this material which did not freeze, it is evident that the high ammonias previous to February 17 were due to large quantities of sewage flowing down through the tank in small areas. If this had not been the condition, it is probable that the ammonias of the effluent would have averaged lower than 30 per cent. of those of the sewage. But, as it was, two-thirds of the ammonias of the sewage were removed by this open sand during these cold months, in which there was more or less frost in the sand.

But, upon the frost being removed, and the temperature of the effluent rising to 39°, nitrification began, and with the rising temperature went on, increasing slowly for ten days and then very rapidly for a month.

For three weeks and a half after the nitrates began to increase, the ammonias of the effluent remained nearly constant at 23 per cent. of those of the sewage; then they decreased rapidly in one month, and became, in the latter half of May, but one-half of one per cent. of those of the sewage. The nitrogen of the organic matter of the sewage was then being oxidized into nitric acid, which combined with the potash or soda or other bases in the sewage forming saltpetre and similar salts; and the remaining organic matter, expressed by the ammonias, was reduced to less than that of the ordinary water supplies of the State.

Purification by Nitrification Continued.

From June 1 to 17, 1888, the quantity applied (150 gallons) continued the same, and the effluent averaged 146 gallons per day, or 29,200 gallons per acre per day. The nitrates averaged 1.140 parts; the nitrites, 0.0004 parts; the ammonias, 0.0141 parts, or but eight-tenths of one per cent. of those of the sewage, — the free ammonia being 0.0008 parts and the albuminoid ammonia 0.0133 parts in 100,000.

From June 18 the quantity of sewage applied was doubled, becoming 300 gallons a day; and the quantity of effluent was a little less or a little greater, depending upon the amount of rainfall. This increased rate of filtration, of about 60,000 gallons per acre per day, continued for the next sixteen months.

Effect of Increased Quantity.

For the remainder of June the nitrates were much less, averaging 0.625 parts; the nitrites continued at 0.0004 parts; the ammonias increased to .0183 parts, or one per cent. of those of the sewage.

For the next five months the nitrates varied from 0.600 parts to 1.540 parts, and averaged 1.092 parts. Nitrification was going on rapidly. The higher nitrification generally followed the application of sewage containing a larger amount of ammonia; and the lower nitrification occurred with increase in free ammonia in the effluent, — also when a slight deposit formed upon the surface, and when the sewage was not evenly distributed over the surface.

Condition of the Surface.

Up to the 1st of August, when sewage had been applied daily for seven months, and 40,000 gallons had been applied, which is the equivalent of 8,000,000 gallons on an acre, the 300 gallons put on in sixteen minutes all disappeared as fast as applied; and when the surface was dry, the next morning, a handful of the sand taken to the nose did not discover any odor.

During the latter part of August the applied sewage was longer in disappearing from the surface, — the time increasing to twenty minutes from the end of the application. On August 21, after 46,000 gallons of sewage had been filtered, a slight deposit of organic matter was observed on the surface; but in a week this had all disappeared, and then the only change apparent in the surface, from the time when sewage was first applied, was the growth of twenty-six small tufts of grass. In September the time required for the 300 gallons of sewage to disappear from the surface was half an hour; and in October, about an hour. During this time of increasing delay in disappearing, it became evident that the larger part of the sewage, though distributed over the surface with care, was flowing to spots in the surface which were lower than the remaining area. These low places at first allowed more than their share of the sewage to pass through, but gradually became choked sufficiently to allow less to pass. Their borders were then overcharged; and, to correct this without changing the surface, the sewage was, during the latter part of October, applied mostly to the outer two feet of the tank surface, where it was supposed less sewage had passed than in other parts of the tank. The effect was to wash down the little bank against the side of the tank, which was restored on November 1 by raking over about one-half the area of the tank. At the same time the tufts of grass before mentioned were pulled up, and the surface levelled where they had been. This was the first disturbance in the surface made after February, and covered about one-half of the area in the outer part of the tank. The remaining portion of the surface was left undisturbed, to show how little accumulation of sediment or slime there would be on the surface of sand where nitrification was active. The organic matter may be said to be burned up so completely that it almost entirely disappears. During the next ten days the sewage was applied with care and disappeared quite evenly; but on November 18 and 19 the sewage was distributed over only about half of the surface. To prevent a recurrence of this condition a distributor was devised, consisting of four flat arms forming a cross, suspended horizontally at the middle, with edges projecting from half an inch to a sixteenth of an inch above the upper surface. Sewage is applied at the middle and flows out on the four arms, overflowing the edges and running out at the ends a foot from the sides of the tank. By revolving the cross ninety degrees and back, while the sewage is running on, it becomes evenly distributed over the surface. This was put up and first operated November 22, since which time the impurities of the effluent have been so much less and so much more constant than for the previous three months, that it becomes more than probable that during those months the results are much affected by the uneven distribution of the sewage over the surface of the tank.

Regimen Essential to Success.

From later experience on this and other tanks it becomes evident that the efficiency of a filter depends much upon steadily following a course of action, and requiring every part of it to accomplish the same work at regular intervals of time. The filter becomes a delicate organization, adapted to what is required of it, if its possibilities are not exceeded; but any change from the requirements is likely to render necessary weeks of time before the filter can become adapted to the changed conditions. This is illustrated by the action in October, when the attempt was made to get a better result by applying sewage to the outer part of the area of the tank, which had not been receiving much sewage. The effect was not a better effluent but a poorer one, because this section of the tank was not prepared by continued use to perform the work required of it.

The preparation required appears to be the introduction by the sewage of the particular organisms fitted to aid in this work, and their accumulation with a proper food supply, and other favorable conditions by which they become in time adapted to accomplish the most complete purification with the quantity of sewage received.

Any change in quantity or mode of application may disorganize this working colony and prevent the best results, until there is time for a readjustment adapted to the new conditions.

After November 22 the application to all parts of the tank became very regular; and the effect of this, and of the exclusion of rain and snow from the tank for the following three months, may best be observed by following the changes which occurred after the middle of June, when the quantity of sewage was increased to 300 gallons a day, or at the rate of 60,000 gallons per acre per day, and was continued at this rate for sixteen months.

The first marked effect of doubling the quantity of sewage applied was a decrease in the nitrates in two weeks from 0.850 parts to 0.450 parts; but this was a temporary decrease, due to the change, and they increased steadily in the next three weeks to 1.500 parts. The filter was becoming adapted to the new conditions. The nitrates in July averaged 1.061 parts, and continued higher through August, averaging 1.304 parts.

The free ammonia did not increase with the increase in quantity until after two weeks, but remained as in the first part of the month, averaging for June 0.0011 parts, or one-tenth of one per cent. of that of the sewage. In July the free ammonia increased a little, averaging 0.0031 parts, which was two-tenths of one per cent. of that of the sewage. After this it kept on increasing irregularly, until on November 17 it amounted to 0.4000 parts. In August it averaged 0.0205 parts; in September, 0.0369 parts; in October, 0.1343 parts; and in November, 0.2030 parts. Then it amounted to ten per cent. of that of the sewage.

After the adoption of the method of regular and even distribution of the sewage and the exclusion of rain and snow by a covering of canvas stretched around and above the tank, the free ammonia decreased rapidly, and in December averaged 0.0436 parts, or 4 per cent. of that of the sewage; and in January was but 0.0079 parts, or seven-tenths of one per cent. of that of the sewage.

The albuminoid ammonia changed but little in June, averaging 0.0149 parts. In July it was higher, averaging 0.0171 parts, and continued increasing through the first three weeks of November, averaging for each month as follows: August, 0.0208 parts; September, 0.0266 parts; October, 0.0296 parts; and November, 0.0355 parts, when it was 8 per cent. of that of the sewage. After November 22 it decreased, and averaged in December 0.0223 parts, and in January 0.0162 parts, or five per cent. of that of the sewage.

The sum of the ammonias, which, in June, 1888, when 30,000 gallons per acre were daily filtering, amounted to 0.0160 parts per 100,000, increased, after the quantity was doubled, month after month, until on November 17 it amounted to 0.4540 parts. After the regulation of November 22 it fell, until on December 1 it was but 0.0810 parts, and averaged for December 0.0659, and for January but 0.0241 parts, when it was but one and six-tenths per cent. of that of the sewage. After this it was higher, being in February 1889 five per cent., and in March eight per cent. After this, with the increase in nitrification in April it decreased, averaging for the month five per cent., and in May was three and seven-tenths per cent.

Nitrification in Winter.

From experience abroad it has been concluded that nitrification would not continue through the winter in this climate, and consequently purification by filtration would be rendered inefficient at this season. The experience of our first winter, 1887–88, showed that nitrification did not begin until the effluent from a tank reached a temperature as high as 39° F.

Through the winter of 1888–89 the tanks in the field were protected from the extreme effects of the climate by excluding snow from their surfaces, by stretching a canvas covering over them upon a frame high enough to allow access for proper distribution of the sewage.

The temperature of the winter of 1888–89 was higher than that of 1887–88, the principal difference being in the month of January, which, in 1888, was colder than for twenty years.

The means of the daily minimum and daily maximum temperatures through the winter months of the two years are given in the following table : —

Table of Maximum and Minimum Temperature of Air.

	1887-88.			1888-89.		
	Mean Max.	Mean Min.	Mean.	Mean Max.	Mean Min.	Mean.
November,	47.16°	28.30°	37.73°	48.40°	31.30°	39.85°
December,	35.54°	20.87°	28.20°	38.09°	21.45°	29.77°
January,	24.61°	6.32°	15.46°	39.77°	23.00°	31.38°
February,	35.03°	12.24°	23.63°	32.75°	11.82°	22.28°
March,	39.13°	20.39°	29.76°	45.38°	26.55°	35.96°

Sewage was applied to the tanks through the winter of 1888–89 at the temperature of 45°, which was but one or two degrees below the temperature of sewage in the main sewer of the city. The temperature of the effluent from Tank No. 1 was 49° in November, 41° in December, 40° in January, and 38° in February.

In March the sewage was applied at the temperature at which it reached the station, and varied from 34° to 41°, and the effluent was from 37° to 41°. For the month from February 16 to March 16 the temperature of the effluent averaged 37½°.

The sewage was applied at the low temperatures given in March, for the purpose of continuing the low temperature of the effluent and reducing it to as low a temperature as it is ever likely to reach in the coldest winter, when applied at the temperature at which sewage from a separate system of sewerage will be discharged from the sewer.

The conditions of nitrification through the winter are shown by the following table, which gives the total nitrogen of the sewage applied, and the nitrogen of the nitrates in the effluent, and the percentage that the latter is of the former, through the eighteen months after nitrates were first formed.

The total nitrogen of the sewage is determined by the approximate method of adding the nitrogen of its free ammonia to two times the nitrogen of the albuminoid ammonia.

Percentage of Nitrogen applied in the Sewage that appears in the Effluent as Nitrates.

[The nitrogen applied is .82 of the *free ammonia* of the sewage, plus two times .82 of the *albuminoid ammonia*.]

Date.	Nitrogen applied in Sewage.	Nitrates in Effluent corrected for Quantity.	Per Cent of Nitrogen applied.	Average Daily Quantity. Gals.	Temperatures. Sewage.	Temperatures. Effluent.
1888.						
May,	3.0238	1.974	65	156	47°	52°
June,	1.7568	.879	50	217	63°	64°
July,	2.0247	1.040	51	283	69°	71°
August,	3.9618	1.319	33	303	72°	73°
September,	4.8287	1.021	21	325	69°	68°
October,	2.4970	1.096	44	313	49°	55°
November,	2.3837	1.125	47	304	45°	49°
December,	1.4652	.794	54	288	45°	41°
1889.						
January,	1.4772	.737	50	283	45°	40°
February,	1.4864	.797	54	290	45°	38°
March,	2.0855	1.148	55	294	37°	38°
April,	2.4395	1.968	81	299	45°	46°
May,	2.3517	2.125	90	262	60°	59°
June,	2.9514	1.842	62	243	66°	66°
July,	3.1160	1.785	57	293	72°	70°
August,	2.5490	2.024	79	287	71°	69°
September,	3.2989	1.470	45	286	68°	67°
October,	2.9411	1.595	54	293	53°	56°

From this presentation it will be seen that during the four cold months of 1888-89, viz., December, January, February and March, 53 per cent. of all of the nitrogen applied in the sewage was found in the nitrates in the effluent; while in the previous four months, during which the same quantity was being filtered, only 33 per cent. of the total nitrogen applied was found in the nitrates of the effluent. That is, during these cold months nitrification was entirely satisfactory, and was much more complete than in the previous four months of August to November, and was but little less complete than for the past year, when it averaged 61 per cent.

It is to be further noted that, whereas, when sewage was first applied in the winter months of 1888-89, no nitrification occurred until in the spring, when the effluent, which had been at a temperature of 35° or 36°, rose to the temperature of 39°, now we find that, after nitrification has become established, the temperature of the applied sewage may be reduced to four degrees below 39°, and the effluent be maintained for weeks at two degrees below 39°, with no diminution in the completeness of nitrification.

This winter's experience with this tank of open sand gives confidence that, if a filtering area of this material is protected from the snow, it will continue to purify sewage by nitrification very efficiently through all seasons of the year.

Increased Nitrification in the Spring.

By examining the table further, it will be seen that with the advent of spring nitrification became more complete, averaging for April 81 per cent. and in May 90 per cent. of the total nitrogen of the sewage; decreasing through June and July, to averages of 62 and 57 per cent. respectively, and increasing in August to 79 per cent., and again decreasing in September and October to 45 and 54 per cent.

More Complete Nitrification the Second Year.

The six months, May to October, of the second year, show the average percentage of nitrates to be 63, while in the corresponding six months of the previous year they averaged 41 per cent. This tank, being constantly in use for nearly two years without any renewal of material or removal of sediment from the surface, nitrifies much more completely during the latter six months of the second year than during the corresponding six months of the first year.

Diagram of Daily Observations and Table of Results.

The results of analyses of the effluent of Tank No. 1, together with the sum of ammonias of the unfiltered sewage, are presented to the eye, as they changed from day to day, by a diagram accompanying the tables at the end of this section. This diagram will be clear from the explanations which it contains; but attention should be given to a peculiarity in the vertical scale, inasmuch as the quantities from .0 to 0.06 are plotted five times as large as quantities between 0.06 and 1.00, in order that very small quantities may be distinguished; and the scale for quantities greater than 1.00 is but one-half of that for quantities between 0.06 and 1.0.

For immediate use the results of the analyses of sewage and of effluents pertaining to Tank No. 1 are grouped in monthly averages in the following table:—

Monthly Averages of Daily Results with Tank No. 1.

Date.		Quantity of Effluent,—Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888.												
January 10-26, .	Sewage, .	–	49.02	25.47	1.2789	.7744	2.0533	2.67	.007	–	–	–
January 11-31, .	Effluent, .	198	4.26	12.02	.5986	.0670	.6656	2.59	.042	–	36°	120,125
	Per cent.,	–	8.7	47.2	46.8	8.7	32.4	–	–	–	–	–
Jan. 27-Feb. 22,	Sewage, .	–	21.55	14.37	1.0673	.5120	1.5793	2.56	.007	–	–	–
February, . .	Effluent, .	158	2.20	10.57	.4323	.0491	.4814	2.29	.015	–	36°	14,593
	Per cent.,	–	10.2	73.6	40.5	9.6	30.5	–	–	–	–	–
Feb. 23-Mar. 24,	Sewage, .	–	15.94	19.23	.5322	.3939	.9261	2.14	.007	.0027	–	–
March, . .	Effluent, .	238	2.14	9.93	.2985	.0224	.3209	2.26	.023	.0008	38°	24,195
	Per cent.,	–	13.4	51.6	56.1	5.7	34.7	–	–	–	–	–
Mar. 25-Apr. 18,	Sewage, .	–	37.55	45.99	1.0772	.7011	1.7783	3.06	.008	–	–	–
April, . .	Effluent, .	153	4.53	12.52	.3613	.0176	.3789	2.66	.348	.0022	42°	2,326
	Per cent.,	–	12.1	27.2	33.5	2.5	21.3	–	–	–	–	–
Apr. 19-May 22,	Sewage, .	–	41.94	47.07	1.1494	1.2642	2.4136	3.62	.008	.0022	–	–
May, . . .	Effluent, .	156	12.40	18.03	.0548	.0100	.0648	3.22	1.975	.0058	52°	3,129
	Per cent.,	–	29.6	38.3	4.8	.8of1	2.7	–	–	–	–	–
May 23-June 25,	Sewage, .	–	17.44	23.53	1.3546	.3887	1.7433	4.35	.008	.0005	–	–
June, . . .	Effluent, .	217	7.33	21.22	.0011	.0149	.0160	5.78	.911	.0004	64°	4,032
	Per cent.,	–	42.0	90.2	.1of1	3.8	.9of1	–	–	–	–	–
June 26-July 24,	Sewage, .	–	15.04	26.60	1.7120	.3730	2.0850	5.96	.009	.0002	–	–
July, . . .	Effluent, .	283	6.25	27.00	.0031	.0171	.0202	7.01	1.061	.0033	71°	4,661
	Per cent.,	–	41.6	101.5	.2of1	4.6	1.0	–	–	–	–	–
July 25-Aug. 24,	Sewage, .	–	53.05	52.23	2.7265	1.0452	3.7717	6.63	.012	.0000	–	–
August, . .	Effluent, .	303	3.88	27.76	.0205	.0208	.0413	7.22	1.304	.0023	73°	58
	Per cent.,	–	7.3	53.1	.8of1	2.0	1.1	–	–	–	–	–
Aug. 25-Sept. 25,	Sewage, .	–	56.29	74.55	2.4605	1.7141	4.1746	10.60	–	.0000	–	–
September, .	Effluent, .	325	3.08	32.11	.0369	.0266	.0635	9.01	.943	.0042	68°	1,062
	Per cent.,	–	5.5	43.1	1.5	1.6	1.5	–	–	–	–	–
Sept. 26-Oct. 27,	Sewage, .	–	17.94	33.05	2.0675	.4888	3.5563	6.80	–	.0000	–	–
October, . .	Effluent, .	313	2.61	25.52	.1343	.0296	.1639	6.20	1.049	.0074	55°	657
	Per cent.,	–	14.5	77.2	6.5	6.1	6.4	–	–	–	–	–

Monthly Averages of Daily Results with Tank No. 1 — Concluded.

Date.		Quantity of Effluent, — Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888 — Con.												
Oct. 28-Nov. 24,	Sewage, .	–	16.33	31.30	2.0400	.4335	2.4735	8.20	–	.0000	–	–
November, .	Effluent, .	304	2.08	26.45	.2030	.0355	.2385	6.41	1.109	.0047	49°	739
	Per cent ,	–	12.7	84.5	10.0	8.2	9.6	–	–	–	–	–
Nov. 25-Dec. 25,	Sewage, .	–	13.83	30.86	1.1694	.2941	1.4635	5.67	.024	.0000	–	–
December, .	Effluent, .	288	1.64	22.61	.0436	.0223	.0659	4.94	.826	.0004	41°	2,394
	Per cent.,	–	11.9	73.3	3.7	7.6	4.5	–	–	–	–	–
1889.												
Dec. 26-Jan. 28,	Sewage, .	–	11.78	24.41	1.1480	.3136	1.4616	4.41	.019	.0025	–	–
January, . .	Effluent, .	283	1.54	22.89	.0079	.0162	.0241	4.92	.781	.0003	40°	4,819
	Per cent.,	–	13.1	93.8	.7 of 1	5.2	1.6	–	–	–	–	–
Jan. 29-Feb. 25,	Sewage, .	–	9.83	18.54	1.1195	.3321	1.4516	3.92	.011	.0128	–	–
February, . .	Effluent, .	290	2.27	19.65	.0498	.0238	.0736	3.93	.825	.0006	38°	4,316
	Per cent.,	–	23.1	106.0	4.4	7.2	5.1	–	–	–	–	–
Feb. 26-Mar 28,	Sewage, .	–	13.53	23.83	1.6783	.4256	2.1039	4.62	.010	.0013	–	–
March, . .	Effluent, .	294	2.56	22.62	.1363	.0376	.1739	4.23	1.172	.0022	38°	1,336
	Per cent.,	–	18.9	94.9	8.1	8.8	8.3	–	–	–	–	–
Mar. 29-Apr. 27,	Sewage, .	–	13.16	24.95	2.0504	.4573	2.5077	4.98	.008	.0002	–	–
April, . .	Effluent, .	299	2.12	28.13	.1067	.0255	.1322	4.70	2.043	.0025	46°	90
	Per cent ,	–	16.1	112.7	5.2	5.6	5.3	–	–	–	–	–
Apr. 28-May 28,	Sewage, .	–	15.92	24.90	2.0029	.4319	2.4348	4.77	.001	.0000	–	–
May, . . .	Effluent, .	262	2.05	30.24	.0544	.0352	.0896	4.74	2.117	.0019	59°	91
	Per cent.,	–	12.9	121.4	2.7	8.2	3.7	–	–	–	–	–
May 29-June 26,	Sewage, .	–	20.21	29.21	2.5593	.5200	3.0793	5.11	.000	.0000	–	–
June, . . .	Effluent, .	243	2.94	26.17	.0394	.0301	.0695	5.17	1.844	.0022	66°	199
	Per cent.,	–	14.5	89.6	1.5	5.8	2.3	–	–	–	–	–
June 27-July 28,	Sewage, .	–	26.56	33.43	2.3686	.7157	3.0843	6.23	.000	.0000	–	–
July, . . .	Effluent. .	293	2.64	26.64	.0059	.0189	.0248	5.81	1.767	.0002	70°	6,838
	Per cent.,	–	9.9	79.7	.2 of 1	2.6	.8 of 1	–	–	–	–	–
July 29-Aug. 27,	Sewage, .	–	21.80	38.69	1.8843	.6121	2.4964	4.83	.000	.0000	–	–
August, . .	Effluent, .	287	1.90	30.10	.0043	.0177	.0220	5.60	2.050	.0003	69°	966
	Per cent.,	–	8.7	77.8	.2 of 1	2.9	.9 of 1	–	–	–	–	–
Aug. 28-Sept. 26,	Sewage, .	–	40.25	56.87	1.9092	1.0569	2.9661	4.37	.000	.0000	–	–
September, .	Effluent, .	286	3.90	25.45	.0583	.0365	.0948	4.06	1.506	.0014	67°	132
	Per cent.,	–	9.7	44.8	3.1	3.5	3.2	–	–	–	–	–
Sept. 27-Oct. 28,	Sewage, .	–	28.10	28.24	1.9853	.8000	2.7853	4.95	.001	.0002	–	–
October, . .	Effluent, .	293	–	–	.0918	.0280	.1198	4.47	1.584	.0022	56°	1,184
	Per cent.,	–	–	–	4.6	3.5	4.3	–	–	–	–	–

Referring to this table and to the diagram of daily observations accompanying the tables of daily observations, the general results of the twenty-two months' use of this filter will be noted; and the results of the second year's use compared with those of the first year, which have already been given with much detail.

The quantity of sewage passing through the filter in the four months previous to June 18, 1888, was at the rate of about 30,000 gallons per acre per day; except during a part of March, when a larger quantity was flowing. After June 18, 1888, through October, 1889, the daily quantity was nearly doubled, averaging 58,000 gallons per acre per day.

This quantity was applied for one year, from June 18, 1888, to June 18, 1889, as follows: — 300 gallons on five days in the week, 600 gallons on Saturday, and none on Sunday. After June 18, 1889, the application was made on four days in the week, 500 gallons at a time.

The Loss on Ignition, through the Two Years.

The loss on ignition of the effluent was, during the first four months of the first year, about twelve per cent. of that of the sewage. It rose rapidly with the nitrates in April, as clearly shown on the diagram of daily results which accompanies the tables, and continued high, even above forty per cent. of that of the sewage, when the ammonias of the effluent were less than one per cent. of those of the sewage. A similar great increase in the loss on ignition accompanied the increase in nitrates, and continued with the decrease in ammonias, in the effluents from other filtering materials; and Mr. Allen Hazen, who has charge of the chemical laboratory of the Experiment Station of the Board at Lawrence, found by experiments that this increase in loss on ignition, accompanying increase in nitrification, was not due to an increase in organic matter. He, for reasons given in his report, which is appended, concluded that previous to the increase in nitrates — including the months previous to April — the loss on ignition expressed, at least roughly, the amount of organic matter in the effluent; but, after nitric acid was generated, the weight of the residue on evaporation was increased by deliquescence of the salts of calcium and magnesium; and on heating to a low red heat there were given off, in addition to the organic matter, hydrochloric and nitric acid and water of crystallization from the magnesium salts, which in some cases increased the loss on ignition to many times the amount of the organic matter. The results of the loss on ignition, after nitrification became rapid, were then indefinite and misleading.

To correct this, Mr. Hazen concluded to add to the water to be evaporated a definite amount of sodium carbonate, which caused the calcium and magnesium to be precipitated as carbonate, and left in solution sodium salts of the acids present, which are only slightly deliquescent, do not contain water of crystallization, and do not give off hydrochloric and nitric acid by the method of ignition used.

This addition of sodium carbonate was found by Mr. Hazen to greatly decrease the loss on ignition, and to cause it to indicate, much more nearly, the organic matter present when the effluent contained hydrochloric, nitric and sulphuric acid in excess over the alkalies, soda and potash. When these acids are not present in excess, the loss on ignition is practically the same, with or without the use of the sodium carbonate.

From Aug. 1, 1888, the loss on ignition and the fixed residue have been determined in all of the effluents from the tanks, and, in the sewage and city water with which they are compared, by the addition of sodium carbonate.

Before nitrification began in Tank No. 1, the loss on ignition was 9, 10 and 13 per cent. of that of the sewage, and amounted in January, 1888, to 4.26 parts; in February, to 2.20 parts; and in March, to 2.14 parts per 100,000. After nitrification began, this loss on ignition, obtained in the usual way, increased to 12.40 parts in May; and in June and July was 7.33 parts and 6.25 parts, or more than 40 per cent. of that of the sewage; while the sum of the ammonias averaged less than one per cent. of that of the sewage. For the reasons already stated, these high losses on ignition, obtained in the usual way, give no indication of the amount of organic matter in the effluent. After August 1, when sodium carbonate was constantly used, the loss on ignition of the effluent was, in August, 3.88 parts, which was 7 per cent. of that of the sewage; and in September it was 3.08 parts, or 6 per cent. of that of the sewage. In the following twelve months the monthly averages varied from 1.54 parts to 3.90 parts, or from 9 to 23 per cent., averaging for the year 2.36 parts, or 14 per cent. of that of the sewage. During the same time the albuminoid ammonia in the effluent averaged 6 per cent. of that in the sewage; so that the percentage, which the loss on ignition in the effluent was of that of the sewage, was about two and a half times the percentage which the albuminoid ammonia of the effluent was of that of the sewage.

During the four cold months of 1888–89, the loss on ignition of the effluent averaged 2.00 parts, or 17 per cent. of that of the sewage; indicating that the efficiency of the filter was nearly as good during the winter as during the rest of the year.

The Fixed Residue in the Two Years.

In the first four months of filtration, when there was little or no nitrification, the fixed residue on evaporation averaged 11.26 parts in 100,000, and was 50 per cent. of that of the sewage. After nitrification began, the fixed residue, which in the effluent is nearly all mineral matter in solution, became more in amount and a greater percentage of the fixed residue of the sewage. In May it averaged 18.03 parts, or 38 per cent.; in June, 21.22 parts, or 90 per cent.; and in July, 27.00 parts, or 101 per cent. of that of the sewage.

After August 1 the fixed residue was determined by the addition of sodium carbonate in fixed quantity, which quantity was deducted from the mineral matter weighed. By experiments made upon the effluent from this tank, the resulting fixed residue, when determined by the addition of sodium carbonate, was found to be a little in excess of that determined in the usual way. At the time of the experiments the excess was about one-fourteenth part.

From August, 1888, to October, 1889, the fixed residue of the effluent varied in monthly averages, from 19.65 parts to 32.11 parts, or from 43 to 121 per cent. of that of the sewage, and gave a general average of 26.17 parts, or 82 per cent. of that of the sewage.

Some of the Mineral Matter of the Sewage removed before reaching the Station.

The sewage brought to the Experiment Station, through the pipe nearly a mile long, must of necessity contain less mineral matter in suspension than the sewage in the sewer; for the reason that some of the mineral matter which enters the pipe is gradually deposited in the upper 500 feet of its length, and has to be blown out of this section by a stream from the city hydrant once in a month or two.

From this cause we do not receive as much sand upon the filters, with the sewage, as would be poured upon them if near the outlet of the sewer; but they probably receive as much mineral matter in suspension as they would receive from sewers conveying sewage only, without the washings from streets, — which is the kind of sewage for which filters are to be used.

Relation of Suspended Matter to Matter in Solution in the Sewage.

To show the relation of the mineral and of the organic matter in suspension to that in solution, the following table of monthly averages of analyses of crude sewage and of sewage filtered through filter paper in the laboratory to remove the suspended matter, is now presented: —

Monthly Average of Analyses of Unfiltered Sewage, and of Sewage Filtered through Filter Paper in the Laboratory.

Date.		Residue on Evaporation.		Ammonia.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum.
1888.						
January,	Unfiltered,	34.85	23.31	1.2006	.6313	–
	Filtered,	5.05	14.24	1.0606	.1438	–
	Per cent.,	14	61	88	23	–
February,	Unfiltered,	21.88	15.69	.9537	.4979	–
	Filtered,	9.24	12.64	.9342	.1621	–
	Per cent.,	42	81	98	33	–
March,	Unfiltered,	20.87	27.57	.7238	.4138	–
	Filtered,	4.68	13.47	.5843	.1095	–
	Per cent.,	22	49	81	26	–
April,	Unfiltered,	34.25	40.80	.8965	.7438	–
	Filtered,	5.29	17.96	.8765	.0944	–
	Per cent.,	15	44	98	13	–
May,	Unfiltered,	40.86	46.14	1.3518	1.2494	–
	Filtered,	6.57	20.64	1.2753	.1148	–
	Per cent.,	16	45	94	9	–
June,	Unfiltered,	16.93	25.22	1.4073	.3627	–
	Filtered,	10.21	21.02	1.3527	.1150	–
	Per cent.,	60	83	96	32	–
July,	Unfiltered,	15.08	25.02	1.8710	.4081	–
	Filtered,	8.46	23.25	1.7767	.1676	–
	Per cent.,	56	93	95	41	–
August,	Unfiltered,	79.01	80.74	2.8461	2.0030	–
	Filtered,	16.40	30.05	2.7239	.2361	–
	Per cent.,	21	37	96	12	–
September,	Unfiltered,	30.05	48.44	2.1543	.7152	–
	Filtered,	13.10	36.45	2.0443	.2057	–
	Per cent.,	44	75	95	29	–
October,	Unfiltered,	17.07	30.26	2.1909	.4632	–
	Filtered,	11.21	27.24	2.1973	.1977	–
	Per cent.,	66	90	100	43	–
November,	Unfiltered,	15.78	32.16	1.8405	.4091	–
	Filtered,	9.57	27.26	1.8486	.1882	–
	Per cent.,	61	85	100	46	–
December,	Unfiltered,	14.48	29.86	1.1967	.3561	–
	Filtered,	9.44	25.87	1.2000	.1978	–
	Per cent.,	65	87	100	56	–
1889.						
January,	Unfiltered,	10.90	22.98	1.1318	.2723	–
	Filtered,	9.27	21.82	1.0955	.1418	–
	Per cent.,	85	95	97	52	–
February,	Unfiltered,	9.88	18.56	1.1605	.3471	–
	Filtered,	7.23	17.50	1.0705	.1569	–
	Per cent.,	73	94	92	45	–
March,	Unfiltered,	13.74	24.24	1.7239	.4357	–
	Filtered,	9.21	20.60	1.6665	.2570	–
	Per cent.,	67	85	97	59	–
April,	Unfiltered,	13.19	25.04	2.0529	.4514	–
	Filtered,	8.30	22.20	2.0076	.2400	–
	Per cent.,	63	89	98	53	–
May,	Unfiltered,	15.81	24.86	2.0877	.4377	–
	Filtered,	11.97	23.36	2.0123	.2341	–
	Per cent.,	76	94	96	53	–
June,	Unfiltered,	25.82	30.51	2.5420	.6095	–
	Filtered,	16.63	23.66	2.4480	.2715	–
	Per cent.,	64	78	96	45	–

Monthly Average of Analyses of Unfiltered Sewage, and of Sewage Filtered through Filter Paper in the Laboratory — Concluded.

Date		Residue on Evaporation.		Ammonia.		
		Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum.
1889 — Con.						
July, ...	Unfiltered, ...	24.57	34.35	2.3920	.6380	–
	Filtered, ...	14.81	23.97	2.3055	.3045	–
	Per cent., ...	60	70	96	48	–
August, ...	Unfiltered, ...	22.16	39.09	1.9268	.6623	–
	Filtered, ...	14.07	24.71	1.8936	.3414	–
	Per cent., ...	63	63	98	52	–
September, ...	Unfiltered, ...	34.73	46.82	1.8640	.9965	–
	Filtered, ...	17.27	26.92	1.7925	.4610	–
	Per cent., ...	50	57	96	46	–
October, ...	Unfiltered, ...	28.29	29.51	1.9231	.7469	–
	Filtered, ...	17.38	24.48	1.9115	.4158	–
	Per cent., ...	61	83	99	56	–
Average of above 22 months,	Unfiltered, ...	24.55	32.78	1.7017	.6296	2.3313
	Filtered, ...	10.70	22.70	1.6399	.2162	1.8561
	Per cent., ...	44	69	96	34	80
Average of last 12 months,	Unfiltered, ...	19.11	29.83	1.8202	.5302	2.3504
	Filtered, ...	12.10	23.53	1.7710	.2675	2.0385
	Per cent., ...	63	79	97	50	87

The mean results for the whole time are given at the foot of the table. Upon examining the cause of the extreme variations from the mean, it is found that in August, 1888, two or three exceptional days control the month; and the same is true, to a less extent, in April and May, 1888. For some reason not clearly seen, the character of the sewage was more uniform during the last twelve months than previously. Taking a mean of the results for the past twelve months, one-third of the organic matter in the crude sewage, shown by the loss on ignition, is in suspension, and two-thirds in solution. Of the mineral matter, one-fifth only is in suspension and four-fifths in solution. One-half of the nitrogenous matter, as shown by the albuminoid ammonia, is in suspension, and one-half in solution. Of the free ammonia, nearly if not quite all is in solution, only three per cent. appearing in suspension.

The average amount of chlorine in the sewage for the last twelve months was 5.25 parts per 100,000.

In has been stated that at one time the fixed residue of the effluent averaged, for one month, 121 per cent. of the fixed residue of the sewage. This was in May, 1889, when the mineral matter in solution in the sewage was 94 per cent. of all of its mineral matter; and the nitrogen, in the form of nitrates, was so great that it is quite certain that, in order to form these nitrates, some mineral matter, in the form of a base which had been previously stored in the sand, must have been taken up by the nitric acid formed, and come out of the tank with the effluent as soluble nitrate, increasing the mineral matter in solution beyond that which was supplied by the sewage during this month.

Analyses of Mineral Constituents of Sewage and of Effluent.

Analyses were made of the mineral constituents of the sewage of Dec. 11, 1888, and of the effluent from this tank of December 15, — about the time that sewage would get through, — with the results given in the following table : —

Mineral Analyses of Sample of Sewage and its Effluent in Parts per 100,000 of the Original Liquid.

	Sewage, Dec. 11, 1888.	Effluent from Tank No. 1, Dec. 15, 1888.		Sewage, Dec. 11, 1888.	Effluent from Tank No. 1, Dec. 15, 1888.
Total solids,	48.4	24.6	Alluminium oxide,	0.17	0.18
Loss on ignition,	18.6	1.6	Ferric oxide,	0.01	0.01
Fixed residue,	29.8	23.0	Manganic oxide,	0.56	0.
Sodium oxide,	5.18	5.24	Nitrogen as nitrate,	0.	0.70
Potassium oxide,	1.96	1.46	Chlorine,	4.98	4.56
Calcium oxide,	3.36	2.98	Sulphuric acid,	1.57	2.11
Magnesium oxide,	0.84	0.86	Silica,	1.86	1.42

These substances may be combined as follows : —

Potassium nitrate,	–	3.04	Magnesium carbonate,	1.76	0.48
Potassium chloride,	3.10	–	Calcium carbonate,	6.00	5.32
Sodium chloride,	5.76	5.69	Alumina,	0.17	0.18
Sodium nitrate,	–	1.61	Ferric oxide,	0.01	0.01
Sodium sulphate,	2.28	3.74	Manganic oxide,	0.56	0.
Sodium carbonate,	1.52	–	Silica,	1.86	1.42
Magnesium chloride,	–	1.49			

General View of the Ammonias of the Effluent.

Taking a general view of the ammonias of the effluent of Tank No. 1, through the two years, they are found to be low at three distinct periods ; one beginning in the last week in May, continued through June, July and August, 1888, when they averaged less than one per cent. of those of the sewage. The first month of this period was when 30,000 gallons per acre were filtering daily ; and the remainder included the first two and a half months, when 60,000 gallons per acre were filtering daily. Continuing the latter quantity, the ammonias of the effluent increased to 10 per cent. of those of the sewage in November, and fell to 1.6 per cent. in January. Again, they rose to 8 per cent. in March, and fell to less than one per cent., which they maintained through July and August, 1889, and rose to 4 per cent. in October. The average percentage that the ammonias in the effluent were of those in the sewage for the eighteen months after nitrification commenced was three and one-quarter.

Comparison of Purification by Intermittent Filtration in Winter with that of the Year.

During the year from Oct. 31, 1888, to Oct. 31, 1889, the monthly averages of the free ammonia of the effluent varied from 0.0043 parts to 0.2030 parts, or from two tenths of one per cent. to 10 per cent. of that of the sewage, and averaged 0.0668 parts, or 3.7 per cent. of that of the sewage.

During the four cold months, December to March, the monthly averages of the free ammonia varied from 0.0079 parts to 0.1363 parts, or from seven-tenths of one per cent. to 8 per cent. of that of the sewage, and averaged 0.0594 parts, or 4.2 per cent. of that of the sewage.

The albuminoid ammonia during the year varied by monthly averages from 0.0162 parts to 0.0376 parts, and from 2.6 per cent. to 8.8 per cent. of that of the sewage, and averaged 0.0273 parts, or 5.7 per cent.

During the cold months the albuminoid ammonia varied from 0.0162 parts to 0.0376 parts, which was from 5 to 9 per cent. of that of the sewage then applied, and averaged 0.0250 parts, or 7.2 per cent.

Bringing together the results of the different examinations of the effluent during the cold months of 1888–89, in comparison with those of the year, we have: —

	For the Year.		For the Cold Months.	
	Parts per 100,000.	Percentage of the same in the Sewage.	Parts per 100,000.	Percentage of the same in the Sewage.
Loss on ignition,	2.36	14.	2.00	17.
Free ammonia,	0.0668	3.7	0.0594	4.2
Albuminoid ammonia,	0.0273	5.7	0.0250	7.2
		Percentage of Total Nitrogen in the Sewage.		Percentage of Total Nitrogen in the Sewage.
Nitrogen as nitrates,	1.4687	62.	0.9010	55.

We find that during the cold months the nitrification was nearly as complete — about nine-tenths as complete — as the mean for the year; and that the loss on ignition and the ammonias of the effluent were but about one-fifth greater percentage of the amounts in the sewage producing the effluents than for the year. This is in all respects a very satisfactory result of continued purification by this filter during the winter.

Comparison of Results of Two Years.

Comparing the quality of the effluent by the ammonias and by the completeness of the nitrification during the last six months of the second year with the corresponding six months of the first year, we have: —

	Percentage the Ammonias of the Effluent are of those of the Applied Sewage.						Percentage the Nitrogen of the Nitrates in the Effluent is of the Total Nitrogen in the Sewage.	
	Free.		Albuminoid.		Sum.			
	1888.	1889.	1888.	1889.	1888.	1889.	1888.	1889.
May,	4.8	2.7	0.8	8.2	2.7	3.7	65	90
June,	0.1	1.5	3.8	5.8	0.9	2.3	52	63
July,	0.2	0.2	4.6	2.6	1.0	0.8	52	57
August,	0.8	0.2	2.0	2.9	1.1	0.9	33	80
September,	1.5	3.1	1.6	3.5	1.5	3.2	20	46
October,	6.5	4.6	6.1	3.5	6.4	4.3	42	54
Average,	2.3	2.0	3.1	4.4	2.3	2.5	44	65

The mean quantity passing through the filter in the last six months has been but four per cent. greater than in the corresponding six months of the first year. The degree of purification averages nearly the same, the sum of the ammonias differing but two-tenths of one per cent. The albuminoid ammonia averaged one and three-tenths per cent. greater in the second year than in the first; but, on the other hand, nitrification was much more complete during the second year, — indicating that the filter was in a better condition to continue purifying than it was during the first year.

The last six months of the second year began when 120,000 gallons of sewage, or the equivalent of 24,000,000 gallons on an acre, had been filtered through this sand; and ended when 171,000 gallons, or the equivalent of 34,200,000 gallons on an acre, had been filtered through the same sand; the whole amount having been filtered without any removal of sediment from the surface, or any cleaning of the sand, except such cleaning as the process of oxidation or of nitrification produces. This cleaning process has the effect of burning up the organic matter of the sewage, both that which at times is deposited upon the surface and that which permeates the sand.

During the last half-year, the effluent from this filter has been generally colorless and clear, with little or no sediment.

STORING OF NITROGENOUS MATTER IN THE SAND.

Reference has been made to the storing up of nitrogenous matter in the sand during the early weeks of filtration; and in some cases it has been evident that, when nitrification was very active, as in the spring, more nitrogen came away from the tank than was then being applied to it, making the conclusion necessary that some of the nitrogenous matter previously stored in the sand was being removed. Upon further examination, it became evident that, taking a series of months, with quite active nitrification, there was not as much nitrogen coming off with the effluent as was being applied; from which it would follow that, if the excess applied was being stored in the sand, the filter would in time become useless.

To test the question, a long series of experiments was first made, under the direction of Professor Drown, to determine the relation of the nitrogen found in the albuminoid ammonia to the total organic nitrogen of the sewage and of the different effluents. He found the relation was not a constant one; but that in both the sewage and the effluents the average amount of total organic nitrogen was a little more than two times the nitrogen of the albuminoid ammonia; and that, for the purposes of comparison of quantities of nitrogen applied and those coming off, it would be reasonable to calculate the total nitrogen in each as two times the nitrogen of the albuminoid ammonia.

The amount of nitrogen in the ammonia is fourteen-seventeenths of the ammonia; hence we shall have, from the above determination, an approximate quantity of total nitrogen in the sewage, or in an effluent, by taking 0.82 of free ammonia, plus two times 0.82 of albuminoid ammonia, plus the nitrogen of nitrates and nitrites.

The amount of nitrogen stored in the sand was determined in a similar way after obtaining, from samples taken at different depths in the tank, the amount of ammonia, by forcing steam containing no ammonia through the sand.

With results thus obtained a complete account has been kept of all the nitrogen applied to the tank, all that has come away in the effluent, and the amount from time to time stored in the sand.

Amount of Nitrogen applied to Tank No. 1, and the Amount which came off in the Effluent.

Date.		Ammonia.		Nitrogen as —		Quantity of Liquid, Gals.	Total Nitrogen.	Total Nitrogen × Quantity.	Total Nitrogen from Beginning.	Quantity of Nitrogen from Beginning, in Pounds.
		Free.	Albuminoid.	Nitrates.	Nitrites.					
1888.	Sand, .	.1985	.5135	–	–	–	1.0049	–	–	–
January 10-26, .	Sewage, .	1.2789	.7744	.007	–	4,950	2.3257	11,512	11,512	.96
January 11-31, .	Effluent, .	.5986	.0670	.042	–	4,161	.6434	2,677	2,677	.22
Jan. 27-Feb. 22, .	Sewage, .	1.0673	.5120	.007	–	3,935	1.7219	6,776	18,288	1.52
February, . .	Effluent, .	.4323	.0491	.015	–	4,583	.4500	2,063	4,740	.39
Feb. 23-Mar. 24, .	Sewage, .	.5322	.3939	.007	.0027	5,850	1.0894	6,373	24,661	2.06
March, . .	Effluent, .	.2985	.0224	.023	.0008	6,678	.3045	2,033	6,773	.56
Mar. 25-Apr. 18,	Sewage, .	1.0772	.7011	.008	–	3,900	2.0421	7,964	32,625	2.72
April, . . .	Effluent, .	.3613	.0176	.348	.0022	4,449	.6732	2,995	9,768	.81
Apr. 19-May 22, .	Sewage, .	1.1494	1.2646	.008	.0022	3,900	3.0238	11,793	44,418	3.70
May, . . .	Effluent, .	.0548	.0100	1.975	.0058	3,898	2.0363	7,938	17,706	1.47
May 23-June 25, .	Sewage, .	1.3546	.3887	.008	.0005	6,750	1.7568	11,858	56,276	4.69
June, . . .	Effluent, .	.0011	.0149	.911	.0004	6,511	.9367	6,099	23,805	1.98
June 26-July 24,	Sewage, .	1.7120	.3730	.009	.0002	9,000	2.0247	18,222	74,498	6.21
July, . . .	Effluent, .	.0031	.0171	1.061	.0033	8,819	1.0948	9,655	33,460	2.79
July 25-Aug. 24,	Sewage, .	2.7265	1.0452	.012	.0000	9,300	3.9618	36,845	111,343	9.28
August, . .	Effluent, .	.0205	.0208	1.304	.0023	9,408	1.3518	12,718	46,178	3.85
Aug. 25-Sept. 25,	Sewage, .	2.4605	1.7141	–	.0000	9,000	4.8287	43,458	154,801	12.90
September, .	Effluent, .	.0369	.0266	.943	.0042	9,746	1.0211	9,951	56,129	4.68
Sept. 26-Oct. 27,	Sewage, .	2.0675	.4888	–	.0000	9,300	2.4970	23,222	178,023	14.84
October, . .	Effluent, .	.1343	.0296	1.049	.0074	9,713	1.2150	11,801	67,930	5.66
Oct. 28-Nov. 24, .	Sewage, .	2.0400	.4335	–	.0000	9,000	2.3837	21,453	199,476	16.62
November, . .	Effluent, .	.2030	.0355	1.109	.0047	9,129	1.3384	12,218	80,148	6.68
Nov. 25-Dec. 25,	Sewage, .	1.1694	.2941	.024	.0000	8,700	1.4652	12,748	212,224	17.69
December, . .	Effluent, .	.0436	.0223	.826	.0004	8,360	.8987	7,513	87,661	7.31
1889.										
Dec. 26-Jan. 28, .	Sewage, .	1.1480	.3136	.019	.0025	9,300	1.4772	13,738	225,962	18.83
January, . .	Effluent, .	.0079	.0162	.781	.0003	8,781	.8143	7,151	94,812	7.90
Jan. 29-Feb. 25, .	Sewage, .	1.1195	.3321	.011	.0128	8,400	1.4864	12,486	238,448	19.87
February, . .	Effluent, .	.0498	.0238	.825	.0006	8,111	.9055	7,345	102,157	8.51
Feb. 26-Mar. 28,	Sewage, .	1.6783	.4256	.010	.0013	9,300	2.0855	19,395	257,843	21.49
March, . .	Effluent, .	.1363	.0376	1.172	.0022	9,107	1.3476	12,263	114,420	9.54
Mar. 29-Apr. 27,	Sewage, .	2.0504	.4573	.008	.0002	9,300	2.4395	22,687	280,530	23.38
April, . . .	Effluent, .	.1067	.0255	2.043	.0025	8,957	2.1748	19,480	133,900	11.16
Apr. 28-May 28, .	Sewage, .	2.0029	.4319	.001	.0000	8,100	2.3517	19,049	299,579	24.96
May, . . .	Effluent, .	.0544	.0352	2.117	.0019	8,129	2.2212	18,056	151,956	12.66
May 29-June 26,	Sewage, .	2.5593	.5200	.000	.0000	7,300	2.9514	21,545	321,124	26.76
June, . . .	Effluent, .	.0394	.0301	1.844	.0022	7,294	1.9279	14,062	166,018	13.83
June 27-July 28,	Sewage, .	2.3686	.7157	.000	.0000	9,000	3.1160	28,044	349,168	29.10
July, . . .	Effluent, .	.0059	.0189	1.767	.0002	9,090	1.8030	16,389	182,407	15.20
July 29-Aug. 27,	Sewage, .	1.8843	.6121	.000	.0000	9,000	2.5490	22,941	372,109	31.01
August, . .	Effluent, .	.0043	.0177	2.050	.0003	8,885	2.0829	18,507	200,914	16.74
Aug. 28-Sept. 26,	Sewage, .	1.9092	1.0569	.000	.0000	8,800	3.2989	29,030	401,139	33.43
September, . .	Effluent, .	.0583	.0365	1.506	.0014	8,588	1.6151	13,870	214,784	17.90
Sept. 27,-Oct. 28,	Sewage, .	1.9853	.8000	.001	.0002	9,000	2.9411	26,470	427,609	35.63
October, . .	Effluent, .	.0918	.0280	1.584	.0022	9,069	1.7074	15,484	230,268	19.19

The quantities of nitrogen found stored in the sand at different depths have been plotted, and the total quantity in the tank determined. From these plottings the following table has been made, giving the quantity of nitrogen in parts per 100,000 of the weight of the dry sand for the different depths, at several dates:—

Distance below Surface. (Inches.)	Dec., 1888.	Feb., 1889.	June, 1889.	Nov., 1889.	Distance below Surface. (Inches.)	Dec., 1888.	Feb., 1889.	June, 1889.	Nov., 1889.
0 to ¼, . . .	32.48	77.65	115.19	405.72	18, ...	3.20	2.55	2.00	1.75
1, ...	18.00	39.80	26.20	42.00	24, ...	3.15	2.40	1.65	1.60
2, ...	12.20	22.20	16.10	28.40	36, ...	3.15	2.40	1.20	1.60
4, ...	6.80	10.60	9.30	14.20	48, ...	2.70	2.40	1.05	1.15
8, ...	3.75	6.00	4.45	5.30	60, ...	1.65	2.40	.95	.75
12, ...	3.30	3.85	2.90	3.05					

From the plottings the total quantity stored in the tank at different dates has been determined, and the results placed in the following table:—

Summary of Total Nitrogen applied to Tank No. 1; the Amount which came off in the Effluent; and the Amount Stored in the Tank, together with a Balance unaccounted for.

	From Jan. 1, 1888, to Dec. 1, 1888.	Per Cent. of Nitrogen applied.	From Dec. 1, 1888, to June 1, 1889.	Per Cent. of Nitrogen applied.	From June 1, 1889, to Nov. 1, 1889.	Per Cent. of Nitrogen applied.	From Jan. 1, 1888, to Nov. 1, 1889.	Per Cent. of Nitrogen applied.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*	
Amount of nitrogen applied, .	16.62		8.34		10.67		35.63	
Amount, came off in effluent, .	6.68	40	5.98	72	6.53	61	19.19	54
Difference, ...	9.94		2.36		4.14		16.44	
Amount stored in tank, . .	4.27	26	—.22	—3	1.76	17	5.81	16
Amount not accounted for, .	5.67	34	2.58	31	2.38	22	10.63	30

In the first year 40 per cent. of the nitrogen applied came off in the effluent; in the second year, 66 per cent.; and in the whole time, 54 per cent. During the six months including the spring nitrification, 72 per cent. came off, and there were two of these months in which more than 90 per cent. came off.

The amount stored in the tank the first year was 26 per cent.; in the second year, 8 per cent.; and in the whole time, 16 per cent. During the six months including the spring nitrification, the amount stored was diminished by 3 per cent. of the amount applied; and from February 1 to June 1, not given in the table, the amount stored was reduced by 23 per cent. of the amount applied, or by 26 per cent. of the whole amount that had been stored to the beginning of this period.

The amount unaccounted for the first year was 34 per cent. of the applied; in the second year, 26 per cent.; and in the whole time, 30 per cent.

This part of the nitrogen we have been unable to find. It may have escaped as ammonia, or as nitrogen gas, in the course of the oxidation of the organic matter; or it may have entered into intermediate nitrogenous compounds which evade our chemical tests. It may be that, if more samples had been taken daily, from which a closer approximation to the mean quantity of nitrogen coming off daily could have been made, the above result would have been somewhat modified; but, upon examination, it is found that the sample analysed has been taken at such a time of the day as to give very nearly the mean quantity of nitrogen shown by series of samples taken at intervals through the twenty-four hours. The sampling during the second year is thought to represent both the sewage and the effluent somewhat better than in the first year.

Removal of Stored Nitrogen by Nitrification.

From the table of total nitrogen in the tank at the several dates, it will be seen that during the two years there has been a general increase in the nitrogen stored in the upper foot in depth. This increase was interrupted, and the quantity decreased, during the period of active nitrification of April and May, 1889.

Beneath the upper foot of sand the quantity of nitrogen found there during the second year has been continually less than at the end of the first year. The smallest quantity found was after the rapid nitrification of the spring months, since which it has remained nearly constant.

The total quantity stored in the tank was, on Dec. 1, 1888, 4.27 pounds. This continued to increase, and, in February, amounted to 5.49 pounds. During the spring nitrification it decreased 1.44 pounds, leaving on June 1, only 4.05 pounds. From this time to

November it increased to 5.81 pounds; making a total increase in the second year of 36 per cent.

Stored Nitrogen increasing near the Surface and Decreasing elsewhere.

Looking for the location of this increase, we find it near the top of the tank; in fact, comparing the different layers at the end of the first and second years, we find that in the upper inch in depth of sand there is nearly five times as much nitrogen at the end of the second year as at the end of the first year; and that below the upper inch there is a little less nitrogen now stored in the tank than at the end of the first year.

This indicates that the way to make this tank the most efficient filter for the coming year would be to remove the upper inch in depth and replace it with clean sand.

Looking further at the effect of nitrification in the spring months in removing stored nitrogen, we find that in the upper inch it was not reduced, but in every inch below it was removed, the percentage removed increasing with the distance below the top; the first two feet losing 24 per cent., and the lower feet losing 40, 50 and 60 per cent. The amount of nitrogen actually removed from each of the lower three feet was greater than in the fourth foot from the bottom; hence we may safely conclude that in this tank of open sand nitrification goes on more completely in the lower than in the upper layers of the sand.

This being the case, the question arises whether this material will not thoroughly cleanse itself of nitrogenous matter, and continue indefinitely an efficient filter, if the upper layer is turned under, as with a plough, at convenient intervals. As this will be a more economical method of treating the upper layer of a large filtering area than to replace the upper inch with new sand, it will first be tried here through a season of rapid nitrification. It is to be remembered that the surface of this sand has not in any way been disturbed during the past year. The sewage has been run over the surface, week after week, and has, at times, formed a tough surface covering, which would allow but little water to pass below it, if it were not curled up by the sun and air in the intervals between the applications.

A mechanical analysis of the sand in the upper inch in depth, recently made, is nearly identical with that made of the clean sand two years ago. There is no increase in the finer particles. About eight per cent. of the volume of this inch was made up of particles of the organic sediment, which, being dried and not pulverized, were in this analysis classed among the coarse particles.

Quality of Effluent at Different Hours in the Day.

At different times in the past year, series of analyses have been made to determine the quality of the effluent at different times in the day, when the rate of flow, — due to the application of sewage being limited to one hour of a day, — differed through a wide range.

In April, 1889, 300 gallons were applied daily. This disappeared from the surface in from one to two hours, showing the surface to be somewhat clogged. The effluent was not so well purified in this as in the six following months; and there was the greatest difference in quality of the effluent with different rates of flow.

When flowing out in the morning, before sewage was applied, at the slow rate of one gallon in fifteen minutes, the average analysis on four days in April was as follows: —

Free ammonia,	0.0220
Albuminoid ammonia,	0.0132
Nitrates,	2.1

When flowing out at the rate of a gallon in a minute, after sewage was applied, the average analysis on the same days was: —

Free ammonia,	0.1634
Albuminoid ammonia,	0.0294
Nitrates,	1.40

The effluent that had come down through the sand at the slow rate had had longer time in which to become purified of its organic matter, as shown by its less amount of ammonia and by the larger amount of nitrates. Probably all that was coming out at this time of slow flow had been as much as three days on the passage; while, of that which came out through this open sand at the increasing rates after sewage had been applied, later experiments have shown that a small percentage of it came directly down from the sewage within an hour and a half; consequently the effluent was very much less purified, the sum of ammonias being five times as great, and the nitrates but seventy per cent. as great.

In August, 1889, when 500 gallons were applied every other day, this amount disappeared from the surface in less than an hour; the effluent was much better purified than in April; and there was much less difference in the quality of effluent between slow and rapid rates of flow, although the rapid rate was four times as great as in April.

When the rate of flow was one gallon in ten minutes, in August, the average analysis was as follows: —

Free ammonia,	0.0022
Albuminoid ammonia,	0.0116
Nitrates,	2.3

When the rate had on the same days increased to four gallons in one minute, the analyses averaged: —

Free ammonia,	0.0148
Albuminoid ammonia,	0.0243
Nitrates,	2.1

Here the sum of the ammonias was three times as great at the rapid flow, and the nitrates were ninety per cent. of those with slow flow.

Other series confirm these results in showing a much less difference in quality, at different rates, when the filter is purifying more completely; and they also indicate that the purifying process of a decrease in free ammonia, and an increase in nitrates, takes place rapidly in this tank, a marked change occurring in one or two hours. A discussion of these later results belongs, however, with the next year's work.

Tables of series of both chemical and biological examinations of the effluent of Tank No. 1 may be found immediately following the tables of daily observations upon this tank.

The increase in the ammonias, the decrease in the nitrates, and the large increase in the number of bacteria in the effluent soon after the increase in flow, due to applying sewage, shown in these tables, is, in the light of recent experiments, plainly due to some of the sewage, first applied, flowing rapidly through the sand, before there is time for the usual complete chemical changes or for the death of the bacteria.

MICROSCOPICAL EXAMINATION OF THE EFFLUENT OF TANK No. 1.

The organisms here designated as microscopic include those readily distinguished by microscopes of ordinary power, but do not include bacteria.

When city water was filtering through this tank, in December, 1887, and in the early part of January, 1888, there were commonly found in five gallons of the effluent a very few small fungi (Leptothrix and Crenothrix) and an occasional ciliated infusorian. After sewage effluent came, in the last of January, the above vegetable forms were more abundant, together with zoospores and yeast. A single specimen each of the diatoms, Asterionella and Melosira, were reported; but none have been seen since. In March, only a few Leptothrix and a single Amœba were found.

In the following months of the year 1888, the number of organisms reported is the number found upon or in the fine cloth strainer, through which five gallons of the effluent had passed.

In June, the number of organisms found in five gallons was: Leptothrix, 15; and yeast, 2. In July, the number of Leptothrix averaged 50, and of Chlorococcus, 5; but the number of animal forms was greater, including Monas, 250; Enchelys, 17; Paramoecium, 5; and Monura, 75. In August, no vegetable forms were found; except on one day Leptothrix to the number of 150. The number of animal forms averaged as follows: Monas, 85; Trachelomonas, 12; Rotifera, 56; and Anguillula, 1.

In September, there were no vegetable forms found, except on one day 100 Leptothrix. The animal forms averaged as follows: Arcella, 2; Monas, 55; ciliate infusoria, 5; Lepadella, 3; Anguillula, 1; Monocerca, 2; and Rotifer, 1. In October, the only vegetable form was Leptothrix, which was found, on two of the five days when observations were made, to the number of 22. In the early part of the month the worms Anguillula and Rotifer were found once, to the number of 2. In November, no organisms were found on three of the four days when observations were made; and on the fourth day, Monas, to the number of 20, and Ciliata, to the number of 100, were found in the five gallons examined.

In December, 1888, no organisms were found. In July, 1889, no organisms were found in the effluent as it ordinarily flowed out; but, the question arising whether any organisms were living in the underdrains, the effluent was, on August 3, stopped until about 30 gallons accumulated in the underdrains and gravel on the floor of the tank. This was allowed to run out rapidly; and there were found, in one sample of 200 cubic centimeters, 1 Crenothrix, 1 Leptothrix and 2 Anguillulas. Again, on August 7, 50 gallons were held back; and, upon being let out rapidly, no organisms were found. On August 12, several samples were examined with great care during the regular flow, as it was increasing in quantity after the application of sewage. The first sample of 200 c.c., flowing at a very slow rate, contained 1 Trachelomonas and 1 fungus hypha. A second sample, at a faster rate of flow, contained 7 Crenothrix, 1 Anguillula and 2 dead infusoria. A third sample, at a still faster rate, contained 8 Asterionella (apparently alive and healthy) and 4 bacterial clots (Zooglœa). The fourth sample, at the most rapid rate of flow, contained 3 yeast groups and 2 fungus spores.

On August 15, about 80 gallons were held back, by closing the outlet. Upon opening the outlet a little, and allowing the stream to flow gently and then increasing the rate up to one-third of the daily maximum rate, no organisms were found in three samples of 200 c.c. each. But, upon opening the outlet and allowing the effluent to rush out many times as fast as the daily flow, there were found in one sample 2 Anguillulas and 3 Euplotes. A second sample, running slower, gave 1 bacterial clot and 1 Anguillula. At still slower rates, no organisms were found; but, after the greatest rate of the daily flow had passed, there were found, in one sample, 50 Chlorococcus, and, two hours later, 5 Tabellaria and 1 Spirostomum.

On Aug. 22, 1889, 16 gallons were backed up in the tank, and when this flowed out in quantity, up to 1,000 c.c. per minute, no organisms were found; but when the rate reached 3,000 c.c. per minute, and for ten minutes after, when the rate was less, there were found four or five organisms in 200 c.c. of water — generally Leptothrix, Anguillula and spores. After this backed-up water had run out, and the rate of flow had reached 4,000 c.c. per minute from the down-coming sewage, which had in the mean time been applied, the same organisms named above were found in six samples of 200 c.c. each, the number averaging: Lepthothrix, 1; Anguillula, 2; and spores, 2. In one or two cases single specimens of yeast, ciliated infusoria, and monads were observed. These organisms were all that were found in samples of 200 c.c. of effluent.

At the same time, a single cubic centimeter of the sewage contained: yeast, 40,000; ciliate infusoria, 6; and Monas, 5, with an occasional Crenothrix.

Of the large number of microscopic organisms in the sewage, it is evident that a very small fraction, if any, get through the sand, and it is probable that some of those found in the effluent increase in the underdrains.

To determine if the underdrains and gravel on the floor of the tank contained more microscopic organisms than the effluent ordinarily flowing through them, experiments were made on Aug. 28 and 30, 1889, by forcing back into the underdrains and gravel 10 or 15 gallons of water, containing no organisms, and allowing it to immediately run out rapidly. The number of organisms in samples of 200 c.c. of each washing are given below:—

	August 28.		August 30.	
	First Washing.	Second Washing.	Third Washing.	Fourth Washing.
Leptothrix,	4	25	-	-
Anguillula,	-	1	1	1
Spores,	-	7	2	-
Infusoria,	3*	1*	-	-
Tabellaria,	23	6	-	4
Zooglœa,	20	30	-	-
Monas,	-	-	-	1
Crenothrix,	-	-	-	1

* Dead.

These washings extended over less than one-fifth of the area of the tank, and gave a rapid flow over perhaps one-tenth of the area of the bottom, and washed out more organisms from the sand on the first day than on the second.

The experiments with effluent held back in the underdrains and let out rapidly, and with water containing no microscopic forms being forced into the underdrains from below, and coming out rapidly, bearing organisms in considerable number at first, but with numbers decreasing when repeated, indicate that organisms grow and increase in the underdrains, but do not prove whether an exceedingly small percentage of some kinds of those applied with the sewage may not come through the sand. It is to be expected that few, if any, vegetable organisms requiring light would survive the passage; and none have been found in the effluent, except Tabellaria, Asterionella and Melosira, which were found on a few occasions under circumstances when it is more than probable that they were accidentally introduced, and did not belong in the effluent; and except Chlorococcus, which probably survives the passage through this sand.

The organisms which are characteristic of the effluent of Tank No. 1 are those species of fungi, worms, and infusoria that live in drains, and on wet stones and sands.

The most common form of the fungi, Leptothrix, has a filamentous form, that would appear to make its passage through the sand improbable. The Anguillulas (vinegar eels), which were found on only three occasions, in the first year in number averaging 2, are found sometimes in the sewage, and are in the upper inch of the sand of this tank, but have not been found by microscopical examination of the sand below the upper layer. Their mode of motion would render it very difficult for them to pass through the sand.

Of the infusoria, the structure and mode of motion of the ciliated forms would seem to render their passage through the sand improbable. The monads are so small that their passage is quite possible; and, as they are more commonly found, and in larger numbers, than other microscopic organisms, we have supposed that some of them came through the sand, although it is quite certain that they increase in the underdrains; but, upon examining by the microscope the sand taken from the tank, from top to bottom, no monads have been found in it.

The zooglœa, or bacterial clots, are found in this sand at different points from top to bottom of the tank; and there is little doubt that they originate from the sewage applied to this tank, but probably come into their present form in the sand and in the underdrains.

The spores found in August, 1889, were at that time abundant in most of the waters at the Station, as well as in waters from other parts of the State, but were only once observed in the sewage. Their nature was not determined.

The greatest numbers of organisms found in the sewage and in the effluent from Tank No. 1 were in August, September and October, 1888. Those most numerous and constant in the sewage were Leptothrix, yeast cells, Chlorococcus and Monas. Of these, Leptothrix was constantly found in the sewage, averaging 237 per gallon. These were found about half of the time in the effluent, to the number of 16 in a gallon. Yeast cells, found constantly in the sewage, averaging 20,000 per gallon, were not found in the effluent. Chlorococcus, found constantly in the sewage, averaging 237 per gallon, were not found in the effluent. Monas, found half of the time in the sewage, to the number of 14 in a gallon, were found as often in the effluent, to the number of 20 in a gallon.

During these three months, yeast cells and Chlorococcus were not found to come through the tank. Leptothrix, if it came through, as it may have done to some extent, was found at about 3 per cent. of the number in the sewage, and Monas was increased in number 40 per cent. It may be the last two organisms came through to some extent, and increased in the gravel and underdrains. In the following two months no microscopic organisms were found in the effluent.

It may be that the spores or eggs of some of the few organisms found in the effluent are able to survive the passage of the sand, and develop in the underdrains, when it is impossible for the mature organisms to pass through. But the number of microscopic organisms found in the effluent being much smaller than the number found in ordinary drinking waters, it becomes evident that the conditions met with in the filter are very unfavorable for the passage and development of such germs.

Bacteria in the Effluent of Tank No. 1.

Organisms still smaller than those which have been designated as microscopic organisms are found in enormous quantities in sewage, and to a less extent in nearly all waters, as well as in the air. These are generally classed as vegetable organisms, but some of them may be animal organisms. The name "bacteria," will be used to include all of the organisms too small to be readily distinguished by microscopes of ordinary power.

Method of determining the Number of Bacteria.

The number of bacteria in any liquid is determined, not by counting, with a microscope of very high magnifying power, the number to be seen in an extremely small particle of the liquid, but by taking a cubic centimeter (somewhat less than a cubic half-inch) of the liquid and mixing it with a larger volume of slightly warmed gelatinous fluid, which will serve for food for bacteria, and pouring the mixture upon a glass plate, where it will stiffen. This, oeing protected from air containing bacteria, is allowed to stand at a proper temperature for two days, or sometimes three days, in which time each live bacterium is supposed to grow into a colony, so large that it can readily be seen by the naked eye; and these colonies are counted, and their number is taken as the number of bacteria in the cubic centimeter of the original liquid.

When the number of bacteria is very large, — as in sewage, where the number in a cubic centimeter often exceeds 1,000,000, — the colonies treated as above would run together so that they could not be counted. To prevent this, the sewage is first diluted by a given number of times its volume of water containing no bacteria, and a cubic centimeter of this liquid is used; and then the counting is limited to a certain fraction, say one-tenth of the whole plate of gelatinous fluid containing the colonies; and the number counted, multiplied by ten, and by the degree of dilution, is taken as the number in a cubic centimeter of the sewage.

The precise method used in these determinations, and the extreme care necessary to be taken in collecting samples, and in all of the manipulations of these samples, may be found described in the accompanying report of Professor Sedgwick. Suffice it to say here, that, with all of the care practicable, there is almost sure to be a small number of bacteria entering the sample from the air; so that, if but two or three bacteria are found in a sample, it may be regarded as containing none. This is probably the case if the number counted is as high as six.

Tables of the number of bacteria found in a cubic centimeter of sewage and of the effluent from this tank, are given at the end of this section.

Effect of First Sewage in increasing the Number of Bacteria.

For the month previous to the application of sewage to this tank, it was filtering city water at a rapid rate. The number of bacteria in a cubic centimeter of the applied water was 76, and in the effluent 24. After applying sewage which contained from half a million to one million and a half bacteria in a cubic centimeter, the number in the effluent increased rapidly, till at the end of ten days it was 387,600 in a cubic centimeter. This was the highest number ever found in this effluent; and in two weeks it fell to 1,443. During the ten days when the number of bacteria was increasing so rapidly, it is probable that sewage obstructed by frost in the tank was entering the lower part of the tank through a few channels, on the edges of which it was mingling more or less with water originally in the tank, which contained some absorbed oxygen and was probably accompanied by some air. When this water was entirely removed, and the sand contained a liquid having so much organic matter that the oxygen which went into the tank with it was quickly reduced, the bacteria appear not to have been able to live during the passage through the sand. The amount of obstruction by frost cannot be definitely known. If there had been no obstruction during the time the bacteria were increasing, the time of passage would have been four days; and the time of passage during the following two weeks, when the number of bacteria was decreasing so rapidly, would have been eight days.

Another condition which may have had an influence in decreasing the number of bacteria was the very cold weather, which was several degrees colder during the latter than during the former period. But it is not plain that this could produce the effect, when we find that the temperature of the applied sewage was within a degree or two of 36°, and the effluent had the same temperature, in both periods.

Examining all of the tanks after sewage was applied, we find the same general condition of enormous numbers of bacteria coming through with the first sewage, — the highest at any time in the experience with the tank, — and then rapidly decreasing soon after sewage takes full possession of the tank. This occurred in tanks numbered 1, 2, 4, 6 and 7, which were all exposed to the same extremely cold weather in January, when it occurred. But it also occurred in quite as marked a degree in tanks numbered 11, 12, 13 and 14, which were housed, and were not exposed to severe cold.

After February 7, when the bacteria of Tank No. 1 numbered 1,443, new holes were cut through the frost, through which sewage entered into parts of the tank not before receiving much if any sewage; and the effect upon bacteria appears to have been like putting sewage upon a new tank, — the number increased to 42,840; and twelve days later was 722.

With the changes which followed in clearing off the ice and removing frost by applying sewage at higher temperatures, the number of bacteria remained high, averaging, from February 23 to March 6, 37,363, or 3 per cent. of the number in the sewage. But after the frost was thawed out the number was uniformly much lower, averaging, from March 20 to 31, 5,840, or one-half of one per cent. of the number in the sewage.

Bacteria much less in Number after Nitrification began.

With April, nitrification began; and the number of bacteria averaged in the month 2,326, which is one-eighth of one per cent. of the number then in the sewage. From this time through the next year and a half, nitrification has continued; and the number of bacteria, varying much from day to day, has generally been a very small fraction of one per cent. of the number in the sewage.

The following table gives the number of bacteria by monthly averages found in a cubic centimeter of the effluent of Tank No. 1, taken generally semiweekly, in the forenoon, through the whole time that it has filtered sewage: —

Monthly Averages of the Number of Bacteria found in Effluent of Tank No. 1.

	Number of Bacteria per Cubic Centimeter.			Number of Bacteria per Cubic Centimeter.	
	1888.	**1889.**		**1888.**	**1889.**
January,	120,125	4,819	July,	4,661	6,838
February,	14,593	4,316	August,	58	966
March,	24,195	1,336	September,	1,062	132
April,	2,326	90	October,	657	1,184
May,	3,129	91	November,	739	–
June,	4,032	199	December,	2,394	–

This table is made up of what have been called the semiweekly counts of bacteria in the effluent. The monthly number of counts varies from four to twelve. They were intended to be taken regularly, twice a week, in the forenoon, with the expectation that such a record would show a fair average of the number in the effluent and the comparative number at different seasons of the year; but during the second year it was found that the number in the effluent of this tank increased very much after the sewage was applied for the day, the maximum occurring near two o'clock in the afternoon; and the relation of the mean number for the day to the number counted at the regular time in the forenoon varied much with the completeness of purification at the time.

Hourly counts made on three days in March, 1889, gave a mean for the twelve hours of the day of 4,492, and indicated that the mean of the twelve night hours would have been about 300. In June, 1889, 86 counts, taken generally at 8 A.M. and 2 and 5 P.M., gave an average number of 11,853; and in July a similar average of 65 counts was 6,667.

The number of bacteria in the effluent, given in the table, averages for the past year and a half 2,054; and for three months of the time, when the nitrates were the highest, the number averaged but 80; while the number applied in the sewage was more than a million.

The Number of Bacteria after an Application of Sewage greater than before.

The number in the effluent of this tank varies much from day to day, and also varies from hour to hour, depending upon the rate of flow. The tank was generally covered with sewage once a day, or once in two days. In about an hour after it was applied the rate of flow at the outlet would increase, and continue increasing for an hour or two, and then decrease.

In December, 1888, the number of bacteria in the morning, before sewage was applied, was found to be 46. After sewage had been on an hour, and the flow at the outlet had increased twelve times, the number of bacteria found in a cubic centimeter was 1,230. The next sample showed 1,748. When at the maximum rate of flow, which was 50 per cent. greater than the last, the number was 1,640. After this, the number fell off in seven hours to about 200. On Jan. 23, 1889, the number in the morning was 98; a little after the maximum rate of flow, the number was 16,478; two hours later, it was 5,000; and after five more hours, it was 1,300. This was a day when the number was unusually large. A week later, the maximum number found was 2,900; and the minimum, 40. In March and April, 1889, series were taken, extending from morning till night, in which the average maximum number was 24,971, and the average minimum number was 57, the maximum number being associated with a rapid rate of flow. Tables giving these and other series of observations may be found following the tables of daily observations on Tank No. 1.

A Few of a Foreign Species of Bacteria pass through the Sand.

On May 21, 1889, an enormous number of bacteria, of a species not found in our sewage, which are easily distinguished by the color of the colonies and rapid liquefaction of the gelatine, were put upon the surface of Tank No. 1; and for ten days three samples of the effluent were examined daily; but none of these bacteria, called Bacillus prodigiosus, were found in the effluent. The number of bacteria found in these ten days varied from 7 to 8,640 per cubic centimeter, and averaged 1,873. It is possible that some of the Bacillus prodigiosus came through and were lost before observations were made for them, as it was then supposed that none could get through in less than twenty-four hours after they were applied, and search for these was begun twenty-one hours after the application.

On June 20, another experiment, like that of May 21, was made, and observations commenced within three hours, and three or more observations were made each day for a month; but none of this species were found.

The experiment was repeated at 11 A.M. of August 27, by the application, on a square foot of the surface of this tank, from which the upper inch in depth of sand had been removed, of two gallons of liquid, containing 1,400,000 of the Bacillus prodigiosus per cubic centimeter, or eleven thousand millions of these organisms. Observations were begun on the effluent in twenty-one hours, and continued hourly. None of this species were found until the thirtieth hour, when a single specimen was found, and again on the thirty-fourth hour a single specimen was found. These are the only specimens that were found. It is possible, as stated above, that some of this liquid, bearing a few bacteria, may have passed before observations were commenced; but, if any survived, the percentage must have been extremely small.

Proof that Bacteria come down through the Sand of this Tank.

In July and August, 1889, a number of experiments were made, to determine whether the increased number of bacteria, with the greater flow, was due to an increased number coming through the sand of the filter at the time, or was due to washing out, by the greater flow, numbers that had accumulated or grown in the underdrains, or gravel on the bottom, exposed to air entering the outlet pipe.

For this purpose the outlet pipe was closed when water was slowly coming through the sand, for several hours, and the accumulated water drawn out at varying velocities. It was found in July, that, when this accumulated water was drawn at a slow rate, very few bacteria were in it, and that the number increased greatly when drawn at a rapid rate, showing that some bacteria were then washed off from their resting places in the drains and in the gravel; but this increase was not as great as the increase from slow to a like rapid motion when the effluent was coming directly, at these varying rates, through the sand. From this it follows that the great increase in the number with the increase in rate from this tank is due to more bacteria coming down through the sand with the increased rate, rather than coming from any accumulation in the underdrains and gravel.

The Greatest Number of Bacteria come through with the Sewage first applied after an Intermission.

In August, many experiments were made to determine the question examined in July.

On August 3 and 7, the number of bacteria found in the effluent that had come slowly through the sand and was drawn out of the underdrains at different rates, was from 14 to 118.

On August 12, at the minimum rate of flow, the number was 143. As the maximum rate was approached, the number reached 13,832, and gradually fell from this number, in an hour and a half, to 4,964.

At 9 P.M., August 14, the outlet was closed; and liquid that slowly came through the sand accumulated till 10.16 A.M., August 15. Then this was let out at varying rates, from the slowest ordinary flow to five times the rate of the maximum daily flow. The number of bacteria varied from 8 to 126, averaging for the two hours 65 per cubic centimeter. At the end of this time the rate of flow began to increase from the 500 gallons of sewage that had been applied. The number of bacteria increased with the rate of flow to a maximum of 4,644, and for five hours averaged 1,540.

These experiments were continued through August with like results, showing that, when the rate of flow was increasing to its maximum, which generally occurred within an hour after sewage was applied, and at the time when the sewage was just disappearing from the surface, the number of bacteria increased from about 150 to 10,000; while an increase in rate of flow through the underdrains, by forcing water into them and allowing it to rush out with as great velocity, increased the number to a few hundred, proving conclusively that these large numbers of bacteria came down through the sand; and the reason for this has been found by experiments made since the work of the first two years was closed. In sand as coarse and even-grained as this of Tank No. 1, the air space, after the filter has drained for a day, is, as has been said, about twice as great as the space then occupied with water. Upon the first application of sewage in large quantity, the air passages are quite large, and the sewage flows into them rapidly, passing by much of the water held in the more minute interstices; and a small percentage of this sewage reaches the outlet within an hour, bearing with it quite a large fraction of the bacteria it contained when applied. In one case, the effluent, within the first hour after sewage was applied, contained nearly twenty per cent. sewage and nearly five per cent. of the number of bacteria in the sewage; that is, the small portion of sewage that came through the sand in the first hour brought with it about one-quarter of the bacteria it contained at starting. In one hour and a half from starting, the number was reduced to one-twelfth; and later still, the fraction was rapidly reduced; until, in twenty-two hours, the number in the effluent was but one-sixth of one per cent. of the number starting.

General Conclusions in Regard to Management.

From these experiments we conclude, that, with a filtering area of coarse, open sand like this, a less number of bacteria will live to get through the sand, if the underdrains are as deep as practicable, and as far apart as will serve to drain the quantity of sewage to be applied; and, if the sewage be applied in small quantities at a time, rather than in large quantities, — that is, if one inch in depth upon the area be applied three times a day, — the number of bacteria reaching the drains will be less than if three inches in depth be applied once a day.

With these precautions, it is probable that the number of bacteria that can survive the passage from the surface to the underdrains may be kept constantly as low as one in a thousand of the number applied, and possibly at a still lower number. But it now appears that, whatever precautions we may take with this coarse sand, we cannot depend upon so complete removal of bacteria as with some layers of finer sand that will make necessary a detention of the most forward particles of the sewage for two or three days within the sand.

In general, we may say that the conditions that give the most complete nitrification of the effluent, and purify it most completely from organic matter, as shown by the small amounts of free and albuminoid ammonia, will also make it most nearly impossible for bacteria to survive the passage.

Bacteria found in the Sand at Different Depths on Different Dates.

The sand of Tank No. 1 has been examined for bacteria by boring a hole from top to bottom, and taking out samples at different depths, and determining the number of bacteria in a gramme of the sand. By the method used in obtaining the specimen from the lower part of the tank, it is probable that some uncertainty enters the results, from sand falling from the upper layers.

Number of Bacteria found in One Gramme of Sand taken from Tank No. 1 at Various Depths, on Different Dates.

Distance from Surface.	December 19, 1888.	February 4, 1889.	May 22, 1889.	Distance from Surface.	December 19, 1888.	February 4, 1889.	May 22, 1889.
0 to ¼ inch, . .	132,400	262,800	–	12 inches, . . .	–	–	34,100
0 to ½ inch, . .	–	–	1,760,000	14 inches, . . .	–	8,900	–
½ to ¾ inch, . .	–	106,300	105,000	15 inches, . . .	10,700	–	–
1¼ to 1½ inch, .	–	–	207,200	19 inches, . . .	–	–	12,300
2 inches, . . .	–	46,200	60,200	24 inches, . . .	12,900	–	–
3 inches, . . .	43,600	–	111,300	32 inches, . . .	–	6,900	31,300
4 inches, . . .	–	40,000	–	36 inches, . . .	10,500	–	–
5 inches, . . .	–	–	63,400	46 inches, . . .	–	–	4,900
8 inches, . . .	17,900	–	30,700	48 inches, . . .	61,000?	6,200	–
9 inches, . . .	–	14,600	–	60 inches, . . .	16,700	–	4,100

In general, there is a very marked decrease in number from the top to the bottom, there being in the lower inch but three per cent. of the number in the upper inch; but the most rapid decrease is in the upper few inches. Below the first foot the number is more nearly constant, and averages about six per cent. of the number in the upper foot.

In the upper foot, particularly near the surface, there is a decided increase in the number from December to May; but this increase is not apparent below the first foot. In this respect it follows the amount of stored nitrogen in the sand given in a previous table.

In December, 1888, nearly all of the bacteria found in the sand were of one kind. In February, the same kind was abundant, but was accompanied by others.

The number of bacteria usually found in the sewage as it is turned upon the several filters, and the number found in the effluent of Tank No. 1, are given in the following table: —

The Number of Bacteria found in a Cubic Centimeter of the Sewage applied to Tank No. 1 by Two Counts, and in the Effluent by One Count on the Dates given.

Date.	Number of Bacteria per Cubic Centimeter.		Date.	Number of Bacteria per Cubic Centimeter.		Date.	Number of Bacteria per Cubic Centimeter.	
	Sewage applied.	Effluent.		Sewage applied.	Effluent.		Sewage applied.	Effluent.
1888.			**1888**—Con.			**1888**—Con.		
Jan. 3, . .	–	27	June 7, . .	1,260,000	–	Dec. 21, . .	409,500	27
5, . .	–	36	9, . .	–	3,168	26, . .	415,800	8,232
7, . .	–	43	14, . .	–	528			
10, . .	897,611	14	16, . .	1,584,000	–	**1889.**		
12, . .	1,071,048	9,094	21, . .	–	8,400	Jan. 2, . .	355,000	11,020
14, . .	873,000	42,170	July 3, . .	–	4,928	8, . .	518,800	1,306
17, . .	765,000	135,900	13, . .	–	5,886	15, . .	228,900	8,910
19, . .	1,512,000	222,234	17, . .	–	4,230	22, . .	2,038,400	41
21, . .	1,848,000	387,600	21, . .	–	3,600	29, . .	305,600	2,820
24, . .	126,000	86,490	Aug. 7, . .	–	38	Feb. 6, . .	173,950	9,828
26, . .	1,050,000	170,080	16, . .	–	72	12, . .	134,600	2,516
28, . .	929,250	15,246	21, . .	–	63	19, . .	137,550	30
31, . .	1,134,000	12,315	Sept. 11, . .	–	2,508	27, . .	102,400	4,890
Feb. 2, . .	211,200	2,119	15, . .	–	113	Mar. 5, . .	126,300	5,075
4, . .	258,000	3,420	20, . .	–	2,442	12, . .	251,300	65
7, . .	873,600	1,443	25, . .	–	183	19, . .	227,000	149
9, . .	960,000	42,840	29, . .	–	62	26, . .	767,600	53
11, . .	237,000	1,613	Oct. 2, . .	167,327	2,122	Apr. 2, . .	625,650	236
14, . .	690,000	23,229	4, . .	90,090	–	9, . .	891,750	82
16, . .	270,000	25,433	6, . .	125,791	150	16, . .	3,963,000	74
18, . .	391,600	8,167	9, . .	313,200	–	24, . .	1,382,600	27
21, . .	1,125,000	722	11, . .	313,420	88	30, . .	624,650	29
23, . .	1,440,000	42,570	13, . .	196,560	–	May 7, . .	1,431,150	32
25, . .	720,000	13,090	16, . .	698,443	817	14, . .	1,679,200	37
28, . .	630,000	10,467	19, . .	498,400	–	21, . .	511,500	249
Mar. 1, . .	1,440,000	22,092	20, . .	859,600	–	28, . .	523,300	45
3, . .	1,440,000	5,761	23, . .	599,640	–	June 4, . .	1,175,750	33
6, . .	984,000	130,200	25, . .	840,000	110	11, . .	1,151,050	26
10, . .	2,317,986	–	27, . .	590,604	–	18, . .	653,800	146
15, . .	3,058,760	–	Nov. 1, . .	155,800	–	26, . .	2,387,400	590
17, . .	1,452,000	30,492	3, . .	–	136	July 2, . .	449,200	–
20, . .	1,144,800	1,661	6, . .	473,040	–	9, . .	–	185
22, . .	891,660	4,697	8, . .	1,539,400	75	16, . .	703,100	26,680
24, . .	1,622,800	2,596	10, . .	270,650	–	23, . .	879,500	138
27, . .	912,825	9,006	13, . .	401,750	74	30, . .	403,200	351
29, . .	3,310,512	11,248	16, . .	150,400	–	Aug. 6, . .	188,850	41
31, . .	2,516,832	–	19, . .	1,106,900	280	12, . .	365,900	–
Apr. 3, . .	1,217,100	1,056	21, . .	277,300	–	19, . .	236,100	1,890
19, . .	1,440,000	119	23, . .	213,800	60	27, . .	660,500	–
25, . .	–	211	26, . .	336,450	–	Sept. 2, . .	699,050	81
28, . .	–	7,920	28, . .	1,762,950	3,799	10, . .	1,310,200	75
May 8, . .	1,900,800	735	30, . .	562,050	–	16, . .	529,500	34
10, . .	–	217	Dec. 5, . .	146,500	56	24, . .	–	337
19, . .	1,320,000	3,232	7, . .	138,600	–	Oct. 2, . .	596,000	45
22, . .	–	4,422	10, . .	148,650	15	10, . .	799,800	4,650
26, . .	–	13,200	12, . .	937,300	–	16, . .	1,272,000	32
29, . .	–	60	14, . .	406,400	3,640	25, . .	1,108,800	9
31, . .	–	40	17, . .	140,000	–			

TABLES OF CHEMICAL ANALYSES OF EFFLUENT,

From Filter Tank No. 1,

FROM JANUARY 1, 1888, TO OCTOBER 13, 1889; TOGETHER WITH THE QUANTITY AND TEMPERATURE OF THE SEWAGE APPLIED AND OF THE EFFLUENT; AND OTHER NOTES; FOLLOWED BY TABLES OF SERIES OF CHEMICAL AND BIOLOGICAL EXAMINATIONS.

FILTER TANK No. 1.

January, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	1,000	1,128	0.60	2.75	.0020	.0082	.0102	.24	.0180	None.	-	-	-
2, . .	1,000	1,072	-	-	-	-	-	-	-	-	-	-	-
3, . .	1,000	1,000	0.85	2.35	.0012	.0076	.0088	.25	.0200	Present.	-	-	-
4, . .	1,000	979	0.80	2.60	.0014	.0080	.0094	.29	.0180	None.	-	-	-
5, . .	1,000	992	0.80	2.45	.0008	.0078	.0086	.24	.0200	None.	-	-	-
6, . .	1,000	952	0.80	2.65	.0010	.0072	.0082	.25	.0200	None.	-	-	-
7, . .	1,000	1,002	-	-	-	-	-	-	-	-	-	-	-
8, . .	1,000	1,011	1.10	2.55	.0010	.0072	.0082	.24	.0200	None.	-	-	-
9, . .	1,000	994	.60	2.60	.0006	.0048	.0054	.24	.0150	Present.	-	-	-
10, . .	408	331	-	-	-	-	-	-	-	-	-	37°	-
11, . .	408	379	10.60	10.25	.3600	.1900	.5500	2.76	.0300	-	-	37°	-
12, . .	300	256	7.10	9.65	.1540	.0530	.2070	2.28	.0600	Present.	-	34°	-
13, . .	300	266	4.95	11.55	.2210	.0480	.2690	3.02	.0550	Present.	-	36°	-
14, . .	300	287	-	-	-	-	-	-	-	-	-	36°	-
15, . .	300	305	3.75	12.75	.5740	.0780	.6520	3.09	.0700	Present.	-	38°	-
16, . .	300	269	2.65	11.65	.4760	.0520	.5280	2.66	.1000	-	-	36°	-
17, . .	300	253	-	-	-	-	-	-	-	-	-	34°	-
18, . .	300	239	3.85	13.85	1.0670	.0800	1.1470	3.09	.0350	Present.	-	34°	-
19, . .	300	224	-	-	-	-	-	-	-	-	-	35°	35°
20, . .	300	215	3.20	12.70	.6600	.0400	.7000	2.62	.0300	Present.	-	34°	-
21, . .	282	185	-	-	-	-	-	-	-	-	-	35°	-
22, . .	252	185	4.20	13.40	.8000	.0400	.8400	2.76	.0180	Present.	-	35°	-
23, . .	150	123	-	-	-	-	-	-	-	-	-	35°	-
24, . .	150	119	2.60	11.60	.7100	.0500	.7600	2.08	.0500	Present.	-	34°	-
25, . .	150	119	1.90	11.60	.6800	.0600	.7400	2.20	.0300	Present.	-	35°	-
26, . .	150	103	-	-	-	-	-	-	-	-	-	34°	-
27, . .	150	115	5.70	11.90	.5600	.0400	.6000	1.95	.0180	Present.	-	35°	-
28, . .	150	119	-	-	-	-	-	-	-	-	-	35°	36°
29, . .	150	129	3.40	14.50	.9600	.0500	1.0100	3.28	.0100	Present.	-	37°	-
30, . .	140	138	-	-	-	-	-	-	-	-	-	36°	-
31, . .	150	133	1.50	10.80	.5600	.0900	.6500	1.89	.0400	Present.	-	36°	36°

City water applied till January 9. January 10. — First sewage applied. January 14. — Two inches of snow and ice on surface. January 17. — Three-eighths inch of ice.

Total effluent to end of month, 4,488 gallons.

Filter Tank No. 1 — Continued.

February, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	150	138	3.10	11.70	.8100	.0750	.8850	2.35	.0200	Present.	-	35°	35°
2, . .	175	100	-	-	-	-	-	-	-	-	-	36°	36°
3, . .	150	137	1.60	11.20	.4600	.0300	.4900	2.15	.0200	Present.	-	35°	36°
4, . .	150	131	-	-	-	-	-	-	-	-	-	37°	36°
5, . .	150	172	5.00	12.40	.6500	.1100	.7600	2.56	.0200	Present.	-	40°	35°
6, . .	150	149	-	-	-	-	-	-	-	-	-	40°	36°
7, . .	150	130	1.60	11.60	.6300	.0200	.6500	2.48	.0150	Present.	-	39°	36°
8, . .	150	145	2.70	12.00	.6200	.0700	.6900	2.66	.0150	Present.	-	37°	35°
9, . .	150	141	-	-	-	-	-	-	-	-	-	-	36°
10, . .	150	133	1.20	13.30	.5700	.0200	.5900	3.04	.0100	Present.	-	38°	-
11, . .	150	129	-	-	-	-	-	-	-	-	-	36°	36°
12, . .	150	114	2.00	12.10	.4600	.0200	.4800	2.66	.0070	Present.	-	44°	-
13, . .	150	131	-	-	-	-	-	-	-	-	-	44°	-
14, . .	150	176	1.30	11.00	.4200	.0400	.4600	2.06	.0200	Present.	-	44°	37°
15, . .	150	155	4.20	10.60	.4500	.0500	.5000	2.10	.0200	Present.	-	44°	36°
16, . .	150	128	-	-	-	-	-	-	-	-	-	44°	36°
17, . .	170	128	1.60	10.20	.2700	.0700	.3400	2.22	.0200	Present.	-	51°	36°
18, . .	150	162	-	-	-	-	-	-	-	-	-	63°	-
19, . .	150	191	-	-	-	-	-	-	-	-	-	54°	-
20, . .	150	325	2.40	11.00	.3400	.0600	.4000	2.68	.0100	Present.	-	44°	36°
21, . .	150	232	-	-	-	-	-	-	-	-	-	44°	35°
22, . .	150	163	1.60	8.30	.2600	.0600	.3200	1.83	.0100	Present.	-	57°	35°
23, . .	150	166	-	-	-	-	-	-	-	-	-	65°	36°
24, . .	150	147	1.60	7.80	.2100	.0500	.2600	1.90	.0100	Present.	-	48°	-
25, . .	150	173	-	-	-	-	-	-	-	-	-	57°	35°
26, . .	150	245	-	-	-	-	-	-	-	-	-	55°	36°
27, . .	150	173	1.20	7.90	.1500	.0500	.2000	1.71	.0150	Present.	-	44°	36°
28, . .	150	145	-	-	-	-	-	-	-	-	-	54°	35°
29, . .	150	126	1.90	7.40	.1850	.0110	.1960	1.90	.0150	.0025	-	54°	36°

February 2. — Two holes cut through 10 inches of frost; 12 inches of snow and ice on surface. February 7 and 14. — Cut through 10 inches of frost. February 17. — A trench 18 inches wide cut through the ice, and through 2 inches of sand, 12 inches from edge of tank. Sewage settled ¾ inch in 12 minutes.

Total quantity of effluent to end of month, 9,071 gallons.

Filter Tank No. 1 — Continued.

March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	150	144	-	-	-	-	-	-	-	-	-	55°	36°
2, . .	150	147	2.30	8.50	.2120	.0210	.2330	2.00	.0180	.0008	-	51°	-
3, . .	150	172	-	-	-	-	-	-	-	-	-	58°	36°
4, . .	150	141	-	-	-	-	-	-	-	-	-	38°	36°
5, . .	150	153	1.80	10.00	.2400	.0230	.2630	2.38	.0180	.0005	-	54°	36°
6, . .	150	146	-	-	-	-	-	-	-	-	-	48°	36°
7, . .	150	148	2.10	8.90	.2400	.0240	.2640	2.18	.0250	.0020	-	51°	35°
8, . .	1,040	-	-	-	-	-	-	-	-	-	-	57°	-
9, . .	1,000	-	-	-	-	-	-	-	-	-	-	55°	-
10, . .	160	-	-	-	-	-	-	-	-	-	-	69°	-
11, . .	-	222	-	-	-	-	-	-	-	-	-	-	37°
12, . .	200	215	2.50	10.60	.2200	.0320	.2520	1.90	.0180	.0002	-	75°	38°
13, . .	200	210	-	-	-	-	-	-	-	-	-	75°	36°
14, . .	200	207	2.00	10.40	.2560	.0250	.2810	2.16	.0200	.0002	-	80°	38°
15, . .	250	214	-	-	-	-	-	-	-	-	-	68°	37°
16, . .	250	2,324	2.60	11.60	.4320	.0330	.4650	2.44	.0080	.0003	3h. 10m.	70°	36°
17, . .	-	61	-	-	-	-	-	-	-	-	-	-	39°
18, . .	-	28	-	-	-	-	-	-	-	-	-	-	42°
19, . .	150	55	1.60	11.70	.3040	.0180	.3220	2.60	.0150	.0004	-	59°	40°
20, . .	150	111	-	-	-	-	-	-	-	-	-	68°	39°
21, . .	150	207	-	-	-	-	-	-	-	-	-	63°	38°
22, . .	150	251	-	-	-	-	-	-	-	-	-	61°	38°
23, . .	150	170	2.70	9.10	.2400	.0140	.2540	2.40	.0250	.0011	0 m.	68°	39°
24, . .	150	112	-	-	-	-	-	-	-	-	-	60°	39°
25, . .	150	125	-	-	-	-	-	-	-	-	-	65°	40°
26, . .	150	141	2.80	9.10	.4000	.0190	.4190	2.44	.0200	.0009	-	67°	39°
27, . .	150	330	-	-	-	-	-	-	-	-	0 m.	65°	39°
28, . .	150	211	1.70	9.50	.3750	.0190	.3940	2.36	.0300	.0009	-	52°	39°
29, . .	150	172	-	-	-	-	-	-	-	-	0 m.	52°	39°
30, . .	150	138	1.40	9.80	.3650	.0180	.3830	1.98	.0550	.0017	-	53°	39°
31, . .	150	123	-	-	-	-	-	-	-	-	-	60°	39°

Effluent colorless, generally nearly clear and with very little sediment.

March 8. — Outlet pipe closed at 7.41 A.M. Twenty gallons water applied at 140° and 20 at 200°. March 10. — Surface entirely covered with sewage. March 11. — Outlet pipe opened at 9.31 A.M. March 12. — Surface covered with sewage. March 14. — Snow all taken from surface. March 16. — Sewage run on side of tank that contained frost. March 17. — Frost on 25 square feet of surface.

Total effluent to end of month, 15,749 gallons.

Filter Tank No. 1 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	150	144	2.00	8.70	.3750	.0290	.4040	2.04	.0850	.0010	-	46°	40°
2, . .	150	340	2.50	10.10	.3650	.0180	.3830	2.10	.0550	.0014	-	43°	40°
3, . .	150	142	2.20	9.40	.3600	.0230	.3830	1.88	.1000	.0016	-	42°	40°
4, . .	150	138	1.70	9.60	.3680	.0170	.3850	1.94	.1100	.0012	-	42°	41°
5, . .	150	119	-	-	-	-	-	-	-	-	-	44°	41°
6, . .	150	250	2.50	9.80	.3150	.0100	.3250	2.13	.1300	.0015	-	46°	41°
7, . .	150	141	-	-	-	-	-	-	-	-	-	45°	-
8, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
9, . .	150	151	2.50	11.80	.4000	.0190	.4190	2.66	.1100	.0012	-	36°	41°
10, . .	150	135	4.00	10.40	.4200	.0200	.4400	2.60	.2000	.0019	0 m.	45°	42°
11, . .	150	229	-	-	-	-	-	-	-	-	-	46°	41°
12, . .	150	120	-	-	-	-	-	-	-	-	-	43°	42°
13, . .	150	151	2.50	12.40	.4200	.0170	.4370	2.70	.2800	.0022	-	42°	42°
14, . .	150	156	-	-	-	-	-	-	-	-	-	45°	42°
15, . .	150	147	-	-	-	-	-	-	-	-	-	45°	42°
16, . .	150	180	3.40	22.30	.3600	.0200	.3800	2.98	.3000	.0022	-	42°	42°
17, . .	150	130	-	-	-	-	-	-	-	-	-	45°	43°
18, . .	150	140	4.00	12.50	.3700	.0200	.3900	2.88	.4000	.0023	-	45°	42°
19, . .	150	143	-	-	-	-	-	-	-	-	-	42°	43°
20, . .	150	138	4.20	14.00	.3850	.0140	.3990	3.05	.5500	.0030	-	43°	42°
21, . .	300	296	-	-	-	-	-	-	-	-	-	44°	43°
22, . .	-	58	-	-	-	-	-	-	-	-	-	-	-
23, . .	150	98	6.00	14.90	.3100	.0130	.3230	3.50	.6500	.0040	-	42°	44°
24, . .	150	140	-	-	-	-	-	-	-	-	15 m.	43°	43°
25, . .	150	137	7.60	14.90	.3350	.0130	.3480	3.57	.9000	.0040	-	42°	44°
26, . .	150	148	-	-	-	-	-	-	-	-	-	46°	44°
27, . .	150	140	18.30	14.50	.2750	.0130	.2880	3.20	1.0000	.0040	-	44°	45°
28, . .	300	280	-	-	-	-	-	-	-	-	-	46°	46°
29, . .	-	52	-	-	-	-	-	-	-	-	-	-	-
30, . .	-	6	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, generally nearly clear and with little sediment.

April 8. — River high; outlet of tank closed at 6.20 A.M. April 9. — Outlet opened at 8.26 A.M. April 30. — River high; outlet closed at 8.35 A.M. Organisms visible to the naked eye in samples throughout the month.

Total effluent to end of month, 20,198 gallons.

Filter Tank No. 1 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
2, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
3, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
4, . .	150	113	13.60	17.80	.1850	.0130	.1980	3.71	2.0000	.0100	0 m.	45°	47°
5, . .	300	227	-	-	-	-	-	-	-	-	-	45°	47°
6, . .	-	49	-	-	-	-	-	-	-	-	-	-	-
7, . .	150	102	14.50	23.70	.1150	.0130	.1280	3.04	3.0000	.0081	0 m.	50°	-
8, . .	150	133	-	-	-	-	-	-	-	-	-	48°	50°
9, . .	150	181	16.90	19.30	.0850	.0110	.0960	3.16	2.8000	.0078	-	50°	50°
10, . .	150	139	-	-	-	-	-	-	-	-	-	51°	50°
11, . .	150	168	-	-	-	-	-	-	-	-	-	51°	50°
12, . .	300	445	18.00	15.50	.0400	.0060	.0460	2.68	2.0000	.0142	-	49°	51°
13, . .	-	41	-	-	-	-	-	-	-	-	-	-	-
14, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
15, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
16, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
17, . .	150	246	-	-	-	-	-	-	-	-	-	49°	51°
18, . .	150	162	-	-	-	-	-	-	-	-	-	49°	51°
19, . .	300	306	9.90	17.10	.0080	.0106	.0186	2.57	2.0000	.0047	-	50°	51°
20, . .	-	44	-	-	-	-	-	-	-	-	-	-	-
21, . .	150	91	-	-	-	-	-	-	-	-	-	51°	52°
22, . .	150	146	-	-	-	-	-	-	-	-	-	52°	53°
23, . .	150	131	10.20	15.60	.0032	.0080	.0112	3.15	2.3000	.0011	-	53°	53°
24, . .	150	128	-	-	-	-	-	-	-	-	-	55°	53°
25, . .	150	153	-	-	-	-	-	-	-	-	-	56°	53°
26, . .	300	237	9.80	15.80	.0008	.0096	.0104	3.79	1.0000	.0003	-	57°	54°
27, . .	-	52	-	-	-	-	-	-	-	-	-	-	-
28, . .	150	125	-	-	-	-	-	-	-	-	-	57°	54°
29, . .	150	174	-	-	-	-	-	-	-	-	-	56°	57°
30, . .	150	168	6.30	19.40	.0012	.0090	.0102	4.46	.7000	.0005	-	57°	57°
31, . .	150	137	-	-	-	-	-	-	-	-	-	57°	56°

Effluent colorless, generally nearly clear and with very little sediment.

May 4. — Outlet opened at 7.48 A.M. May 13. — River high; outlet closed at 2.55 P.M. May 17. — Outlet opened at 7.39 A.M. Organisms visible to the naked eye in samples throughout the month.

Total effluent to end of month, 24,096 gallons.

Filter Tank No. 1 — Continued.

June, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	150	141	–	–	–	–	–	–	–	–	–	58°	57°
2, . .	300	251	10.10	22.10	.0004	.0152	.0156	4.59	.8500	.0001	–	60°	58°
3, . .	–	45	–	–	–	–	–	–	–	–	–	–	–
4, . .	150	99	–	–	–	–	–	–	–	–	–	59°	59°
5, . .	150	152	–	–	–	–	–	–	–	–	–	61°	59°
6, . .	150	179	7.40	19.40	.0006	.0134	.0140	4.40	1.8000	.0010	–	61°	62°
7, . .	150	148	–	–	–	–	–	–	–	–	–	64°	62°
8, . .	150	98	–	–	–	–	–	–	–	–	–	64°	61°
9, . .	300	250	11.20	14.40	.0010	.0148	.0158	4.44	.9500	.0002	–	66°	61°
10, . .	–	50	–	–	–	–	–	–	–	–	–	–	–
11, . .	150	90	–	–	–	–	–	–	–	–	–	68°	63°
12, . .	150	131	–	–	–	–	–	–	–	–	–	65°	62°
13, . .	150	141	8.70	21.10	.0004	.0096	.0100	5.58	1.2500	.0004	–	64°	63°
14, . .	150	154	–	–	–	–	–	–	–	–	–	65°	62°
15, . .	150	217	–	–	–	–	–	–	–	–	–	65°	63°
16, . .	300	287	5.60	26.30	.0016	.0136	.0152	7.46	.8500	.0002	–	66°	65°
17, . .	–	50	–	–	–	–	–	–	–	–	–	–	–
18, . .	300	273	–	–	–	–	–	–	–	–	–	68°	67°
19, . .	300	256	–	–	–	–	–	–	–	–	–	68°	66°
20, . .	300	291	8.60	24.20	.0018	.0130	.0148	7.52	.8000	.0007	–	70°	66°
21, . .	300	278	–	–	–	–	–	–	–	–	–	69°	66°
22, . .	300	281	–	–	–	–	–	–	–	–	–	69°	68°
23, . .	600	551	4.00	16.50	.0018	.0126	.0144	4.00	.6000	.0002	–	73°	68°
24, . .	–	52	–	–	–	–	–	–	–	–	–	–	–
25, . .	300	275	–	–	–	–	–	–	–	–	–	71°	69°
26, . .	300	289	–	–	–	–	–	–	–	–	–	69°	68°
27, . .	300	357	6.20	23.30	.0018	.0128	.0146	7.15	.6500	.0002	–	69°	69°
28, . .	300	283	–	–	–	–	–	–	–	–	–	68°	67°
29, . .	300	290	–	–	–	–	–	–	–	–	–	66°	68°
30, . .	600	552	4.20	23.70	.0006	.0288	.0294	6.85	.4500	.0004	–	67°	69°

Effluent colorless, generally very nearly clear and with very little sediment. Organisms visible to the naked eye in samples throughout the month.

April 30. — Sample deposited a white crystalline precipitate on standing.

Total effluent to end of month, 30,607 gallons.

Filter Tank No. 1 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	-	54	-	-	-	-	-	-	-	-	-	-	-
2, . .	300	221	-	-	-	-	-	-	-	-	-	65°	68°
3, . .	300	300	-	-	-	-	-	-	-	-	-	65°	69°
4, . .	300	279	4.40	26.00	.0006	.0172	.0178	7.17	.6000	.0014	-	67°	70°
5, . .	300	295	-	-	-	-	-	-	-	-	-	68°	69°
6, . .	300	290	-	-	-	-	-	-	-	-	-	68°	69°
7, . .	600	546	4.40	26.90	.0026	.0152	.0178	6.98	.8000	.0004	-	70°	72°
8, . .	-	60	-	-	-	-	-	-	-	-	-	-	-
9, . .	300	239	-	-	-	-	-	-	-	-	-	69°	69°
10, . .	300	277	-	-	-	-	-	-	-	-	-	69°	70°
11, . .	300	283	6.20	26.10	.0016	.0200	.0216	7.91	.9000	.0008	-	69°	72°
12, . .	300	367	-	-	-	-	-	-	-	-	0 m.	69°	69°
13, . .	300	284	-	-	-	-	-	-	-	-	-	69°	69°
14, . .	600	570	3.20	23.60	.0012	.0138	.0150	5.03	1.0700	.0003	-	69°	72°
15, . .	-	49	-	-	-	-	-	-	-	-	-	-	-
16, . .	300	247	-	-	-	-	-	-	-	-	-	69°	70°
17, . .	300	275	-	-	-	-	-	-	-	-	-	69°	71°
18, . .	300	270	10.00	28.50	.0012	.0160	.0172	8.85	1.1000	.0003	-	71°	69°
19, . .	300	358	-	-	-	-	-	-	-	-	-	71°	71°
20, . .	300	352	-	-	-	-	-	-	-	-	-	70°	73°
21, . .	600	558	7.20	27.80	.0122	.0180	.0302	5.91	1.5000	.0200	-	71°	73°
22, . .	-	55	-	-	-	-	-	-	-	-	-	-	-
23, . .	300	312	-	-	-	-	-	-	-	-	-	72°	72°
24, . .	300	291	-	-	-	-	-	-	-	-	-	72°	73°
25, . .	300	292	6.80	31.00	.0048	.0140	.0188	7.72	1.3000	.0010	-	73°	73°
26, . .	300	281	-	-	-	-	-	-	-	-	-	73°	73°
27, . .	300	294	-	-	-	-	-	-	-	-	-	72°	71°
28, . .	600	547	7.80	26.10	.0006	.0224	.0230	6.50	1.2200	.0020	-	72°	74°
29, . .	-	50	-	-	-	-	-	-	-	-	-	-	-
30, . .	300	233	-	-	-	-	-	-	-	-	-	71°	72°
31, . .	300	290	-	-	-	-	-	-	-	-	-	72°	74°

Effluent colorless, generally very nearly clear and with very little or no sediment.

July 4. — White sediment deposited in sample. July 7. — Na Cl in sample 11.50 parts. Loss on ignition obtained by adding $Na_2 CO_3$ and filtering, 4.90 parts.

Organisms visible to the naked eye in samples throughout the month.

Total effluent to end of month, 39,426 gallons.

Filter Tank No. 1 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	300	299	1.80	31.60	.0014	.0164	.0178	8.39	1.4300	.0010	-	73°	75°
2, . .	300	284	-	-	-	-	-	-	-	-	-	73°	74°
3, . .	300	293	-	-	-	-	-	-	-	-	-	73°	73°
4, . .	600	573	2.10	28.80	.0106	.0236	.0342	6.57	1.4000	.0060	-	74°	74°
5, . .	-	52	-	-	-	-	-	-	-	-	-	-	-
6, . .	300	272	-	-	-	-	-	-	-	-	-	74°	74°
7, . .	300	382	-	-	-	-	-	-	-	-	-	72°	75°
8, . .	300	285	3.40	23.10	.0000	.0210	.0210	5.22	1.4300	.0004	-	72°	74°
9, . .	300	296	-	-	-	-	-	-	-	-	-	73°	73°
10, . .	300	286	-	-	-	-	-	-	-	-	-	72°	75°
11, . .	600	573	-	-	-	-	-	-	-	-	-	73°	73°
12, . .	-	51	-	-	-	-	-	-	-	-	-	-	-
13, . .	300	415	-	-	-	-	-	-	-	-	-	70°	72°
14, . .	300	312	-	-	-	-	-	-	-	-	-	-	73°
15, . .	300	259	2.00	21.60	.0080	.0150	.0230	4.80	1.1000	.0003	20 m.	69°	72°
16, . .	300	291	-	-	-	-	-	-	-	-	-	69°	74°
17, . .	300	328	-	-	-	-	-	-	-	-	-	70°	72°
18, . .	600	603	8.40	20.60	.0010	.0252	.0262	5.40	1.3000	.0040	-	71°	73°
19, . .	-	60	-	-	-	-	-	-	-	-	-	-	-
20, . .	300	239	-	-	-	-	-	-	-	-	-	71°	74°
21, . .	300	284	-	-	-	-	-	-	-	-	-	71°	74°
22, . .	300	455	5.60	27.90	.0466	.0248	.0714	6.20	1.4000	.0012	-	70°	73°
23, . .	300	290	-	-	-	-	-	-	-	-	18 m.	70°	73°
24, . .	300	280	-	-	-	-	-	-	-	-	-	70°	74°
25, . .	600	560	3.60	29.20	.0122	.0192	.0314	8.94	1.2500	.0024	-	70°	73°
26, . .	-	50	-	-	-	-	-	-	-	-	-	-	-
27, . .	300	230	-	-	-	-	-	-	-	-	-	71°	73°
28, . .	300	282	-	-	-	-	-	-	-	-	20 m.	70°	71°
29, . .	300	271	4.10	39.30	.0840	.0210	.1050	12.24	1.1250	.0030	-	69°	73°
30, . .	300	278	-	-	-	-	-	-	-	-	21 m.	70°	73°
31, . .	300	275	-	-	-	-	-	-	-	-	-	70°	73°

Effluent generally colorless; from very slightly to distinctly turbid; occasionally milky and with very little sediment.

From August 1, onward, residue on evaporation obtained with Na_2 CO_3. August 15. — Sewage disappeared from surface more slowly than a few days before. August 18 and 25. — First 300 gallons of sewage applied disappeared in about 20 minutes. August 21. — First sediment noticed on surface.

Organisms visible to the naked eye in samples throughout the month.

Total effluent to end of month, 48,834 gallons.

Filter Tank No. 1 — Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	600	606	4.80	.4210	.1160	.0450	.1610	14.70	.8000	.0040	-	71°	73°
2, . .	-	56	-	-	-	-	-	-	-	-	-	-	-
3, . .	300	242	-	-	-	-	-	-	-	-	22 m.	70°	74°
4, . .	300	328	-	-	-	-	-	-	-	-	-	71°	70°
5, . .	300	255	2.70	43.80	.0320	.0260	.0580	14.00	1.1200	.0010	20 m.	70°	72°
6, . .	300	268	-	-	-	-	-	-	-	-	42 m.	68°	72°
7, . .	300	283	-	-	-	-	-	-	-	-	22 m.	68°	71°
8, . .	600	768	1.90	41.40	.0344	.0240	.0584	12.60	1.0800	.0030	-	66°	72°
9, . .	-	91	-	-	-	-	-	-	-	-	-	-	-
10, . .	300	246	-	-	-	-	-	-	-	-	20m.30s.	67°	70°
11, . .	300	307	-	-	-	-	-	-	-	-	-	67°	71°
12, . .	300	378	3.70	30.00	.0056	.0166	.0222	8.85	1.1500	.0006	-	66°	69°
13, . .	300	285	-	-	-	-	-	-	-	-	-	66°	70°
14, . .	300	274	-	-	-	-	-	-	-	-	26 m.	64°	70°
15, . .	600	555	9.00	31.70	.0242	.0470	.0712	8.63	1.0400	.0034	-	64°	70°
16, . .	-	60	-	-	-	-	-	-	-	-	-	-	-
17, . .	300	226	-	-	-	-	-	-	-	-	20 m.	65°	70°
18, . .	300	508	-	-	-	-	-	-	-	-	-	65°	67°
19, . .	300	287	.60	24.50	.0252	.0286	.0538	4.78	.7000	.0010	21 m.	64°	67°
20, . .	300	288	-	-	-	-	-	-	-	-	24 m.	64°	68°
21, . .	300	460	-	-	-	-	-	-	-	-	-	63°	66°
22, . .	600	635	2.10	23.00	.0360	.0198	.0558	5.27	.8000	.0140	-	61°	66°
23, . .	-	59	-	-	-	-	-	-	-	-	-	-	-
24, . .	300	232	-	-	-	-	-	-	-	-	-	58°	65°
25, . .	300	286	-	-	-	-	-	-	-	-	-	58°	65°
26, . .	300	561	.70	24.40	.0160	.0088	.0248	5.02	.9800	.0028	-	58°	63°
27, . .	300	295	-	-	-	-	-	-	-	-	38 m.	58°	65°
28, . .	300	279	-	-	-	-	-	-	-	-	-	57°	63°
29, . .	600	567	2.20	28.10	.0424	.0234	.0658	7.24	.8200	.0080	-	55°	61°
30, . .	-	61	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, generally slightly turbid and with very little sediment.

September 6. — Sewage disappeared from surface slowly, as it was thicker than usual. September 8. — First 300 gallons applied disappeared in 20 minutes, and on August 15 in 23 minutes. September 15. — White precipitate in sample.

Total effluent to end of month, 58,580 gallons.

Filter Tank No 1 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	300	239	-	-	-	-	-	-	-	-	23 m.	53°	61°
2, . .	300	397	-	-	-	-	-	-	-	-	-	53°	61°
3, . .	300	314	1.70	28.10	.0120	.0188	.0308	6.80	1.0500	.0080	-	51°	61°
4, . .	300	289	-	-	-	-	-	-	-	-	-	50°	60°
5, . .	300	295	-	-	-	-	-	-	-	-	33 m.	50°	59°
6, . .	600	573	2.20	36.60	.1600	.0388	.1988	12.01	1.0000	.0060	-	50°	58°
7, . .	-	224	-	-	-	-	-	-	-	-	-	-	-
8, . .	300	323	-	-	-	-	-	-	-	-	-	52°	57°
9, . .	300	292	-	-	-	-	-	-	-	-	55 m.	51°	56°
10, . .	300	298	2.60	25.30	.1448	.0312	.1760	5.70	1.0000	.0080	-	49°	57°
11, . .	300	284	-	-	-	-	-	-	-	-	36 m.	49°	57°
12, . .	300	298	-	-	-	-	-	-	-	-	-	47°	55°
13, . .	600	603	3.70	25.30	.1600	.0346	.1946	5.37	1.0000	.0020	-	47°	54°
14, . .	-	62	-	-	-	-	-	-	-	-	-	-	-
15, . .	300	258	-	-	-	-	-	-	-	-	-	47°	54°
16, . .	300	295	-	-	-	-	-	-	-	-	1h.11m.	47°	55°
17, . .	300	351	2.80	24.40	.1376	.0250	.1626	4.80	1.0400	.0070	-	48°	53°
18, . .	300	327	-	-	-	-	-	-	-	-	-	47°	53°
19, . .	300	271	-	-	-	-	-	-	-	-	1h. 2m.	46°	54°
20, . .	600	605	1.50	21.20	.0616	.0148	.0764	4.12	1.0000	.0090	-	47°	52°
21, . .	-	73	-	-	-	-	-	-	-	-	-	-	-
22, . .	300	230	-	-	-	-	-	-	-	-	55 m.	45°	54°
23, . .	300	291	-	-	-	-	-	-	-	-	-	45°	53°
24, . .	300	406	1.80	21.30	.1320	.0390	.1710	4.12	1.2000	.0180	-	45°	51°
25, . .	300	310	-	-	-	-	-	-	-	-	-	45°	51°
26, . .	300	282	-	-	-	-	-	-	-	-	48 m.	45°	-
27, . .	600	582	4.40	21.50	.1920	.0434	.2354	4.91	1.0800	.0030	-	46°	51°
28, . .	-	97	-	-	-	-	-	-	-	-	-	-	-
29, . .	300	271	-	-	-	-	-	-	-	-	1h.17m.	46°	52°
30, . .	300	295	-	-	-	-	-	-	-	-	1h. 6m.	46°	52°
31, . .	300	279	2.80	26.00	.2090	.0210	.2300	7.93	1.0700	.0060	-	45°	52°

Effluent generally colorless and slightly turbid, and with very little sediment.
Total effluent to end of month, 68,293 gallons.

Filter Tank No. 1 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	300	289	-	-	-	-	-	-	-	-	-	47°	52°
2, . .	300	293	-	-	-	-	-	-	-	-	31 m.	46°	52°
3, . .	600	583	1.50	26.20	.1280	.0230	.1510	5.53	1.1500	.0060	-	48°	51°
4, . .	-	62	-	-	-	-	-	-	-	-	-	-	-
5, . .	300	229	-	-	-	-	-	-	-	-	-	48°	53°
6, . .	300	294	-	-	-	-	-	-	-	-	33 m.	49°	53°
7, . .	300	293	.90	34.40	.1680	.0190	.1870	9.71	1.5400	.0060	26 m.	50°	53°
8, . .	300	273	-	-	-	-	-	-	-	-	27 m.	49°	53°
9, . .	300	355	-	-	-	-	-	-	-	-	-	49°	54°
10, . .	600	703	1.10	33.20	.0600	.0090	.0690	8.90	1.5000	.0050	-	48°	53°
11, . .	-	89	-	-	-	-	-	-	-	-	-	-	-
12, . .	300	235	-	-	-	-	-	-	-	-	35 m.	45°	53°
13, . .	300	300	-	-	-	-	-	-	-	-	-	43°	52°
14, . .	300	317	4.00	22.60	.2280	.0940	.3220	5.26	.8000	.0025	-	43°	51°
15, . .	300	317	-	-	-	-	-	-	-	-	-	42°	50°
16, . .	300	341	-	-	-	-	-	-	-	-	-	42°	49°
17, . .	600	604	3.80	26.40	.4000	.0540	.4540	7.65	.8100	.0150	-	42°	47°
18, . .	-	46	-	-	-	-	-	-	-	-	-	-	-
19, . .	300	278	-	-	-	-	-	-	-	-	-	40°	48°
20, . .	300	307	-	-	-	-	-	-	-	-	31 m.	40°	48°
21, . .	300	281	2.10	23.60	.2600	.0460	.3060	5.00	.9000	.0012	-	38°	47°
22, . .	300	283	-	-	-	-	-	-	-	-	-	45°	47°
23, . .	300	293	-	-	-	-	-	-	-	-	-	44°	46°
24, . .	600	586	1.60	23.50	.2120	.0260	.2380	5.39	1.0700	.0012	-	45°	44°
25, . .	-	61	-	-	-	-	-	-	-	-	-	-	-
26, . .	300	251	-	-	-	-	-	-	-	-	-	45°	45°
27, . .	300	310	-	-	-	-	-	-	-	-	-	45°	43°
28, . .	300	321	1.60	21.70	.1680	.0130	.1810	3.87	1.1000	.0008	-	44°	44°
29, . .	300	287	-	-	-	-	-	-	-	-	-	46°	43°
30, . .	300	254	-	-	-	-	-	-	-	-	25 m.	46°	43°

Effluent generally colorless, very nearly clear and with very slight sediment.

November 1. — Tufts of grass pulled up and surface levelled over half the area, — the first change since February. November 22. — Canvas cover put over tank. An arrangement to distribute sewage more equally over surface put on. First 300 gallons applied November 3 disappeared in 35 minutes; November 17, in 22 minutes; November 24, in 25 minutes.

Total effluent to end of month, 77,422 gallons.

Filter Tank No. 1 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	600	598	2.30	19.80	.0680	.0130	.0810	3.90	1.0000	.0004	-	44°	42°
2, . .	-	62	-	-	-	-	-	-	-	-	-	-	-
3, . .	300	239	-	-	-	-	-	-	-	-	-	44°	44°
4, . .	300	291	-	-	-	-	-	-	-	-	24 m.	45°	43°
5, . .	300	283	2.00	23.70	.0520	.0160	.0680	5.00	.9200	.0008	22 m.	44°	43°
6, . .	300	302	-	-	-	-	-	-	-	-	-	46°	43°
7, . .	300	308	-	-	-	-	-	-	-	-	-	45°	43°
8, . .	600	570	1.50	31.80	.0520	.0220	.0740	9.60	.8500	.0004	47 m.	45°	43°
9, . .	-	65	-	-	-	-	-	-	-	-	-	-	-
10, . .	300	216	-	-	-	-	-	-	-	-	23 m.	45°	43°
11, . .	300	271	-	-	-	-	-	-	-	-	-	45°	41°
12, . .	300	322	1.80	22.80	.0280	.0290	.0570	5.15	.8000	.0004	-	44°	42°
13, . .	300	272	-	-	-	-	-	-	-	-	-	44°	41°
14, . .	300	283	-	-	-	-	-	-	-	-	27 m.	46°	39°
15, . .	600	552	2.60	22.50	.0490	.0230	.0720	4.56	.7000	.0004	-	45°	41°
16, . .	-	67	-	-	-	-	-	-	-	-	-	-	-
17, . .	300	255	-	-	-	-	-	-	-	-	25 m.	41°	41°
18, . .	300	258	-	-	-	-	-	-	-	-	-	45°	41°
19, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
20, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
21, . .	300	269	-	-	-	-	-	-	-	-	21 m.	46°	40°
22, . .	600	531	.70	18.70	.0370	.0310	.0680	3.46	.5700	.0005	-	45°	39°
23, . .	-	60	-	-	-	-	-	-	-	-	-	-	-
24, . .	300	234	-	-	-	-	-	-	-	-	23 m.	42°	40°
25, . .	300	298	-	-	-	-	-	-	-	-	-	45°	-
26, . .	300	305	.80	18.90	.0340	.0160	.0500	3.54	1.0000	.0003	-	45°	39°
27, . .	300	292	-	-	-	-	-	-	-	-	-	46°	39°
28, . .	300	299	-	-	-	-	-	-	-	-	24 m.	45°	39°
29, . .	600	556	1.40	22.70	.0290	.0280	.0570	4.30	.7700	.0003	-	45°	39°
30, . .	-	60	-	-	-	-	-	-	-	-	-	-	-
31, . .	300	242	-	-	-	-	-	-	-	-	-	45°	40°

Effluent generally colorless and slightly turbid, and with very little or no sediment.

December 8. — First 300 gallons sewage applied disappeared in 23 minutes, second 300 gallons in 24 minutes. December 15. — First 300 gallons disappeared in 24 minutes. December 19. — River high; outlet of tank closed at 5.10 A.M. One-half inch of frost on surface. December 21. — Outlet opened at 7.46 A.M. Two and one-half inches of frost on surface. December 29. — First 300 gallons sewage applied disappeared in 21 minutes.

Total effluent to end of month, 85,782 gallons.

Filter Tank No. 1 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	300	276	-	-	-	-	-	-	-	-	27 m.	45°	39°
2, . .	300	289	2.5	23.4	.0360	.0230	.0590	7.04	.6000	.0003	-	45°	40°
3, . .	300	276	-	-	-	-	-	-	-	-	26 m.	45°	40°
4, . .	300	291	-	-	-	-	-	-	-	-	21 m.	45°	40°
5, . .	600	570	1.4	25.0	.0130	.0140	.0270	5.71	.7500	.0004	-	45°	40°
6, . .	-	60	-	-	-	-	-	-	-	-	-	-	-
7, . .	300	230	-	-	-	-	-	-	-	-	26 m.	45°	40°
8, . .	300	281	-	-	-	-	-	-	-	-	-	45°	40°
9, . .	300	271	2.1	23.8	.0084	.0160	.0244	4.30	.7000	.0006	26 m.	45°	41°
10, . .	300	286	-	-	-	-	-	-	-	-	-	45°	40°
11, . .	300	282	-	-	-	-	-	-	-	-	27 m.	45°	41°
12, . .	600	568	1.4	22.9	.0010	.0172	.0182	4.45	.9800	.0003	-	44°	41°
13, . .	-	57	-	-	-	-	-	-	-	-	-	-	-
14, . .	300	234	-	-	-	-	-	-	-	-	23 m.	44°	41°
15, . .	300	272	-	-	-	-	-	-	-	-	20 m.	45°	40°
16, . .	300	285	0.6	26.0	.0008	.0178	.0186	6.33	.7000	.0002	-	44°	41°
17, . .	300	292	-	-	-	-	-	-	-	-	-	46°	41°
18, . .	300	280	-	-	-	-	-	-	-	-	26 m.	45°	40°
19, . .	600	551	0.6	21.7	.0038	.0166	.0204	4.39	.7000	.0001	-	44°	39°
20, . .	-	68	-	-	-	-	-	-	-	-	-	-	-
21, . .	300	223	-	-	-	-	-	-	-	-	24 m.	44°	39°
22, . .	300	278	-	-	-	-	-	-	-	-	23 m.	44°	39°
23, . .	300	284	1.4	20.4	.0008	.0118	.0126	3.85	.8000	.0001	24 m.	46°	39°
24, . .	300	299	-	-	-	-	-	-	-	-	25 m.	-	39°
25, . .	300	284	-	-	-	-	-	-	-	-	25 m.	44°	39°
26, . .	600	568	2.4	21.0	.0064	.0170	.0234	4.03	.8000	.0003	-	44°	38°
27, . .	-	59	-	-	-	-	-	-	-	-	-	-	-
28, . .	300	232	-	-	-	-	-	-	-	-	25 m.	44°	38°
29, . .	300	301	-	-	-	-	-	-	-	-	22 m.	45°	38°
30, . .	300	279	1.5	21.8	.0012	.0124	.0136	4.15	1.0000	.0001	-	46°	38°
31, . .	300	255	-	-	-	-	-	-	-	-	-	44°	38°

Effluent generally colorless and nearly clear, with little or no sediment.

January 5.— A little manganese in sample. January 22.—One inch of frost on surface. January 26.— First 300 gallons sewage applied disappeared in 24 minutes. One-half inch of frost on surface. January 29.— No frost on surface.

Total effluent to end of month, 94,563 gallons.

Filter Tank No. 1 — Continued.

February, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	300	300	-	-	-	-	-	-	-	-	25 m.	45°	39°
2, . .	600	588	2.3	19.4	.0114	.0218	.0332	4.22	.9000	.0006	-	44°	38°
3, . .	-	58	-	-	-	-	-	-	-	-	-	-	-
4, . .	300	225	-	-	-	-	-	-	-	-	-	44°	38°
5, . .	300	293	-	-	-	-	-	-	-	-	-	46°	38°
6, . .	300	298	2.2	19.8	.0720	.0350	.1070	4.04	.8000	.0006	-	44°	38°
7, . .	300	268	-	-	-	-	-	-	-	-	23 m.	45°	38°
8, . .	300	269	-	-	-	-	-	-	-	-	26 m.	44°	37°
9, . .	600	598	1.7	20.3	.0650	.0250	.0900	4.28	.8000	.0006	-	45°	37°
10, . .	-	57	-	-	-	-	-	-	-	-	-	-	-
11, . .	300	238	-	-	-	-	-	-	-	-	26 m.	44°	37°
12, . .	300	297	-	-	-	-	-	-	-	-	-	46°	38°
13, . .	300	306	2.5	19.4	.0590	.0240	.0830	3.80	.8000	.0008	24 m.	46°	37°
14, . .	300	283	-	-	-	-	-	-	-	-	24 m.	45°	37°
15, . .	300	294	-	-	-	-	-	-	-	-	-	45°	38°
16, . .	600	568	2.6	21.1	.0580	.0300	.0880	4.83	.7000	.0004	-	45°	37°
17, . .	-	54	-	-	-	-	-	-	-	-	-	-	-
18, . .	300	244	-	-	-	-	-	-	-	-	23 m.	44°	37°
19, . .	300	286	-	-	-	-	-	-	-	-	-	44°	38°
20, . .	300	306	1.1	20.1	.0150	.0170	.0320	3.11	.9000	.0005	24 m.	45°	38°
21, . .	300	271	-	-	-	-	-	-	-	-	-	45°	38°
22, . .	300	301	-	-	-	-	-	-	-	-	24 m.	46°	38°
23, . .	600	568	2.4	19.0	.0550	.0180	.0730	3.73	.9000	.0008	-	45°	37°
24, . .	-	59	-	-	-	-	-	-	-	-	-	-	-
25, . .	300	209	-	-	-	-	-	-	-	-	22 m.	45°	37°
26, . .	300	277	-	-	-	-	-	-	-	-	26 m.	45°	37°
27, . .	300	295	3.4	18.1	.0630	.0200	.0830	3.40	.8000	.0008	-	45°	37°
28, . .	300	301	-	-	-	-	-	-	-	-	-	45°	37°

Effluent generally colorless and nearly clear, with little sediment.

February 2.—The first 300 gallons sewage applied disappeared in 28 minutes; February 23, in 22 minutes.

Frost on surface as follows:—February 2, 1 inch; February 5, 1 inch; February 7, 3 inches; February 9, 3½ inches; February 20, 1½ inches; February 23, 1 inch; February 25, 3½ inches.

Total effluent to end of month, 102,674 gallons.

Filter Tank No. 1 — Continued.

March, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	300	304	-	-	-	-	-	-	-	-	23 m.	44°	37°
2, . .	600	567	2.2	20.4	.0710	.0270	.0980	4.15	.8000	.0006	-	35°	36°
3, . .	-	59	-	-	-	-	-	-	-	-	-	-	-
4, . .	300	238	-	-	-	-	-	-	-	-	27 m.	35°	38°
5, . .	300	299	-	-	-	-	-	-	-	-	32 m.	35°	37°
6, . .	300	296	2.6	18.9	.0400	.0190	.0590	3.02	.8000	.0004	-	35°	38°
7, . .	300	288	-	-	-	-	-	-	-	-	-	35°	37°
8, . .	300	279	-	-	-	-	-	-	-	-	-	34°	37°
9, . .	600	582	1.3	19.0	.0640	.0210	.0850	2.83	1.1000	.0010	-	33°	37°
10, . .	-	65	-	-	-	-	-	-	-	-	-	-	-
11, . .	300	235	-	-	-	-	-	-	-	-	-	33°	37°
12, . .	300	295	-	-	-	-	-	-	-	-	-	33°	37°
13, . .	300	304	2.0	21.1	.1680	.0280	.1960	3.57	1.1500	.0017	-	35°	37°
14, . .	300	284	-	-	-	-	-	-	-	-	39 m.	36°	37°
15, . .	300	292	-	-	-	-	-	-	-	-	31 m.	35°	37°
16, . .	600	586	3.6	24.1	.1360	.0790	.2150	3.71	1.4000	.0050	-	36°	37°
17, . .	-	60	-	-	-	-	-	-	-	-	-	-	-
18, . .	300	283	-	-	-	-	-	-	-	-	1 h. 1 m.	36°	37°
19, . .	300	290	-	-	-	-	-	-	-	-	52 m.	37°	38°
20, . .	300	288	3.5	20.1	.1760	.0530	.2290	4.02	1.0000	.0040	50 m.	38°	38°
21, . .	300	286	-	-	-	-	-	-	-	-	54 m.	37°	38°
22, . .	300	281	-	-	-	-	-	-	-	-	-	37°	38°
23, . .	600	564	2.4	22.7	.2120	.0320	.2440	3.89	1.4000	.0035	-	39°	38°
24, . .	-	63	-	-	-	-	-	-	-	-	-	-	-
25, . .	300	210	-	-	-	-	-	-	-	-	36 m.	41°	40°
26, . .	300	289	-	-	-	-	-	-	-	-	-	-	40°
27, . .	300	282	1.8	31.0	.1800	.0320	.2120	6.70	1.5000	.0020	-	41°	40°
28, . .	300	297	-	-	-	-	-	-	-	-	57 m.	41°	41°
29, . .	300	308	-	-	-	-	-	-	-	-	-	39°	41°
30, . .	600	566	3.6	26.3	.1800	.0470	.2270	6.14	1.4000	.0016	-	36°	41°
31, . .	-	67	-	-	-	-	-	-	-	-	-	-	-

Effluent from slightly to decidedly turbid, generally with very slight sediment, and with color from 0 to 0.15.

March 2. — No frost in surface except within 6 inches of outer edge. March 9. — Second 300 gallons sewage applied disappeared in 38 minutes; March 16, in 54 minutes. March 13. — Canvas cover removed from tank.

Total effluent to end of month, 111,781 gallons.

Filter Tank No. 1 — Continued.

April, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	300	321	-	-	-	-	-	-	-	-	32 m.	39°	41°
2, . .	300	383	-	-	-	-	-	-	-	-	-	38°	41°
3, . .	300	298	0.6	25.1	.0880	.0210	.1090	4.65	1.5000	.0010	-	38°	41°
4, . .	300	294	-	-	-	-	-	-	-	-	-	39°	41°
5, . .	300	291	-	-	-	-	-	-	-	-	1 h. 8 m.	39°	40°
6, . .	600	581	1.6	26.2	.1560	.0260	.1820	5.46	1.0000	.0020	-	41°	40°
7, . .	-	67	-	-	-	-	-	-	-	-	54 m.	-	-
8, . .	300	224	-	-	-	-	-	-	-	-	-	41°	41°
9, . .	300	271	-	-	-	-	-	-	-	-	-	42°	41°
10, . .	300	285	1.9	24.9	.1680	.0360	.2040	4.30	1.4000	.0060	-	41°	42°
11, . .	300	285	-	-	-	-	-	-	-	-	-	44°	43°
12, . .	300	292	-	-	-	-	-	-	-	-	1h. 17 m.	46°	43°
13, . .	600	565	-	-	-	-	-	-	-	-	-	47°	44°
14, . .	-	63	-	-	-	-	-	-	-	-	-	-	-
15, . .	300	227	-	-	-	-	-	-	-	-	-	45°	45°
16, . .	300	273	-	-	-	-	-	-	-	-	-	46°	46°
17, . .	300	278	3.8	31.4	.1360	.0320	.1680	5.60	2.4000	.0035	1h. 51m.	46°	46°
18, . .	300	336	-	-	-	-	-	-	-	-	-	48°	47°
19, . .	300	304	-	-	-	-	-	-	-	-	-	48°	48°
20, . .	600	569	2.0	27.8	.0880	.0300	.1180	4.60	2.0000	.0035	-	52°	48°
21, . .	-	70	-	-	-	-	-	-	-	-	-	-	-
22, . .	300	224	-	-	-	-	-	-	-	-	-	52°	49°
23, . .	300	265	-	-	-	-	-	-	-	-	-	51°	50°
24, . .	300	278	-	-	-	-	-	4.16	3.0000	.0009	2 h. 8 m.	50°	51°
25, . .	300	260	-	-	-	-	-	-	-	-	-	52°	52°
26, . .	300	405	-	-	-	-	-	-	-	-	-	53°	52°
27, . .	600	678	2.8	33.4	.0040	.0080	.0120	4.13	3.0000	.0003	-	53°	52°
28, . .	-	92	-	-	-	-	-	-	-	-	-	-	-
29, . .	300	217	-	-	-	-	-	-	-	-	-	54°	53°
30, . .	300	261	-	-	-	-	-	-	-	-	-	53°	53°

Effluent generally colorless and nearly clear, and with very slight sediment.
Total effluent to end of month, 120,738 gallons.

Filter Tank No. 1 — Continued.

May, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Nitrates.	Nitrites.
1, . .	300	259	1.8	27.4	.0096	.0174	.0270	4.25	2.6000	.0006	3 h.	51°	53°
2, . .	300	268	-	-	-	-	-	-	-	-	-	52°	53°
3, . .	300	285	-	-	-	-	-	-	-	-	-	52°	53°
4, . .	600	522	2.1	26.9	.1080	.0380	.1460	4.98	1.6000	.0030	-	52°	54°
5, . .	-	80	-	-	-	-	-	-	-	-	-	-	-
6, . .	300	226	-	-	-	-	-	-	-	-	1h. 44m.	54°	54°
7, . .	300	264	-	-	-	-	-	-	-	-	-	57°	54°
8, . .	300	263	0.8	33.3	.0240	.0100	.0340	4.82	3.0000	.0008	3h. 40m.	57°	55°
9, . .	300	262	-	-	-	-	-	-	-	-	-	59°	56°
10, . .	300	281	-	-	-	-	-	-	-	-	-	61°	57°
11, . .	600	513	3.2	32.2	.1040	.0450	.1490	4.67	1.7000	.0050	-	63°	57°
12, . .	-	99	-	-	-	-	-	-	-	-	-	-	-
13, . .	300	217	-	-	-	-	-	-	-	-	3 h.	63°	58°
14, . .	300	300	-	-	-	-	-	-	-	-	-	64°	59°
15, . .	300	295	2.5	26.8	.0560	.0340	.0900	4.76	2.0000	.0012	9h. 25m.	64°	60°
16, . .	300	249	-	-	-	-	-	-	-	-	-	65°	60°
17, . .	300	243	-	-	-	-	-	-	-	-	-	65°	61°
18, . .	-	90	1.2	32.1	.0040	.0136	.0176	4.82	2.6000	.0001	-	-	65°
19, . .	-	48	-	-	-	-	-	-	-	-	-	-	-
20, . .	300	295	-	-	-	-	-	-	-	-	-	67°	61°
21, . .	300	466	-	-	-	-	-	-	-	-	-	67°	62°
22, . .	300	351	3.8	33.0	.0240	.0500	.0740	4.42	2.5000	.0014	-	62°	63°
23, . .	300	262	-	-	-	-	-	-	-	-	2 h.	66°	63°
24, . .	300	274	-	-	-	-	-	-	-	-	3h. 45m.	63°	63°
25, . .	300	279	-	-	.1280	.0950	.2230	4.92	1.2000	.0038	-	62°	64°
26, . .	-	51	-	-	-	-	-	-	-	-	-	-	-
27, . .	300	271	-	-	-	-	-	-	-	-	-	59°	62°
28, . .	300	312	-	-	-	-	-	-	-	-	-	60°	63°
29, . .	300	278	1.0	30.2	.0320	.0140	.0460	5.01	1.8500	.0008	7h. 10m.	59°	62°
30, . .	300	269	-	-	-	-	-	-	-	-	-	60°	62°
31, . .	300	257	-	-	-	-	-	-	-	-	-	61°	61°

Effluent generally colorless and nearly clear, and with slight sediment.

May 18. — Sewage applied yesterday not yet disappeared. May 22. — Growth of short grass on surface. 28. — Sewage applied did not disappear till night.

Total effluent to end of month, 128,867 gallons.

Filter Tank No. 1 — Continued.

June, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	300	274	3.6	25.4	.1120	.0460	.1580	4.80	1.8000	.0050	-	64°	61°
2, . .	-	169	-	-	-	-	-	-	-	-	-	-	-
3, . .	300	228	-	-	-	-	-	-	-	-	-	64°	61°
4, . .	300	311	-	-	-	-	-	-	-	-	-	65°	62°
5, . .	300	249	2.5	23.5	.0360	.0270	.0630	4.80	1.3000	.0008	-	66°	62°
6, . .	-	129	-	-	-	-	-	-	-	-	-	-	63°
7, . .	300	208	-	-	-	-	-	-	-	-	-	65°	63°
8, . .	300	274	4.3	26.6	.1280	.0480	.1760	4.61	1.6000	.0024	-	65°	61°
9, . .	-	101	-	-	-	-	-	-	-	-	-	-	-
10, . .	300	165	-	-	-	-	-	-	-	-	-	66°	64°
11, . .	300	281	-	-	-	-	-	-	-	-	-	68°	64°
12, . .	-	129	3.5	26.5	.0040	.0126	0.166	4.55	2.0000	.0003	-	-	64°
13, . .	-	69	-	-	-	-	-	-	-	-	-	-	66°
14, . .	300	228	-	-	-	-	-	-	-	-	2h.18m.	68°	65°
15, . .	600	555	2.6	27.0	.0026	.0470	.0496	4.39	2.0000	.0100	-	69°	66°
16, . .	-	56	-	-	-	-	-	-	-	-	-	-	-
17, . .	-	27	-	-	-	-	-	-	-	-	-	-	68°
18, . .	600	489	-	-	-	-	-	-	-	-	1h. 32m.	69°	67°
19, . .	500	453	2.3	24.7	.0140	.0140	.0280	5.25	1.6000	.0002	-	70°	68°
20, . .	500	482	-	-	-	-	-	-	-	-	1h. 28m.	70°	68°
21, . .	-	57	-	-	-	-	-	-	-	-	-	-	71°
22, . .	500	434	-	-	.0310	.0440	.0750	6.07	1.8000	.0012	55 m.	71°	68°
23, . .	-	39	-	-	-	-	-	-	-	-	-	-	-
24, . .	500	407	-	-	-	-	-	-	-	-	54 m.	70°	68°
25, . .	500	449	-	-	-	-	-	-	-	-	-	70°	69°
26, . .	-	54	2.1	27.6	.0240	.0160	.0400	6.07	2.2000	.0002	-	-	69°
27, . .	500	409	-	-	-	-	-	-	-	-	58 m.	70°	69°
28, . .	250	200	-	-	-	-	-	-	-	-	-	-	70°
29, . .	250	325	2.6	28.1	.0030	.0164	.0194	5.97	2.3000	.0000	31 m.	72°	69°
30, . .	-	43	-	-	-	-	-	-	-	-	-	-	-

Effluent generally clear and colorless, and nearly free from sediment.
Sewage applied the day before had not disappeared on the mornings of June 5, 6, 7, 8, 11 and 12.
June 15. — First 300 gallons applied disappeared in 37 minutes. June 29. — Grass cut from surface.
Total effluent to end of month, 136,161 gallons.

Filter Tank No. 1 — Continued.

July, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	500	344	-	-	-	-	-	-	-	-	-	71°	-
2, . .	500	504	-	-	-	-	-	-	-	-	55 m.	72°	70°
3, . .	-	65	2.8	31.1	.0048	.0194	.0242	7.63	2.1000	.0000	-	-	71°
4, . .	500	492	-	-	-	-	-	-	-	-	-	74°	-
5, . .	-	46	-	-	-	-	-	-	-	-	-	-	-
6, . .	500	398	3.0	29.2	.0134	.0360	.0494	6.72	2.1000	.0008	57 m.	73°	71°
7, . .	-	42	-	-	-	-	-	-	-	-	-	-	-
8, . .	500	412	-	-	-	-	-	-	-	-	49 m.	73°	71°
9, . .	500	450	-	-	-	-	-	-	-	-	54 m.	73°	71°
10, . .	-	54	2.0	25.3	.0038	.0138	.0176	5.20	1.7000	.0001	-	-	68°
11, . .	500	413	-	-	-	-	-	-	-	-	52 m.	73°	71°
12, . .	-	56	-	-	-	-	-	-	-	-	-	-	71°
13, . .	500	417	3.1	32.3	.0128	.0280	.0408	8.42	2.0000	.0003	56 m.	72°	69°
14, . .	-	40	-	-	-	-	-	-	-	-	-	-	-
15, . .	500	490	-	-	-	-	-	-	-	-	-	72°	68°
16, . .	500	480	-	-	-	-	-	-	-	-	53 m.	71°	69°
17, . .	-	51	2.8	27.5	.0032	.0130	.0162	6.37	1.8000	.0001	-	-	68°
18, . .	500	447	-	-	-	-	-	-	-	-	53 m.	72°	68°
19, . .	-	52	2.0	28.6	.0032	.0136	.0168	5.79	1.8000	.0000	-	-	69°
20, . .	500	765	-	-	-	-	-	-	-	-	-	72°	69°
21, . .	-	49	-	-	-	-	-	-	-	-	-	-	-
22, . .	500	405	-	-	-	-	-	-	-	-	1 h.	72°	68°
23, . .	500	519	-	-	-	-	-	-	-	-	-	72°	68°
24, . .	-	63	2.0	19.4	.0026	.0120	.0146	3.67	1.3000	.0002	-	-	70°
25, . .	500	404	-	-	-	-	-	-	-	-	-	68°	70°
26, . .	-	57	-	-	-	-	-	-	-	-	-	-	71°
27, . .	500	529	2.9	23.4	.0068	.0214	.0282	4.37	1.6000	.0002	-	70°	70°
28, . .	-	50	-	-	-	-	-	-	-	-	-	-	-
29, . .	500	459	-	-	-	-	-	-	-	-	-	-	70°
30, . .	500	493	-	-	-	-	-	-	-	-	-	72°	70°
31, . .	-	44	3.2	23.0	.0024	.0130	.0154	4.10	1.5000	.0002	-	-	71°

Effluent colorless, very slightly turbid, occasionally milky and generally with very slight sediment.

Outlet of tank closed July 1, 2.32 P.M., to July 2, 10 5 A.M.; July 5, 11.42 A.M., to July 6, 11.40 A.M.; July 31, 4 33 P.M., to August 1, 1 P.M.

Total effluent to end of month, 145,251 gallons.

Filter Tank No. 1 — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	500	634	-	-	-	-	-	-	-	-	-	72°	70°
2, . .	-	54	-	-	-	-	-	-	-	-	-	-	72°
3, . .	500	450	-	-	-	-	-	-	-	-	-	72°	70°
4, . .	-	52	-	-	-	-	-	-	-	-	-	-	-
5, . .	500	436	-	-	-	-	-	-	-	-	-	71°	70°
6, . .	500	447	-	-	-	-	-	-	-	-	59 m.	71°	70°
7, . .	-	104	-	-	-	-	-	-	-	-	-	-	70°
8, . .	500	405	-	-	-	-	-	-	-	-	47 m.	72°	70°
9, . .	-	51	-	-	-	-	-	-	-	-	-	-	71°
10, . .	500	426	2.3	25.8	.0140	.0230	.0370	5.21	2.0000	.0010	48 m.	71°	71°
11, . .	-	47	-	-	-	-	-	-	-	-	-	-	-
12, . .	500	419	-	-	-	-	-	-	-	-	54 m.	70°	70°
13, . .	500	467	-	-	-	-	-	-	-	-	51 m.	71°	70°
14, . .	-	102	-	-	.0012	.0128	.0140	4.79	2.0000	.0000	-	-	69°
15, . .	500	565	-	-	-	-	-	-	-	-	-	68°	69°
16, . .	-	49	-	-	-	-	-	-	-	-	-	-	70°
17, . .	500	427	-	-	.0000	.0162	.0162	4.47	2.2000	.0000	52 m.	69°	69°
18, . .	-	46	-	-	-	-	-	-	-	-	-	-	-
19, . .	500	412	-	-	-	-	-	-	-	-	51 m.	68°	68°
20, . .	500	470	-	-	-	-	-	-	-	-	-	70°	67°
21, . .	-	44	-	-	-	-	-	-	-	-	-	-	68°
22, . .	500	431	-	-	-	-	-	-	-	-	-	70°	69°
23, . .	-	47	-	-	-	-	-	-	-	-	-	-	70°
24, . .	500	376	-	-	.0106	.0244	.0350	4.54	1.9000	.0008	-	71°	70°
25, . .	-	10	-	-	-	-	-	-	-	-	-	-	-
26, . .	500	504	-	-	.0002	.0158	.0160	4.55	2.5000	.0002	-	70°	70°
27, . .	500	477	-	-	-	-	-	-	-	-	-	71°	69°
28, . .	-	55	-	-	.0024	.0122	.0146	7.02	2.1500	.0000	-	-	69°
29, . .	500	400	-	-	-	-	-	-	-	-	-	70°	69°
30, . .	-	49	-	-	-	-	-	-	-	-	-	-	70°
31, . .	500	429	1.5	34.4	.0014	.0198	.0212	8.60	1.6000	.0001	58 m.	72°	69°

Effluent colorless, generally clear or nearly so, and with very slight or no sediment.

Outlet of tank closed August 2, 7 P.M., to August 3, 12.8 P.M.; August 6, 8.46 P.M., to August 7, 1 P.M.; August 14, 8.48 P.M., to August 15, 11.30 A.M.; August 21, 8.45 P.M., to August 22, 11.8 A.M.; August 24, 8.15 P.M., to August 26, 10 A.M.

August 6. — Grass cut from surface. August 27 and 29. — Bacillus prodigiosus applied. August 28 and 30. — Under-drains washed out twice each day by forcing in effluent of Tank No. 8.

Total effluent to end of month, 154,136 gallons.

Filter Tank No. 1 — Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	-	42	-	-	-	-	-	-	-	-	-	-	-
2, . .	500	412	-	-	-	-	-	-	-	-	-	71°	68°
3, . .	500	461	-	-	-	-	-	-	-	-	-	71°	69°
4, . .	-	60	-	-	-	-	-	-	-	-	-	-	69°
5, . .	500	426	-	-	-	-	-	-	-	-	1 h.	72°	69°
6, . .	-	37	-	-	-	-	-	-	-	-	-	-	71°
7, . .	500	432	-	-	.0044	.0216	.0260	4.32	2.6000	.0002	-	72°	69°
8, . .	-	45	-	-	-	-	-	-	-	-	-	-	-
9, . .	500	421	-	-	-	-	-	-	-	-	-	72°	69°
10, . .	500	470	-	-	-	-	-	-	-	-	-	71°	69°
11, . .	-	50	-	-	-	-	-	-	-	-	-	-	68°
12, . .	500	414	-	-	-	-	-	-	-	-	1 h. 3 m.	68°	69°
13, . .	-	54	-	-	-	-	-	-	-	-	-	-	68°
14, . .	500	519	3.8	27.2	.1180	.0670	.1850	4.53	1.6000	.0014	-	67°	69°
15, . .	-	50	-	-	-	-	-	-	-	-	-	-	-
16, . .	500	445	4.0	23.7	.0960	.0470	.1430	4.14	1.3000	.0014	-	68°	71°
17, . .	500	490	-	-	-	-	-	-	-	-	-	70°	68°
18, . .	-	60	-	-	-	-	-	-	-	-	-	-	67°
19, . .	800	763	-	-	-	-	-	-	-	-	-	68°	68°
20, . .	-	71	-	-	-	-	-	-	-	-	-	-	67°
21, . .	500	458	-	-	.0520	.0300	.0820	2.90	.8300	.0020	-	67°	68°
22, . .	-	50	-	-	-	-	-	-	-	-	-	-	-
23, . .	500	423	-	-	-	-	-	-	-	-	52 m.	61°	65°
24, . .	500	476	-	-	-	-	-	-	-	-	-	62°	65°
25, . .	-	60	-	-	-	-	-	-	-	-	-	-	65°
26, . .	500	435	-	-	.0210	.0170	.0380	4.42	1.2000	.0018	-	59°	64°
27, . .	-	57	-	-	-	-	-	-	-	-	-	-	63°
28, . .	500	430	-	-	-	-	-	-	-	-	-	59°	63°
29, . .	-	50	-	-	-	-	-	-	-	-	-	-	-
30, . .	500	427	-	-	-	-	-	-	-	-	-	58°	60°

Effluent generally colorless, slightly turbid at first, increasing to decidedly turbid, owing to rain, and with slight or no sediment.

September 19. — Some effluent lost.

Total effluent to end of month, 162,724 gallons.

Filter Tank No. 1 — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	500	529	-	-	-	-	-	-	-	-	-	60°	62°
2, . .	-	66	-	-	-	-	-	-	-	-	-	-	61°
3, . .	500	425	-	-	.0046	.0214	.0260	4.61	1.6000	.0004	-	59°	61°
4, . .	-	58	-	-	-	-	-	-	-	-	-	-	61°
5, . .	500	425	-	-	-	-	-	-	-	-	-	57°	60°
6, . .	-	53	-	-	-	-	-	-	-	-	-	-	-
7, . .	500	531	-	-	-	-	-	-	-	-	-	56°	60°
8, . .	500	484	-	-	-	-	-	-	-	-	-	56°	59°
9, . .	-	74	-	-	-	-	-	-	-	-	-	-	59°
10, . .	500	414	-	-	.0260	.0248	.0508	4.30	1.5000	.0012	-	52°	58°
11, . .	-	61	-	-	-	-	-	-	-	-	-	-	58°
12, . .	500	422	-	-	-	-	-	-	-	-	-	50°	58°
13, . .	-	132	-	-	-	-	-	-	-	-	-	-	-
14, . .	500	472	-	-	-	-	-	-	-	-	2h.22m.	49°	56°
15, . .	500	465	-	-	-	-	-	-	-	-	-	49°	55°
16, . .	-	71	-	-	-	-	-	-	-	-	-	-	54°
17, . .	500	398	-	-	.0960	.0196	.1156	4.49	1.6000	.0026	-	49°	55°
18, . .	-	67	-	-	-	-	-	-	-	-	-	-	55°
19, . .	500	410	-	-	-	-	-	-	-	-	-	49°	54°
20, . .	-	57	-	-	-	-	-	-	-	-	-	-	-
21, . .	500	437	-	-	-	-	-	-	-	-	-	51°	54°
22, . .	500	490	-	-	-	-	-	-	-	-	-	49°	53°
23, . .	-	71	-	-	-	-	-	-	-	-	-	-	52°
24, . .	500	429	-	-	.0282	.0182	.0464	4.35	2.3000	.0016	-	48°	53°
25, . .	-	68	-	-	-	-	-	-	-	-	-	-	52°
26, . .	500	418	-	-	-	-	-	-	-	-	5h.11m.	48°	52°
27, . .	-	60	-	-	-	-	-	-	-	-	-	-	-
28, . .	500	425	-	-	-	-	-	-	-	-	-	49°	51°
29, . .	500	541	-	-	-	-	-	-	-	-	-	49°	51°
30, . .	-	147	-	-	-	-	-	-	-	-	-	-	51
31, . .	500	369	-	-	.3040	.0560	.3600	4.61	.9200	.0050	-	48°	51°

Effluent colorless and generally very nearly clear, and free from sediment.
October 9. — Some effluent lost. October 11. — Trap put on outlet pipe at 3 P.M.
Total effluent to end of month, 171,793 gallons.

SERIES OF CHEMICAL AND BIOLOGICAL EXAMINATIONS OF EFFLUENT OF TANK No. 1.

Time of Collection.		Residue on Evaporation.		Ammonia.				Nitrogen as				
Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.	Acid Number.
1889.												
Mar. 15,	8.55	1.4	23.0	.0920	.0120	.1040	3.60	1.2000	.0004	-	-	-
15,	11.38	1.5	22.1	.1600	.0220	.1820	3.70	1.1000	.0008	-	-	-
15,	12.7	1.8	22.3	.1400	.0200	.1600	3.57	1.1000	.0016	-	-	-
15,	3.45	0.9	22.3	.1320	.0210	.1530	3.63	1.2000	.0007	-	-	-
15,	7.0	1.0	22.9	.1120	.0170	.1290	3.62	1.3000	.0008	-	-	-
16,	11.30	3.6	24.1	.1360	.0790	.2150	3.71	1.4000	.0050	-	-	-

March 15.—300 gallons sewage applied from 10.39 to 11.1.

Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.	Acid Number.
April 5,	9.50	0.8	30.2	.0280	.0120	.0400	7.00	1.4000	.0004	-	208	-
5,	10.55	0.6	27.2	.1400	.0200	.1600	7.15	.9000	.0018	-	3160	-
5,	11.17	0.9	28.2	.1440	.0170	.1610	7.30	1.0000	.0014	-	3800	-
5,	1.40	1.3	27.3	.0800	.0140	.0940	7.01	1.2000	.0006	-	1640	-
5,	4.40	1.3	28.1	.0560	.0110	.0670	6.71	1.3500	.0004	-	820	-
6,	9.15	1.7	28.4	.0280	.0120	.0400	6.25	1.4000	.0003	-	216	-
6,	11.48	1.6	26.2	.1560	.0260	.1820	5.46	1.0000	.0020	-	3560	-

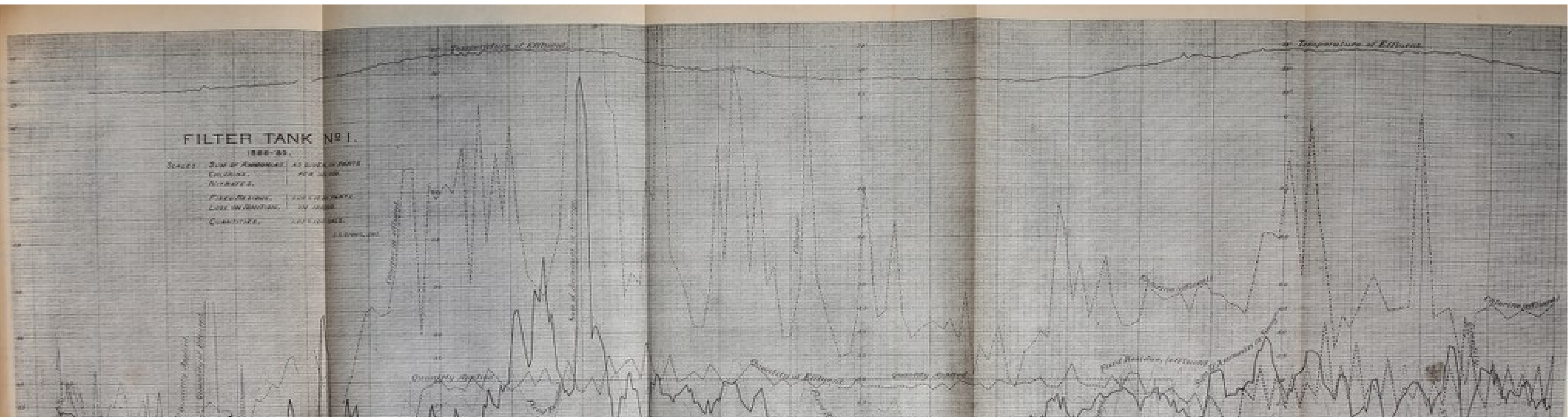
April 5.—300 gallons sewage applied from 9.52 to 10.15. April 6—300 gallons applied from 10.36 to 10.58.

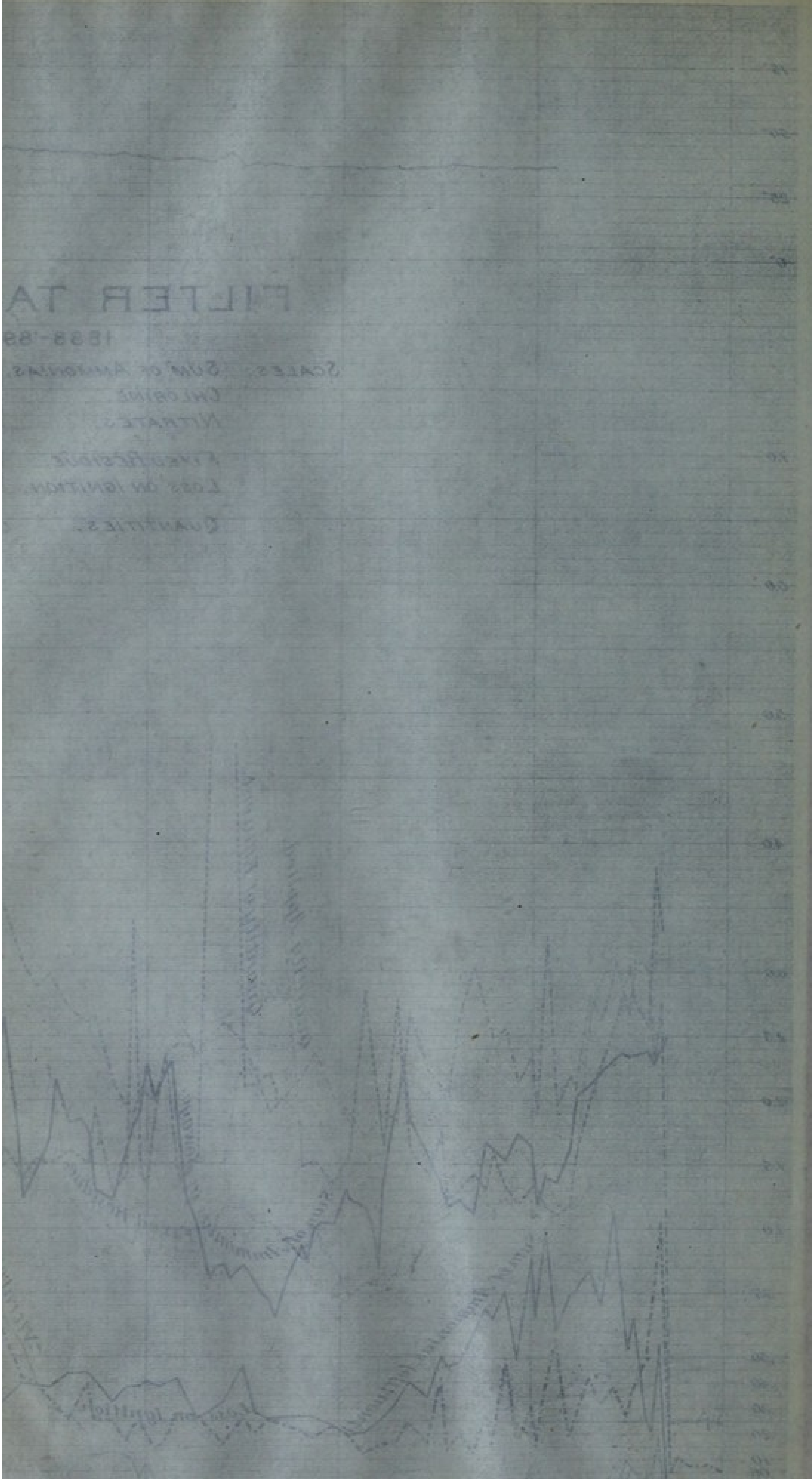
Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.	Acid Number.
April 10,	9.35	0.6	28.1	.0240	.0190	.0430	4.55	1.9000	.0003	-	-	-
10,	10.51	1.9	24.9	.1680	.0360	.2040	4.30	1.4000	.0060	-	-	-

300 gallons sewage applied from 9.47 to 10.10.

Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.	Acid Number.
April 12,	9.50	0.5	30.9	.0160	.0160	.0320	4.55	2.0000	.0003	67	228	.047
12,	11.35	1.5	26.7	.1440	.0290	.1730	4.53	1.6500	.0030	25,300	2960	.053
12,	12.00	2.3	28.5	.0880	.0220	.1100	4.50	1.8000	.0020	16,100	3040	.051
12,	12.26	1.2	28.3	.0800	.0230	.1030	4.51	1.9000	.0015	11,300	2840	.047
12,	1.46	1.8	28.9	.0480	.0160	.0640	4.45	1.9000	.0010	4,551	1840	.045
12,	5.00	1.6	29.3	.0360	.0150	.0510	4.45	2.0000	.0006	675	930	.045
12,	9.00	0.8	29.6	.0200	.0100	.0300	4.51	2.1000	.0004	108	550	.044

300 gallons sewage applied from 10.2 to 10.26.


FILTER TANK No. 1.
Scales:
Temperature of Effluent
Quantity of Effluent
Quantity Applied
Fixed Residue, (effluent)
Albuminoid Ammonia, (effluent)
Sum of Ammonias (effluent)
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.



Series of Chemical and Biological Examinations of Effluent of Tank No. 1 — Con.

Time of Collection.		Residue on Evaporation.		Ammonia.				Nitrogen as				
Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.	Acid Number.
1889.												
Apr. 26,	9.55	2.3	33.8	.0160	.0130	.0290	4.15	3.5000	.0004	56	240	.045
26,	11.	4.6	24.8	.3080	.0570	.3650	4.15	1.7000	.0060	33,000	1,940	.067
26,	11.15	3.0	24.4	.3920	.0690	.4610	4.18	1.5500	.0050	16,850	2,733	.070
26,	12.	2.8	28.4	.1400	.0320	.1720	4.15	2.6000	.0015	4,983	2,300	.047
26,	4.1	3.4	31.6	.0360	.0150	.0510	4.13	2.6000	.0005	589	1,060	.040
26,	9.	2.9	32.3	.0120	.0100	.0220	4.16	2.9000	.0003	228	590	.035
27,	10.30	2.8	33.4	.0040	.0080	.0120	4.13	3.0000	.0003	35	580	.035

April 26. — Three hundred gallons sewage applied from 9.59 to 10.21.

Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.	Acid Number.
June 25,	10.10	1.0	27.0	.0320	.0180	.0500	5.75	1.7000	.0000	530	144	-
25,	12.2	2.8	27.2	.0520	.0430	.0950	5.77	1.7000	.0012	18,166	7,800	-
25,	12.11	2.7	27.1	.0560	.0470	.1030	5.77	1.9000	.0018	10,180	11,400	-
25,	2.37	2.2	27.0	.0520	.0300	.0820	5.85	2.1000	.0010	16,272	2,340	-
25,	5.30	-	-	-	-	-	-	-	-	5,148	1,020	-
26,	10.10	2.1	27.6	.0240	.0160	.0400	6.07	2.2000	.0002	-	-	-
26,	2.5	-	-	-	-	-	-	-	-	7,772	156	-
26,	3.50	2.0	27.8	.0320	.0210	.0530	5.87	2.2000	.0002	1,360	132	-

June 25. — Five hundred gallons applied from 11.11 to 11.57. June 26. — None applied.

Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.	Acid Number.
July 29,	10.18	2.0	26.1	.0048	.0122	.0170	4.80	1.6000	.0007	2,680	4,080	-
29,	10.29	2.1	26.3	.0012	.0110	.0122	4.57	1.5000	.0003	1,419	3,900	-
29,	10.45	2.4	25.1	.0034	.0138	.0172	4.54	1.5000	.0006	2,400	1,100	-

Samples from flow of water held back in underdrains.

Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.	Acid Number.
Aug. 1,	9.56	4.0	23.4	.0026	.0118	.0144	4.20	1.6000	.0006	24	1,010	-
1,	11.17	3.4	24.3	.0024	.0116	.0140	4.18	1.8000	.0003	19	850	-
1,	12.55	3.8	22.8	.0010	.0110	.0120	4.20	1.7000	.0002	12	780	-

Samples from flow of water held back in underdrains.

Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.	Acid Number.
Aug. 3,	10.24	1.6	25.6	.0080	.0158	.0238	4.02	2.0000	.0006	14	260	-
3,	11.3	1.8	25.8	.0018	.0116	.0134	3.87	1.8000	.0003	22	1,480	-
3,	12.8	1.4	25.1	.0050	.0116	.0166	3.90	1.6000	.0003	14	150	-

Samples from flow of water held back in underdrains.

Microscopical examination of 200 cubic centimeters: —

Aug. 3,	10.24	Water discolored by small, brown gelatinous masses.
3,	11.3	No organisms.
3,	12.8	Crenothrix, 1. Leptothrix, 1. Anguillula, 2. Brown masses.

Series of Chemical and Biological Examinations of Effluent of Tank No. 1 — Con.

Time of Collection. Day.	Hour.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.
1889.											
Aug. 7, . .	10.15	2.5	27.5	.0022	.0152	.0174	5.02	2.0000	.0002	118	830
7, . .	10.33	1.4	28.1	.0024	.0136	.0160	4.94	2.4000	.0000	61	760
7, . .	10.50	1.1	28.6	.0032	.0154	.0186	4.94	2.4000	.0000	63	720
7, . .	11.10	1.0	28.2	.0016	.0122	.0138	4.92	2.4000	.0000	66	700
7, . .	12.50	2.0	27.3	.0012	.0116	.0128	5.00	2.2000	.0000	19	480

Samples from flow of water held back in underdrains.

Microscopical examination of 200 c.c. showed no organisms except a few fragments of Crenothrix.

Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Bacteria.	Rate of Flow.
Aug. 12, . .	10.5	1.3	26.5	.0018	.0090	.0108	5.06	2.0000	.0002	143	76
12, . .	10.52	3.3	26.7	.0004	.0146	.0150	5.02	2.2000	.0002	-	800
12, . .	10.58	-	-	-	-	-	-	-	-	7,992	1,500
12, . .	11.7	4.5	24.1	.0354	.0340	.0694	4.84	2.3000	.0007	13,832	9,600
12, . .	11.25	3.4	25.9	.0308	.0280	.0588	4.82	2.4000	.0007	7,438	15,000
12, . .	1.40	2.9	26.5	.0120	.0234	.0354	4.82	2.8000	.0004	4,964	2,080

Samples from flow of water held back in underdrains. Five hundred gallons sewage applied from 10.11 to 10.57.

Microscopical examination of 200 c.c.: —

Aug. 12, . .	10.5	Trachelomonas, 1. Fungus Hypha, 1.
12, . .	10.52	Crenothrix, 7. Anguillula, 1. Infusoria, 2 (dead).
12, . .	11.7	Asterionella, 8 (alive and healthy). Zoöglœa, 4.
12, . .	11.25	Yeast groups, 3. Fungus spores, 2.

Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Bacteria.	Rate of Flow.
Aug. 15, . .	11.10	-	-	.0045	.0114	.0159	4.77	2.7000	.0004	11	97
15, . .	11.20	-	-	.0016	.0126	.0142	4.79	2.7000	.0004	58	1,780
15, . .	11.27	-	-	.0014	.0116	.0130	4.79	2.7000	.0001	28	5,590
15, . .	11.31	-	-	.0006	.0118	.0124	4.82	2.6000	.0001	84	76,000
15, . .	11.33	-	-	.0010	.0112	.0122	4.82	2.4000	.0003	42	25,000
15, . .	11.46	-	-	.0010	.0124	.0134	4.82	2.3000	.0003	117	1,800
15, . .	12.58	-	-	.0044	.0182	.0226	4.64	2.2000	.0002	2,604	15,200
15, . .	1.22	-	-	.0038	.0168	.0206	4.62	2.3000	.0002	726	10,000
15, . .	3.2	-	-	.0026	.0148	.0174	4.52	2.3000	.0002	1,568	2,900

Samples from flow of water held back in underdrains up to and including 11.33, then from increased flow due to application of 500 gallons sewage from 11.38 to 12.24.

Microscopical examination of 200 c.c.: —

Aug. 15, . .	10.50	A few masses of rust and debris.
15, . .	11.20	No organisms.
15, . .	11.27	No organisms.
15, . .	11.31	Anguillula, 2. Euplotes (?) 2. Much sediment.
15, . .	11.33	Anguillula, 1. Zoöglœa, 1. Little sediment.
15, . .	11.46	No organisms.
15, . .	12.42	No organisms. Rate, 12,840 c.c.
15, . .	1.	Chlorococcus, 50. Rate, 13,000 c.c.
15, . .	3.2	Tabellaria, 5. Spirostomum, 1.

Series of Chemical and Biological Examinations of Effluent of Tank No. 1 — Con.

Time of Collection.		Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Number of Bacteria per Cubic Centimeter.	Rate of Flow, c.c. per Minute.	Dissolved Oxygen.
Day.	Hour.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1889.												
Aug. 22, .	10.	-	-	-	-	-	-	-	-	-	-	.000
22, .	10.30	-	-	.0028	.0104	.0132	4.64	2.4000	.0003	228	300	.273
22, .	10.45	-	-	.0008	.0098	.0106	4.74	2.1000	.0000	123	1,000	.397
22, .	10.55	-	-	.0012	.0100	.0112	4.70	2.0000	.0000	600	3,000	.425
22, .	11.3	-	-	.0026	.0106	.0132	4.72	1.7000	.0004	598	250	.550
22, .	11.58	-	-	.0006	.0190	·0196	4.62	1.3000	.0000	1,892	4,600	.637
22, .	12.3	-	-	.0018	.0186	.0204	4.65	1.6000	.0000	9,500	7,980	.640
22, .	12.20	-	-	.0046	.0206	.0252	4.67	1.8000	.0000	14,958	13,000	.716
22, .	12.40	-	-	.0048	.0228	.0276	4.62	2.0000	.0001	8,690	9,100	.674
22, .	1.34	-	-	.0026	.0196	.0222	4.66	2.1000	.0001	8,184	4,440	-
22, .	3.31	-	-	.0014	.0166	.0180	4.65	2.3000	.0000	9,750	1,600	.820

Samples from water held back in underdrains up to and including 11.3, then from increased flow due to application of 500 gallons of sewage from 11.11 to 11.50. Temperature of effluent at the beginning, 21° C; at 12.20 and 3.31, 20.5° C.

Microscopical examination of 200 c.c.: —

Aug. 22, .	10.30	No organisms. Much rust.
22, .	10.45	No organisms. Less rust.
22, .	10.55	Anguillula, 1. Infusoria, 1. Spores, 1. Synedra, 1 (dead). Yeast, 1.
22, .	11.3	Anguillula, 2. Leptothrix, 1. Spores, 1.
22, .	11.58	Anguillula, 4. Spores, 2.
22, .	12.3	Anguillula, 6. Leptothrix, 2. Spores, 2.
22, .	12.20	Anguillula, 3. Infusoria, 1 (dead). Spores, 3.
22, .	12.40	Anguillula, 1. Infusoria, 2. Leptothrix, 1. Trachelomonas, 1. Spores, 1.
22, .	1.34	Leptothrix, 2. Spores, 2.
22, .	3.31	Spores, 2.

RESULTS OF CHEMICAL ANALYSES OF SEWAGE,

PUMPED FROM THE MAIN SEWER OF THE CITY OF LAWRENCE FROM DECEMBER, 1887, TO OCTOBER, 1889, AND APPLIED TO THE FILTER TANKS OF THE EXPERIMENT STATION OF THE STATE BOARD OF HEALTH; FOLLOWED BY TABLES OF ANALYSES OF THE SAME SEWAGE AFTER PASSING THROUGH FILTER PAPER IN THE LABORATORY.

December, 1887.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
19, . . .	6.40	17.95	.9280	.2450	1.1730	3.43	.0020	.0000	-	-	1.1730
20, . . .	-	-	-	-	-	-	-	-	-	-	-
21, . . .	-	-	-	-	-	-	-	-	-	-	-
22, . . .	41.95	21.70	1.3120	.4100	1.7220	3.68	.0100	.0000	-	-	1.4475
23, . . .	7.55	15.55	.3000	.3200	.6200	2.41	.0050	.0000	-	-	1.1717
24, . . .	-	-	-	-	-	-	-	-	-	-	-
25, . . .	-	-	-	-	-	-	-	-	-	-	-
26, . . .	-	-	-	-	-	-	-	-	-	-	-
27, . . .	12.60	19.60	.8800	.3900	1.2700	2.98	.0070	.0000	-	-	1.1962
28, . . .	-	-	-	-	-	-	-	-	-	-	-
29, . . .	27.80	23.40	2.1400	.8100	2.9500	4.14	.0050	.0000	-	-	1.6405
30, . . .	-	-	-	-	-	-	-	-	-	-	-
31, . . .	-	-	-	-	-	-	-	-	-	-	-

Unfiltered Sewage — Continued.

January, 1888.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, . . .	10.6	17.2	1.1100	.5300	1.6400	2.50	.0050	.0200	-	-	1.6200
2, . . .	-	-	-	-	-	-	-	-	-	-	-
3, . . .	5.0	19.8	.9300	.1800	1.1100	2.22	.0050	Present.	-	-	1.7425
4, . . .	-	-	-	-	-	-	-	-	-	-	-
5, . . .	20.8	24.6	1.3200	.6300	1.9500	3.49	.0080	Present.	-	-	1.9125
6, . . .	-	-	-	-	-	-	-	-	-	-	-
7, . . .	-	-	-	-	-	-	-	-	-	-	-
8, . . .	48.6	43.6	1.5300	.8300	2.3600	2.94	.0060	Present.	-	-	1.7650
9, . . .	-	-	-	-	-	-	-	-	-	-	-
10, . . .	18.2	18.2	2.0400	.4700	2.5100	3.48	.0080	Present.	-	-	1.9825
11, . . .	-	-	-	-	-	-	-	-	-	-	-
12, . . .	29.4	25.2	1.6600	.6300	2.2900	3.13	.0050	.0000	-	-	2.2775
13, . . .	44.4	27.2	1.5700	.7800	2.3500	3.68	.0080	.0000	-	-	2.3775
14, . . .	-	-	-	-	-	-	-	-	-	-	-
15, . . .	-	-	-	-	-	-	-	-	-	-	-
16, . . .	41.4	26.8	1.3800	.8400	2.2200	2.92	.0080	.0200	-	-	2.3425
17, . . .	131.8	46.4	1.3600	1.2700	2.6300	2.82	.0050	Present.	-	-	2.3725
18, . . .	-	-	-	-	-	-	-	-	-	-	-
19, . . .	-	-	-	-	-	-	-	-	-	-	-
20, . . .	75.6	30.6	.7300	1.0400	1.7700	2.08	.0020	.0000	-	-	2.2425
21, . . .	-	-	-	-	-	-	-	-	47°	0.46	-
22, . . .	27.6	16.6	1.2800	.5700	1.8500	2.11	.0030	Present.	-	-	2.1175
23, . . .	-	-	-	-	-	-	-	-	-	-	-
24, . . .	65.6	27.0	.6700	1.2100	1.8800	1.91	.0120	Present.	-	-	2.0325
25, . . .	7.2	11.2	.8200	.1600	.9800	1.88	.0100	Present.	-	-	1.6200
26, . . .	-	-	-	-	-	-	-	-	-	-	-
27, . . .	7.0	13.8	.5200	.2200	.7400	1.97	.0030	Present.	-	-	1.3625
28, . . .	-	-	-	-	-	-	-	-	46°	0.54	-
29, . . .	8.6	11.6	1.7000	.2900	1.9900	1.94	.0090	.0000	-	-	1.3975
30, . . .	-	-	-	-	-	-	-	-	-	-	-
31, . . .	15.8	13.2	.5900	.4500	1.0400	1.51	.0180	.0100	-	-	1.1875

January 21.—Sewage pipe clogged so that pumps would not work. Screen in sewer cleaned.
January 28.—Screen again cleaned.

Unfiltered Sewage — Continued.

February, 1888.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, . . .	65.2	23.8	.6600	2.1400	2.8000	1.64	.0060	.0010	-	-	1.6425
2, . . .	-	-	-	-	-	-	-	-	-	-	-
3, . . .	9.2	12.6	.8000	.3300	1.1300	1.68	.0070	.0010	42°	0.58	1.7400
4, . . .	-	-	-	-	-	-	-	-	-	-	-
5, . . .	15.6	14.2	.7900	.3900	1.1800	2.02	.0070	.0000	-	-	1.5375
6, . . .	-	-	-	-	-	-	-	-	-	-	-
7, . . .	26.8	25.2	-	-	-	-	-	-	-	-	-
8, . . .	17.4	10.2	1.2600	.3100	1.5700	2.96	.0060	.0000	-	-	1.6700
9, . . .	-	-	-	-	-	-	-	-	44°	0.58	-
10, . . .	14.0	6.0	.3500	.2200	.5700	1.40	.0000	-	-	-	1.1125
11, . . .	-	-	-	-	-	-	-	-	-	-	-
12, . . .	35.6	17.0	.8400	.7600	1.6000	2.78	-	Present.	-	-	1.2300
13, . . .	-	-	-	-	-	-	-	-	44°	0.56	-
14, . . .	30.6	6.0	.6100	.3200	.9300	2.14	.0050	Present.	-	-	1.1675
15, . . .	29.0	20.6	1.7300	.5000	2.2300	6.04	.0050	Present.	-	-	1.3325
16, . . .	-	-	-	-	-	-	-	-	-	-	-
17, . . .	12.0	11.6	1.0400	.3600	1.4000	2.12	.0080	Present.	42°	0.48	1.5400
18, . . .	-	-	-	-	-	-	-	-	-	-	-
19, . . .	-	-	-	-	-	-	-	-	-	-	-
20, . . .	21.2	16.0	2.2800	.5200	2.8000	4.00	.0080	Present.	44°	0.50	1.8400
21, . . .	23.6	18.4	2.1500	.5900	2.7400	4.10	.0080	.0000	-	-	2.2925
22, . . .	13.2	9.8	.6900	.2800	.9700	2.04	.0050	Present.	-	-	1.9775
23, . . .	12.6	10.0	.3300	.2500	.5800	1.42	.0080	.0000	36°	0.92	1.7725
24, . . .	14.8	15.0	.8100	.3400	1.1500	2.70	.0050	.0000	-	-	1.3600
25, . . .	8.6	11.4	.5300	.1400	.6700	2.19	.0050	.0000	-	-	.8425
26, . . .	27.2	28.4	1.0000	.7500	1.7500	2.72	.0080	.0000	-	-	1.0375
27, . . .	21.6	17.2	.7500	.3600	1.1100	2.04	.0050	.0000	39°	0.83	1.1700
28, . . .	-	-	-	-	-	-	-	-	-	-	-
29, . . .	30.2	23.8	.6500	.7500	1.4000	2.08	.0050	.0000	-	-	1.2325
29, . . .	9.2	16.6	.8500	.1500	1.0000	2.80	.0070	.0000	-	-	1.3150

End of sewage pipe and screen in Lawrence Street sewer cleaned as follows: — February 3, 9, 13, 17, 20, 23 and 27.

Unfiltered Sewage — Continued.

March, 1888.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, ...	-	-	-	-	-	-	-	-	-	-	-
2, ...	7.4	13.6	.2500	.4000	.6500	2.20	.0050	.0020	42°	0.54	1.0400
3, ...	-	-	-	-	-	-	-	-	-	-	-
4, ...	19.0	22.0	.6400	.5200	1.1600	2.80	.0080	.0000	-	-	1.0525
5, ...	14.6	19.2	.8600	.3800	1.2400	2.88	.0050	.0000	42°	0.56	1.0125
6, ...	11.6	14.8	.2100	.2600	.4700	1.96	.0030	.0000	-	-	.8800
7, ...	18.2	16.4	.2900	.6000	.8900	1.56	.0070	.0057	-	-	.9400
8, ...	-	-	-	-	-	-	-	-	-	-	-
9, ...	17.2	17.6	.2000	.4300	.6300	1.80	.0050	.0222	37°	0.72	.8075
10, ...	-	-	-	-	-	-	-	-	-	-	-
11, ...	5.8	13.0	.3700	.2500	.6200	2.00	.0250	.0200	-	-	.6525
12, ...	9.4	15.6	.5900	.2000	.7900	2.06	.0060	.0000	-	-	.7325
13, ...	20.6	17.8	.5400	.3900	.9300	2.02	.0050	.0000	43°	0.50	.7425
14, ...	14.0	16.6	.4500	.3200	.7700	1.86	.0100	.0000	-	-	.7775
15, ...	-	-	-	-	-	-	-	-	-	-	-
16, ...	10.6	15.6	.6900	.2600	.9500	2.20	.0030	.0000	42°	0.80	.8600
17, ...	-	-	-	-	-	-	-	-	-	-	-
18, ...	6.4	14.8	.4000	.1700	.5700	2.20	.0080	.0133	-	-	.8050
19, ...	18.0	20.8	.7800	.3700	1.1500	2.38	.0100	.0000	-	-	.8600
20, ...	8.2	18.6	.4800	.2400	.7200	2.28	.0080	.0000	37°	0.90	.8475
21.	12.2	23.8	.3400	.4300	.7700	1.60	.0070	.0000	-	-	.8025
22, ...	-	-	-	-	-	-	-	-	-	-	-
23, ...	49.2	59.6	.2300	1.1000	1.3300	1.56	.0050	.0000	42°	0.66	.9925
24, ...	-	-	-	-	-	-	-	-	-	-	-
25, ...	75.0	93.8	1.5300	.6900	2.2200	3.72	.0100	.0000	-	-	1.2600
26, ...	16.4	27.8	2.4000	.2700	2.6700	1.82	.0070	.0200	-	-	1.7475
27, ...	56.6	54.2	2.3200	.6500	2.9700	4.42	.0080	.0000	36°	0.88	2.2975
28, ...	19.4	38.4	.5800	.4500	1.0300	2.14	.0020	.0000	-	-	2.2225
29, ...	-	-	-	-	-	-	-	-	-	-	-
30, ...	28.4	45.0	1.0500	.3100	1.3600	2.22	.0080	.0000	-	-	2.0075
31, ...	-	-	-	-	-	-	-	-	44°	0.65	-

End of sewage pipe and screen in Lawrence Street sewer cleaned as follows: — March 2, 5, 9, 13, 16, 20, 23, 27 and 31.

Unfiltered Sewage — Continued.

April, 1888.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, ...	126.6	90.4	1.5100	2.2500	3.7600	3.84	.0080	.0000	-	-	2.2800
2, ...	54.2	80.6	.3900	1.0700	1.4600	2.00	.0080	Present.	-	-	1.9025
3, ...	11.6	24.2	.2800	.3500	.6300	1.80	.0200	.0400	-	-	1.8025
4, ...	13.4	21.6	.3900	.3400	.7300	2.00	.0080	.0000	-	-	1.6450
5, ...	-	-	-	-	-	-	-	-	-	-	-
6, ...	56.8	47.2	1.2800	.8300	2.1100	4.08	.0080	.0000	47°	0.62	1.2325
7, ...	-	-	-	-	-	-	-	-	-	-	-
8, ...	-	-	-	-	-	-	-	-	-	-	-
9, ...	14.0	31.2	1.3700	.3700	1.7400	4.80	.0080	.0000	-	-	1.3025
10, ...	36.6	45.0	1.6800	.7900	2.4700	3.94	.0050	.0000	-	-	1.7675
11, ...	25.0	33.8	.4700	.6300	1.1000	2.05	.0050	.0000	-	-	1.8550
12, ...	-	-	-	-	-	-	-	-	45°	0.60	-
13, ...	19.6	31.4	1.4100	.5500	1.9600	3.80	.0050	Present.	-	-	1.8175
14, ...	-	-	-	-	-	-	-	-	-	-	-
15, ...	66.0	61.6	1.8300	1.2900	3.1200	4.20	.0050	.0000	-	-	2.1625
16, ...	3.8	26.0	.3400	.3200	.6600	2.80	.0120	.0000	-	-	1.7100
17, ...	10.2	22.0	.2500	.3100	.5600	2.80	.0050	.0000	-	-	1.5750
18, ...	42.4	53.6	.3100	1.1500	1.4600	2.66	.0050	.0000	46°	0.68	1.4500
19, ...	-	-	-	-	-	-	-	-	-	-	-
20, ...	39.0	46.4	1.7500	.5500	2.3000	4.60	.0100	.0000	-	-	1.2450
21, ...	49.6	51.0	1.6000	1.2900	2.8900	4.76	.0030	.0000	-	-	1.8025
22, ...	-	-	-	-	-	-	-	-	-	-	-
23, ...	92.2	80.6	1.7400	2.2000	3.9400	5.06	.0060	.0000	-	-	2.6475
24, ...	4.2	19.2	.3300	.1000	.4300	2.58	.0020	.0200	47°	0.69	2.3900
25, ...	10.0	20.0	.4200	.2700	.6900	2.62	.0030	.0000	-	-	1.9875
26, ...	-	-	-	-	-	-	-	-	-	-	-
27, ...	5.0	16.2	.3600	.1000	.4600	2.40	.0050	.0200	51°	0.79	1.3800
28, ...	4.8	14.0	.2200	.1160	.3360	2.60	.0050	.0000	-	-	.4790
29, ...	-	-	-	-	-	-	-	-	-	-	-
30, ...	-	-	-	-	-	-	-	-	-	-	-

April 6 and 12. — End of sewage pipe and screen in Lawrence Street sewer cleaned. April 18. — Entrance to pipe cleaned. Screen removed.

Unfiltered Sewage — Continued.

May, 1888.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, ...	-	-	-	-	-	-	-	-	-	-	-
2, ...	-	-	-	-	-	-	-	-	-	-	-
3, ...	-	-	-	-	-	-	-	-	-	-	-
4, ...	63.2	44.8	2.1600	1.8500	4.0100	3.84	.0050	.0000	51°	0.69	1.3740
5, ...	22.4	26.8	1.6200	.6600	2.2800	4.30	.0050	.0000	-	-	1.7715
6, ...	-	-	-	-	-	-	-	-	-	-	-
7, ...	158.0	103.4	2.7200	8.0000	10.7200	4.64	.0200	.0000	-	-	4.3365
8, ...	11.2	21.6	.3200	.4800	.8000	2.60	.0100	.0000	51°	0.69	4.4525
9, ...	17.8	26.0	.5100	.6200	1.1300	2.50	.0050	.0000	-	-	3.7325
10, ...	-	-	-	-	-	-	-	-	-	-	-
11, ...	21.2	60.4	.7500	1.0300	1.7800	2.50	.0150	.0000	51°	0.68	3.6075
12, ...	57.2	104.8	1.4800	1.5400	3.0200	4.02	.0070	.0000	-	-	1.6825
13, ...	-	-	-	-	-	-	-	-	-	-	-
14, ...	-	-	-	-	-	-	-	-	-	-	-
15, ...	-	-	-	-	-	-	-	-	-	-	-
16, ...	-	-	-	-	-	-	-	-	-	-	-
17, ...	-	-	-	-	-	-	-	-	51°	0.70	-
18, ...	36.0	40.8	1.6400	.8600	2.5000	4.64	.0060	.0000	-	-	2.1075
19, ...	9.0	23.4	.4300	.2600	.6900	2.84	.0100	.0000	-	-	1.9975
20, ...	-	-	-	-	-	-	-	-	-	-	-
21, ...	135.4	124.8	2.0600	2.3300	4.3900	5.76	.0080	.0000	-	-	2.6500
22, ...	18.8	23.0	.5800	.5000	1.0800	2.90	.0150	.0000	53°	0.65	2.1650
23, ...	49.2	53.8	1.7500	1.1500	2.9000	4.38	.0100	.0000	-	-	2.2650
24, ...	-	-	-	-	-	-	-	-	-	-	-
25, ...	38.4	34.6	1.0300	.7200	1.7500	4.06	.0040	.0000	55°	0.67	2.5300
26, ...	16.2	23.8	1.6400	.2500	1.8900	5.90	.0080	.0005	-	-	1.9050
27, ...	-	-	-	-	-	-	-	-	-	-	-
28, ...	7.6	17.2	.5000	.2700	.7700	2.60	.0060	.0000	-	-	1.8275
29, ...	-	-	-	-	-	-	-	-	57°	0.57	-
30, ...	20.4	31.2	1.4700	.4000	1.8700	5.06	.0060	.0000	-	-	1.5700
31, ...	12.6	24.0	2.3200	.3200	2.6400	4.80	.0100	.0000	57°	0.55	1.7925

Unfiltered Sewage — Continued.

June, 1888.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, . . .	10.6	21.8	.7100	.4300	1.1400	3.60	.0080	.0000	-	-	1.6050
2, . . .	26.2	29.0	1.4800	.5500	2.0300	5.02	.0150	.0000	-	-	1.9200
3, . . .	-	-	-	-	-	-	-	-	-	-	-
4, . . .	11.8	20.2	.9800	.4300	1.4100	3.22	.0080	.0000	-	-	1.8050
5, . . .	-	-	-	-	-	-	-	-	57°	0.63	-
6, . . .	20.8	23.8	1.3900	.5400	1.9300	5.20	.0070	.0060	-	-	1.6275
7, . . .	-	-	1.8900	.3400	2.2300	4.22	.0050	.0024	-	-	1.9000
8, . . .	6.0	17.4	.7600	.2100	.9700	4.74	.0050	.0004	57°	0.59	1.6350
9, . . .	24.3	18.2	2.3500	.5700	2.9200	4.54	.0070	.0002	-	-	2.0125
10, . . .	-	-	-	-	-	-	-	-	-	-	-
11, . . .	17.0	19.8	.5200	.1500	.6700	4.87	.0070	.0006	-	-	1.6975
12, . . .	-	-	-	-	-	-	-	-	57°	0.59	-
13, . . .	37.9	30.3	1.7000	.6500	2.3500	6.21	.0050	.0004	-	-	1.7275
14, . . .	19.1	25.3	1.7000	.4500	2.1500	5.80	.0070	.0008	-	-	2.0225
15, . . .	17.4	32.4	.7300	.2100	.9400	2.57	.0050	.0002	57°	0.58	1.5275
16, . . .	24.0	32.4	1.3500	.2200	1.5700	5.05	.0070	.0002	-	-	1.7525
17, . . .	-	-	-	-	-	-	-	-	-	-	-
18, . . .	5.5	16.9	.4300	.1800	.6100	3.37	.0070	.0000	-	-	1.3175
19, . . .	-	-	-	-	-	-	-	-	-	-	-
20, . . .	9.3	16.1	.7000	.2100	.9100	3.05	.0070	.0001	62°	0.62	1.0075
21, . . .	9.8	17.6	.5600	.1300	.6900	2.98	.0070	.0001	-	-	.9450
22, . . .	12.8	19.9	2.7100	.4200	3.1300	4.65	.0100	.0000	62°	0.59	1.3350
23, . . .	11.2	18.6	1.9300	.3300	2.2600	4.10	.0100	.0002	-	-	1.7475
24, . . .	-	-	-	-	-	-	-	-	-	-	-
25, . . .	10.4	20.4	1.9000	.2000	2.1000	4.30	.0120	.0004	-	-	2.0450
26, . . .	-	-	-	-	-	-	-	-	63°	0.57	-
27, . . .	23.6	60.9	2.0800	.5300	2.6100	4.40	.0050	.0002	-	-	2.5250
28, . . .	17.2	27.4	1.8100	.3000	2.1100	5.82	.0070	.0004	-	-	2.2700
29, . . .	21.0	26.6	1.7000	.4100	2.1100	5.05	.0070	.0004	60°	-	2.2325
30, . . .	19.6	34.6	1.5800	.5200	2.1000	9.55	.0050	.0004	-	-	2.2325

June 4.—Pipe from Lawrence Street sewer cleaned out by forcing in city water. Pipe was nearly full of sediment. June 29.—Entrance to pipe cleaned. June 30.—Chlorine at different hours as follows:—9.15, 5.30 parts; 9.30, 6.70; 10.20, 4.82; 11.10, 5.81; 11.45, 8.24; 3.30, 18.87; 4.35, 11.25.

Unfiltered Sewage — Continued.

July, 1888.

Date.	Residue on Evaporation.		Ammonia.				Nitrogen as				
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
1, ...	-	-	-	-	-	-	-	-	-	-	-
2, ...	8.7	16.4	.7700	.2000	.9700	3.10	.0050	.0006	-	-	1.8225
3, ...	-	-	-	-	-	-	-	-	62°	0.57	-
4, ...	28.0	34.2	1.7600	.5800	2.3400	7.80	.0100	.0000	-	-	1.8800
5, ...	22.8	27.1	2.1000	.4300	2.5300	7.12	.0070	.0010	-	-	1.9850
6, ...	20.6	27.4	1.8400	.5200	2.3600	6.22	.0100	.0000	62°	0.56	2.0500
7, ...	18.0	29.8	2.0700	.4300	2.5000	8.47	.0070	.0004	-	-	2.4325
8, ...	-	-	-	-	-	-	-	-	-	-	-
9, ...	10.6	16.6	.5700	.3200	.8900	3.06	.0070	.0000	-	-	2.0700
10, ...	-	-	-	-	-	-	-	-	63°	0.56	-
11, ...	24.4	35.6	2.0300	.5300	2.5600	10.42	.0070	.0000	-	-	2.0775
12, ...	5.4	19.8	.9100	.1400	1.0500	3.58	.0100	.0000	-	-	1.7500
13, ...	4.8	17.5	.9200	.1300	1.0500	4.06	.0050	.0000	61°	0.50	1.3875
14, ...	5.0	15.7	.8400	.2500	1.0900	3.56	.0070	.0000	-	-	1.4375
15, ...	-	-	-	-	-	-	-	-	-	-	-
16, ...	5.6	13.0	1.1200	.4300	1.5500	3.40	.0050	.0000	-	-	1.1850
17, ...	-	-	-	-	-	-	-	-	63°	0.50	-
18, ...	13.7	23.9	3.5700	.3100	3.8800	6.70	.0070	.0000	-	-	1.8925
19, ...	19.4	20.9	3.1300	.4100	3.5400	5.85	.0100	.0000	-	-	2.5150
20, ...	9.2	24.4	.5400	.2500	.7900	4.07	.0100	.0000	64°	0.66	2.4400
21, ...	11.6	33.5	2.6600	.4800	3.1400	12.75	.0100	.0000	-	-	2.8375
22, ...	-	-	-	-	-	-	-	-	-	-	-
23, ...	11.6	23.6	2.2400	.2900	2.5300	4.24	.0350	.0000	-	-	2.5000
24, ...	-	-	-	-	-	-	-	-	65°	0.53	-
25, ...	21.7	39.7	2.8900	.3700	3.2600	15.15	.0100	.0000	-	-	2.4300
26, ...	12.9	20.1	2.3800	.3800	2.7600	4.10	.0070	.0000	-	-	2.9225
27, ...	9.5	19.2	2.1500	.3700	2.5200	4.07	.0070	.0000	65°	0.54	2.7675
28, ...	33.9	26.0	1.8500	1.1800	3.0300	5.53	.0070	.0000	-	-	2.8925
29, ...	-	-	-	-	-	-	-	-	-	-	-
30, ...	19.2	38.0	2.9500	.5700	3.5200	15.75	.0070	.0000	-	-	2.9575
31, ...	-	-	-	-	-	-	-	-	66°	0.56	-

July 3 and 13. — Entrance to sewage pipe cleaned. July 13. — Entrance was half obstructed by sand. July 19. — Sediment washed out of pipe with city water.

Unfiltered Sewage — Continued.

August, 1888.

Date.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
1, ...	113.9	60.2	3.3000	2.6900	5.9900	5.96	.0070	.0000	-	-	3.7650
2, ...	76.1	50.3	3.1800	1.7500	4.9300	4.83	.0000	.0000	-	-	4.3675
3, ...	14.3	27.2	3.1200	.4300	3.5500	8.90	.0100	.0000	68°	0.61	4.4975
4, ...	19.5	23.4	2.9900	.5000	3.4900	5.35	.0100	.0000	-	-	4.4900
5, ...	-	-	-	-	-	-	-	-	-	-	-
6, ...	17.2	24.3	2.6800	.4100	3.0900	3.90	.0070	.0000	-	-	3.7650
7, ...	-	-	-	-	-	-	-	-	67°	0.60	-
8, ...	14.8	26.8	2.6700	.3600	3.0300	9.00	.0070	.0000	-	-	3.2900
9, ...	90.6	71.0	3.3300	.8100	4.1400	4.93	.0100	.0000	-	-	3.4375
10, ...	116.0	77.4	3.9800	2.8900	6.8700	4.80	.0100	.0000	67°	0.57	4.2825
11, ...	143.8	106.4	3.1500	2.5400	5.6900	6.10	-	.0000	-	-	4.9325
12, ...	-	-	-	-	-	-	-	-	-	-	-
13, ...	20.4	39.4	1.4800	.4800	1.9600	4.15	-	.0000	-	-	4.6650
14, ...	-	-	-	-	-	5.65	-	-	66°	0.58	-
15, ...	256.2	315.2	3.2600	4.7000	7.9600	6.50	.0200	.0000	-	-	5.6200
16, ...	36.2	31.8	2.5800	.6000	3.1800	5.10	-	.0000	-	-	4.6975
17, ...	44.8	27.6	2.8000	.9300	3.7300	6.20	.0200	.0000	-	-	4.2075
18, ...	61.4	80.2	2.2800	.5800	2.8600	8.05	.0200	.0000	67°	0.52	4.4325
19, ...	-	-	-	-	-	-	-	-	-	-	-
20, ...	29.4	21.4	2.8700	.4100	3.2800	6.42	.0100	.0000	-	-	3.2625
21, ...	-	-	-	-	-	6.09	-	-	-	-	-
22, ...	27.6	22.6	1.9100	.3400	2.2500	5.80	.0200	.0000	67°	0.52	3.0300
23, ...	21.0	24.6	2.3200	.2700	2.5900	5.70	.0250	.0000	-	-	2.7450
24, ...	20.4	28.4	2.5900	.4800	3.0700	7.80	.0100	.0000	65°	0.57	2.7975
25, ...	20.4	39.0	2.4000	.3700	2.7700	6.25	.0100	.0000	-	-	2.6700
26, ...	-	-	-	-	-	-	-	-	-	-	-
27, ...	27.4	41.0	2.4200	.4300	2.8500	4.22	.0300	.0000	-	-	2.8200
28, ...	-	-	-	-	-	-	-	-	69°	0.53	-
29, ...	184.2	193.2	3.2400	4.7400	7.9800	16.75	.0300	.0000	-	-	4.1675
30, ...	418.4	477.2	4.0600	18.6500	22.7100	29.50	.0350	.0000	-	-	9.0775
31, ...	43.2	48.4	2.8500	.7100	3.5600	11.50	-	.0000	68°	0.45	9.2750

Residue on evaporation after August 1 obtained with sodium carbonate. August 11. — Chlorine in sample collected in the afternoon, 7.10 parts; 18, 9.90; 21, 6.09; 25, 6.00. August 17. — Sewage high in sewer. August 25. — Sample turned black on standing.

Unfiltered Sewage — Continued.

September, 1888.

Date	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, ...	51.6	74.8	2.4100	1.0000	3.4100	11.25	-	.0000	-	-	9.4150
2, ...	-	-	-	-	-	-	-	-	-	-	-
3, ...	41.8	49.2	3.3500	1.1000	4.4500	15.70	-	.0000	-	-	8.5325
4, ...	-	-	-	-	-	-	-	-	67°	0.56	-
5, ...	39.0	36.0	2.9600	1.1500	4.1100	7.00	-	.0000	-	-	3.8825
6, ...	63.0	85.2	3.1400	1.4900	4.6300	9.41	-	.0000	-	-	4.1500
7, ...	21.8	41.4	2.7100	.6800	3.3900	10.60	-	.0000	66°	0.54	4.1450
8, ...	31.2	56.0	2.8100	.8500	3.6600	20.25	-	.0000	-	-	3.9475
9, ...	-	-	-	-	-	-	-	-	-	-	-
10, ...	26.4	56.4	2.2300	.6800	2.9100	15.90	-	.0000	-	-	3.6475
11, ...	-	-	-	-	-	-	-	-	66°	0.54	-
12, ...	14.8	29.6	.5400	.2700	.8100	2.51	-	.0000	-	-	2.6925
13, ...	23.4	38.6	2.5700	.5700	3.1400	7.31	-	.0000	-	-	2.6300
14, ...	9.8	33.0	.8400	.1500	.9900	8.35	-	.0000	62°	0.58	1.9625
15, ...	37.2	45.8	2.5100	.6700	3.1800	14.28	-	.0000	-	-	2.0300
16, ...	-	-	-	-	-	-	-	-	-	-	-
17, ...	24.8	40.2	2.6100	.7400	3.3500	10.70	-	.0000	-	-	2.6650
18, ...	-	-	-	-	-	-	-	-	-	-	-
19, ...	20.2	33.2	2.3800	.4700	2.8500	7.28	-	.0000	64°	0.66	2.5925
20, ...	16.8	29.8	2.5000	.3900	2.8900	6.90	-	.0000	-	-	3.0675
21, ...	89.0	133.6	1.7000	1.8600	3.5600	5.50	-	.0000	-	-	3.1625
22, ...	14.8	31.2	1.5500	.3900	1.9400	5.75	-	.0000	62°	0.61	2.8100
23, ...	-	-	-	-	-	-	-	-	-	-	-
24, ...	19.2	27.4	2.3500	.3500	2.7000	5.87	-	.0000	-	-	2.7725
25, ...	-	-	-	-	-	-	-	-	63°	0.57	-
26, ...	21.4	34.4	.2500	.2700	.5200	1.45	-	.0000	-	-	2.1800
27, ...	17.0	36.0	1.9200	.6800	2.6000	5.35	-	.0000	-	-	1.9400
28, ...	25.6	52.0	1.3200	.6900	2.0100	6.08	-	.0000	-	-	1.9575
29, ...	22.2	53.4	2.5900	.5700	3.1600	18.67	-	.0000	-	-	2.0725
30, ...	-	-	-	-	-	-	-	-	-	-	-

September 11. — Entrance to sewage pipe cleaned. Was almost wholly obstructed by sand. September 14 and 28. Sediment in pipe washed out with city water. September 14 and 20. — Little sediment in samples analyzed.

Unfiltered Sewage — Continued.

October, 1888.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, ...	31.6	28.0	2.5000	1.5100	4.0100	5.53	-	.0000	-	-	2.9450
2, ...	-	-	-	-	-	-	-	-	-	-	-
3, ...	8.2	33.2	1.9800	.3800	2.3600	6.07	-	.0000	58°	0.68	2.8850
4, ...	18.8	27.2	2.4000	.4600	2.8600	7.26	-	.0000	-	-	3.0975
5, ...	20.0	30.6	2.4900	.6400	3.1300	6.24	-	.0000	-	-	3.0900
6, ...	14.2	59.0	1.9400	.4100	2.3500	24.97	-	.0000	59°	0.65	2.6750
7, ...	-	-	-	-	-	-	-	-	-	-	-
8, ...	26.6	30.8	1.8300	.5800	2.4100	5.40	-	.0000	-	-	2.6875
9, ...	-	-	-	-	-	-	-	-	59°	0.69	-
10, ...	13.2	25.0	2.3500	.3800	2.7300	5.25	-	.0000	-	-	2.6550
11, ...	13.8	28.0	2.2100	.3400	2.5500	5.30	-	.0000	-	-	2.5100
12, ...	19.2	25.6	2.6000	.4100	3.0100	5.77	-	.0000	-	-	2.6750
13, ...	14.2	25.4	1.9700	.4000	2.3700	4.97	-	.0000	55°	0.72	2.6650
14, ...	-	-	-	-	-	-	-	-	-	-	-
15, ...	18.2	26.8	2.6100	.5300	3.1400	5.35	-	.0000	-	-	2.7675
16, ...	-	-	-	-	-	-	-	-	54°	0.66	-
17, ...	13.4	25.4	2.6900	.3700	3.0600	4.92	-	.0000	-	-	2.8950
18, ...	12.6	35.2	1.9800	.3800	2.3600	4.40	-	.0000	-	-	2.7325
19, ...	12.8	28.2	2.3600	.3000	2.6600	5.63	-	.0000	-	-	2.8050
20, ...	18.6	27.0	1.5100	.4100	1.9200	4.68	-	.0000	56°	0.65	2.5000
21, ...	-	-	-	-	-	-	-	-	-	-	-
22, ...	13.8	26.8	2.6400	.4700	3.1100	5.05	-	.0000	-	-	2.5125
23, ...	-	-	-	-	-	-	-	-	56°	0.61	-
24, ...	32.0	49.2	.9100	.5900	1.5000	3.00	-	.0000	-	-	2.2975
25, ...	11.0	23.1	2.2400	.2900	2.5300	4.74	-	.0000	-	-	2.2650
26, ...	16.6	23.8	2.7800	.3600	3.1400	4.95	-	.0000	55°	0.67	2.5700
27, ...	15.6	39.0	1.5500	.3100	1.8600	12.10	-	.0000	-	-	2.2575
28, ...	-	-	-	-	-	-	-	-	-	-	-
29, ...	17.2	26.8	2.1200	.3700	2.4900	4.70	-	.0000	-	-	2.5050
30, ...	13.0	29.2	-	-	-	10.85	-	.0000	55°	0.62	-
31, ...	18.0	22.6	2.5400	.3000	2.8400	4.61	-	-	-	-	2.5825

October 13. — Chlorine in sample collected in the afternoon, 4.90. October 19, 24 and 31. — Nitrates not read owing to presence of organic matter.

Unfiltered Sewage — Continued.

November, 1888.

Date.	Residue on Evaporation.		Ammonia.				Nitrogen as				
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
1, ...	14.0	23.0	2.4700	.4300	2.9000	4.79	-	.0000	-	-	2.5225
2, ...	16.4	24.2	2.3800	.4400	2.8200	5.02	-	.0000	-	-	2.7625
3, ...	16.4	23.6	2.8200	.4600	3.2800	4.50	-	.0000	-	-	2.9600
4, ...	-	-	-	-	-	-	-	-	-	-	-
5, ...	17.8	25.6	2.0900	.5700	2.6600	4.45	.0120	.0000	-	-	2.9150
6, ...	13.2	53.2	-	-	-	22.42	-	.0000	-	-	-
7, ...	14.2	28.8	2.4200	.4400	2.8600	4.69	-	.0000	-	-	2.9050
8, ...	17.6	50.4	2.6300	.4800	3.1100	18.72	.0100	.0000	-	-	2.9775
9, ...	21.4	25.4	1.9400	.4400	2.3800	5.05	-	.0000	-	-	2.7525
10, ...	10.8	40.4	1.5500	.4000	1.9500	14.67	.0120	.0000	-	-	2.5750
11, ...	-	-	-	-	-	-	-	-	-	-	-
12, ...	14.2	40.2	1.8100	.4400	2.2500	4.56	.0100	.0000	-	-	2.4225
13, ...	-	-	-	-	-	-	-	-	-	-	-
14, ...	29.0	29.2	2.2000	.4700	2.6700	4.80	.0100	.0000	-	-	2.3125
15, ...	11.0	25.0	2.3800	.4400	2.8200	11.15	.0100	.0000	-	-	2.4225
16, ...	13.2	40.6	2.1800	.5700	2.7500	5.19	.0100	.0000	-	-	2.6225
17, ...	21.5	55.5	1.9300	.6000	2.5300	25.10	.0070	.0000	-	-	2.6925
18, ...	-	-	-	-	-	-	-	-	-	-	-
19, ...	29.0	31.6	2.5200	.6300	3.1500	5.43	.0100	.0000	50°	0.63	2.8125
20, ...	-	-	-	-	-	-	-	-	-	-	-
21, ...	9.4	17.0	.7000	.1800	.8800	3.31	.0100	.0000	-	-	2.3275
22, ...	10.2	24.6	1.1300	.2400	1.3700	4.50	.0100	.0000	-	-	1.9825
23, ...	17.4	28.6	1.5500	.4100	1.9600	7.25	.0100	.0000	52°	0.68	1.8400
24, ...	14.4	23.0	1.4400	.3600	1.8000	4.54	.0100	.0000	-	-	1.5025
25, ...	-	-	-	-	-	-	-	-	-	-	-
26, ...	20.2	24.4	1.8400	.3100	2.1500	5.10	less than .0200	.0000	-	-	1.8200
27, ...	-	-	-	-	-	-	-	-	-	-	-
28, ...	13.6	43.4	.5100	.3200	.8300	2.10	.0070	.0000	-	-	1.6850
29, ...	12.0	25.6	.9900	.1600	1.1500	4.26	.0100	.0000	-	-	1.4825
30, ...	6.0	31.4	1.0100	.2100	1.2200	5.02	.0100	.0000	-	-	1.3375

November 1 and 7. — Nitrates not read owing to presence of organic matter. November 17. — Manganese in sample for first time in two weeks. November 20. — Pipe from Lawrence Street sewer cleaned out. November 30. — Much hydrogen sulphide in sample.

Unfiltered Sewage — Continued.

December, 1888.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, . . .	9.2	31.0	1.2400	.3400	1.5800	7.57	.2000	.0000	-	-	1.1950
2, . . .	-	-	-	-	-	-	-	-	-	-	-
3, . . .	14.0	29.0	1.2700	.2600	1.5300	5.00	.0100	.0000	-	-	1.3700
4, . . .	-	-	-	-	-	-	-	-	47°	0.43	-
5, . . .	17.4	25.4	1.4300	.3600	1.7900	5.18	.0100	.0000	-	-	1.5300
6, . . .	13.4	56.6	1.3700	.3600	1.7300	24.30	.0100	.0000	-	-	1.6575
7, . . .	16.4	26.2	1.4100	.3300	1.7400	4.80	.0100	.0000	-	-	1.6975
8, . . .	14.8	25.0	1.4300	.4300	1.8600	5.00	.0100	.0000	-	-	1.7800
9, . . .	-	-	-	-	-	-	-	-	-	-	-
10, . . .	14.8	27.0	1.3400	.3700	1.7100	5.04	.0150	.0000	-	-	1.7600
11, . . .	18.6	29.8	-	-	-	4.98	.0100	.0000	-	-	-
12, . . .	22.6	60.0	.8800	.3600	1.2400	3.80	.0100	.0000	-	-	1.6375
13, . . .	10.4	27.0	1.6000	.1900	1.7900	4.76	.0200	.0000	-	-	1.6500
14, . . .	11.7	24.6	1.4100	.2400	1.6500	5.03	.0150	.0000	48°	0.72	1.5975
15, . . .	20.0	18.6	.7800	.3700	1.1500	2.70	.0300	.0000	-	-	1.4575
16, . . .	-	-	-	-	-	-	-	-	-	-	-
17, . . .	5.2	18.2	.2300	.1100	.3400	2.89	.0130	.0000	-	-	1.2325
18, . . .	-	-	-	-	-	-	-	-	-	-	-
19, . . .	-	-	-	-	-	-	-	-	-	-	-
20, . . .	-	-	-	-	-	-	-	-	-	-	-
21, . . .	-	-	-	-	-	-	-	-	-	-	-
22, . . .	8.6	27.2	1.1400	.2800	1.4200	4.61	.0100	.0000	45°	0.71	1.1400
23, . . .	-	-	-	-	-	-	-	-	-	-	-
24, . . .	-	-	-	-	-	-	-	-	-	-	-
25, . . .	-	-	-	-	-	-	-	-	-	-	-
26, . . .	28.0	37.0	.6900	.3700	1.5600	4.23	.0100	.0000	-	-	1.1175
27, . . .	16.6	25.0	1.4800	.6600	2.1400	5.52	.0070	.0000	-	-	1.3650
28, . . .	12.0	33.2	1.2500	.3000	1.5500	3.63	.0120	.0000	-	-	1.6675
29, . . .	9.4	22.8	1.1400	.2900	1.4300	4.42	.0100	.0000	46°	0.73	1.6700
30, . . .	-	-	-	-	-	-	-	-	-	-	-
31, . . .	12.0	23.8	1.4500	.2900	1.7400	3.78	.0100	.0000	-	-	1.7150

Sample of December 1 again analyzed December 3, showed nitrates .1250 parts. December 5, 7, 8, 10, 12, 13, 14, 26 and 31. Samples contained manganese. December 27 and 28. — No manganese.

Unfiltered Sewage — Continued.

January, 1889.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, . . .	-	-	-	-	-	-	-	-	45°	0.75	-
2, . . .	8.4	22.0	1.0700	.2700	1.3400	4.10	-	.0000	-	-	1.5150
3, . . .	11.4	23.2	1.0600	.2500	1.3100	5.40	.0070	.0000	-	-	1.4550
4, . . .	10.4	23.0	1.3900	.3300	1.7200	4.57	.0100	.0000	47°	0.69	1.5275
5, . . .	10.8	24.6	1.2500	.2600	1.5100	4.92	.0100	.0000	-	-	1.4700
6, . . .	-	-	-	-	-	-	-	-	-	-	-
7, . . .	13.8	24.6	1.4500	.2600	1.7100	4.27	.0100	.0000	-	-	1.5625
8, . . .	-	-	-	-	-	-	-	-	47°	0.88	-
9, . . .	13.2	24.0	1.1900	.2600	1.4500	4.15	.0150	.0000	-	-	1.5975
10, . . .	12.2	23.0	1.2600	.2700	1.5300	4.60	.0100	.0000	-	-	1,5500
11, . . .	11.6	23.4	1.1700	.2200	1.3900	4.80	.1000	.0040	-	-	1.5200
12, . . .	13.0	24.2	1.1400	.2800	1.4200	4.87	.0050	.0000	46°	0.79	1.4475
13, . . .	-	-	-	-	-	-	-	-	-	-	-
14, . . .	14.8	28.0	1.1500	.2400	1.3900	6.71	.0050	.0000	-	-	1.4325
15, . . .	-	-	-	-	-	-	-	-	47°	0.77	-
16, . . .	12.0	23.2	1.3500	.3500	1.7000	4.93	.0100	.0000	-	-	1.4750
17, . . .	10.8	22.2	1.0900	.3000	1.3900	4.40	.0100	.0000	-	-	1.4750
18, . . .	8.4	34.0	.4700	.2000	.6700	2.70	.0050	.0000	-	-	1.2875
19, . . .	8.4	23.0	1.0100	.3100	1.3200	4.20	.0100	.0000	46°	0.75	1.2700
20, . . .	-	-	-	-	-	-	-	-	-	-	-
21, . . .	3.8	16.0	.6600	.1300	.7900	2.68	.1600	.0500	-	-	1.0425
22, . . .	-	-	-	-	-	-	-	-	-	-	-
23, . . .	12.0	22.8	1.1500	.2500	1.4000	4.48	.0100	.0000	45°	0.71	1.0450
24, . . .	10.0	20.2	1.1100	.3500	1.4600	3.98	.0100	.0000	-	-	1.2425
25, . . .	10.6	21.2	1.3000	.3100	1.6100	4.10	.0100	.0000	-	-	1.3150
26, . . .	8.4	21.6	1.0200	.3500	1.3700	4.70	.0100	.0080	46°	0.77	1.4600
27, . . .	-	-	-	-	-	-	-	-	-	-	-
28, . . .	12.4	24.2	1.4000	.2400	1.6400	4.00	.0100	.0000	-	-	1.5200
29, . . .	-	-	-	-	-	-	-	-	-	-	-
30, . . .	13.8	19.2	1.2000	.2100	1.4100	4.13	.0150	.0030	44°	0.71	1.5075
31, . . .	9.6	18.0	1.0100	.3500	1.3600	4.43	.0100	.0000	-	-	1.4450

January 5.— Sample contained manganese. Sewage pipe from Lawrence Street sewer cleaned out.

Unfiltered Sewage — Continued.

February, 1889.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, ...	8.8	19.4	1.3400	.2400	1.5800	4.20	.0100	.0000	-	-	1.4975
2, ...	12.0	20.4	1.5800	.3200	1.9000	4.65	.0100	.0040	48°	0.68	1.5625
3, ...	-	-	-	-	-	-	-	-	-	-	-
4, ...	3.6	11.2	.2100	.1800	.3900	2.03	.1200	.0400	-	-	1.3075
5, ...	-	-	-	-	-	-	-	-	43°	0.72	-
6, ...	11.8	21.0	1.3900	.3500	1.7400	4.87	-	.0000	-	-	1.4025
7, ...	5.6	18.8	1.0600	.1900	1.2500	3.98	-	.0000	-	-	1.3200
8, ...	8.8	20.6	1.3300	.2600	1.5900	4.40	.0100	.0000	45°	0.80	1.2425
9, ...	8.0	18.4	1.1500	.3000	1.4500	4.55	.0200	.0100	-	-	1.5075
10, ...	-	-	-	-	-	-	-	-	-	-	-
11, ...	1.8	14.2	.2000	.1900	.3900	2.16	.0030	.0000	-	-	1.1700
12, ...	-	-	-	-	-	-	-	-	45°	0.69	-
13, ...	10.0	17.2	1.0300	.2900	1.3200	3.57	.0020	.0050	-	-	1.1875
14, ...	13.2	20.8	1.4300	.3800	1.8100	4.50	.0040	.0000	-	-	1.2425
15, ...	13.0	24.2	1.4100	.5000	1.9100	6.07	.0150	.0000	-	-	1.3575
16, ...	13.0	22.6	1.3200	.3700	1.6900	4.70	.0050	.0050	45°	0.65	1.6825
17, ...	-	-	-	-	-	-	-	-	-	-	-
18, ...	2.0	13.4	.4800	.0500	.5300	1.97	.0230	.0200	-	-	1.4850
19, ...	-	-	-	-	-	-	-	-	-	-	-
20, ...	12.6	19.4	1.0700	.2400	1.3100	3.68	.0050	.0100	43°	0.67	1.3600
21, ...	16.0	22.6	1.5200	.3400	1.8600	4.50	.0030	.0000	-	-	1.3475
22, ...	11.6	20.2	1.7900	.3200	2.1100	4.10	.0030	.0100	-	-	1.4525
23, ...	15.0	18.2	1.4900	1.4300	2.9200	4.07	.0100	.0000	44°	0.71	2.0500
24, ...	-	-	-	-	-	-	-	-	-	-	-
25, ...	6.4	11.0	.3800	.1320	.5120	1.90	.0350	.1500	-	-	1.8505
26, ...	-	-	-	-	-	-	-	-	-	-	-
27, ...	13.4	19.4	1.5900	.3700	1.9600	3.82	.0100	.0000	43°	0.70	1.8755
28, ...	11.0	18.2	1.4400	.4900	1.9300	4.80	.0070	.0000	-	-	1.8305

February 4. — Manganese not present. February 6. — Present. February 18. — Sewage pipe from Lawrence Street sewer cleaned out.

Unfiltered Sewage — Continued.

March, 1889.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, ...	17.4	22.4	1.8000	.5500	2.3500	4.50	.0100	.0000	-	-	1.6880
2, ...	12.8	22.0	1.7100	.3400	2.0500	3.72	.0100	.0000	40°	0.95	2.0725
3, ...	-	-	-	-	-	-	-	-	-	-	-
4, ...	15.0	20.6	1.2100	.3000	1.5100	3.00	.0050	.0000	-	-	1.9600
5, ...	-	-	-	-	-	-	-	-	-	-	-
6, ...	17.2	33.2	.8200	.3200	1.1400	2.40	.0100	.0020	-	-	1.7625
7, ...	9.6	23.8	.7600	.1800	.9400	3.70	.0050	.0000	44°	0.88	1.4100
8, ...	7.0	24.6	1.3500	.2300	1.5800	3.55	.0200	.0000	-	-	1.2925
9, ...	11.8	18.0	1.6200	.3600	1.9800	3.72	.0070	.0100	-	-	1.4100
10, ...	-	-	-	-	-	-	-	-	44°	0.74	-
11, ...	11.4	20.4	1.8100	.4100	2.2200	3.50	.0100	.0000	-	-	1.6800
12, ...	11.2	20.0	-	-	-	3.90	-	-	47°	0.71	-
13, ...	12.2	19.6	1.6800	.3500	2.0300	3.89	.0070	.0000	-	-	1.9525
14, ...	10.4	20.0	1.6900	.3400	2.0300	3.46	.0300	.0000	-	-	2.0650
15, ...	12.8	20.6	1.8900	.4700	2.3600	4.25	.0100	.0150	45°	0.59	2.1600
16, ...	12.8	20.2	2.0100	.5000	2.5100	3.80	.0100	.0000	-	-	2.2325
17, ...	-	-	-	-	-	-	-	-	-	-	-
18, ...	15.0	38.6	1.2300	.3300	1.5600	2.80	.0070	.0000	-	-	2.1150
19, ...	-	-	-	-	-	-	-	-	46°	0.66	-
20, ...	15.2	19.8	1.7900	.4700	2.2600	4.05	.0150	.0000	-	-	2.1725
21, ...	17.2	22.6	2.0200	.5600	2.5800	3.94	.0100	.0000	-	-	2.2275
22, ...	13.2	18.4	1.7000	.4300	2.1300	3.80	.0070	.0000	-	-	2.1325
23, ...	20.0	23.6	2.3600	.7300	2.0900	3.83	.0120	.0000	47°	0.72	2.5150
24, ...	-	-	-	-	-	-	-	-	-	-	-
25, ...	18.8	39.2	2.0000	.6100	2.6100	14.82	.0100	.0000	-	-	2.6025
26, ...	12.0	20.8	1.7900	.4500	2.2400	3.76	.0100	.0000	47°	0.67	2.5175
27, ...	13.0	24.0	2.3500	.5000	2.8500	6.48	.0100	.0040	-	-	2.6975
28, ...	14.4	41.8	1.9800	.5000	2.4800	11.47	.0050	.0000	-	-	2.5450
29, ...	12.6	21.2	1.4000	.4600	1.8600	5.18	.0050	.0000	-	-	2.3575
30, ...	16.8	26.4	2.6800	.6300	3.3100	3.88	.0050	.0000	47°	0.75	2.6250
31, ...	-	-	-	-	-	-	-	-	-	-	-

Unfiltered Sewage — Continued.

April, 1889.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1,	14.2	25.6	1.2000	.4200	1.6200	2.70	.0050	.0000	–	–	2.3175
2,	–	–	–	–	–	–	–	–	45°	0.81	–
3,	6.8	53.4	1.2600	.4800	1.7400	19.40	.0200	.0000	–	–	2.1325
4,	11.2	27.4	1.7900	.4900	2.2800	4.22	.0150	.0000	–	–	2.2375
5,	14.4	20.6	2.0700	.5000	3.5700	4.02	.0050	.0100	–	–	2.0525
6,	7.4	20.2	2.1000	.3600	2.4600	3.95	.0250	.0000	47°	0.65	2.2625
7,	–	–	–	–	–	–	–	–	–	–	–
8,	12.0	26.2	1.8600	.3600	2.2200	3.98	.0050	.0000	–	–	2.3825
9,	–	–	–	–	–	–	–	–	48°	0.64	–
10,	9.4	20.8	1.8000	.3500	2.1500	4.67	.0050	.0000	–	–	2.3500
11,	9.6	22.4	2.1700	.4400	2.6100	4.76	.0030	.0000	–	–	2.3600
12,	11.2	21.6	2.3800	.3200	2.7000	3.82	.0050	.0010	–	–	2.4200
13,	19.2	23.6	2.1700	.5800	2.7500	4.27	.0100	.0000	49°	0.75	2.5525
14,	–	–	–	–	–	–	–	–	–	–	–
15,	14.6	27.6	2.2200	.5800	2.8000	4.02	.0100	.0020	–	–	2.7150
16,	–	–	–	–	–	–	–	–	51°	0.65	–
17,	11.8	25.0	1.8100	.4100	2.2200	5.45	.0100	.0000	–	–	2.6175
18,	14.4	25.2	2.2200	.4400	2.6600	4.60	.0100	.0010	–	–	2.6075
19,	13.2	24.0	2.4100	.5400	2.9500	4.47	.0070	.0000	–	–	2.6575
20,	13.2	23.2	2.4500	.6100	3.0600	3.58	.0030	.0000	–	–	2.7525
21,	–	–	–	–	–	–	–	–	–	–	–
22,	21.6	26.4	1.8300	.5000	2.3300	3.49	.0100	.0000	–	–	2.7500
23,	–	–	–	–	–	–	–	–	–	–	–
24,	12.6	20.2	2.3800	.3600	2.7400	4.21	.0050	.0000	–	–	2.7700
25,	16.2	20.6	2.7200	.4200	3.1400	4.05	.0050	.0000	–	–	2.8175
26,	12.8	21.4	2.5500	.4000	2.9500	4.15	.0050	.0000	–	–	2.7900
27,	14.4	26.0	1.6400	.4100	2.0500	6.66	.0050	.0000	–	–	2.7200
28,	–	–	–	–	–	–	–	–	–	–	–
29,	16.8	24.4	2.0800	.5100	2.5900	4.00	.0150	.0000	–	–	2.6825
30,	–	–	–	–	–	–	–	–	57	0.61	–

Unfiltered Sewage — Continued.

May, 1889.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, . . .	11.6	21.8	2.2100	.2600	2.4700	4.00	.0050	.0000	-	-	2.5150
2, . . .	11.0	23.6	1.9400	.2700	2.2100	4.91	.0000	.0000	-	-	2.3300
3, . . .	9.6	24.0	2.4400	.3900	2.8300	5.49	.0000	.0000	-	-	2.5250
4, . . .	16.0	25.2	2.3900	.5400	2.9300	4.98	.0000	.0000	-	-	2.6100
5, . . .	-	-	-	-	-	-	-	-	-	-	-
6, . . .	17.2	22.0	1.9900	.6600	2.6500	4.50	.0000	.0000	-	-	2.6550
7, . . .	-	-	-	-	-	-	-	-	56°	0.65	-
8, . . .	11.0	22.6	2.4500	.3500	2.8000	4.20	.0000	.0000	-	-	2.8025
9, . . .	26.2	29.0	2.3700	.5900	2.9600	5.48	.0000	.0000	-	-	2.8350
10, . . .	17.6	25.6	1.4800	.3600	1.8400	5.24	.0000	.0000	-	-	2.5625
11, . . .	22.4	24.0	2.7100	.5200	3.2300	4.40	.0000	.0000	56°	0.66	2.7075
12, . . .	-	-	-	-	-	-	-	-	-	-	-
13, . . .	21.2	26.2	1.9500	.5800	2.5300	5.65	.0000	.0000	-	-	2.6400
14, . . .	-	-	-	-	-	-	-	-	-	-	-
15, . . .	16.4	32.8	1.7600	.3000	2.0600	3.75	.0000	.0000	-	-	2.4150
16, . . .	16.2	24.4	2.0800	.4000	2.4800	5.12	.0000	.0000	-	-	2.5750
17, . . .	15.2	19.8	2.0000	.3200	2.3200	4.00	.0000	.0000	-	-	2.3475
18, . . .	20.4	25.6	1.8000	.4800	2.2800	5.10	.0000	.0000	57°	0.73	2.2850
19, . . .	-	-	-	-	-	-	-	-	-	-	-
20, . . .	22.4	23.0	1.8500	.6400	2.4900	3.67	.0000	.0000	-	-	2.3925
21, . . .	-	-	-	-	-	-	-	-	-	-	-
22, . . .	9.6	24.0	1.4000	.3000	1.7000	5.32	.0000	.0000	-	-	2.1975
23, . . .	11.4	27.4	2.0400	.2600	2.3000	6.30	.0000	.0000	-	-	2.1925
24, . . .	7.6	27.4	1.7600	.3500	2.1100	4.57	.0000	.0000	-	-	2.1500
25, . . .	12.6	25.6	1.9200	.4600	2.3800	5.22	.0000	.0000	61°	0.65	2.1225
26, . . .	-	-	-	-	-	-	-	-	-	-	-
27, . . .	22.0	24.4	1.4400	.5300	1.9700	4.22	.0000	.0000	-	-	2.1900
28, . . .	-	-	-	-	-	-	-	-	-	-	-
29, . . .	13.6	24.2	1.9600	.4300	2.3900	4.70	.0000	.0000	-	-	2.2125
30, . . .	14.4	25.2	2.5900	.4400	3.0300	5.52	.0000	.0000	-	-	2.4425
31, . . .	18.0	24.0	2.8000	.5000	3.3000	4.41	.0000	.0000	-	-	2.6725

May 4. — Sewage pipe from Lawrence Street sewer cleaned out.

Unfiltered Sewage — Continued.

June, 1889.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, . . .	26.6	26.8	3.1200	.6500	3.7700	5.37	.0000	.0000	60°	0.71	3.1225
2, . . .	-	-	-	-	-	-	-	-	-	-	-
3, . . .	-	-	-	-	-	-	-	-	-	-	-
4, . . .	-	-	-	-	-	-	-	-	-	-	-
5, . . .	26.0	77.8	2.0000	.7200	2.7200	4.00	.0000	.0000	-	-	3.2050
6, . . .	35.6	41.6	2.1200	.7600	2.8800	6.12	.0000	.0000	-	-	3.1675
7, . . .	10.0	22.8	2.0000	.4100	2.4100	4.30	.0000	.0000	-	-	2.9450
8, . . .	23.0	25.0	2.0800	.4300	2.5100	5.21	.0000	.0000	62°	0.81	2.6300
9, . . .	-	-	-	-	-	-	-	-	-	-	-
10, . . .	19.2	27.2	2.5200	.4600	2.9800	4.25	.0000	.0000	-	-	2.6950
11, . . .	-	-	-	-	-	-	-	-	-	-	-
12, . . .	41.4	36.8	2.0000	.8600	2.8600	5.12	.0000	.0000	-	-	2.6900
13, . . .	25.8	28.2	2.4000	.5600	2.9600	6.63	.0000	.0000	-	-	2.8275
14, . . .	23.2	30.4	2.0000	.4000	2.4000	4.85	.0000	.0000	-	-	2.8000
15, . . .	17.2	23.2	2.7200	.2900	3.0100	4.70	.0000	.0000	64°	0.72	2.8075
16, . . .	-	-	-	-	-	-	-	-	-	-	-
17, . . .	25.0	24.2	2.8000	.6700	3.4700	4.59	.0000	.0000	-	-	2.9600
18, . . .	-	-	-	-	-	-	-	-	-	-	-
19, . . .	21.2	26.4	2.4000	.5000	2.9000	8.20	.0000	.0000	-	-	2.9450
20, . . .	23.6	26.4	3.3200	.8500	4.1700	5.71	.0000	.0000	-	-	3.3875
21, . . .	32.4	27.8	3.4000	.6200	4.0200	5.59	.0000	.0000	-	-	3.6400
22, . . .	21.6	23.6	2.9200	.4200	3.3400	5.45	.0000	.0000	65°	0.72	3.6075
23, . . .	-	-	-	-	-	-	-	-	-	-	-
24, . . .	25.4	26.0	3.4000	.7800	4.1800	4.81	.0000	.0000	-	-	3.9275
25, . . .	-	-	-	-	-	-	-	-	-	-	-
26, . . .	28.8	24.4	2.8000	.6600	3.4600	4.38	.0000	.0000	-	-	3.7500
27, . . .	33.8	22.8	1.7600	.7600	2.5200	5.36	.0000	.0000	-	-	3.3750
28, . . .	26.0	22.8	2.4000	.5300	2.9300	5.52	.0000	.0000	-	-	3.2725
29, . . .	30.6	46.0	2.6800	.8600	3.5400	16.50	.0000	.0000	66°	0.74	3.1125
30, . . .	-	-	-	-	-	-	-	-	-	-	-

Unfiltered Sewage — Continued.

July, 1889.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, . . .	32.4	30.4	-	-	-	4.98	.0000	.0000	-	-	-
2, . . .	-	-	-	-	-	-	-	-	-	-	-
3, . . .	19.6	26.0	1.3600	.4400	1.8000	6.22	.0000	.0000	-	-	2.6975
4, . . .	10.2	26.6	1.6400	.6200	2.2600	6.60	.0000	.0000	-	-	2.6325
5, . . .	16.0	24.4	3.1200	.5200	3.6400	6.87	.0000	.0000	-	-	2.8100
6, . . .	28.6	22.2	2.6000	.6800	3.2800	4.20	.0000	.0000	65°	0.63	2.7450
7, . . .	-	-	-	-	-	-	-	-	-	-	-
8, . . .	28.4	25.6	2.3200	.9200	3.2400	4.53	.0000	.0000	-	-	3.1050
9, . . .	-	-	-	-	-	-	-	-	-	-	-
10, . . .	29.6	37.6	1.6800	.7400	2.4200	9.74	.0000	.0000	-	-	3.1450
11, . . .	25.6	35.2	3.0000	.7900	3.7900	11.01	.0000	.0000	-	-	3.1825
12, . . .	18.0	22.8	3.2400	.5900	3.8300	5.01	.0000	.0000	-	-	3.3200
13, . . .	39.4	29.8	3.4800	.9100	4.3900	7.42	.0000	.0000	54°	0.65	3.6075
14, . . .	-	-	-	-	-	-	-	-	-	-	-
15, . . .	26.8	32.8	1.7200	.7700	2.4900	5.04	.0000	.0000	-	-	3.6250
16, . . .	-	-	-	-	-	-	-	-	-	-	-
17, . . .	22.4	24.8	2.9200	.6000	3.5200	6.41	.0000	.0000	-	-	3.5575
18, . . .	22.8	38.4	2.7200	.7200	3.4400	6.21	.0000	.0000	-	-	3.4600
19, . . .	22.4	21.2	2.4800	.6600	3.1400	5.18	.0000	.0000	-	-	3.1475
20, . . .	26.4	79.4	.8400	.7000	1.5400	1.44	.0000	.0000	-	-	2.9100
21, . . .	-	-	-	-	-	-	-	-	-	-	-
22, . . .	23.4	28.2	2.4000	.7000	3.1000	4.52	.0000	.0000	-	-	2.8050
23, . . .	-	-	-	-	-	-	-	-	-	-	-
24, . . .	24.6	57.2	2.0800	.6200	2.7000	4.72	.0000	.0000	-	-	2.6200
25, . . .	25.2	34.4	2.2800	.7100	2.9900	5.10	.0000	.0000	-	-	2.5825
26, . . .	16.4	24.8	2.6800	.4300	3.1100	5.49	.0000	.0000	-	-	2.9750
27, . . .	18.8	26.8	3.3200	.3500	3.6700	4.97	.0000	.0000	-	-	3.1175
28, . . .	-	-	-	-	-	-	-	-	-	-	-
29, . . .	21.6	40.0	2.2000	.3000	2.5000	3.70	.0000	.0000	-	-	3.0675
30, . . .	-	-	-	-	-	-	-	-	-	-	-
31, . . .	42.0	67.2	1.4000	.6100	2.0100	4.07	.0000	.0000	-	-	2.8225

July 2. — Sewage pipe from Lawrence Street sewer cleaned out.

Unfiltered Sewage — Continued.

August, 1889.

Date.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
1,	15.2	34.0	1.6800	.3800	2.0600	3.87	.0000	.0000	-	-	2.5600
2,	18.0	84.0	1.7200	.5300	2.2500	4.60	.0000	.0000	-	-	2.2050
3,	22.8	43.2	2.2000	.4800	2.6800	5.68	.0000	.0000	-	-	2.2500
4,	-	-	-	-	-	-	-	-	-	-	-
5,	19.2	34.8	1.7200	.4800	2.2000	7.21	.0000	.0000	-	-	2.2975
6,	-	-	-	-	-	-	-	-	66°	0.74	-
7,	18.2	22.8	2.0400	.6800	2.7200	4.88	.0000	.0000	-	-	2.4625
8,	26.2	35.0	2.0200	.6600	2.6800	5.40	.0000	.0000	-	-	2.3200
9,	22.8	28.4	2.2000	.7000	2.9000	5.63	.0000	.0000	-	-	2.6300
10,	27.0	80.2	2.3300	1.3300	3.6600	4.58	.0000	.0000	67°	0.69	2.9950
11,	-	-	-	-	-	-	-	-	-	-	-
12,	27.2	29.4	2.2000	.6700	2.8700	4.65	.0000	.0000	-	-	3.0325
13,	-	-	-	-	-	-	-	-	-	-	-
14,	16.0	40.2	.4600	.3900	.8500	2.25	.0000	.0000	-	-	2.5750
15,	14.4	33.6	1.3000	.3800	1.6800	5.31	.0000	.0000	-	-	2.2650
16,	17.6	29.2	1.8000	.4400	2.2400	5.74	.0000	.0000	-	-	1.9100
17,	22.8	26.8	1.9000	.5000	2.4000	3.91	.0000	.0000	64°	0.82	1.7925
18,	-	-	-	-	-	-	-	-	-	-	-
19,	27.4	28.4	1.8000	.6300	2.4300	6.42	.0000	.0000	-	-	2.1875
20,	-	-	-	-	-	-	-	-	-	-	-
21,	-	-	2.0000	.5200	2.5200	4.84	.0000	.0000	-	-	2.3975
22,	-	-	2.1000	.7000	2.8000	4.56	.0000	.0000	-	-	2.5375
23,	-	-	-	-	-	11.94	.0000	.0000	-	-	-
24,	-	-	2.1200	.9000	3.0200	4.74	.0000	.0000	65°	0.65	2.6925
25,	-	-	-	-	-	-	-	-	-	-	-
26,	-	-	2.3500	.7700	3.1200	5.32	.0000	.0000	-	-	2.8650
27,	-	-	-	-	-	-	-	-	-	-	-
28,	-	-	2.1200	.8800	3.0000	4.45	.0000	.0040	-	-	2.9850
29,	-	-	2.0000	.7000	2.7000	4.35	.0000	.0000	-	-	2.9600
30,	-	-	2.0000	.8500	2.8500	5.03	.0000	.0000	-	-	2.9175
31,	37.6	36.4	2.3300	1.0000	3.3300	4.20	.0000	.0000	66°	0.68	2.9700

August 27. — Sewage pipe from Lawrence Street sewer cleaned out.

Unfiltered Sewage — Continued.

September, 1889.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1,	-	-	-	-	-	-	-	-	-	-	-
2,	32.2	29.4	1.3300	.8700	2.2000	4.51	.0000	.0000	-	-	2.7700
3,	-	-	-	-	-	-	-	-	-	-	-
4,	30.0	29.2	1.5000	.4700	1.9700	6.10	.0000	.0000	-	-	2.5875
5,	-	-	2.1000	.8200	2.9200	4.72	.0000	.0000	-	-	2.6050
6,	22.4	28.2	1.3300	.7000	2.0300	6.12	.0000	.0000	-	-	2.2800
7,	35.4	30.0	2.0000	1.1400	3.1400	3.10	.0000	.0000	66°	0.78	2.5150
8,	-	-	-	-	-	-	-	-	-	-	-
9,	32.8	27.8	1.8000	1.0000	2.8000	5.60	.0000	.0000	-	-	2.7225
10,	-	-	-	-	-	-	-	-	-	-	-
11,	34.2	41.2	2.4000	.7600	3.1600	16.98	.0000	.0000	-	-	2.7825
12,	41.6	33.2	2.8300	1.2700	4.1000	5.21	.0000	.0000	-	-	3.3000
13,	42.0	32.0	2.5000	.9300	3.4300	7.50	.0000	.0000	-	-	3.3725
14,	105.6	244.8	1.6500	2.6000	4.2500	3.63	.0000	.0000	65°	0.80	3.7350
15,	-	-	-	-	-	-	-	-	-	-	-
16,	41.2	75.2	1.9000	1.0400	2.9400	4.45	.0000	.0000	-	-	3.6800
17,	-	-	-	-	-	-	-	-	-	-	-
18,	25.0	36.6	.8600	.7000	1.5600	3.24	.0000	.0000	-	-	3.0450
19,	34.6	51.2	.5600	.9000	1.4600	2.11	.0000	.0000	-	-	2.5525
20,	19.6	29.6	1.7000	.7400	2.4400	5.16	.0000	.0000	-	-	2.1000
21,	18.4	25.0	2.0000	.4800	2.4800	5.31	.0000	.0000	66°	0.77	1.9850
22,	-	-	-	-	-	-	-	-	-	-	-
23,	34.6	40.8	2.2000	1.0000	3.2000	4.46	.0000	.0000	-	-	2.3950
24,	-	-	-	-	-	-	-	-	-	-	-
25,	24.4	22.8	2.0000	.6400	2.6400	4.80	.0000	.0000	-	-	2.6900
26,	28.8	31.8	2.1200	.9200	3.0400	5.16	.0000	.0000	-	-	2.8400
27,	22.4	34.0	2.0000	.9500	2.9500	5.41	.0000	.0000	-	-	2.9575
28,	-	-	2.5000	2.0000	4.5000	4.90	.0000	.0000	66°	0.68	3.2825
29,	-	-	-	-	-	-	-	-	-	-	-
30,	-	-	-	-	-	-	-	-	-	-	-

Unfiltered Sewage — Continued.

October, 1889.

Date.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature in Sewer. Fah.	Depth in Sewer. Feet.	Average of Sum of Ammonias for Previous Week.
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.			
1, ...	20.2	32.0	1.7000	.5100	2.2100	8.72	.0000	.0000	-	-	3.1750
2, ...	24.2	35.4	2.0000	.8500	2.8500	4.58	.0000	.0000	-	-	3.1275
3, ...	27.0	29.6	2.7500	.7800	3.5300	5.34	.0000	.0000	-	-	3.2725
4, ...	23.6	28.4	2.2500	.7200	2.9700	5.23	.0000	.0000	-	-	2.8900
5, ...	40.1	30.6	2.1500	1.0200	3.1700	4.28	.0000	.0000	61°	0.68	3.1300
6, ...	-	-	-	-	-	-	-	-	-	-	-
7, ...	16.0	25.2	1.4000	.3200	1.7200	3.05	.0100	.0020	-	-	7.8475
8, ...	22.0	32.0	2.0000	.5600	2.5600	5.23	-	-	-	-	2.6050
9, ...	44.8	41.6	2.2500	.9000	3.1500	6.58	-	-	-	-	2.6500
10, ...	23.0	28.8	2.0000	.5800	2.5800	5.76	.0000	.0000	-	-	2.5025
11, ...	25.8	24.2	2.0000	.7900	2.7900	4.97	-	-	-	-	2.7700
12, ...	32.0	23.8	1.7500	.8000	2.5500	4.33	.0000	.0004	59°	0.68	2.7675
13, ...	-	-	-	-	-	-	-	-	-	-	-
14, ...	22.2	23.2	2.0000	.7500	2.7500	4.88	.0000	.0000	-	-	2.6675
15, ...	29.6	25.6	2.0000	.6300	2.6300	4.94	.0000	.0000	-	-	2.6800
16, ...	29.2	23.6	1.7000	.9400	2.6400	4.27	-	-	-	-	2.6425
17, ...	45.6	34.8	2.2500	1.3300	3.5800	4.55	.0000	.0000	-	-	2.9000
18, ...	21.2	23.6	1.9000	.6700	2.5700	4.94	-	-	-	-	2.8550
19, ...	34.4	30.4	2.3000	.9000	3.2000	4.51	.0000	.0000	58°	0.77	2.9975
20, ...	-	-	-	-	-	-	-	-	-	-	-
21, ...	19.6	23.2	1.5000	.4700	1.9700	5.70	.0000	.0000	-	-	2.8300
22, ...	23.8	22.4	1.9000	.6600	2.5600	4.93	-	-	-	-	2.5750
23, ...	27.2	23.6	1.8000	.6900	2.4900	4.43	.0000	.0000	-	-	2.5550
24, ...	30.8	26.2	1.8000	.6200	2.4200	4.32	.0000	.0004	-	-	2.3600
25, ...	-	-	-	-	-	-	-	-	-	-	-
26, ...	-	-	1.9000	.7500	2.6500	4.17	.0000	.0000	51°	0.70	2.5300
27, ...	-	-	-	-	-	-	-	-	-	-	-
28, ...	35.2	30.8	1.8500	.9200	2.7700	4.50	.0000	.0000	-	-	2.5825
29, ...	30.4	58.8	.8500	.6700	1.5200	3.79	-	-	-	-	2.3400
30, ...	-	-	1.7500	.8200	2.5700	3.99	.0000	.0000	-	-	2.3775
31, ...	31.0	25.4	2.2500	.7700	3.0200	4.76	.0000	.0000	-	-	2.4700

For monthly averages see pp. 35 and 36.

FILTERED SEWAGE.

January, 1888.

Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.
1, . .	4.80	15.00	1.0500	.1500	1.2000
2, . .	–	–	–	–	–
3, . .	2.80	16.00	.8000	.1300	.9300
4, . .	–	–	–	–	–
5, . .	7.40	19.80	1.4000	.2600	1.6600
6, . .	–	–	–	–	–
7, . .	–	–	–	–	–
8, . .	5.80	16.00	1.2400	.1500	1.3900
9, . .	–	–	–	–	–
10, . .	10.60	16.20	1.7900	.2000	1.9900
11, . .	–	–	–	–	–
12, . .	4.60	14.80	1.3000	.3300	1.6300
13, . .	9.40	17.00	1.5000	.1500	1.6500
14, . .	–	–	–	–	–
15, . .	–	–	–	–	–
16, . .	4.60	15.00	1.4300	.1800	1.6100
17, . .	4.40	15.80	1.2700	.1800	1.4500
18, . .	–	–	–	–	–
19, . .	–	–	–	–	–
20, . .	4.40	14.00	.7400	.0110	.7510
21, . .	–	–	–	–	–
22, . .	4.00	12.40	1.2400	.0900	1.3300
23, . .	–	–	–	–	–
24, . .	4.20	11.80	.6400	.1600	.8000
25, . .	3.00	11.00	.6900	.0600	.7500
26, . .	–	–	–	–	–
27, . .	2.60	13.00	.5300	.0700	.6000
28, . .	–	–	–	–	–
29, . .	5.40	9.80	.7500	.1100	.8600
30, . .	–	–	–	–	–
31, . .	2.80	10.20	.6000	.0700	.6700

February, 1888.

Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.
1, . .	3.60	10.40	.5900	.1300	.7200
2, . .	–	–	–	–	–
3, . .	3.40	11.80	.7900	.1700	.9600
4, . .	–	–	–	–	–
5, . .	5.20	12.00	.7400	.1100	.8500
6, . .	–	–	–	–	–
7, . .	14.00	24.60	–	–	–
8, . .	11.60	16.00	1.2800	.2500	1.5300
9, . .	–	–	–	–	–
10, . .	6.00	6.60	.3400	.0400	.3800
11, . .	–	–	–	–	–
12, . .	10.80	9.60	.8100	.0800	.8900
13, . .	–	–	–	–	–
14, . .	25.40	6.00	.6500	.1700	.8200
15, . .	18.40	16.80	1.7800	.3400	2.1200
16, . .	–	–	–	–	–
17, . .	6.40	9.66	.9300	.1500	1.0800
18, . .	–	–	–	–	–
19, . .	–	–	–	–	–
20, . .	6.40	16.00	2.1800	.3300	2.5100
21, . .	13.80	16.80	2.1400	.2900	2.4300
22, . .	9.00	11.00	.6900	.1900	.8800
23, . .	6.20	8.80	.3200	.0700	.3900
24, . .	8.60	12.20	.8200	.1600	.9800
25, . .	3.60	14.80	.5300	.0900	.6200
26, . .	10.00	15.40	.9900	.1500	1.1400
27, . .	8.00	10.60	.7500	.1400	.8900
28, . .	–	–	–	–	–
29, . .	9.00	9.20	.6700	.1000	.7700
29, . .	5.30	14.60	.7500	.1200	.8700

Filtered Sewage — Continued.

March, 1888. **April, 1888.**

Date.	Residue on Evaporation.		Ammonia.			Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.
1, . .	-	-	-	-	-	1, . .	10.00	18.40	1.5800	.1500	1.7300
2, . .	2.70	13.20	.1200	.0200	.1400	2, . .	2.40	15.80	.3700	.1200	.4900
3, . .	-	-	-	-	-	3, . .	3.20	18.40	.2800	.0500	.3300
4, . .	8.60	13.00	.6600	.2400	.9000	4, . .	3.40	11.80	.4000	.1000	.5000
5, . .	6.00	15.60	.8300	.1800	1.0100	5, . .	-	-	-	-	-
6, . .	4.40	12.00	.2300	.0900	.3200	6, . .	9.60	19.00	1.2300	.0500	1.2800
7, . .	2.80	11.60	.2800	.0800	.3600	7, . .	-	-	-	-	-
8, . .	-	-	-	-	-	8, . .	-	-	-	-	-
9, . .	3.00	11.00	.2100	.0600	.2700	9, . .	4.60	25.20	1.3700	.1500	1.5200
10, . .	-	-	-	-	-	10, . .	7.60	19.00	1.7200	.0500	1.7700
11, . .	2.20	12.40	.3700	.1000	.4700	11, . .	5.40	14.00	.5200	.0400	.5600
12, . .	5.40	12.80	.6000	.1300	.7300	12, . .	-	-	-	-	-
13, . .	4.40	11.60	.5300	.1800	.7100	13, . .	5.00	20.20	1.4000	.1700	1.5700
14, . .	3.20	10.40	.3600	.0800	.4400	14, . .	-	-	-	-	-
15, . .	-	-	-	-	-	15, . .	9.80	24.20	1.7700	.2000	1.9700
16, . .	4.60	11.80	.6700	.0500	.7200	16, . .	3.20	16.00	.3300	.0800	.4100
17, . .	-	-	-	-	-	17, . .	3.20	15.80	.2600	.0500	.3100
18, . .	4.80	13.40	.4000	.0600	.4600	18, . .	3.60	16.00	.2500	.0500	.3000
19, . .	4.80	14.60	.7400	.1500	.8900	19, . .	-	-	-	-	-
20, . .	3.20	14.20	.4600	.0400	.5000	20, . .	8.20	22.00	1.6000	.1400	1.7400
21, . .	3.80	8.80	.2900	.1100	.4000	21, . .	8.80	23.00	1.6200	.1700	1.7900
22, . .	-	-	-	-	-	22, . .	-	-	-	-	-
23, . .	6.40	16.00	.1600	.0100	.1700	23, . .	6.20	20.00	1.6100	.2200	1.8300
24, . .	-	-	-	-	-	24, . .	3.40	14.80	.3000	.0500	.3500
25, . .	8.40	18.00	1.5200	.2400	1.7600	25, . .	1.60	16.40	.4300	.0200	.4500
26, . .	2.40	13.80	.2200	.0100	.2300	26, . .	-	-	-	-	-
27, . .	6.00	22.60	2.0300	.1700	2.2000	27, . .	3.00	15.80	.2700	.0000	.2700
28, . .	5.00	12.60	.5900	.1500	.7400	28, . .	3.60	13.40	.2200	.0280	.2480
29, . .	-	-	-	-	-	29, . .	-	-	-	-	-
30, . .	6.20	13.40	1.0000	.1500	1.1500	30, . .	-	-	-	-	-
31, . .	-	-	-	-	-						

Filtered Sewage — Continued.

May, 1888.

Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.
1, . .	-	-	-	-	-
2, . .	-	-	-	-	-
3, . .	-	-	-	-	-
4, . .	4.80	15.20	2.0600	.1500	2.2100
5, . .	6.00	17.80	1.9700	.1000	2.0700
6, . .	-	-	-	-	-
7, . .	16.60	23.20	2.6000	.2700	2.8700
8, . .	5.00	17.00	.2300	.0600	.2900
9, . .	4.20	13.00	.3300	.0300	.3600
10, . .	-	-	-	-	-
11, . .	6.30	26.70	.6500	.0110	.6610
12, . .	6.20	20.00	1.4200	.0300	1.4500
13, . .	-	-	-	-	-
14, . .	-	-	-	-	-
15, . .	-	-	-	-	-
16, . .	-	-	-	-	-
17, . .	-	-	-	-	-
18, . .	6.00	27.00	1.5700	.1000	1.6700
19, . .	2.80	16.80	.4300	.0600	.4900
20, . .	-	-	-	-	-
21, . .	9.60	24.60	1.6600	.0900	1.7500
22, . .	6.00	18.80	.5100	.1100	.6200
23, . .	9.20	25.20	1.2000	.3300	1.5300
24, . .	-	-	-	-	-
25, . .	7.20	20.80	1.1100	.0700	1.1800
26, . .	5.20	24.40	1.6500	.1100	1.7600
27, . .	-	-	-	-	-
28, . .	4.20	15.40	.5500	.2300	.7800
29, . .	-	-	-	-	-
30, . .	5.60	23.20	1.4300	.0700	1.5000
31, . .	6.80	21.80	2.3100	.1300	2.4400

June, 1888.

Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.
1, . .	2.20	18.00	.7000	.0500	.7500
2, . .	11.20	27.00	1.4300	.0700	1.5000
3, . .	-	-	-	-	-
4, . .	5.60	19.20	.9900	.0700	1.0600
5, . .	-	-	-	-	-
6, . .	11.00	22.80	1.4900	.1900	1.6800
7, . .	-	-	1.9100	.1500	2.0600
8, . .	6.10	16.90	.6600	.0800	.7400
9, . .	12.20	17.10	1.9300	.0200	1.9500
10, . .	-	-	-	-	-
11, . .	8.90	19.40	.5000	.0500	.5500
12, . .	-	-	-	-	-
13, . .	17.50	23.60	1.5900	.1900	1.7800
14, . .	14.70	25.10	1.5700	.1400	1.7100
15, . .	20.70	18.30	.7400	.0500	.7900
16, . .	15.70	26.90	1.2900	.1600	1.4500
17, . .	-	-	-	-	-
18, . .	4.90	16.50	.3500	.0700	.4200
19, . .	-	-	-	-	-
20, . .	5.80	15.60	.6700	.0800	.7500
21, . .	3.30	15.70	.5700	.0700	.6400
22, . .	8.80	18.60	2.8200	.1500	2.9700
23, . .	7.00	18.00	1.6900	.1800	1.8700
24, . .	-	-	-	-	-
25, . .	9.40	20.40	1.7500	.1100	1.8600
26, . .	-	-	-	-	-
27, . .	11.00	20.20	2.0000	.1000	2.1000
28, . .	12.80	25.40	1.8500	.0600	1.9100
29, . .	13.80	24.40	1.6700	.2700	1.9400
30, . .	11.80	32.40	1.5900	.2200	1.8100

Filtered Sewage — Continued.

July, 1888.						August, 1888.					
Date.	Residue on Evaporation.		Ammonia.			Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.
1, . .	-	-	-	-	-	1, . .	25.30	26.80	3.1500	.4200	3.5700
2, . .	4.70	15.00	.7600	.0700	.8300	2, . .	18.80	22.70	3.0000	.2200	3.2200
3, . .	-	-	-	-	-	3, . .	12.00	25.80	3.1200	.2000	3.3200
4, . .	15.80	30.00	1.7600	.2000	1.9600	4, . .	15.50	22.70	2.8800	.2100	3.0900
5, . .	9.10	23.40	2.0000	.1300	2.1300	5, . .	-	-	-		-
6, . .	14.50	26.00	1.8400	.1900	2.0300	6, . .	14.30	22.80	2.4800	.2200	2.7000
7, . .	10.40	29.10	2.0100	.1900	2.2000	7, . .	-	-	-	-	-
8, . .	-	-	-	-	-	8, . .	11.10	26.20	2.5800	.2000	2.7800
9, . .	4.30	15.60	.4900	.1600	.6500	9, . .	14.00	22.40	3.3200	.3200	3.6400
10, . .	-	-	-	-	-	10, . .	11.80	20.20	3.3800	.1600	3.5400
11, . .	13.00	32.20	1.9200	.2400	2.1600	11, . .	21.60	26.60	2.7300	.3800	3.1100
12, . .	4.40	19.10	.9000	.0800	.9800	12, . .	-	-	-	-	-
13, . .	3.90	18.10	.9000	.0600	.9600	13, . .	11.40	19.00	1.4800	.2300	1.7100
14, . .	3.50	15.80	.8300	.0400	.8700	14, . .	-	-	-	-	-
15, . .	-	-	-	-	-	15, . .	18.40	25.00	3.1000	.1900	3.2900
16, . .	4.40	16.10	1.0600	.0900	1.1500	16, . .	6.40	21.20	2.5500	.3100	2.8600
17, . .	-	-	-	-	-	17, . .	21.60	18.60	2.6300	.4300	3.0600
18, . .	12.50	23.70	2.9600	.2300	3.1900	18, . .	2.00	44.60	2.3800	.2100	2.5900
19, . .	12.40	19.80	2.9800	.1400	3.1200	19, . .	-	-	-	-	-
20, . .	6.00	17.50	.5400	.1400	.6800	20, . .	26.00	24.20	2.8900	.2000	3.0900
21, . .	9.10	32.70	2.4000	.2300	2.6300	21, . .	-	-	-	-	-
22, . .	-	-	-	-	-	22, . .	10.60	29.00	1.9500	.1800	2.1300
23, . .	7.00	19.10	2.3000	.2200	2.5200	23, . .	13.40	24.60	2.2800	.1500	2.4300
24, . .	-	-	-		-	24, . .	15.60	27.40	2.0600	.2000	2.2600
25, . .	8.60	36.40	2.4400	.2400	2.6800	25, . .	19.20	39.20	2.2700	.1300	2.4000
26, . .	8.10	19.90	2.4700	.1700	2.6400	26, . .	-	-	-	-	-
27, . .	7.50	18.40	2.1500	.1300	2.2800	27, . .	18.80	41.60	3.0000	.2400	3.2400
28, . .	7.30	23.00	1.8300	.2900	2.1200	28, . .	-	-	-	-	-
29, . .	-	-	-	-	-	29, . .	22.80	48.00	2.8900	.2100	3.1000
30, . .	11.20	37.30	2.7700	.2800	3.0500	30, . .	31.00	76.80	3.6000	.2400	3.8400
31, . .	-	-	-	-	-	31, . .	15.60	35.80	2.9300	.1800	3.1100

Filtered Sewage — Continued.

September, 1888.

Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.
1, . .	7.80	41.40	2.1400	.2100	2.3500
2, . .	-	-	-	-	-
3, . .	17.60	43.60	3.0700	.2500	3.3200
4, . .	-	-	-	-	-
5, . .	12.80	24.60	2.2500	.2300	2.4800
6, . .	12.80	27.80	2.6100	.2200	2.8300
7, . .	13.00	36.20	2.8000	.1800	2.9800
8, . .	16.80	51.40	2.6300	.3600	2.9900
9, . .	-	-	-	-	-
10, . .	14.00	50.40	2.1900	.2000	2.3900
11, . .	-	-	-	-	-
12, . .	12.00	15.40	.5700	.1600	.7300
13, . .	10.00	27.00	2.5900	.1500	2.7400
14, . .	9.60	33.00	.8600	.0500	.9100
15, . .	27.00	45.00	2.4800	.2100	2.6900
16, . .	-	-	-	-	-
17, . .	17.20	36.80	2.4800	.3200	2.8000
18, . .	-	-	-	-	-
19, . .	13.20	29.80	2.3800	.2000	2.5800
20, . .	13.80	31.00	2.5300	.2800	2.8100
21, . .	12.00	88.20	1.7800	.1400	1.9200
22, . .	13.00	30.20	1.5500	.1600	1.7100
23, . .	-	-	-	-	-
24, . .	17.80	25.60	2.1400	.2800	2.4200
25, . .	-	-	-	-	-
26, . .	3.40	14.00	.2500	.0500	.3000
27, . .	10.40	29.00	1.9200	.2100	2.1300
28, . .	5.20	31.60	1.1200	.1400	1.2600
29, . .	15.80	54.00	2.5900	.3200	2.9100
30, . .	-	-	-	-	-

October, 1888.

Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.
1, . .	23.60	27.20	2.7000	.4400	3.1400
2, . .	-	-	-	-	-
3, . .	9.00	29.80	1.9800	.2000	2.1800
4, . .	14.40	26.60	2.3300	.2100	2.5400
5, . .	19.20	29.60	2.5300	.3000	2.8300
6, . .	11.60	58.40	1.9200	.2200	2.1400
7, . .	-	-	-	-	-
8, . .	13.00	28.80	1.8300	.1500	1.9800
9, . .	-	-	-	-	-
10, . .	9.40	24.40	2.4300	.2700	2.7000
11, . .	9.80	26.60	2.2800	.2100	2.4900
12, . .	12.80	24.60	2.5400	.2000	2.7400
13, . .	8.80	25.80	1.9700	.2800	2.2500
14, . .	-	-	-	-	-
15, . .	12.40	26.00	2.4600	.2400	2.7000
16, . .	-	-	-	-	-
17, . .	12.00	23.40	2.5700	.2300	2.8000
18, . .	6.40	24.20	1.9900	.1400	2.1300
19, . .	8.00	25.60	2.3600	.1800	2.5400
20, . .	9.20	24.80	1.5400	.0900	1.6300
21, . .	-	-	-	-	-
22, . .	9.20	24.80	2.6400	.2500	2.8900
23, . .	-	-	-	-	-
24, . .	10.20	19.00	.9700	.1000	1.0700
25, . .	7.20	21.20	2.2200	.1500	2.3700
26, . .	9.60	21.00	2.8700	.2400	3.1100
27, . .	9.80	36.80	1.5300	.0900	1.6200
28, . .	-	-	-	-	-
29, . .	13.60	26.00	2.1400	.0600	2.2000
30, . .	9.60	31.60	-	-	-
31, . .	9.00	20.40	2.5400	.1000	2.6400

Filtered Sewage — Continued.

Date. (November, 1888.)	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albu-minoid.	Ammonia. Sum of.	Date. (December, 1888.)	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albu-minoid.	Ammonia. Sum of.
1, . .	10.20	22.40	2.5500	.2300	2.7800	1, . .	5.20	31.00	1.2400	.1700	1.4100
2, . .	11.20	22.60	2.1800	.1800	2.3600	2, . .	-	-	-	-	-
3, . .	14.40	23.20	3.0000	.2800	3.2800	3, . .	9.60	27.40	1.3000	.1100	1.4100
4, . .	-	-	-	-	-	4, . .	-	-	-	-	-
5, . .	10.60	21.40	2.0900	.3200	2.4100	5, . .	15.80	25.20	1.4200	.1900	1.6100
6, . .	8.80	52.40	-	-	-	6, . .	7.00	56.00	1.3700	.2000	1.5700
7, . .	10.60	25.40	2.4200	.1200	2.5400	7, . .	7.40	24.60	1.3700	.1600	1.5300
8, . .	11.00	44.20	2.7600	.1500	2.9100	8, . .	12.80	25.40	1.4300	.2300	1.6600
9, . .	7.80	21.40	1.9500	.1600	2.1100	9, . .	-	-	-	-	-
10, . .	9.60	37.00	1.5500	.2200	1.7700	10, . .	10.40	26.40	1.4000	.1800	1.5800
11, . .	-	-	-	-	-	11, . .	13.20	24.80	1.0400	.2600	1.3000
12, . .	6.20	22.20	1.8300	.1800	2.0100	12, . .	14.20	27.20	.8600	.1400	1.0000
13, . .	-	-	-	-	-	13, . .	8.80	25.00	1.7300	.1300	1.8600
14, . .	8.00	24.60	2.2000	.2200	2.4200	14, . .	10.10	24.70	1.4100	.1600	1.5700
15, . .	8.20	23.60	2.4500	.2200	2.6700	15, . .	16.00	16.60	.7800	.1000	.8800
16, . .	10.00	23.40	2.1800	.1800	2.3600	16, . .	-	-	-	-	-
17, . .	13.40	55.60	1.8500	.2400	2.0900	17, . .	4.60	18.20	.2300	.0500	.2800
18, . .	-	-	-	-	-	18, . .	-	-	-	-	-
19, . .	6.20	23.40	2.6200	.2100	2.8300	19, . .	-	-	-	-	-
20, . .	-	-	-	-	-	20, . .	-	-	-	-	-
21, . .	4.60	16.60	.7000	.1300	.8300	21, . .	-	-	-	-	-
22, . .	7.20	23.80	1.1300	.1100	1.2400	22, . .	6.00	25.00	1.0900	.1800	1.2700
23, . .	11.40	28.20	1.5500	.2100	1.7600	23, . .	-	-	-	-	-
24, . .	9.60	21.40	1.4900	.3300	1.8200	24, . .	-	-	-	-	-
25, . .	-	-	-	-	-	25, . .	-	-	-	-	-
26, . .	18.80	24.20	1.7700	.1800	1.9500	26, . .	7.40	21.80	.7300	.8000	1.5300
27, . .	-	-	-	-	-	27, . .	10.40	24.40	1.5200	.2200	1.7400
28, . .	6.80	16.20	.4800	.0900	.5700	28, . .	6.00	22.20	1.2800	.2200	1.5000
29, . .	11.40	24.60	.9200	.0900	1.0100	29, . .	5.60	21.80	1.1300	.1800	1.3100
30, . .	4.20	29.20	1.0000	.0900	1.0900	30, . .	-	-	-	-	-
						31, . .	8.80	23.80	1.3100	.1400	1.4500

Filtered Sewage — Continued.

January, 1889.

Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.
1, . .	-	-	-	-	-
2, . .	7.40	22.20	1.0200	.1900	1.2100
3, . .	8.10	17.50	.9000	.1000	1.0000
4, . .	9.20	21.80	1.3900	.2300	1.6200
5, . .	11.60	23.40	1.2200	.1700	1.3900
6, . .	-	-	-	-	-
7, . .	12.40	24.00	1.4400	.1700	1.6100
8, . .	-	-	-	-	-
9, . .	8.40	24.20	1.0200	.1400	1.1600
10, . .	10.80	24.20	1.2300	.0900	1.3200
11, . .	11.00	23.80	1.1700	.1200	1.2900
12, . .	11.00	22.80	1.0900	.1600	1.2500
13, . .	-	-	-	-	-
14, . .	11.60	27.00	1.0200	.1300	1.1500
15, . .	-	-	-	-	-
16, . .	11.20	22.60	1.3300	.1600	1.4900
17, . .	9.40	21.00	1.1500	.1800	1.3300
18, . .	5.40	20.20	.5300	.1300	.6600
19, . .	5.40	22.80	.9400	.1300	1.0700
20, . .	-	-	-	-	-
21, . .	3.40	16.20	.6200	.1100	.7300
22, . .	-	-	-	-	-
23, . .	11.00	21.40	1.1500	.1300	1.2800
24, . .	8.60	21.00	1.0700	.0900	1.1600
25, . .	8.20	20.60	1.2500	.1100	1.3600
26, . .	7.80	19.80	1.0000	.1500	1.1500
27, . .	-	-	-	-	-
28, . .	10.40	25.20	1.3300	.1200	1.4500
29, . .	-	-	-	-	-
30, . .	12.80	20.00	1.1200	.1500	1.2700
31, . .	8.80	18.40	1.1100	.1600	1.2700

February, 1889.

Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.
1, . .	7.80	19.20	1.3000	.1200	1.4200
2, . .	11.80	19.80	1.4300	.1600	1.5900
3, . .	-	-	-	-	-
4, . .	3.20	12.80	.2400	.1100	.3500
5, . .	-	-	-	-	-
6, . .	8.40	20.60	1.4200	.2100	1.6300
7, . .	4.00	18.00	1.0000	.1500	1.1500
8, . .	6.40	19.20	1.2300	.1700	1.4000
9, . .	6.00	17.80	1.1000	.2100	1.3100
10, . .	-	-	-	-	-
11, . .	1.60	13.60	.1000	.0100	.1100
12, . .	-	-	-	-	-
13, . .	8.60	17.60	1.0900	.1800	1.2700
14, . .	9.40	20.60	1.4000	.1100	1.5100
15, . .	9.60	21.60	1.4200	.2100	1.6300
16, . .	9.00	20.00	1.3300	.1800	1.5100
17, . .	-	-	-	-	-
18, . .	1.80	13.20	.4200	.0300	.4500
19, . .	-	-	-	-	-
20, . .	11.20	17.20	1.1800	.1400	1.3200
21, . .	8.80	19.20	1.4700	.1900	1.6600
22, . .	6.00	18.60	1.6900	.1900	1.8800
23, . .	11.00	14.40	.3400	.2500	.5900
24, . .	-	-	-	-	-
25, . .	2.60	11.20	.3600	.0380	.3980
26, . .	-	-	-	-	-
27, . .	9.60	18.40	1.5400	.2600	1.8000
28, . .	7.80	17.00	1.3500	.2200	1.5700

Filtered Sewage — Continued.

March, 1889. **April, 1889.**

Date.	Residue on Evaporation.		Ammonia.			Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.
1, . .	11.00	20.40	1.7300	.2100	1.9400	1, . .	7.00	19.40	1.0900	.1200	1.2100
2, . .	10.20	18.40	1.5700	.3100	1.8800	2, . .	-	-	-	-	-
3, . .	-	-	-	-	-	3, . .	3.40	46.00	1.2800	.3300	1.6100
4, . .	11.60	19.60	1.1700	.2600	1.4300	4, . .	7.20	19.40	1.5200	.3300	1.8500
5, . .	-	-	-	-	-	5, . .	6.40	19.80	2.0900	.1700	2.2600
6, . .	8.80	21.00	.8100	.2000	1.0100	6, . .	6.60	17.40	2.0500	.2200	2.2700
7, . .	6.40	16.60	.6600	.1400	.8000	7, . .	-	-	-	-	-
8, . .	6.20	15.80	1.3500	.2200	1.5700	8, . .	6.40	20.40	1.9200	.1800	2.1000
9, . .	10.20	16.10	1.5500	.2100	1.7600	9, . .	-	-	-	-	-
10, . .	-	-	-	-	-	10, . .	5.60	20.60	2.0300	.2500	2.2800
11, . .	7.80	19.00	1.7500	.2500	2.0000	11, . .	8.80	21.80	2.1300	.2300	2.3600
12, . .	9.40	18.40	-	-	-	12, . .	8.80	20.20	2.0600	.2300	2.2900
13, . .	8.00	18.80	1.5200	.2500	1.7700	13, . .	11.20	21.40	2.1300	.2800	2.4100
14, . .	7.00	18.20	1.7400	.2100	1.9500	14, . .	-	-	-	-	-
15, . .	9.20	18.40	1.8800	.2500	2.1300	15, . .	5.40	22.40	2.1000	.2100	2.3100
16, . .	8.80	18.80	1.9700	.2000	2.1700	16, . .	-	-	-	-	-
17, . .	-	-	-	-	-	17, . .	8.40	23.40	1.7800	.3700	2.1500
18, . .	7.20	19.00	1.2000	.0900	1.2900	18, . .	8.00	24.00	2.2500	.2000	2.4500
19, . .	-	-	-	-	-	19, . .	8.00	21.60	2.3500	.2900	2.6400
20, . .	10.40	19.00	1.8500	.3000	2.1500	20, . .	7.60	19.00	2.2800	.2500	2.5300
21, . .	12.00	20.80	2.0500	.3500	2.4000	21, . .	-	-	-	-	-
22, . .	9.80	17.80	1.8100	.2900	2.1000	22, . .	11.60	22.80	1.9300	.2300	2.1600
23, . .	13.80	21.40	2.1200	.3700	2.4900	23, . .	-	-	-	-	-
24, . .	-	-	-	-	-	24, . .	9.80	19.40	2.3100	.1700	2.4800
25, . .	10.40	39.00	2.0000	.4100	2.4100	25, . .	10.40	20.00	2.5500	.2300	2.7800
26, . .	5.80	19.00	1.7300	.2300	1.9600	26, . .	12.60	21.20	2.4500	.2600	2.7100
27, . .	9.00	22.40	2.3400	.3100	2.6500	27, . .	12.00	25.20	1.6800	.2200	1.9000
28, . .	6.80	33.00	1.7500	.2600	2.0100	28, . .	-	-	-	-	-
29, . .	9.20	19.40	1.3900	.1800	1.5700	29, . .	9.20	20.80	2.1800	.2700	2.4500
30, . .	12.00	24.20	2.3900	.4100	2.8000	30, . .	-	-	-	-	-
31, . .	-	-	-	-	-						

Filtered Sewage — Continued.

May, 1889.

Date.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.
1, . .	9.20	21.60	1.1900	.1500	1.3400
2, . .	6.80	23.20	1.9900	.1600	2.1500
3, . .	6.40	22.80	2.4300	.1900	2.6200
4, . .	12.00	24.00	2 3700	.2500	2.6200
5, . .	-	-	-	-	-
6, . .	12.20	21.00	1.8200	.2600	2.0800
7, . .	-	-	-	-	-
8, . .	7.60	20.00	2.4800	.2000	2.6800
9, . .	16.80	26.80	2.3800	.3400	2.7200
10, . .	13.20	25.60	1.4800	.2200	1.7000
11, . .	16.60	21.60	2.6300	.3300	2.9600
12, . .	-	-	-	-	-
13, . .	15.00	25.40	2.0400	.2600	2.3000
14, . .	-	-	-	-	-
15, . .	8.40	21.60	1.6800	.1900	1.8700
16, . .	12.20	23.40	2.0000	.2200	2.2200
17, . .	12.00	19.80	1.9200	.1900	2.1100
18, . .	14.60	24.20	1.8800	.2000	2.0800
19, . .	-	-	-	-	-
20, . .	17.60	21.40	1.8100	.2900	2.1000
21, . .	-	-	-	-	-
22, . .	8.00	22.40	-	.1600	-
23, . .	10.40	26.80	1.9600	.1800	2.1400
24, . .	7.40	24.80	1.8400	.2000	2.0400
25, . .	12.20	26.00	1.9600	.2800	2.2400
26, . .	-	-	-	-	-
27, . .	16.40	24.60	1.4000	.3300	1.7300
28, . .	-	-	-	-	-
29, . .	12.00	21.80	1.9600	.2200	2.1800
30, . .	14.40	25.20	2.2500	.2600	2.5100
31, . .	13.80	23.40	2.8000	.2300	3.0300

June, 1889

Date.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.
1, . .	18.6	21.6	3.0000	.2700	3.2700
2, . .	-	-	-	-	-
3, . .	-	-	-	-	-
4, . .	-	-	-	-	-
5, . .	10.2	20.4	2.0000	.2100	2.2100
6, . .	15.6	26.8	2.0000	.3000	2.3000
7, . .	8.8	21.6	2.0000	.2500	2.2500
8, . .	16.4	22.0	1.9600	.2500	2.2100
9, . .	-	-	-	-	-
10, . .	15.4	23.8	2.0000	.2600	2.4600
11, . .	-	-	-	-	-
12, . .	16.4	19.8	2.0000	.2700	2.2700
13, . .	16.2	23.0	2.1600	.2600	2.4200
14, . .	17.2	25.4	2.0400	.0900	2.1300
15, . .	16.8	24.0	2.6400	.1500	2.7900
16, . .	-	-	-	-	-
17, . .	16.0	21.6	2.7200	.2300	2.9500
18, . .	-	-	-	-	-
19, . .	14.6	27.0	2.4000	.2900	2.6900
20, . .	16.8	22.4	3.1600	.2700	3.4300
21, . .	18.8	23.0	3.2000	.3800	3.5800
22, . .	16.4	22.8	2.6800	.2700	2.9500
23, . .	-	-	-	-	-
24, . .	14.8	22.0	3.2000	.4100	3.6100
25, . .	-	-	-	-	-
26, . .	18.8	21.2	2.8000	.3200	3.1200
27, . .	24.4	24.8	1.7200	.3600	2.0800
28, . .	20.0	21.2	2.4000	.3100	2.7100
29, . .	20.4	38.8	2.6800	.2800	2.9600
30, . .	-	-	-	-	-

Filtered Sewage — Continued.

July, 1889. **August, 1889.**

Date.	Residue on Evaporation.		Ammonia.			Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.		Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.
1, . .	18.0	24.8	-	-	-	1, . .	10.8	24.0	1.6000	.1700	1.7700
2, . .	-	-	-	-	-	2, . .	9.8	25.0	1.6800	.1400	1.8200
3, . .	16.0	23.2	1.3600	.2200	1.5800	3, . .	15.2	29.2	2.1200	.2200	2.3400
4, . .	8.6	24.0	-	-	-	4, . .	-	-	-	-	-
5, . .	11.8	23.8	2.7600	.4400	3.2000	5, . .	13.4	30.8	1.6000	.3600	1.9600
6, . .	16.4	19.8	2.6000	.3100	2.9100	6, . .	-	-	-	-	-
7, . .	-	-	-	-	-	7, . .	11.8	21.4	1.9200	.3200	2.2400
8, . .	16.8	23.0	2.3600	.3100	2.6700	8, . .	11.8	25.6	2.0000	.3000	2.3000
9, . .	-	-	-	-	-	9, . .	15.2	25.6	2.1000	.3400	2.4400
10, . .	20.4	35.6	1.6800	.3100	1.9900	10, . .	21.6	23.8	2.3300	.5000	2.8300
11, . .	14.0	30.2	3.0000	.2800	3.2800	11, . .	-	-	-	-	-
12, . .	15.6	20.0	2.7200	.4300	3.1500	12, . .	15.2	23.6	2.1000	.2700	2.3700
13, . .	18.4	27.0	3.0800	.3400	3.4200	13, . .	-	-	-	-	-
14, . .	-	-	-	-	-	14, . .	11.4	23.0	.4700	.1500	.6200
15, . .	19.4	24.4	2.0500	.3600	2.4100	15, . .	12.8	21.6	1.4000	.2600	1.6600
16, . .	-	-	-	-	-	16, . .	8.8	27.2	1.7700	.2900	2.0600
17, . .	14.4	25.4	2.7200	.3400	3.0600	17, . .	18.0	19.6	1.9000	.3000	2.2000
18, . .	12.4	24.4	2.6000	.5000	3.1000	18, . .	-	-	-	-	-
19, . .	14.8	20.8	2.5200	.3200	2.8400	19, . .	20.4	25.4	1.8000	.3200	2.1200
20, . .	7.6	16.4	.7200	.2100	.9300	20, . .	-	-	-	-	-
21, . .	-	-	-	-	-	21, . .	-	-	2.0000	.2400	2.2400
22, . .	22.0	26.0	2.4000	.2600	2.6600	22, . .	-	-	2.0000	.4300	2.4300
23, . .	-	-	-	-	-	23, . .	-	-	-	-	-
24, . .	10.8	22.0	1.9600	.3000	2.2600	24, . .	-	-	2.1200	.5600	2.6800
25, . .	19.2	21.6	2.2000	.2500	2.4500	25, . .	-	-	-	-	-
26, . .	10.4	24.6	2.6800	.2500	2.9300	26, . .	-	-	2.3700	.4500	2.8200
27, . .	12.8	21.8	3.0000	.3300	3.3300	27, . .	-	-	-	-	-
28, . .	-	-	-	-	-	28, . .	-	-	2.0500	.4500	2.5000
29, . .	14.8	23.4	2.3000	.1700	2.4700	29, . .	-	-	2.0000	.3700	2.3700
30, . .	-	-	-	-	-	30, . .	-	-	2.0000	.6000	2.6000
31, . .	11.2	25.2	1.4000	.1600	1.5600	31, . .	14.8	24.8	2.3300	.4700	2.8000

Filtered Sewage — Continued.

September, 1889. **October, 1889.**

Date.	Residue on Evaporation.		Ammonia.			Date.	Residue on Evaporation.		Ammonia.		
	Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.		Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.
1, . .	-	-	-	-	-	1, . .	14.0	31.4	1.7000	.2800	1.9800
2, . .	18.0	26.4	1.3300	.5000	1.8300	2, . .	12.0	24.6	1.9000	.4000	2.3000
3, . .	-	-	-	-	-	3, . .	16.8	24.4	2.7500	.5200	3.2700
4, . .	16.0	26.4	1.4300	.4300	1.8600	4, . .	14.4	25.2	2.2500	.3800	2.6300
5, . .	-	-	2.0000	.3600	2.3600	5, . .	23.2	23.6	2.1500	.4500	2.6000
6, . .	18.2	27.4	1.3300	.4300	1.7600	6, . .	-	-	-	-	-
7, . .	19.6	21.0	2.1000	.3800	2.4800	7, . .	11.6	19.6	1.4000	.2700	1.6700
8, . .	-	-	-	-	-	8, . .	13.2	29.6	2.0000	.2800	2.2800
9, . .	20.8	23.4	1.7000	.5200	2.2200	9, . .	31.4	27.0	2.1500	.5000	2.6500
10, . .	-	-	-	-	-	10, . .	14.6	26.2	2.0000	.4300	2.4300
11, . .	18.4	35.6	2.2000	.4400	2.6400	11, . .	17.2	21.6	2.0000	.4300	2.4300
12, . .	18.4	24.0	2.7300	.7000	3.4300	12, . .	20.0	24.4	1.7500	.5000	2.2500
13, . .	16.0	27.6	2.3500	.5300	2.8800	13, . .	-	-	-	-	-
14, . .	29.2	56.0	1.3000	.5200	1.8200	14, . .	14.4	22.0	2.0000	.3800	2.3800
15, . .	-	-	-	-	-	15, . .	16.6	24.0	2.0000	.5000	2.5000
16, . .	22.4	26.4	1.9000	.5000	2.4000	16, . .	22.4	25.2	1.7500	.6600	2.4100
17, . .	-	-	-	-	-	17, . .	18.4	22.8	2.1500	.4200	2.5700
18, . .	11.0	20.2	.9000	.4600	1.3600	18, . .	16.0	24.0	2.0000	.4000	2.4000
19, . .	10.8	18.2	.4000	.3400	.7400	19, . .	18.0	23.6	2.3000	.4000	2.7000
20, . .	16.0	25.2	1.6600	.5000	2.1600	20, . .	-	-	-	-	-
21, . .	16.0	25.2	1.8000	.1400	1.9400	21, . .	12.8	22.4	1.5000	.3100	1.8100
22, . .	-	-	-	-	-	22, . .	17.0	22.2	1.9000	.4500	2.3500
23, . .	23.2	30.0	2.1000	.5400	2.6400	23, . .	21.2	20.8	1.8000	.4700	2.2700
24, . .	-	-	-	-	-	24, . .	17.6	19.2	1.8000	.3200	2.1200
25, . .	12.4	22.0	2.0000	.4600	2.4600	25, . .	-	-	-	-	-
26, . .	10.0	26.4	2.1200	.4500	2.5700	26, . .	-	-	1.7500	.3900	2.1400
27, . .	14.4	23.2	2.0000	.4500	2.4500	27, . .	-	-	-	-	-
28, . .	-	-	2.5000	.5700	3.0700	28, . .	17.6	21.2	1.8500	.4100	2.2600
29, . .	-	-	-	-	-	29, . .	17.2	39.2	.8500	.3900	1.2400
30, . .	-	-	-	-	-	30, . .	-	-	1.7500	.4400	2.1900
						31, . .	19.6	23.2	2.2500	.4300	2.6800

For monthly averages see pp. 35 and 36.

FILTER TANKS Nos. 12, 13 AND 14.

Three galvanized iron tanks, numbered 12, 13 and 14, having a horizontal area of one-hundredth of that of No. 1, or one twenty-thousandth of an acre, were filled to the same depth, and with the same kind of material, as Tank No. 1. They were placed within the long building at the station, and were consequently not exposed to snow, and only occasionally to a temperature as low as freezing.

EFFECT OF POURING HOT WATER UPON FILTERING MATERIAL.

Tanks Nos. 13 and 14 were filled with sand thrown into water in the same manner as No. 1; but in filling Tank No. 12 hot water was used. The lower seven inches of assorted gravel and sand were placed in the tank on Feb. 10, 1888, and sufficient water to saturate it was poured over it at a temperature of 202° Fah. This water was taken directly from a boiler where it had been boiling an hour or more. On February 13, twenty-four gallons of water at 207° were poured into the tank from a boiler where it had been boiling, and into this was sprinkled sand until it appeared above the water; then six gallons more of boiled water, at the same temperature, were added, and sufficient sand to fill the tank to five feet and seven inches above the bottom. The water stood in the sand three days, and upon being drawn out it was found to contain seven bacteria per cubic centimeter.

Sewage was first applied on February 16. On the fifth day after, the number of bacteria in the effluent was 36,950; on the seventh day, 635,160; and on the ninth day, 757,500 per cubic centimeter, while the average number in the sewage for the previous week was 919,150. The number of bacteria in the effluent of No. 12 was at this time twice the number ever found in that of No. 13 and three times the number in No. 14, and for the following two months the number found in the effluent of No. 12 was many times the number found in any other similar material. The cause appears to be that, while boiling the water first applied undoubtedly killed all the bacteria which it contained, it also prepared its organic matter to be a good food for bacteria; and probably the scattering of sand into water at 207° also prepared the organic matter of the sand to support bacteria.

Effect of Applying Different Quantities of Sewage to Similar Filters.

With the exception of heating the water first applied to the sand of No. 12, — which appears to have had no permanent effect upon its purifying efficiency, — the conditions of No. 12, No. 13 and No. 14 were identical; and we have now to see the effect of applying to similar tanks very different quantities of sewage.

After sewage reached the outlet, — which in No. 12 was Feb. 19, 1888; in No. 13, March 2; and in No. 14, March 1, — sewage was applied daily, for several months, at the rate of 30,000 gallons per acre on No. 12, 60,000 gallons per acre on No. 13 and 120,000 gallons per acre on No. 14.

Each tank stored nearly the same amount of impurity before the effluent increased rapidly in ammonia.

From No. 12 the sum of the ammonias for 57 days averaged 0.0386 parts per 100,000, or 3 per cent. of the sum of the ammonias of the applied sewage. From No. 13, for 23 days, the ammonias averaged 0.0413 parts, or 5 per cent. of those of the sewage; and from No. 14, for 14 days, they averaged 0.1155 parts, or 12 per cent. of those of the sewage.

During these periods the nitrates were low in each, being less than 0.045 parts in 100,000, and generally about 0.020 parts. At the end of these periods the ammonias of each began to increase more rapidly than previously.

Beginning of Nitrification.

Nitrification began to increase in these tanks, and in No. 1 of the same material, at about the same time, — March 26 to 30, — when the temperature of the effluent was at 39° or 40° Fah.

The time during which sewage had been applied to each, previous to the increase in nitrification, and the average daily quantity applied per acre, together with the total quantity of sewage applied up to this time and the average percentage which the ammonias of the effluent have borne to those of the sewage, are as follows: —

Number of Tank.	Number of Days on which Sewage had been applied.	Average Daily Quantity applied per Acre. Gallons.	Total Quantity of Sewage applied per Acre. Gallons.	Ratio of Average Ammonias of Effluent to those of the Sewage.
1, ...	77	39,800	3,064,600	0.37
12, ...	41	33,600	1,377,600	0.03
13, ...	31	62,000	1,922,000	0.06
14, ...	27	124,400	3,358,800	0.20

During the next three weeks, with temperature of effluent from 39° to 45°, the nitrates increased from 0.025 parts per 100,000 to 0.250 parts; after which, with temperature from 45° to 50°, they increased much more rapidly, and were the highest for the season May 6 to 10, when they became from 2.5 to 3.0 parts per 100,000.

Rapidity and Completeness of Nitrification Greatest where the Most Nitrogenous Matter is Stored.

The two tanks, among all experimented upon in which the nitrates first increased with the greatest rapidity and first attained their maximum for the year, were the two tanks filled with the sand of coarse, even grain, through which the air could most freely pass, which had received the greatest amount of sewage and which presumably had the greatest amount of impurity stored in them, viz., Tanks No. 14 and No. 1. The same two tanks, — and the one having the most impurity stored taking the lead, — were the first to have their ammonias removed from the effluent and to reach an established condition of purification through nitrification.

The effluent from No. 14 decreased in ammonias rapidly from April 15, when they were 0.6690 parts, to May 11, when they were 0.0150 parts, and were only three-tenths of one per cent. of those of the sewage. That from No. 1 decreased in ammonias from April 20, when they were 0.3990 parts, to May 23, when they were 0.0112 parts, and were seven-tenths of one per cent. of those of the sewage. That from No. 13 decreased in ammonias from April 25, when they were 0.5250 parts, to May 31, when they were 0.0102 parts, and were but five-tenths of one per cent. of those of the sewage; and that from No. 12, which had received the least amount of sewage, did not begin to decrease in ammonias until May 11, when they were 0.3780 parts, and continued decreasing much less rapidly than the others to June 18 — more than a month after No. 14 — when they were 0.0210 parts, which is one and three-tenths per cent. of those of the sewage.

It is to be observed in comparing these four tanks of like material,

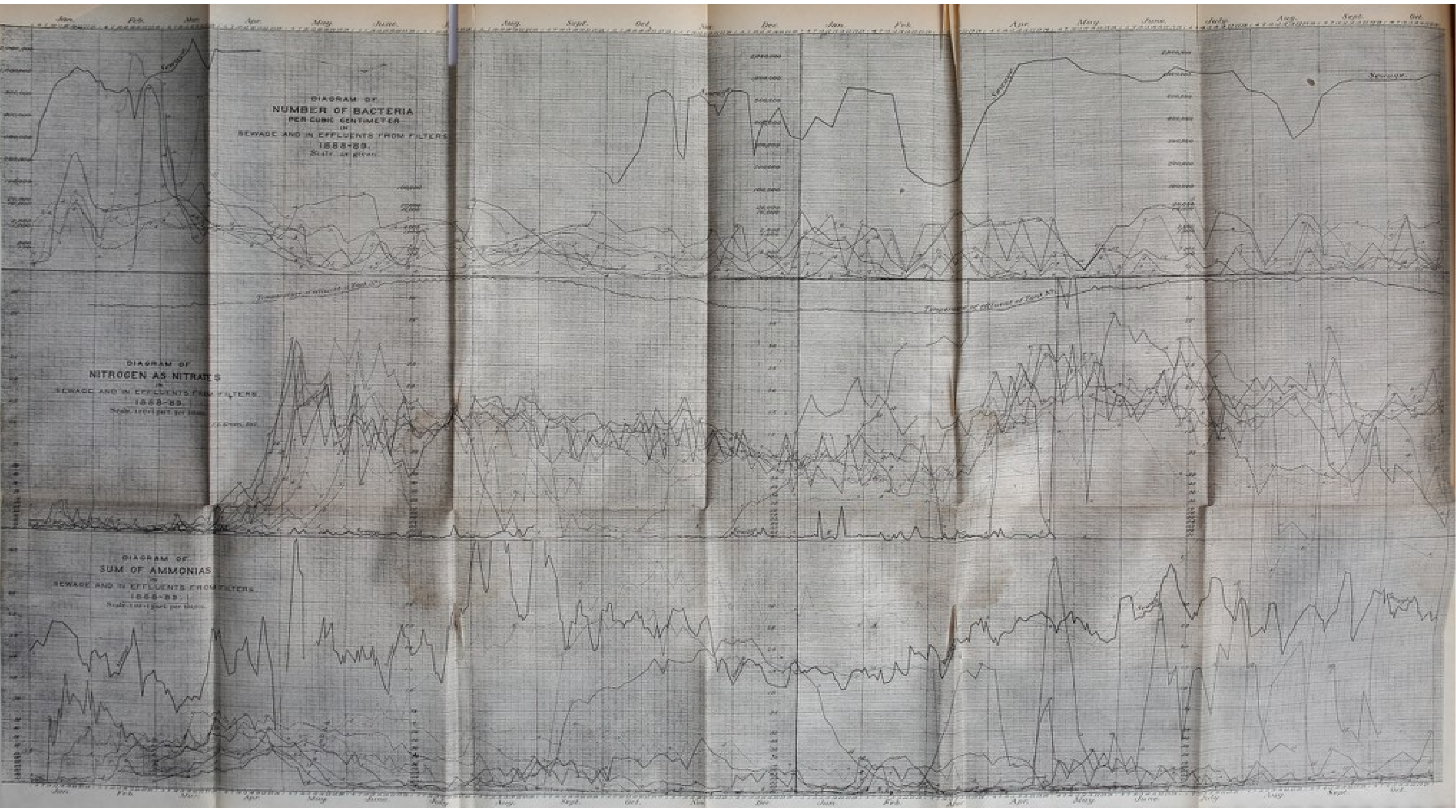


DIAGRAM OF
NUMBER OF BACTERIA
PER CUBIC CENTIMETER
IN
SEWAGE AND IN EFFLUENTS FROM FILTERS.
1888-89.
Scale as given.
DIAGRAM OF
NITROGEN AS NITRATES
IN
SEWAGE AND IN EFFLUENTS FROM FILTERS.
1888-89.
DIAGRAM OF
SUM OF AMMONIAS
IN
SEWAGE AND IN EFFLUENTS FROM FILTERS.
1888-89.
Sewage
Jan.
Feb.
Mar.
Apr.
May
June
Aug.
Sept.
Oct.
Dec.
July

that, during the first three weeks or more in which the nitrates were increasing, the ammonias also increased and became the highest in the effluents from the tanks in which the greatest amount of organic matter had been stored; and that the purification of the effluents from organic matter, as shown by the ammonias, began first and progressed most rapidly in those tanks in which there was stored the greatest amount of organic matter. The potency of the process of purification by nitrification appears in these cases to depend directly upon the actual amount of organic matter stored in the filter.

General Diagram of the Nitrates and Ammonias of All the Filters.

That we may see more clearly the relation of nitrification and purification from nitrogenous organic matter in the effluent from the several filters, the accompanying diagram is presented, showing the temperature of the effluent from Tank No. 1, and the nitrates of the applied sewage and of the effluent from each of the tanks, and the sum of the ammonias of the sewage and of the effluent from each of the tanks, throughout the year 1888.

It will be noticed that, in order to make clear the representation of both the nitrates and ammonias, when they are very small, the scales of each between 0 and 0.06 parts per 100,000 are five times as large as for greater quantities.

This diagram will be referred to as the Diagram of Nitrates.

The First Month of Purification.

During the month after each of the tanks of coarse sand had reached an established condition of purification through nitrification, the quantities of sewage applied daily continued as before, and the characteristics of the effluents are expressed in the following table: —

Number of Tank.	Date—1888. From	Date—1888. To	Quantity of Sewage applied Daily. Gallons per Acre.		Average of Nitrates.	Average of Ammonias.
1,	May 23,	June 23,	30,000	Sewage,	0.008	1.8000
				Effluent,	0.978	0.0134
				Per cent.,	-	0.7 of 1
12,	June 18,	July 18,	30,000	Sewage,	0.007	1.8948
				Effluent,	1.044	0.0196
				Per cent.,	-	1.
13,	May 31,	June 30,	60,000	Sewage,	0.008	1.7836
				Effluent,	1.034	0.0119
				Per cent.,	-	0.7 of 1
14,	May 11,	June 11,	120,000	Sewage,	0.008	1.9535
				Effluent,	1.257	0.0210
				Per cent.,	-	1.1

The tables of daily results with these tanks may be found at the end of this section.

The general results with Tank No. 12 by monthly averages, showing the character of sewage and effluent, are given in the following table: —

Monthly Averages of Daily Results with Tank No. 12.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888.												
February 16-23,	Sewage, .	–	16.52	13.16	1.2980	.4000	1.6980	2.74	.007	–	–	–
February 16-29,	Effluent, .	2.06	3.93	8.86	.0155	.0244	.0399	1.98	.013	–	40°	501,653
	Per cent.,	–	24	67	1	6	2	–	–	–	–	–
Feb. 24-Mar. 23,	Sewage, .	–	16.09	19.65	.5414	.4004	.9418	2.18	.007	.0029	–	–
March, . .	Effluent, .	1.41	2.41	8.92	.0234	.0116	.0350	2.00	.015	.0043	40°	69,657
	Per cent.,	–	15	45	4	2.9	4	–	–	–	–	–
Mar. 24-Apr. 22,	Sewage, .	–	38.23	46.26	1.1370	.7230	1.8600	3.22	.007	–	–	–
April, . .	Effluent, .	1.52	3.29	12.76	.1350	.0152	.1502	3.02	.143	.0042	42°	4,078
	Per cent.,	–	9	28	12	2	8	–	–	–	–	–
Apr. 23-May 24,	Sewage, .	–	42.09	47.27	1.1229	1.2980	2.4209	3.54	.008	.0024	–	–
May, . . .	Effluent, .	1.51	14.08	17.00	.2808	.0158	.2966	3.27	1.650	.0152	–	691
	Per cent.,	–	33	36	25	1.2	12	–	–	–	–	–
May 25-June 22,	Sewage, .	–	17.38	23.60	1.2819	.3643	1.6462	4.36	.007	.0006	–	–
June, . . .	Effluent, .	1.42	11.16	27.61	.0569	.0102	.0671	8.18	1.000	.0129	66°	166
	Per cent.,	–	64	117	4	2.8	4	–	–	–	–	–
June 23-July 19,	Sewage, .	–	15.26	25.76	1.7174	.3668	2.0842	5.61	.008	.0002	–	–
July 1-26, . .	Effluent, .	1.42	6.91	27.20	.0062	.0105	.0167	6.81	1.153	.0062	69°	891
	Per cent.,	–	45	106	.4of1	2.9	.8of1	–	–	–	–	–
July 24-Aug. 12,	Sewage, .	–	35.08	34.38	2.6115	.8265	3.4380	5.90	.008	.0000	–	–
August, . .	Effluent, .	1.51	3.94	30.66	.0098	.0257	.0355	6.96	.175	.0024	–	20,527
	Per cent.,	–	11	89	.4of1	3.1	1	–	–	–	–	–
Aug. 13-Sept. 10,	Sewage, .	–	70.75	85.19	2.6986	1.9352	4.6338	9.82	–	.0000	–	–
September, .	Effluent, .	1.50	4.61	34.03	.5212	.0380	.5592	10.23	.009	.0000	–	127
	Per cent.,	–	7	40	19	2	12	–	–	–	–	–
Sept. 11-Oct. 12,	Sewage, .	–	22.69	39.37	1.9970	.5730	2.5700	7.75	–	.0000	–	–
October, . .	Effluent, .	1.58	4.79	25.48	1.2622	.0307	1.2929	7.73	.009	.0000	–	18
	Per cent.,	–	21	65	63	5.4	50	–	–	–	–	–
Oct. 13-Nov. 23,	Sewage, .	–	16.37	31.10	2.0867	.4240	2.5107	7.36	–	.0000	–	–
November, .	Effluent, .	1.50	3.26	23.36	1.8325	.0374	1.8699	6.50	.008	.0000	–	19
	Per cent.,	–	20	75	88	9	74	–	–	–	–	–
Nov. 24-Dec. 24,	Sewage, .	–	19.12	30.44	1.1844	.2978	1.4822	5.61	.023	.0000	–	–
December, .	Effluent, .	1.50	2.12	25.77	1.8556	.0360	1.8916	4.76	.307	.0004	43°	1,804
	Per cent ,	–	11	85	157	12	128	–	–	–	–	–
1889.												
Dec. 25-Jan. 24,	Sewage, .	–	11.95	24.69	1.1355	.3154	1.4509	4.42	.021	.0025	–	–
January, . .	Effluent, .	1.51	1.32	35.07	.6420	.0210	6.6630	5.01	1.713	.0216	45°	1,584
	Per cent.,	–	11	142	56	7	46	–	–	–	–	–
Jan. 25-Feb. 21,	Sewage, .	–	9.75	19.42	1.1225	.2830	1.4055	4.06	.016	.0052	–	–
February, . .	Effluent, .	1.50	1.35	27.55	.0203	.0127	.0330	4.11	1.450	.0049	43°	44
	Per cent.,	–	14	142	1.8	4.5	2.3	–	–	–	–	–
Feb. 22-Mar 25,	Sewage, .	–	13.27	22.27	1.5713	.4443	2.0156	4.14	.011	.0081	–	–
March, . .	Effluent, .	1.52	1.07	26.78	.0041	.0110	.0151	3.61	1.406	.0035	45°	118
	Per cent.,	–	8	120	.3of1	2.5	.7of1	–	–	–	–	–

Intermittent filtration of sewage continued with this tank from February 16 to July 26, 1888. In the last month the effluent was a clear, bright and colorless water, containing less free and albuminoid ammonia than ordinary public drinking water supplies.

The organic matter of the sewage was being nearly all burned up, 99.2 per cent. of the nitrogenous organic matter being removed, as shown by the sum of the ammonias; and the nitrogen of the nitrates of the effluent contained 52 per cent. of the total nitrogen of the sewage.

Filter No. 12 Changed from Intermittent to Continuous Filtration.

On July 27 the outlet of Tank No. 12 was closed and the tank filled with sewage; after which, for four months, the surface of the sand was kept covered with sewage, and the same quantity as previously applied was daily drawn through the tank. The conditions of the filter were thus changed from intermittent filtration — in which the sewage was applied once in a day and disappeared from the surface within a minute, and, accompanied with air, slowly moved in thin laminæ over the particles of sand — to continuous filtration, in which the surface was continually covered with sewage, so that no air could enter, and the liquid, as it passed down through the sand, filled all of the space between the particles.

The first marked result due to the change in method of filtration was the immediate and continued decrease in the nitrates, which, taken at intervals of three and four days, were as follows: 1.250, 1.050, 0.750, 0.400, 0.260, 0.060 and 0.020 parts per 100,000; and at the end of a month the nitrates entirely disappeared.

The ammonias, which had been 0 0158 parts in 100,000, were immediately doubled; and then continued nearly a month with little increase, reaching 0.0464 parts. During the second month they increased rapidly, reaching 0.9460 parts, or about one-third of those of the sewage; and in the third month they reached 1.7790 parts, or nearly two-thirds of those of the sewage; and at the end of the fourth month they reached 2 2200 parts, or five-sixths of those of the sewage.

During the three months after the nitrates were reduced to zero, they continued low, averaging about 0.010 parts per 100,000.

There appears to be a definite and sufficient reason why the ammonias of the effluent did not, after nitrification ceased, grow to be equal to those of the applied sewage, in the fact observed, that there was much animal life in the sewage covering the sand, which, without doubt, lived upon the organic matter therein. That the ammonias of the sewage covering the sand were less than the average of the ammonias of the sewage applied in the previous week was observed on several occasions. In the third month they were found to be but three-quarters of those of the applied sewage; and in the fourth month, but five-sixths of those of the applied sewage. Hence we find that the ammonias of the effluent, at the end of the fourth month, though but five-sixths of those of the applied sewage, were equal to those of the sewage as it stood upon the top of the sand.

The peculiar condition of the ammonias during this time should be noted.

The albuminoid ammonia, which, during July, had averaged 0.0105 parts, or two and nine-tenths per cent. of that of the sewage, was, three days after filling the tank with sewage, increased to 0.0278 parts, and during the month of August averaged 0.0257 parts; but the albuminoid ammonia of the sewage had increased in nearly the same ratio, so that the 0.0257 parts was but 3 per cent. of that of the sewage.

Again, in September, the albuminoid ammonia of the effluent was higher, averaging 0.0380 parts; but, owing to a greater increase in the sewage, this was but 2 per cent. of that of the sewage.

In October, November and December, the albuminoid ammonia of the sewage decreased rapidly, averaging monthly 0.5730 parts, 0.4240 parts and 0.2978 parts; while that of the effluent was nearly constant, averaging 0.0307, 0.0374 and 0.0360 parts, or 5.4 per cent., 9 per cent. and 12 per cent. of that of the sewage.

The free ammonia, which in July was 0.0062, did not increase for three weeks after the tank was filled with sewage; while the nitrates were decreasing rapidly from 1.250 parts to 0.020 parts; but the free ammonia increased, in the two following weeks, from 0.0046 to 0.0208 at the end of August, and then increased rapidly through September to 1.7400 parts, averaging for the month 0.5212 parts, or 19 per cent. of that of the sewage. For the next two months it continued to increase, averaging, for October, 1.2622 parts, or 63 per cent., and for November, 1.8325 parts, or 88 per cent., of that of the sewage. On November 26, the free ammonia of the effluent was 2.1700 parts, and the albuminoid ammonia was 0.0500 parts and the nitrates 0.0070 parts.

Continuous filtration resulted in a complete cessation of the burning up of the nitrogenous organic matter of the sewage. Some of this was stored in the filter, thus reducing the albuminoid ammonia of the effluent, but the sum of ammonias grew to be as great as those in the sewage on the surface. The effluent became somewhat turbid and had a strong odor.

Intermittent Filtration Resumed.

On November 28 the sewage was drained from the tank and intermittent filtration resumed. The nitrates immediately increased as follows: December 1, 0.0300; 3, 0.0500; 6, 0.1200; 10, 0.2300; 17, 0.2600; 24, 0.4000; and 31, 1.0200.

The free ammonia continued for two weeks above 2.0000 parts, and then gradually fell in the remainder of the month to 1.3900 parts; averaging for the month 1.8556 parts, which was 157 per cent. of that of the sewage applied in this month.

The albuminoid ammonia varied but little from the previous month and averaged 0.0360 parts, or 12 per cent. of that of the sewage. The quantity of sewage applied continued the same for this and the next three months as it had been in the previous eight months, — 1.5 gallons a day, or the equivalent of 30,000 gallons per acre per day.

Nitrogenous Matter Stored in the Filter during Continuous Filtration is now Being Removed.

During January, 1889, the nitrates continued to increase to 2.3000 parts, and averaged 1.7130 parts; they were more than double those of any of the tanks which had continued nitrifying during the season.

This large amount of nitrogen as nitrates, coming off after a period when little or no nitrification had occurred, corresponds with the condition of nearly all of the tanks when, in the spring and early summer, they first came into the condition of rapid nitrification. It is evident that the nitrogen now coming off as nitrates is in part from ammonia which had been stored in the tank before this rapid nitrification began. The nitrogen that came from the filter this month was 56 per cent. more than was put on.

In February the nitrates continued higher than those of other tanks, averaging 1.4500 parts; and through March they averaged 1.4060 parts.

The nitrites, which in September, October and November were zero, appeared again with the nitrates, averaging: 0.0004 in December; 0.0216 in January; 0.0049 in February; and 0.0035 in March. The free ammonia decreased rapidly in January from 1.4300 parts to 0.0920 parts, averaging 0.6420 parts, or 56 per cent. of that of the sewage. It continued decreasing through February to 0.0070 parts, averaging 0.0203 parts, or one and eight-tenths per cent. of that of the sewage; and in March it decreased to 0.0022 parts, averaging 0.0041 parts, or three-tenths of one per cent. of that of the sewage.

The albuminoid ammonia decreased in the three months, averaging in January 0.0210 parts or 7 per cent., in February 0.0127 parts or 4.5 per cent., and in March 0.0110 parts or 2.5 per cent., of that of the sewage.

After sewage was drawn out of the tank on November 28, and intermittent filtration was resumed, the total nitrogen that came away in the effluent was in December 27 per cent. more than was in the sewage applied this month, in January it was 56 per cent. more than was applied, and in February it was 6 per cent. more than was applied, — that is, during these three months the nitrifying process was causing to be removed from the filter a large amount of nitrogenous matter that had, during the continuous filtration, been stored in the sand of the filter.

That more inorganic matter also was removed than was applied is shown by the fixed residue of the effluent for January and February being 142 per cent. of that of the applied sewage, and for March being 120 per cent.

Difference in Results from Intermittent and from Continuous Filtration.

Following Tank No. 12 from July, 1888, to March, 1889, through a period of intermittent filtration followed by one of continuous filtration and a return to intermittent, we have clearly presented the essential differences in results by the two methods. These changes are strikingly represented upon the diagram of observations on Tank No. 12 accompanying the tables of observations. The same amount of sewage — the equivalent of 30,000 gallons per acre — was applied daily throughout the whole time.

In the first period, July, when intermittent filtration with nitrification had been in progress three months, the resulting effluent averaged, for the month, as follows: —

Free ammonia, . . .	0.0062, or 0.4 of 1 per cent. of that of the sewage.
Albuminoid ammonia, .	0.0105, or 2.9 per cent. of that of the sewage.
Sum of ammonias, . .	0.0167, or 0.8 of 1 per cent. of that of the sewage.
Nitrates, ...	1.1530.
Nitrites, ...	0.0062.

The nitrogen of the nitrates was 52 per cent. of all of the nitrogen of the applied sewage. The ammonias show that more than 99 per cent. of the nitrogenous organic matter contained in the applied sewage was removed from the effluent, leaving it to compare favorably with many of the drinking waters of the State.

Upon making the filtration continuous, nitrification ceased in the course of a month, — that is, the organic matter was no longer burned up; and the ammonias increased, until, at the end of four months, they were equal to those of the sewage applied. The sand had, up to this time, held back some of the ammonia applied; but finally it came out in full amount, — the albuminoid ammonia much less, but the free ammonia much greater, than in the applied sewage.

One process of purification was going on: the albuminoid ammonia was growing less by being stored in the sand or by being converted to free ammonia; but there was no oxygen by which this could be converted to nitrates.

The resulting effluent, on November 26, was as follows: —

Free ammonia, ...	2.1700
Albuminoid ammonia, ...	0.0500
Nitrates, ...	0.0070

On resuming intermittent filtration the sewage disappeared from the surface in a few minutes after it was applied, carrying with it oxygen from the air. Nitrification increased rapidly, burning up much of the nitrogenous matter that had been stored in the sand during continuous filtration; so that, in January, while 46 per cent. as much ammonia came from the tank in the effluent as was applied in the sewage, there also came in the effluent 117 per cent. as much nitrogen as nitrates, as there was nitrogen in the applied sewage, — or 56 per cent. more nitrogen came off than was applied to the tank.

This process of removing stored impurity from the filter continued through February; and in March the filter, having been purified by nitrification, was in condition to purify sewage a little more completely than eight months before, when, in July, intermittent filtration was interrupted.

The average of the analyses of the effluent for March gave the following result: —

Free ammonia, . . .	0.0041, or 0.3 of 1 per cent. of that of the sewage.
Albuminoid ammonia, .	0.0110, or 2.5 per cent. of that of the sewage.
Sum of ammonias, . .	0.0151, or 0.7 of 1 per cent. of that of the sewage.
Nitrates, ...	1.4060.
Nitrites, ...	0.0035.

This result shows that this sand, like that of Tank No. 1, can, for an indefinite period, filter more than 30,000 gallons per acre per day, with as good an effluent as it gave in July, 1888, and in March, 1889. It is to be noted that a water-trap was put upon the outlet of this tank on June 27, 1888, which remained there till Feb. 5, 1889, when it was removed. While it was on, no air could enter the underdrains from below.

Filtration of sewage was continued in this tank with slightly improving results for two weeks longer, until April 15; after which it was supplied with city water containing one or more of the substances contained in sewage, that the action of each might be more definitely observed. The details and the results of these experiments continued through the year 1889 may be found in the appended report of Professor Drown and Mr. Hazen. Some of the general results will here be stated.

Application of Water Containing Insoluble Albumen.

From April 16 to June 20, 1889, instead of sewage there was applied daily to Tank No. 12 one and a half gallons of city water into which had been stirred a sufficient amount of baked and pulverized egg-albumen to supply to the mixture 2.8 parts of nitrogen per 100,000 parts.

Albuminoid ammonia is so named because it is ammonia that may be obtained from organic substances by the same method of analysis by which ammonia may be obtained from egg-albumen; hence this egg-albumen may be regarded as the substance typical of albuminoid ammonia. It contains about 16 per cent. of its weight of nitrogen, which, by the method of analysis, is nearly all converted into ammonia; which would, in our tables, be recorded as about 19,000.0 parts per 100,000 of albuminoid ammonia.

This egg-albumen being nearly insoluble in water, and being typical of albuminoid ammonia, it was of especial interest to see to what extent it would be rendered soluble, or would be converted to free ammonia, or would be carried another step in oxidation and become nitrified, when passed through this filter. The characteristic element in the result of an analysis of the mixture when applied would have been albuminoid ammonia 1.7 parts per 100,000.

Unfortunately on June 20, a solution intended for Tank No. 13 was, by mistake, applied to this tank, which seriously interrupted the completeness of the experiment; and the short time of but two months, in which this egg-albumen was applied, does not enable us to determine to what extent the results were affected by the nitrogen previously stored in the tank.

Within two weeks from the time of the first application, the nitrates of the effluent became 1.7 parts per 100,000; and this was the amount of the nitrates during the following two months, which makes it probable that, if the experiment had been continued longer, the result would not have differed very materially from those which have been obtained. The constancy of the results indicates that, during this time, they express the change that occurred in the material applied, rather than the removal of stored material. It would appear from these results that this insoluble nitrogenous matter is, within the tank, rendered soluble and converted into nitrates to the extent of 61 per cent. of the total nitrogen contained in the albumen applied. The part of the nitrogenous matter applied that was found in the effluent was nearly all in the form of nitrates; the free ammonia of the last analysis being but 0.0002 parts and the albuminoid ammonia 0.0064 parts, while the nitrates were 1.7000 parts. How much of the insoluble nitrogenous matter applied was stored in the sand we have no means of determining. Comparing with results obtained with sewage it appears probable that but little was stored, for the percentage which the nitrogen of the nitrates was of the total nitrogen applied is but little below that which we have found the nitrates of the effluent from sewage to be of the total nitrogen then applied, when no nitrogenous matter was being stored in the tank.

From July 10 to August 7 there were applied daily three gallons of city water containing baked and pulverized blood-albumen sufficient to supply 1.4 parts of nitrogen per 100,000. This mixture appears not to have been applied long enough without interruption to give a result that can be relied upon. When it was first applied the nitrates were decreasing from nearly double the amount of nitrogen which this charge contained, and they continued falling for ten days; after which the nitrates were nearly constant for two weeks, and averaged 1.2750 parts, which is 91 per cent. of the nitrogen applied in the albumen. The last analysis of this experiment was as follows: —

Free ammonia,	0.0004
Albuminoid ammonia,	0.0066
Chlorine,	0.5000
Nitrates,	1.3000

Here the nitrates of the effluent amounted to 90 per cent. of the total nitrogen of the mixture applied, and, judging from our experiments with the sewage, it is not probable that any of the albuminoid ammonia, which, when applied, was insoluble, has been stored in the filter.

Application of Water Containing Sugar causes Nitrification to Cease.

From Oct. 23 to Dec. 8, 1889, three gallons of city water containing sufficient granulated sugar to be equal to 100 parts per 100,000 of the solution were applied daily. The nitrification decreased immediately after applying this solution, and in the last two and a half weeks there were no nitrates; from which it appears that, with the small amount of nitrogenous organic matter contained in the water applied, this amount of sugar, — equivalent to one-tenth of one per cent. of the solution, — is able to cause nitrification to cease at least for a time, which in this case continued about three weeks; but a different result was found when a smaller amount of sugar was applied to sewage containing a large amount of nitrogenous matter.

Nitrification Resumed in Winter upon the Application of Sewage.

There being no nitrification in this tank, the application of sewage was resumed on December 9, and, with the temperature of the effluent varying from 49° to 40° Fah., in five days the nitrates amounted to 0.2200 parts. One week later the nitrates amounted to 0.8600 parts, showing that with nitrification entirely stopped within this filter the application of sewage even in December may cause it to again start and become quite active.

Sugar Applied with Sewage Checks but Does not Prevent Nitrification.

On Jan. 1, 1890, sugar was added to the sewage in sufficient quantity to form 10 parts in 100,000. The nitrates decreased about one-half, or to 0.4400 parts, but the ammonias did not increase. After ten days the free ammonia was 0.0028 parts, and the albuminoid ammonia 0.0158.

On January 13 the quantity of sugar was increased to 20 parts per 100,000, and the ammonias remaining about the same, the nitrates continued decreasing for two weeks, when they were but 0.0800 parts; but after this they increased steadily for a month, and at the end of February were 1.1000 parts. The free ammonia at this time was 0.0060 parts, and the albuminoid ammonia 0.0190 parts; so that the sum of ammonias was but 1.3 per cent. of the sum of ammonias of the sewage. The sugar, amounting in this case to one-fiftieth of one per cent. of the solution, causes the nitrates to decrease for a while without increasing the ammonias; but, when the filter becomes adapted to the work demanded of it, the nitrates are formed as completely as when no sugar is added, and purification becomes satisfactory in winter with 60,000 gallons of sewage applied per acre daily.

Tank No. 13 Resumed.

The results obtained with Tank No. 13 have been given to the end of June, 1888. Sewage was applied daily in the same quantity — which was at the rate of 60,000 gallons per acre per day — until Jan. 13, 1889.

The results were remarkably uniform, as may be seen by inspection of the diagram accompanying the tables of daily observations, and they were remarkably satisfactory.

The monthly averages of daily observations and analyses are given in the following table, which also contains the number of bacteria observed in the effluent : —

Monthly Averages of Daily Results with Tank No. 13.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888.												
Feb. 29-Mar. 27,	Sewage, .	–	20.47	25.52	.7176	.4205	1.1381	2.30	.007	.0040	–	–
March, . .	Effluent, .	2.87	2.33	8.82	.0577	.0093	.0670	2.19	.019	.0024	41°	56,894
	Per cent.,	–	11	35	8	2.2	6	–	–	–	–	–
Mar. 28-Apr. 26,	Sewage, .	–	36.15	43.46	.9490	.7710	1.7200	3.24	.007	–	–	–
April, . .	Effluent, .	3.02	2.80	13.52	.2872	.0107	.2979	2.13	.108	.0008	42°	1,019
	Per cent.,	–	8	31	30	1.4	17	–	–	–	–	–
Apr. 27-May 28,	Sewage, .	–	39.49	44.67	1.1629	1.2198	2.3827	3.68	.008	.0012	–	–
May, . . .	Effluent, .	2.96	9.21	18.85	.1217	.0092	.1309	3.46	1.144	.0035	–	75
	Per cent.,	–	23	42	10	.8of1	5	–	–	–	–	–
May 29-June 28,	Sewage, .	–	16.57	24.93	1.4304	.3532	1.7836	4.43	.008	.0006	–	–
June, . . .	Effluent, .	2.94	7.91	25.78	.0018	.0101	.0119	6.60	1.034	.0008	66°	72
	Per cent.,	–	48	103	.1of1	2.9	.7of1	–	–	–	–	–
June 29-July 27,	Sewage, .	–	14.48	24.89	1.7986	.3690	2.1676	6.30	.009	.0001	–	–
July, . . .	Effluent, .	2.96	5.33	27.40	.0012	.0102	.0114	6.76	1.233	.0006	69°	40
	Per cent.,	–	37	110	.1of1	2.8	.5of1	–	–	–	–	–
July 28-Aug. 28,	Sewage, .	–	55.66	54.65	2.7323	1.0782	3.8105	6.37	.013	.0000	–	–
August, . .	Effluent, .	2.96	4.38	32.07	.0016	.0109	.0125	6.92	1.647	.0010	70°	98
	Per cent.,	–	8	59	.1of1	1	.3of1	–	–	–	–	–
Aug. 29-Sept. 27,	Sewage, .	–	55.86	74.12	2.3400	1.7209	4.0609	10.43	–	.0000	–	–
September, .	Effluent, .	3.02	2.39	40.11	.0019	.0112	.0131	10.46	1.345	.0006	64°	66
	Per cent.,	–	4	54	.1of1	.7of1	.3of1	–	–	–	–	–
Sept. 28-Oct. 27,	Sewage, .	–	17.83	32.85	2.1568	.4900	2.6468	7.11	–	.0000	–	–
October, . .	Effluent, .	2.95	2.01	30.59	.0007	.0102	.0109	6.87	1.226	.0001	55°	185
	Per cent.,	–	11	93	.03of1	2.1	.4of1	–	–	–	–	–
Oct. 28-Nov. 24,	Sewage, .	–	16.33	31.30	2.0400	.4335	2.4735	8.20	–	.0000	–	–
November, .	Effluent, .	2.95	1.59	32.70	.0007	.0106	.0113	8.34	1.300	.0002	52°	61
	Per cent.,	–	10	104	.03of1	2.4	.5of1	–	–	–	–	–
Nov. 25-Dec. 28,	Sewage, .	–	14.55	30.98	1.1650	.3415	1.5065	5.50	.021	.0000	–	–
December, .	Effluent, .	2.97	1.70	23.10	.0005	.0101	.0106	4.41	.767	.0001	42°	6
	Per cent.,	–	12	75	.04of1	3	.7of1	–	–	–	–	–

The nitrogen as nitrates in the effluent, from July to December, 1888, averaged 1.253 parts per 100,000, — varying from an average in August of 1.647 parts to one in December of 0.767 parts. It varied nearly with the nitrogen of the free ammonia of the sewage, being between seven and eight tenths as much as the latter.

The following table gives the percentage of nitrogen applied in the sewage that appears in the effluent as nitrates for Tanks Nos. 12, 13 and 14 : —

Percentage of Nitrogen applied in the Sewage that appears in the Effluent as Nitrates.

Date.	Tank No. 12.						Tank No. 13.						Tank No. 14.					
	Nitrogen applied in Sewage.	Nitrates in Effluent corrected for Quantity.	Per Cent. of Nitrogen applied.	Average Daily Quantity. Gals.	Temperature.		Nitrogen applied in Sewage.	Nitrates in Effluent corrected for Quantity.	Per Cent. of Nitrogen applied.	Average Daily Quantity. Gals.	Temperature.		Nitrogen applied in Sewage.	Nitrates in Effluent corrected for Quantity.	Per Cent. of Nitrogen applied.	Average Daily Quantity. Gals.	Temperature.	
					Sewage.	Effluent.					Sewage.	Effluent.					Sewage.	Effluent.
1888.																		
May, . .	3.0599	1.663	54.	1.51	48°	–	2.9633	1.129	38	2.96	50°	–	3.1190	1.462	47	5.85	51°	–
June, .	1.6562	.977	59.	1.42	63°	66°	1.7608	1.012	57	2.94	65°	66°	1.7744	1.137	64	5.92	65°	66°
July, . .	2.0180	1.052	52.	1.42	69°	69°	2.0891	1.233	59	2.96	69°	69°	2.1551	1.071	50	5.74	69°	69°
August, .	3.5049	.155	4.4	1.51	72°	–	4.0217	1.609	40	2.96	71°	70°	5.6274	1.397	25	6.70	71°	70°
September,	5.3866	.009	0.2	1.50	70°	–	4.7411	1.355	29	3.02	65°	64°	2.9606	.993	34	8.92	65°	64°
October, .	2.5773	.008	0.3	1.58	57°	–	2.5722	1.206	47	2.95	49°	55°	2.5781	.998	39	8.92	48°	55°
November,	2.4064	.008	0.3	1.50	45°	–	2.4165	1.308	54	2.95	45°	52°	2.3673	.993	42	8.91	45°	52°
December,	1.4826	.342	23.	1.50	44°	43°	1.5364	.769	50	2.97	44°	42°	1.5060	.712	47	8.95	44°	42°
1889.																		
January, .	1.4719	1.719	117.	1.51	45°	45°	–	–	–	–	–	–	1.4106	.558	40	8.57	45°	45°
February, .	1.4058	1.456	104.	1.50	43°	43°	–	–	–	–	–	–	–	–	–	–	–	–
March, .	2.0362	1.383	68.	1.52	36°	45°	–	–	–	–	–	–	–	–	–	–	–	–

Summary of Results with Tank No. 13.

During the last six months with Tank No. 13 44 per cent. of all the nitrogen applied in the sewage came out in the effluent in nitrates.

The free ammonia of the effluent was nearly constant and very small in amount, varying from 0.0019 parts to 0.0005 parts per 100,000, or from eight-hundredths of one per cent. to three-hundredths of one per cent. of the free ammonia of the sewage.

The albuminoid ammonia of the effluent was nearly constant,— the highest amount being 0.0112 parts in September, and the lowest being 0.0101 parts in December; varying from seven-tenths of one per cent. to three per cent. of the albuminoid ammonia of the sewage.

The sum of ammonias of the effluent varied from three-tenths of one per cent. to seven-tenths of one per cent. of those of the sewage.

The loss on ignition, as determined, was 2.39 parts per 100,000 in September and 1.70 parts in December, — varying from 4 to 12 per cent. of that of the sewage.

The fixed residue of the effluent averaged, for the six months, 31.00 parts per 100,000, — which was 75 per cent. of that of the sewage.

The chlorine of the effluent averaged 7.3 parts per 100,000, — which was within one per cent. of the chlorine of the sewage. No rain fell upon this tank.

The results from this Tank No. 13 are among the most satisfactory, in all respects, obtained from any of the filters. The quantity has, from the beginning, been at the rate of 60,000 gallons per acre per day.

The average result of analyses for the last six months of 1888 was as follows: —

Free ammonia,	0.0011
Albuminoid ammonia,	0.0105
Sum of ammonias,	0.0116
Nitrates,	1.2530
Nitrites,	0.0004

The effluent was generally a clear, colorless, bright water. There was no indication that the filter would not continue indefinitely giving as good results.

The amount of nitrogen stored in Tank No. 13 at different dates was not determined by examinations of the sand; but during the seven months, June to December, 1888, the effluent was so nearly constant, and contained so small an amount of nitrogenous organic matter, that it is not probable that any nitrogen was stored in the sand during this time. If this is the case, it appears that a large part of the nitrogen has escaped our observation; for only 44 per cent. of the amount applied has been found in the effluent. Experiments are now in progress to determine how much of the remainder escapes into the air.

Application of Water Containing Free Ammonia to Tank No. 13.

During the year 1889 this tank was treated with ammonium chloride and sodium carbonate dissolved in city water, in proportions varying from time to time from one part of ammonia per 100,000 parts to 68 parts of ammonia, and with different quantities of sodium carbonate.

These experiments are discussed in detail in the appended report of the chemists. The general conclusions only will be presented here.

The object of these experiments was to determine what part of the nitrogen applied in a solution of free ammonia would be found in the effluent. With nitrogen thus applied in quantities from 3.2 parts per 100,000 to 28 parts per 100,000, the nitrogen in the effluent, finally becoming nearly all in the form of nitrates, was equivalent to 90 per cent. of the applied nitrogen; and, as it is probable that the method of determining the nitrates gave results as much as 5 per cent. too low, it appears that as much as 95 per cent. of the nitrogen applied came through the filter, and that the amount lost was not more than 5 per cent. When the quantity of free ammonia was increased so that the solution contained 56 parts of nitrogen per 100,000, a less percentage was found in the effluent, the determinations showing from 80 to 84 per cent.

When a smaller quantity of sodium carbonate was applied than was necessary to neutralize the acids formed, the nitrates of the effluent were correspondingly reduced and the free ammonia increased. Sewage generally is sufficiently alkaline to supply the bases necessary for complete nitrification; but when this is not the case nitrification may be made more complete by the addition of lime or other base.

When a marked increase was made in the quantity of nitrogen applied, the effect was like increasing the amount of sewage, — the effluent for some time contained increased amounts of ammonia, — but after some days or weeks, when the filter had become adapted to its new work, the purification became more complete: the ammonias decreased and the nitrogen came out in nitrates.

Tank No. 14 Resumed.

Tank No. 14 continued, through June and July and till August 22, to receive 6 gallons of sewage on five days of the week and 12 gallons on the sixth day, or the equivalent of 120,000 gallons per acre per day.

The general results from the beginning are expressed in the following table of monthly averages of daily observations and analyses: —

Monthly Averages of Daily Results with Tank No. 14.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888.												
Feb. 29-Mar. 22,	Sewage, .	–	13.68	17.68	.5053	.3600	.8653	2.16	.007	.0037	–	–
March 1-25, .	Effluent, .	5.82	2.40	10.25	.1643	.0213	.1856	2.00	.024	.0029	41°	78,186
	Per cent.,	–	18	58	33	6	21	–	–	–	–	–
Mar. 23-Apr. 13,	Sewage, .	–	40.19	48.28	1.1260	.7100	1.8360	2.95	.008	–	–	–
Mar. 26-Apr. 15,	Effluent, .	6.24	2.54	15.50	.5444	.0204	.5648	2.99	.172	.0025	41°	3,205
	Per cent.,	–	6	32	48	2.9	31	–	–	–	–	–
Apr. 14-May 7,	Sewage, .	–	39.36	41.13	1.1373	1.2504	2.3877	3.58	.006	.0029	–	–
Apr. 16-May 10,	Effluent, .	5.70	6.06	19.85	.3095	.0147	.3242	3.33	.967	.0046	–	6,837
	Per cent.,	–	15	48	27	1.2	14	–	–	–	–	–
May 8-28, . .	Sewage, .	–	34.83	46.18	1.0575	.8342	1.8917	3.72	.009	.0000	–	–
May 11-31, .	Effluent, .	5.83	7.68	22.52	.0023	.0172	.0195	4.09	1.200	.0014	–	46,280
	Per cent.,	–	22	49	.2 of 1	2.1	1	–	–	–	–	–
May 29-June 29,	Sewage, .	–	16.77	25.01	1.4422	.3556	1.7978	4.46	.008	.0006	–	–
June, . . .	Effluent, .	5.92	7.99	32.31	.0044	.0202	.0246	7.96	1.191	.0029	66°	48,821
	Per cent.,	–	48	129	.3 of 1	6	1.4	–	–	–	–	–
June 30-July 29,	Sewage, .	–	15.10	24.86	1.8057	.4057	2.2114	6.32	.009	.0001	–	–
July, . . .	Effluent, .	5.74	6.54	28.60	.0078	.0221	.0299	7.47	1.083	.0121	69°	2,670
	Per cent.,	–	43	115	.4 of 1	5	1.4	–	–	–	–	–
July 30-Aug. 20,	Sewage, .	–	67.11	63.79	2.9138	1.2906	4.2044	6.56	.011	.0000	–	–
August 1-22, .	Effluent, .	5.85	3.42	30.13	.0242	.0386	.0628	5.84	1.518	.0218	70°	470
	Per cent.,	–	5	47	.8 of 1	3	1.5	–	–	–	–	–
Aug. 21-30, .	Sewage, .	–	117.06	103.71	2.7057	3.6114	6.3171	10.26	.023	.0000	–	–
August 23-31, .	Effluent, .	8.76	5.57	39.96	.0872	.0351	.1223	11.06	1.323	.0147	70°	712
	Per cent.,	–	5	39	3	1	2	–	–	–	–	–
Aug. 31-Sept. 28,	Sewage, .	–	31.05	48.20	2.1667	.7219	2.8886	9.02	–	.0000	–	–
September, .	Effluent, .	8.92	2.88	32.56	.0595	.0278	.0873	8.17	.999	.0099	64°	8,169
	Per cent.,	–	9	68	3	4	3	–	–	–	–	–
Sept. 29-Oct. 30,	Sewage, .	–	17.25	31.60	2.1932	.4754	2.6686	7.21	–	.0000	–	–
October, . .	Effluent, .	8.92	2.78	29.70	.0142	.0224	.0366	7.28	1.011	.0034	55°	2,432
	Per cent.,	–	16	94	.6 of 1	5	1.4	–	–	–	–	–
Oct. 31-Nov. 27,	Sewage, .	–	16.63	31.28	2.0260	.4305	2.4565	8.09	–	.0000	–	–
November, .	Effluent, .	8.91	2.29	29.81	.0045	.0189	.0234	7.40	1.003	.0017	52°	1,453
	Per cent.,	–	14	95	.2 of 1	4	1	–	–	–	–	–
Nov. 28-Dec. 29,	Sewage, .	–	14.03	30.90	1.1300	.3405	1.4705	5.47	.021	.0000	–	–
December, .	Effluent, .	8.95	1.82	23.90	.0210	.0183	.0393	4.10	.716	.0015	42°	116
	Per cent.,	–	13	77	1.9	5	2.7	–	–	–	–	–
1889.												
Dec. 30-Jan. 30,	Sewage, .	–	11.01	23.25	1.1518	.2696	1.4214	4.39	.021	.0030	–	–
January, . .	Effluent, .	8.57	2.15	26.42	.0207	.0178	.0385	5.11	.567	.0044	45°	535
	Per cent.,	–	20	114	1.8	7	2.7	–	–	–	–	–

The nitrates, which reached their maximum in the middle of May, continued high, being, for June, 1.191 parts per 100,000; for July, 1.083 parts; and for August, 1.518 parts; but while these were increasing they did not increase as much as the nitrogen in the sewage, — as will be seen by the table of nitrogen as nitrates given with Tank No. 13: the percentage of the nitrogen of the sewage that appeared as nitrates in this tank was, for June, 64 per cent.;

for July, 50 per cent.; and for August, 25 per cent. This decrease in percentage may be due, in part at least, to the fact that, on June 27, a water-trap was put upon the outlet and remained there several months; and air, which was at every application of sewage pushed out through the outlet, had not so free movement, nor was it so well renewed in the lower part of the tank as when the outlet was kept open. Even with this hindrance to the complete nitrification of the applied organic matter, the effluent had but one and a half per cent. as much ammonia as the sewage, — or 98.5 per cent. had been removed.

The free ammonia increased somewhat faster than that of the sewage, being, in June, 0.0044 parts or three-tenths of one per cent.; in July, 0.0078 parts, or four-tenths of one per cent.; and in August, 0.0242 parts or eight-tenths of one per cent. of that of the sewage.

The albuminoid ammonia did not increase as fast as that of the sewage, being, for the three months, 0.0202, 0.0221 and 0.0386 parts, or 6, 5 and 3 per cent. of that of the sewage.

The sum of ammonias were 1.4, 1.4 and 1.5 per cent. of those of the sewage.

The nitrites increased after the trap was put on the outlet, being 0.0029 parts in June, 0.0121 parts in July and 0.0218 parts in August.

Quantity Increased to 180,000 Gallons per Acre per Day.

The filter had done so well with the unprecedented quantity of 120,000 gallons per acre per day for three and a half months, that on Aug. 23, 1888, the quantity was increased to 9 gallons a day or the equivalent of 180,000 gallons per acre per day. This decreased the nitrates a little, and increased the ammonias of the effluent for about three weeks; but soon the quality of the effluent improved, and in November became better than in July. The mean monthly results were as follows: The nitrates were, in September, 0.999 parts; in October, 1.011 parts; and in November, 1.003 parts. These contained 34, 39 and 42 per cent. of the total nitrogen applied in the sewage. The nitrites decreased in the three months, being 0.0099 parts, 0.0034 parts and 0.0017 parts.

The free ammonia, which, in the last week in August, — immediately after the increase in quantity, — rose to 0.0872 parts, averaged in September 0.0595 parts; in October, 0.0142 parts; and in November, 0.0045 parts, — or three per cent., six-tenths of one per cent., and two-tenths of one per cent. of that in the sewage.

The albuminoid ammonia was, in the first week after increasing the quantity, 0.0351 parts. In September, it averaged 0.0278 parts, or 4 per cent. of that of the sewage; in October, 0.0224 parts, or 5 per cent.; and in November, 0.0189 parts, or 4 per cent. of that of the sewage; the sum of ammonias being 3, 1.4 and 1 per cent. of those of the sewage.

This was a remarkable purification, — at the rate of 180,000 gallons per acre per day, after the equivalent of more than 38,000,000 gallons had been filtered through an acre.

The Filter Becoming Overburdened.

In the latter part of November it became evident that this filter was having more required of it than it could accomplish. The upper layers of the sand were becoming clogged by organic matter; so that, on November 26, the nine gallons of sewage applied took twenty-five minutes to settle away, while in October the sewage disappeared in two minutes. In the early part of January, 1889, the time of disappearance increased to more than two hours; and the purification became less complete. More than 97 per cent. of the organic matter, as shown by the ammonias, was, however, removed from the effluent through December and January. The nitrates fell off a little faster than the ammonia of the sewage, being, in December, 0.716 parts, — which was 47 per cent. of the total nitrogen of the sewage; and in January, 1889, 0.567 parts, or 40 per cent. of the nitrogen of the sewage.

The ammonias for the two months were nearly alike: The free ammonia averaged 0.0208 parts, or 1.8 per cent. of that of the sewage; the albuminoid ammonia averaged 0.0180 parts, or 6 per cent. of that of the sewage; and the sum of ammonias was 2.7 per cent. of that of the sewage.

In the latter part of January, 1889, the surface of the tank became so clogged that for several days the nine gallons of sewage, — which was the equivalent of a little more than six and a half inches in depth upon the surface, — did not all disappear before the next application. The nitrates decreased in this time to 0.4200 parts, and the ammonias increased to 0.1690 parts.

This condition was, however, changed by working over the upper inch in depth of the sand, — the first time since the tank was in use. Heretofore there had been some disturbance of the surface by pouring on the sewage, and at this time the surface was depressed two or three inches in the middle, while the sand stood firm and compact around the edges. On January 31 the outer part was dug over to the depth of about an inch, and the material filled into the depressions; thus enabling the sewage to settle away more evenly over the whole area of the surface. The effect upon the effluent was quite marked. The nitrates, in a week, had increased to 0.7000 parts, and the ammonias had decreased to 0.0600 parts.

These experiments, however, were not continued, as the tank was taken to make some special experiments upon the amount of oxygen necessary to carry on nitrification, which are detailed in the accompanying report of Mr. Hazen.

A few results of interest in connection with the subjects already treated will be given.

Special Experiments on Nitrification.

From February 11 to 21 no sewage was applied, but in its place 9 gallons of city water were applied daily: whereupon the free ammonia decreased from 0.0760 parts to 0.0002 parts; the albuminoid ammonia, from 0.0260 to 0.0192; the chlorine, from 5.08 to 0.44; and the nitrates, from 0.6000 to 0.3200. At the end of this time a cover having a mercury seal was put upon the tank to exclude air. Above the cover and soldered to it was a large funnel into which the sewage was poured; and, before all was allowed to flow into the tank, a stop-cock between the funnel and cover was closed, thus preventing the entrance of air. The outlet at the bottom was also trapped. For a few days a little air appeared to leak in; and, on February 28, the result of analysis of the effluent was as follows: —

Free ammonia,	0.0042
Albuminoid ammonia,	0.0174
Nitrates,	1.0000

Effect of Complete Exclusion of Air.

On March 1 the tank was pronounced air tight; and on March 14 the ammonias had increased and the nitrates decreased to the following figures: —

Free ammonia,	0.9000
Albuminoid ammonia,	0.0790
Nitrates,	0.0250

The stop-cock between the funnel and the cover was, after March 16, left open, so that air could follow the sewage into the space between the cover and the surface of the sand: but it is evident that but little if any air entered the sand; because the ammonias continued to increase, and the nitrates to decrease, until, on March 28, we had the following result: —

Free ammonia, ...	1.5200
Albuminoid ammonia, ...	0.1010
Nitrates, ...	0.0050

Nitrification had ceased, and the ammonias were 60 per cent. of those of the applied sewage.

On March 27 the cover was removed, when it was found that while air was excluded organic matter had accumulated on the surface of the sand to such an extent that, while the pressure through the funnel of about ten inches of water would easily push nine gallons of sewage through, the weight of sewage on the surface, after the cover was removed, would cause but three gallons to pass through.

Effect of Drawing Air through the Sand.

On April 2 seven pounds, or about one-half inch in depth of sand and sediment, was removed from the surface of the tank; a trap was put on the outlet to prevent air entering there, and an aspirator was attached to a side cock four feet below the surface, which would draw about sixteen gallons of air down through the sand in an hour.

This aspirator was run constantly day and night, renewing the air in the upper four feet of the tank every hour. The result was very marked in the immediate increase of the nitrates, in two days, from 0.0100 parts to 1.2000 parts; and a further increase in the next week to 2.3000 parts, — which was 101 per cent. of all of the nitrogen in the sewage applied. The free ammonia did not change so rapidly. Two days after the aspirator was attached, the free ammonia was 1.4300 parts. One week later it had decreased to 0.0680; and in the same time the albuminoid ammonia decreased from 0.0620 to 0.0250 parts.

On April 17 the cover was again put upon the tank and air was excluded. In eleven days the nitrates decreased from 1.8000 parts to 0.0150 parts; the free ammonia increased from 0.0720 to 0.7840 parts; and the albuminoid ammonia, from 0.0290 to 0.0960 parts.

On April 27 the aspirator was again attached and air admitted; and the amount of sewage applied after this day was three gallons per day. The nitrates increased in three days to 4.5000 parts; and on May 9 were 5.0000 parts; when the free ammonia had decreased to 0.0240 parts and the albuminoid ammonia to 0.0220 parts. When the nitrogen of the nitrates was at the very high figures just given, it amounted to about 180 per cent. of the nitrogen applied in the sewage; that is, under the influence of the air drawn through the sand by the aspirator, nitrification became so active that it removed from the tank 80 per cent. more than was being applied.

On May 6 the aspirator was shut off and air was excluded from the tank. The ammonias increased and the nitrates decreased as before; and on May 20, 1889, the aspirator was so arranged that the air drawn out from the bottom was returned to the top, and experiments were made to determine how small an amount of oxygen, so kept in motion through the sand, would enable all of the organic matter to be nitrified. These experiments will be detailed in the accompanying report of Mr. Hazen.

Difference in Character of Effluent at Different Hours after Sewage is Applied.

Some interesting series of observations on the chemical character of the effluent of Tank No. 14, before and after sewage was applied, were made on several days in October, 1888.

On October 20 the following results were obtained: —

Time.		Free Ammonia.	Albuminoid Ammonia.	Nitrates.	Nitrites.	
Hours.	Minutes.					
9	40	0.0068	0.0208	1.3000	0.0090	Before sewage came through.
10	0	0.0092	0.0196	1.1500	0.0050	After air had blown out and liquid above the air began to come.
10	10	0.0048	0.0224	1.2500	0.0008	After passing 3.6 gallons after applying sewage.
11	0	0.0032	0.0248	1.3000	0.0007	After passing 5. gallons.
11	40	0.0028	0.0276	1.5400	0.0008	After passing 5.5 gallons.

It is most probable that some of the forward particles of sewage passed the liquid contained in the smaller interstices of the upper part of the tank, and reached the bottom mixed with a less number of particles of previously held water than at any later time, just after the air, which the sewage was pushing down, was expelled. This would decrease the nitrification and increase the free ammonia, as at 10 o'clock. After the first rush of sewage into the open interstices, the nine gallons applied mixed more generally with the eleven gallons previously held in the sand; and, the process of changing free ammonia into nitrates going on rapidly, the free ammonia grows less and the nitrates increase continually.

On October 26, a similar result was obtained; and, as the series was continued until nine hours after sewage was applied, the nitrates increased to a greater extent and the albuminoid ammonia decreased as well as the free.

The following are the results of analyses: —

Time.		Free Ammonia.	Albuminoid Ammonia.	Nitrates.	Nitrites.	
Hours.	Minutes.					
10	49	0.0032	0.0180	1.2000	0.0025	Before sewage reached outlet.
11	10	0.0032	0.0196	0.9700	0.0014	After passing 1.7 gallons after application of sewage. Time of air passage not noted.
11	28	0.0024	0.0224	0.9400	0.0002	After passing 4 gallons.
12	15	0.0032	0.0248	1.4300	0.0002	After passing 5.7 gallons.
3	17	0.0016	0.0200	1.7500	0.0002	After passing 7.3 gallons.
8	42	0.0024	0.0180	1.9000	0.0008	After passing 8.3 gallons.

With the slower rates of the last eight hours there was time enough for very marked changes to occur in the reduction of ammonias and the increase in nitrates. The sewage applied this day had the following composition: —

Free ammonia,	2.7800
Albuminoid ammonia,	0.3600
Nitrates and nitrites,	none.

The explanation above given of the causes of the changes in chemical composition of the effluent is confirmed by the series of observations upon the number of bacteria in the effluent taken at the same time, and at other times, and given in the following pages. The number of bacteria increased much when the forward particles of sewage reached the bottom.

Observations on Bacteria in Tanks Nos. 12, 13 and 14.

The number of bacteria in a cubic centimeter of the effluent from these tanks, by a single count on the days mentioned throughout the twenty months since filtration commenced, may be found in the following table: —

Number of Bacteria found in the Effluent from Tanks Nos. 12, 13 and 14.

Date.	Tank No. 12.	Tank No. 13.	Tank No. 14.	Date.	Tank No. 12.	Tank No. 13.	Tank No. 14.	Date.	Tank No. 12.	Tank No. 13.	Tank No. 14.
1888.				**1888**-Con.				**1888**-Con.			
Feb. 16,	9	-	-	June 12,	64	3,696?	94,230	Nov. 16,	7	27	618
18,	6	-	-	16,	735	98	1,232?	21,	6	27	4,200
21,	36,951	-	-	23,	23	22	-	26,	87	247	382
23,	635,160	-	-	29,	56	68	-	Dec. 5,	10,416	-	-
25,	757,500	-	-	July 5,	2,275	-	3,780	7,	34	3	64
28,	577,000	-	-	10,	220	17	-	10,	156	-	-
Mar. 1,	193,600	-	-	24,	650	57	4,000	12,	17	5	224
3,	53,400	423,900	222,000	26,	421	-	-	17,	39	10	154
6,	34,776	91,650	291,600	28,	-	46	230	26,	163	7	21
8,	51,118	83,505	90,877	Aug. 2,	55,902	-	-	**1889.**			
10,	37,643	12,609	14,604	4,	40,304	52	320	Jan. 2,	829	-	369
15,	23,044	9,038	-	7,	21,120	-	-	8,	3,410	-	737
17,	49,620	181	4,500	14,	10,804	40	389	15,	720	-	403
20,	106,038	569	879	18,	8,274	156	701	22,	2,880	-	317
22,	164,308	176	628	21,	3,745	-	-	29,	80	-	848
24,	64,235	105	401	23,	3,540	146	712	Feb. 4,	-	-	3,072
27,	37,837	2,582	-	Sept. 11,	64	-	-	6,	71	-	1,127
29,	20,260	1,517	3,205	13,	219	-	-	12,	20	-	85
April 19,	9,126	-	-	18,	238	120	4,576	19,	11	-	33
25,	1,500?	1,953?	1,328	22,	88	24	2,630	27,	74	-	174
28,	1,609	85	434	27,	26	55	17,300	Mar. 5,	19	-	1,350
May 8,	1,170	39	18,749	Oct. 2,	14	-	-	12,	189	-	11,620
10,	3,074	106	-	4,	35	47	-	19,	230	-	11,934
12,	25?	100?	-	9,	16	27	1,073	23,	-	-	5,056
19,	41	173	27,720	13,	6	66	1,332	26,	34	-	4,446
22,	88	33	43,680	23,	30	18	6,210	April 9,	-	-	4,200
26,	174	51	67,440	27,	8	26	1,115	24,	-	-	7,105
29,	264	26	-	Nov. 1,	13	50	2,640	30,	-	-	1,470
June 2,	19	16	-	6,	0	2	297	May 7,	-	-	110
7,	97	154	51,000	10,	4	12	584				

In each of these tanks the number of bacteria rose to the highest it has ever been, a few days after sewage was applied, and the maximum number observed was the smallest in the tank receiving the greatest amount of sewage. In No. 12, receiving 1.5 gallons daily, the number reached 757,500 per cubic centimeter; in No. 13, receiving 3 gallons, the number reached 423,900; and in No. 14, receiving 6 gallons, the number reached 291,600. The large maximum in No. 12 was undoubtedly due to applying boiling water to the sand when it was first filled, and this appears to be the reason for the number continuing high for the next two months. Within two weeks the numbers were reduced as follows: in No. 12 to 34,776; in No. 13 to 181; and in No. 14 to 401.

There was no freezing in the tanks: the temperature of the sewage was, at the time of the above changes, about 44°, and of the effluent about 39° Fah. The result indicates that it is mechanically possible for about the full number of bacteria in the sewage to be carried through this coarse sand, and, if accompanied by sufficient oxygen and suitable food, a very large part of those applied may live to be carried through; but, as the sewage occupies the space in the sand more and more completely, the amount of oxygen that was in the sand, or was carried down mechanically with the sewage, becomes used up in forming carbonic acid or other compounds, to such a degree that there is little left to support bacteria.

The bacteria of No. 12, though much reduced from the maximum number, continued high through March (1888), averaging above 60,000 and decreasing to 20,000. When nitrification began, in the latter part of April, the number decreased to 1,600, and in the latter half of May, when the nitrates were 1.5 parts per 100,000 and the sum of the ammonias 0.25 parts, the number of bacteria averaged 118, or one in ten thousand of the number applied. In June, with varying nitrification and much less free ammonia, the number averaged 166. In July, while intermittent filtration was continued, the number averaged 891.

Although the conditions in Tank No. 12 appear to have been so favorable to the life of bacteria that at one time eighty-three per cent. of the number of bacteria in the sewage lived to pass through the filter, the number decreasing to a very small fraction of one per cent., when nitrification was purifying the sewage, indicates that then the conditions for bacterial life were very unfavorable.

The same process that removes other organic matter from a liquid also removes bacteria.

In Continuous Filtration the Bacteria at first Increased and then Decreased.

On July 27, 1888, the outlet was closed and the tank was filled with sewage, and continuous filtration was continued till November 27. On August 2, after as much effluent had been drawn from the tank as it contained before it was filled, the effluent contained 55,900 bacteria per cubic centimeter. The nitrates, in the meantime, had been reduced from 1.250 to 0.750 parts, and the albuminoid ammonia had increased from 0.0098 parts to 0.0396 parts.

The number of bacteria decreased steadily through the month of August, and on September 11 was but 64. In the meantime nitrification had ceased, and free ammonia had increased to 0.1600 parts.

Some of the liquid containing the highest number of bacteria, after the outlet was closed, probably came through the sand in a few hours, and the conditions appear to be such that they could live for a number of days, in decreasing number, in the lower part of the tank; but, after those which came in with the first sewage had passed, no bacteria could pass through the sand in less than three weeks. The number in September averaged 127; in October, 18; and in November, 19. In the latter month there was no nitrification, — the free ammonia averaged 1.8325 parts and the albuminoid ammonia 0.0374 parts. The time of passage without oxygen was too long, although food was abundant. To determine if these small numbers grew in the faucet below the spigot, this was sterilized by heat, after which the first sample contained 8 and the second sample 2, — which probably represented a sterile liquid within the tank at the bottom.

Three days later, sewage standing on the surface contained only 16,400 per cubic centimeter, due no doubt to microscopic and other organisms there which lived on bacteria. Samples taken by plugs in the side of tank at different distances below the surface contained, at one foot below, 4,270 bacteria; at 2.5 feet, 3,944; at 4 feet, 147, and the effluent from the bottom contained 3.

Effect of Resuming Intermittent Filtration.

After draining the tank on Nov. 28, 1888, to resume intermittent filtration, and before sewage, applied at the surface with air in the sand, had reached the outlet, the number of bacteria on December 5 was 10,416. The number at this time was large, evidently because the food supply was large; nitrification was not yet sufficiently complete to kill them, and the time of passing through the filter was short, being but one-third as long as in the previous week. At this time air could freely enter the outlet pipe and nitrification had begun, and the nitrates had become 0.0900 parts, while the ammonias were 2.18 parts. Two days later, the number of bacteria in the effluent that had come down from the surface mingled with air was but 34; and the average number in the month, after the fifth, was 82. During this time the nitrates were increasing from 0.1200 parts to 0.4500 parts, and the ammonias were about 1.9 parts.

In January, 1889, the average number was 1,584, while the nitrates averaged 1.713 parts, — which was 17 per cent. more than the amount of nitrogen applied; but at the same time the ammonias amounted to 0.6630 parts. On January 17, twelve counts were made from hour to hour, varying from 322 to 1,892, and averaging 651. In February and March, the nitrates continued high; and the ammonias decreased, becoming 0.0330 parts and 0.0151 parts, and the numbers of bacteria were 44 and 118.

In December, with nitrates low and ammonias very high, there were but few bacteria. In January, with nitrogen of nitrates in excess of that applied, but with high ammonias, the number of bacteria, though much greater, was but one-quarter of one per cent. of the number in the sewage. In February and March, with high nitrates and low ammonias, the number was much reduced, but was still nearly the same as in December, when ammonias were very high and nitrates low.

From all of the observations upon Tank No. 12 we may expect that, when applying the sewage once a day and filtering at the rate of 30,000 gallons of sewage to the acre and removing 99 per cent. of the organic matter, there will be found in the effluent a small fraction of one per cent. of the number of bacteria applied.

Number of Bacteria when Filtering Water Containing Different Substances.

After the application of sewage to this tank was discontinued (April 15, 1889), and it was used for the filtration of egg-albumen and of sugar in city water, some interesting experiments were made upon the removal of bacteria, which will be presented in detail in the report of Professor Sedgwick, which is to follow. Some of the more important results will here be presented.

While filtering egg-albumen in city water from April 16 to June 20, the average number of bacteria in the effluent was 14. Through July and the early part of August the number averaged 26. At this time nitrification was nearly complete.

Addition of Bacillus Prodigiosus in Bouillon.

On August 7, a litre of bouillon, containing many millions of Bacillus prodigiosus, was mixed with the water and applied to the filter in the morning at half-past ten. On August 8, the number of bacteria found in the effluent was 60 per cubic centimeter. At 1 P.M. the number counted was 13,440; two hours later the number was 58,800; two hours after this the number had increased to 81,700; and the count at 9 P.M. gave 108,100. Upon the culture plates of this afternoon Bacillus prodigiosus was found in abundance. On August 9 the number of bacteria found at different hours in the day was high in the forenoon, reaching 12,964 at noon and decreasing to 494 at nine in the evening. The average number found on August 10 was before 1 o'clock, 648, but at 9 P.M. the number was but 3; and three counts of samples taken on August 11 averaged 4.

The great increase of the number in the effluent, due to the large number applied, and due also to a large amount of food material prepared for their sustenance, was limited through the time from noon of August 8 to the evening of August 9; and by the evening of August 10 the effect of this seems to have been spent. There were a few high numbers found on August 12, 13 and 14, when the effluent was flowing out most rapidly. The average number found by 41 counts, from August 12 to the end of the month, was 187. On September 18, 19 and 20, the average number counted in the effluent was 199.

Application of Bouillon Containing no Bacteria.

On September 20, the same quantity of bouillon, like that applied on August 7, was again applied. This consisted of 900 cubic centimeters of water, and 9 grams of peptone which was put into the three gallons of city water daily applied. The bouillon applied at this time differed essentially from that applied on August 7 by being completely sterilized, so that it contained no bacteria. Some of this solution reached the outlet in regular course on September 21; and at 10.30 A.M., when the effluent was flowing out very slowly, the number of bacteria found was 54,600, in contrast with 9, which were found under the same conditions on the previous day; and at 1.55 P.M., when the effluent was flowing most rapidly, the number counted was 57,600, instead of 125 found under the same conditions on the previous day. In the following hours of the afternoon, the number decreased slowly, until at 9 P.M. it was 26,400. At the time of greatest flow, on September 23, the number was 4,485. On September 26 it was 1,820; and on October 2 the number counted at the time of most rapid flow was 736.

On August 8, we very naturally attributed the very large numbers in the effluent to the millions of bacteria that were applied to the surface; but we find, on September 21, nearly as large numbers in the effluent upon applying the especially prepared food material which contained no bacteria. This supply of food material, applied suddenly without sufficient time to become nitrified, must have made the conditions for passage through the tank much more favorable, and probably caused bacteria existing there to multiply rapidly as long as the food material lasted and while nitrification was incomplete.

This food material was nearly all removed from the tank, when, in four days, a quantity of water had been passed through somewhat in excess of the quantity which the tank ordinarily contains.

On October 3 another application of bouillon containing Bacillus prodigiosus was applied, with a result similar to that of August 8, but with less increase of numbers, — thought to be due to the bouillon not being so rich in food material. The Bacillus prodigiosus were abundant in the effluent on the following day.

Bacteria Greatly Increased and then Decreased by Applying Sugar.

On October 23, granulated sugar, to the amount of one-tenth of one per cent. was applied to the three gallons of city water; and when this came through the tank three days later, the number of bacteria counted was 93,030, — which is one hundred and fifty times the number found in the previous three days. The average number in the last six days of October was 16,505. The same solution was applied continually through November and until December 8. The number of bacteria continued high until November 21, averaging 2,884; after which the number was much smaller, averaging, from November 22 to December 8, 62.

The reason of this decrease is not entirely clear, for during this time nitrification ceased; but it may be due to the amount of ammonia becoming very small. The loss on ignition at this time was very high, being above 70 parts, — due to the carbon of the sugar. The temperature of the water applied, which had been above 50°, was from 50° to 44°.

It is worthy of notice, that, with small amount of ammonia and no nitrates, the conditions for life of bacteria appear to be unfavorable even with a large amount of carbonaceous organic matter.

After December 9, three gallons of sewage were applied instead of the city water which had been previously applied; and three days later, before the effect of the sewage could be observed, a quantity of bouillon containing Bacillus prodigiosus was applied; and on December 26, the same quantity was again applied. The result of the increase in numbers was very much less than in August and September, the greatest number immediately following being but a little more than 3,000. On the latter date it is interesting to note that the Bacillus prodigiosus were applied at 10 A.M., and the same species was found in the effluent at 1 P.M., and in samples taken at each half-hour the rest of the afternoon.

When sugar was applied with the sewage, through January and February, 1890, the number of bacteria increased from 38 on January 7 to 4,749 on February 4, and averaged in this time 1,247. During this time the loss on ignition was 3.78 parts, the ammonias were nearly constant at about 0.02 parts, and the nitrates decreased from 0.60 parts to 0.08 parts.

In the following month, with the ammonias a little higher, (0.024 parts) and the nitrates constantly increasing until they reached 1.10 parts, the number of bacteria averaged but 36 per cubic centimeter.

Bacteria in Effluent of Tank No. 13.

The number of bacteria in the effluent of Tank No. 13, in the latter half of March, 1888, averaged 855; but when nitrification began the number was much reduced, and for the next eight months averaged 75, — which is about one in 10,000 of the number applied.

The average number counted for each month was as follows: —

March,	56,894	August,	98
April,	1,019	September,	66
May,	75	October,	185
June,	72	November,	61
July,	40	December,	6

No series were taken from hour to hour during the application of sewage to this tank. It is probable that the number in the effluent was greater at certain hours in the day.

On December 5, a very large number of Bacillus prodigiosus were added to the sewage. At 5 P.M. December 7, and 11 A.M. December 8, this species of bacteria was found in the effluent; showing that it was possible for a few representatives of this species to live to be carried through this sand when two and three days on the passage.

Effect on Bacteria of Filtering Water Containing Ammonia.

The average number of bacteria in the effluent during December, 1888, was 6. At this time the average number in the sewage applied was 343,000, and the nitrates of the effluent contained 50 per cent. of the total nitrogen of the sewage. Upon changing the liquid applied to the filter from sewage to city water containing ammonium chloride and sodium carbonate, which probably contained about 60 bacteria, the number found in the effluent until March 6, 1889, averaged 31 per cubic centimeter.

From March 7 to April 29, 1889, the water which was applied was boiled and then cooled. It was probably nearly sterile when applied to the filter, but the number found in the effluent during this time averaged 49. During this time the nitrification in the filter was nearly complete; and, although few or none were applied in the water, examinations of the sand half an inch below the surface were made on March 6, April 3 and April 20, and the number of bacteria found in one gram of sand was 327,000, 333,000 and 400,000 on the several days; showing that while applying water which had been sterilized, containing a large amount of ammonia, the number of bacteria in the sand near the surface had not decreased but had slightly increased.

From April 29 to August 30 the applied water was not boiled, and the number of bacteria in the effluent was very much increased. On the following day the number was 722. In May the number increased from 851 to 2,656, averaging 1,784. In this month a large number of colonies of one kind was found in all the samples from this tank. In June the number averaged 2,255. In July the number was but 210 in the middle of the month when the ammonias were lowest, but increased to 156,800 in the latter part of the month when the ammonias were very high, and other conditions soon to be mentioned existed, and averaged for the month 49,000 per cubic centimeter.

Effect of Forcing Boiling Water into the Bottom of the Filter.

Several times during this month an attempt was made to sterilize the lower portion of this tank by forcing boiling water in through the outlet faucet, and allowing it to run out through six taps in the side of the tank that were six inches from the bottom. Upon drawing out through the outlet faucet the water last introduced, it was generally found to be quite sterile, and, for a short time after it had flowed out, the number of bacteria found in the effluent was very small; but some hours later, when the liquid from the upper part of the tank had come down through this sand which appears to have been sterilized, the number of bacteria found in the effluent was enormously increased, being often from twenty to fifty times the number found in the effluent before the hot water was introduced. It is probable that the water, which was heated to boiling when poured into the faucet, prepared the organic matter which was in the sand so that it was a better food supply for the bacteria, and that they consequently increased in much larger numbers than usual, when coming down through it; the increase in temperature was also favorable to their growth. These hot water applications were made on July 2, 6, 9, 18 and 29; also on August, 2, 13 and 22. All the very high numbers found in July and in the following month of August were thus associated with the application of hot water to the lower part of the tank, and were probably caused by it. In August the average number was 9,250.

Number of Bacteria Found in the Sand at Different Depths.

On August 27, after the lower part of the tank had been sterilized by hot water several times, and after the very large numbers of bacteria had been found in the effluent, a hole two inches in diameter was bored down through the sand from top to bottom, and the number of bacteria found in a gram of the sand taken at different depths was determined with the following results: —

Distance below the Surface. Inches.	Number of Bacteria in a Gram of Sand.	Distance below the Surface. Inches.	Number of Bacteria in a Gram of Sand.	Distance below the Surface. Inches.	Number of Bacteria in a Gram of Sand.
0¼	99,200	7	8,100	31	5,500
2	28,400	15	10,000	47	6,100
4	10,900				

Here the number of bacteria decreases, rapidly at first, from 99,200 in the upper quarter of an inch to 6,100 at 47 inches below the surface. During these months the average number in the applied city water was 55 per cubic centimeter, but the number in the solution applied was not determined. It was regarded as quite certain that the method of making the solution, up to about April 17, caused it to be sterile. After that time there is some question whether a small number of bacteria were not added with the sodium carbonate, which would increase the number above that found in the city water.

Number of Bacteria Continues Greater in the Effluent than in the Applied Liquid.

From August 30 to the end of the year, the city water used in making the solution was again boiled, and the number of bacteria found in the effluent was high for a time, and then much less. In September the average number found in the first half of the month was 997; in the latter half of the month many observations were made at different hours of the day, and the average number was found to be 360. At this time nitrification in the tank was nearly complete, and the free ammonia was much less than before or after; it was, however, from 0.2 to 0.8 parts per 100,000. In the month of October, although the nitrates were very much less and the free ammonia much higher than previously, the number of bacteria found, as the average of forty-two counts, was 94. In November, when the free ammonia amounted to 23 parts per 100,000 and the nitrates to 22 parts, the average number of bacteria was 175; and, with a somewhat similar condition in December, they averaged 845. On November 1 a sample of the solution applied to the tank, supposed to be nearly sterilized by boiling, was examined after it had stood three days: it was found to contain 21 bacteria per cubic centimeter.

In this filter we find that, although the solution applied contained a very small number of bacteria, the number growing in the sand near its upper surface was large; and the large amount of ammonia applied appears to have kept these alive in the sand in decreasing numbers from the top downward, but supplying enough to the passing liquid to cause the number in the effluent to be nearly all the time much larger than the number applied daily; the filter was a breeding place for bacteria. This is a very different result from those which have been obtained from this and from the other filters when sewage has been applied to the surface.

The previous heating of the sand in the lower part of the tank and the use of boiled water may have prepared food particularly suited to support bacteria on the passage, as in Tank No. 11.

Bacteria in Effluent of Tank No. 14.

The number of bacteria found in the effluent of Tank No. 14 varied much from day to day. It was generally much greater than in the effluent from No. 13, where the quantity of sewage filtering was one-half and one-third as much. The low number, 401, reached in March did not continue.

The average number from Tank No. 14, counted in the several months, is as follows: —

March, 1888,	78,186	September, 1888,	8,169
April, 1888,	881	October, 1888,	2,432
May, 1888,	39,397	November, 1888,	1,453
June, 1888,	48,821	December, 1888,	116
July, 1888,	2,670	January, 1889,	535
August, 1888,	530		

It is to be remembered that, on June 27, a trap was put on the outlet holding water about six inches deep on the bottom of the tank, and that, on August 23, the quantity of sewage applied was increased from the rate of 120,000 gallons per acre per day to 180,000 gallons per acre. The average number counted after the latter quantity was applied was 2,541, — or about one-half of one per cent. of the number applied.

Bacteria in Liquid Drawn from Filter at Different Depths below the Surface.

Many series of observations have been made upon the effluent of Tank No. 14; and, to aid in obtaining an understanding of where changes took place, small taps were inserted in the side of the tank, at different heights, from some of which liquid could be drawn.

On Oct. 20, 1838, nine gallons of sewage were applied at 9.40 A.M. This sewage contained 859,600 bacteria per cubic centimeter. About four minutes after the beginning of the application, liquid, drawn from the tap sixteen inches below the top, contained 626,400 per cubic centimeter. Seven minutes later, a sample drawn from the tap thirty-two inches down contained 370,800 per cubic centimeter. In the meantime, water that was coming out with air through the faucet at the bottom of the tank contained 5,930 per cubic centimeter. The number found in the effluent before the sewage was applied was 709; and the effluent which came twenty-five minutes after sewage was applied (which was after air that was in the sand had been forced out through the bottom outlet, and probably some of the applied sewage had reached the bottom) contained 11,304 per cubic centimeter.

Increased Number of Bacteria Immediately Following an Application of Sewage.

On Nov. 17, 1888, the effluent, when slowly dropping from the trapped outlet, contained 110 bacteria. One minute after beginning to apply sewage, the rate of flow being more rapid, the number was 1,000. Five minutes later, with much more rapid flow, the number was 2,600. Up to this time the flow was from liquid standing in the bottom of the tank. This looks as if bacteria settled, or were attached to solid particles of sand, and did not come freely when the motion at the outlet was extremely slow; and the number increased with the rate of flow. Fifteen minutes after beginning to apply sewage, the water in the bottom of tank had been all forced out, and air, which the sewage was pushing down through the sand, was coming out violently with a little water; this contained 3,332 bacteria. Ten minutes later, the air being all out and water beginning to flow, it contained 4,000 bacteria. Ten minutes later, the number was 13,400; and after another ten minutes, or 45 minutes after beginning to apply sewage, the number was 23,400. Probably a portion of the effluent at the last two counts came directly from the sewage, which when applied contained 923,800 bacteria per cubic centimeter.

On November 24 a similar experiment was made. The sewage, then, was not entering through the surface of the filter quite so freely, and probably less sewage went directly down; it may have merely pushed down liquid that was near the upper part of the tank. Before sewage was applied, the number counted was 255; after sewage was applied, the number increased gradually, for an hour, to 18,500; and, in the next forty minutes, decreased to 8,428. The number in the sewage was not counted this day, but the average number in the week previous was 437,000 per cubic centimeter.

Fourteen minutes after the application of sewage was begun, the number in liquid from the tap, sixteen inches below the top, was 46,500; and, four minutes later, liquid from the tap, thirty-two inches down, contained 30,840 at the same time that the number in the effluent from the bottom was 13,400 and was decreasing.

On December 5, the surface being still more clogged, the liquid in the lower part of the tank contained from 197 to 565; and, after this had been pushed out, the number counted was 400 and 355. It is evident that, with this condition of the upper layer, no sewage came directly down through the tank.

On December 8, when it took more than two hours for the sewage to disappear from the surface, the number in the effluent, for the first hour and a half after beginning to apply sewage, varied from 40 to 129 — averaging 69 per cubic centimeter.

On Dec. 15, 1888, the number before sewage was applied was 274. The number increased to 4,020 an hour after the application. On December 29 the number before application was 335. In one hour after application it rose to 10,619; and, forty minutes later, had fallen to 4,864. The number in the sewage was 180,200. Similar experiments were continued through January with like results.

These observations, with others upon similar sand in other tanks, show that, when a large amount of sewage is put on after the sand is drained, some of the sewage first applied reaches the bottom in a short time, carrying with it many bacteria. The remaining sewage comes more slowly and is mingled with liquid previously in the tank, in the whole of which processes are going on which are not favorable to the existence of bacteria. They decrease in numbers from the top down; and, at other hours in the day than that immediately following the application, the number to be found in the effluent is but a small fraction of one per cent. of the number applied; and, at the hour when greatest, the highest number found in these experiments was six per cent. of the number applied.

Bacillus Prodigiosus Carried through the Filter.

On Nov. 21, 1888, a large number, — many millions, — of Bacillus prodigiosus were applied with the sewage. Samples were taken; and this species was found in all of them, as follows: —

From tap sixteen inches below the surface, at seven minutes and at ten minutes after sewage was on.

From tap thirty-two inches down, at twelve minutes after sewage was on; also, on the next morning.

From the bottom they were found on the next day at 10.25, 11.30 and 1.55; also, on the morning of the fourth day. They were not looked for on the day when applied.

Effect of Applying City Water.

During the special experiments with Tank No. 14, from February to May, 1889, it may be observed that, when the city water was flowing through the tank from February 11 to 21, the number of bacteria counted in the effluent was much less than usual, being 85 and 35 per cubic centimeter.

From examinations of similar sand in other tanks it is probable that at this time, large numbers of bacteria were stored in the sand of this tank from top to bottom; and it is remarkable that, when city water was running through, the number in the effluent was little if any greater than the number in the water applied. This condition of few bacteria in the effluent when many were stored in the tank has been frequently noticed; and suggests that the kinds of bacteria that are found distributed through the sand are not moving from top to bottom with the liquid, but are adapted to live there, and are so permanently attached to the sand that they are only occasionally moved along by the passing liquid.

This suggestion is supported by the fact already mentioned, that in December, 1888, the bacteria distributed through the sand of Tank No. 1 were nearly all of one kind. At the same time those in the lower part of Tank No. 4 were of the same kind, none of which kind were then found in the effluent.

Bacteria Increased during Exclusion of Air and Increase of Ammonias, and Decreased by Nitrification.

Upon again applying sewage, and excluding air from the tank, by which the nitrates were very much reduced and the ammonias increased, the number of bacteria increased to 11,620 per cubic centimeter; but the tank continuing in similar condition they decreased to 4,446.

When the cover was again removed, and the aspirator had been run for a week, and the nitrates contained as much nitrogen as the applied sewage, the number of bacteria was still 4,200.

Upon putting on the cover again, and excluding air, the number increased to 7,105; but, upon again applying the aspirator, and causing the nitrogen of the nitrates to increase to 180 per cent. of the nitrogen applied in the sewage, the number decreased to 110.

After this time, from June to Dec. 17, 1889, the aspirator was moving the air within the tank; the nitrates were high and the ammonias low, and the number of bacteria averaged 57. The quantity of sewage filtered during this time was at the rate of 60,000 gallons per acre per day; and the number of bacteria in a cubic centimeter of the sewage was about 500,000.

After Dec. 17, 1889, air was excluded from the tank, and the ammonias increased to 1.4 parts per 100,000; and from Jan. 4, 1890, to February 14 there was no nitrification and probably no free oxygen in the tank; and the number of bacteria averaged 2,606. It appears that this number, equal to one-half of one per cent. of the number applied, is able to survive the passage, even without oxygen. This is not surprising when we consider that, with this coarse sand, some of the sewage gets through in a few hours after it is applied; and, with this quantity flowing, nearly all the liquid that is in the tank is renewed in three days.

TABLES OF CHEMICAL ANALYSES OF EFFLUENT

FROM

Tanks No. 12, No. 13 and No. 14;

TOGETHER WITH THE DAILY QUANTITY AND TEMPERATURE OF THE SEWAGE APPLIED AND OF THE EFFLUENT; AND OTHER OBSERVATIONS.

FILTER TANK No. 12.

February, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
16, ...	1.5	1.3	5.70	11.80	.0222	.0480	.0702	1.76	.0200	Present.	44°	–
17, ...	–	–	–	–	–	–	–	–	–	–	–	–
18, ...	10.5	10.8	4.70	9.00	.0290	.0350	.0640	1.70	.0100	Present.	43°	40°
19, ...	1.5	0.9	–	–	–	–	–	–	–	–	43°	–
20, ...	1.5	1.8	3.20	8.70	.0194	.0194	.0388	1.64	.0150	Present.	44°	–
21, ...	1.5	1.1	3.20	8.30	.0186	.0182	.0368	1.60	.0250	Present.	44°	–
21, ...	–	–	3.40	8.20	.0128	.0186	.0314	1.62	.0150	Present.	–	–
22, ...	1.5	1.1	3.40	7.50	.0102	.0240	.0342	1.85	.0150	Present.	44°	–
23, ...	1.5	2.4	–	–	–	–	–	–	–	–	44°	41°
24, ...	1.5	1.4	4.80	9.00	.0052	.0236	.0288	2.37	.0090	Present.	44°	43°
25, ...	1.5	1.8	4.20	8.60	.0072	.0242	.0314	2.54	.0070	Present.	42°	40°
26, ...	1.5	1.3	–	–	–	–	–	–	–	–	44°	–
27, ...	1.5	1.6	3.40	8.80	.0146	.0168	.0314	2.45	.0050	Present.	44°	41°
28, ...	1.5	1.8	–	–	–	–	–	–	–	–	44°	38°
29, ...	1.5	1.6	3.30	8.70	.0160	.0162	.0322	2.27	.0050	Present.	44°	–

February 16.—First sewage applied.
Total effluent to end of month, 28.9 gallons.

Filter Tank No. 12 — Continued.

March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	1.5	1.5	-	-	-	-	-	-	-	-	-	44°	38°
2, . .	1.5	1.3	3.30	8.90	.0176	.0116	.0292	2.00	.0060	.0025	-	44°	37°
3, . .	1.5	1.5	-	-	-	-	-	-	-	-	-	44°	39°
4, . .	1.5	1.3	-	-	-	-	-	-	-	-	-	44°	36°
5, . .	1.5	1.5	3.50	7.60	.0200	.0120	.0320	2.00	.0150	.0030	-	44°	-
6, . .	1.5	1.3	-	-	-	-	-	-	-	-	-	43°	36°
7, . .	1.5	0.8	3.00	8.50	.0196	.0106	.0302	2.08	.0100	.0050	-	42°	40°
8, . .	1.5	2.2	3.00	9.40	.0210	.0118	.0328	2.44	.0120	.0044	-	44°	-
9, . .	1.5	1.5	-	-	-	-	-	-	-	-	-	42°	38°
10, . .	1.5	1.6	-	-	-	-	-	-	-	-	-	44°	40°
11, . .	1.5	1.3	-	-	-	-	-	-	-	-	-	44°	40°
12, . .	1.5	1.5	2.60	9.00	.0210	.0110	.0320	1.88	.0150	.0055	-	44°	-
13, . .	1.5	1.4	-	-	-	-	-	-	-	-	-	44°	41°
14, . .	1.5	1.5	1.90	9.00	.0190	.0106	.0296	1.82	.0230	.0071	-	44°	40°
15, . .	1.5	1.7	2.70	8.30	.0216	.0066	.0282	1.90	.0150	.0080	-	-	40°
16, . .	1.5	1.4	-	-	-	-	-	-	-	-	-	43°	-
17, . .	1.5	1.5	-	-	-	-	-	-	-	-	-	43°	40°
18, . .	1.5	1.1	-	-	-	-	-	-	-	-	-	44°	-
19, . .	1.5	1.8	2.70	8.70	.0206	.0106	.0312	2.02	.0150	.0033	-	43°	44°
20, . .	1.5	1.4	-	-	-	-	-	-	-	-	-	44°	-
21, . .	1.5	1.6	1.70	8.80	.0258	.0112	.0370	1.90	.0220	.0040	-	44°	43°
22, . .	1.5	1.5	2.60	8.80	.0280	.0162	.0442	2.16	.0180	.0042	-	40°	43°
23, . .	1.5	1.3	-	-	-	-	-	-	-	-	-	44°	-
24, . .	1.5	1.4	-	-	-	-	-	-	-	-	20 s.	44°	-
25, . .	1.5	1.5	1.60	8.90	.0264	.0126	.0390	1.80	.0100	.0028	-	44°	38°
26, . .	1.5	1.5	-	-	-	-	-	-	-	-	20 s.	44°	41°
27, . .	1.5	1.6	1.10	9.70	.0294	.0122	.0416	1.64	.0180	.0036	20 s.	44°	39°
28, . .	1.5	1.6	-	-	-	-	-	-	-	-	-	44°	-
29, . .	1.5	1.4	1.60	10.40	.0344	.0132	.0476	2.34	.0200	.0026	-	43°	42°
30, . .	1.5	1.1	-	-	-	-	-	-	-	-	20 s.	44°	41°
31, . .	1.5	0.2	-	-	-	-	-	-	-	-	-	44°	-

Effluent colorless, generally clear and with very little or no sediment.
March 31. — Outlet closed at 10.59 A.M. River high.
Total effluent to end of month, 72.7 gallons.

Filter Tank No. 12 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
2, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
3, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
4, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
5, . .	1.5	2.1	-	-	-	-	-	-	-	-	45 s.	43°	39°
6, . .	1.5	1.1	2.10	8.80	.0304	.0130	.0434	2.50	.0200	.0037	20 s.	46°	-
7, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
8, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
9, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
10, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
11, . .	1.5	1.1	2.70	11.60	.0400	.0128	.0528	2.30	.0350	.0038	50 s.	44°	39°
12, . .	1.5	1.9	2.20	10.10	.0400	.0138	.0538	2.45	.0300	.0003	25 s.	40°	-
13, . .	1.5	1.4	-	-	-	-	-	-	-	-	20 s.	-	-
14, . .	1.5	1.4	-	-	-	-	-	-	-	-	-	45°	-
15, . .	1.5	1.5	2.60	10.30	.0840	.0136	.0976	2.60	.0850	.0021	30 s.	45°	-
16, . .	1.5	1.5	-	-	-	-	-	-	-	-	35 s.	43°	-
17, . .	1.5	1.5	2.50	12.50	.1120	.0210	.1330	3.14	.0250	.0035	-	42°	-
18, . .	1.5	1.4	-	-	-	-	-	-	-	-	35 s.	45°	43°
19, . .	1.5	1.5	3.30	12.60	.1360	.0260	.1620	3.12	.1200	.0033	35 s.	42°	-
20, . .	1.5	1.4	-	-	-	-	-	-	-	-	40 s.	43°	43°
21, . .	3.0	2.8	-	-	-	-	-	-	-	-	40 s.	42°	45°
22, . .	-	1.9	3.50	13.90	.1800	.0170	.1970	3.20	.1600	.0040	-	-	-
23, . .	1.5	0.8	-	-	-	-	-	-	-	-	-	43°	-
24, . .	-	1.5	3.70	15.50	.1800	.0090	.1890	3.75	.1900	.0040	-	42°	-
25, . .	-	1.5	-	-	-	-	-	-	-	-	-	42°	-
26, . .	-	1.4	-	-	-	-	-	-	-	-	-	46°	-
27, . .	-	1.6	5.90	16.80	.2760	.0090	.2850	3.98	.4000	.0080	-	44°	-
28, . .	3.0	2.6	4.40	15.50	.2720	.0170	.2890	3.20	.3600	.0090	-	46°	-
29, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
30, . .	-	-	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, clear or nearly so and generally with little sediment.

April 5.—Outlet opened at 7.16 A.M. Outlet closed from 5.05 P.M., April 6, to 7.43 A.M., April 11. River high. April 29.—Outlet closed at 6.38 P.M. River high.

Total effluent to end of month, 104.6 gallons.

Filter Tank No. 12 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	-	-	-	-	-	-	-	-	-	-	-	-
2, ...	-	-	-	-	-	-	-	-	-	-	-	-
3, ...	-	-	-	-	-	-	-	-	-	-	-	-
4, ...	1.5	2.0	-	-	-	-	-	-	-	-	45°	-
5, ...	3.0	2.9	11.20	16.00	.2700	.0240	.2940	2.78	1.0000	.0120	45°	-
6, ...	-	0.7	-	-	-	-	-	-	-	-	-	-
7, ...	1.5	.7	-	-	-	-	-	-	-	-	50°	-
8, ...	1.5	1.6	-	-	-	-	-	-	-	-	48°	-
9, ...	1.5	1.5	16.40	18.60	.3250	.0220	.3470	3.03	2.6000	.0100	50°	-
10, ...	1.5	1.4	-	-	-	-	-	-	-	-	51°	-
11, ...	1.5	1.4	14.00	16.80	.3550	.0230	.3780	3.11	1.5000	.0333	51°	-
12, ...	3.0	2.1	-	-	-	-	-	-	-	-	49°	-
13, ...	-	-	-	-	-	-	-	-	-	-	-	-
14, ...	-	-	-	-	-	-	-	-	-	-	-	-
15, ...	-	-	-	-	-	-	-	-	-	-	-	-
16, ...	-	-	-	-	-	-	-	-	-	-	-	-
17, ...	1.5	2.5	-	-	-	-	-	-	-	-	49°	-
18, ...	1.5	1.6	-	-	-	-	-	-	-	-	49°	-
19, ...	3.0	2.9	14.40	16.90	.2800	.0130	.2930	3.19	1.8000	.0154	50°	-
20, ...	-	0.7	-	-	-	-	-	-	-	-	-	-
21, ...	1.5	.8	-	-	-	-	-	-	-	-	51°	-
22, ...	1.5	1.7	14.70	15.10	.2350	.0070	.2420	3.63	2.0000	.0100	52°	-
23, ...	1.5	1.4	-	-	-	-	-	-	-	-	53°	-
24, ...	1.5	1.5	-	-	-	-	-	-	-	-	55°	-
25, ...	1.5	1.4	-	-	-	-	-	-	-	-	56°	-
26, ...	3.0	3.0	13.80	18.60	.2200	.0060	.2260	3.90	1.0000	.0105	57°	-
27, ...	-	0.6	-	-	-	-	-	-	-	-	-	-
28, ...	1.5	.7	-	-	-	-	-	-	-	-	57°	-
29, ...	1.5	1.7	-	-	-	-	-	-	-	-	56°	-
30, ...	1.5	1.5	-	-	-	-	-	-	-	-	57°	-
31, ...	1.5	1.5	-	-	-	-	-	-	-	-	57°	-

Effluent colorless and generally clear and with very little sediment.

May 4. — Outlet opened at 9.35 A.M. May 9. — Much sand in sample. Outlet closed from 8.40 P.M., May 12, to 8.08 A.M., April 17.

Total effluent to end of month, 142.4 gallons.

Filter Tank No. 12 — Continued.

June, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	1.5	1.4	8.80	20.20	.0800	.0110	.0910	4.68	1.1000	.0080	58°	-
2, ...	3.0	2.7	-	-	-	-	-	-	-	-	60°	-
3, ...	-	0.6	-	-	-	-	-	-	-	-	-	-
4, ...	1.5	.7	-	-	-	-	-	-	-	-	59°	-
5, ...	1.5	1.7	17.00	23.10	.2320	.0080	.2400	4.66	2.0000	.0101	61°	-
6, ...	1.5	1.4	-	-	-	-	-	-	-	-	61°	-
7, ...	1.5	1.5	16.90	39.00	.0640	.0140	.0780	13.68	.3500	.0200	64°	67°
8, ...	1.5	1.4	-	-	-	-	-	-	-	-	64°	65°
9, ...	3.0	2.9	-	-	-	-	-	-	-	-	66°	67°
10, ...	-	0.7	-	-	-	-	-	-	-	-	-	-
11, ...	1.5	.8	11.80	29.80	.0440	.0110	.0550	10.72	.6300	.0190	68°	66°
12, ...	1.5	1.4	-	-	-	-	-	-	-	-	65°	66°
13, ...	1.5	1.5	-	-	-	-	-	-	-	-	64°	66°
14, ...	1.5	1.5	11.20	23.30	.0320	.0120	.0440	7.13	1.1000	.0070	65°	61°
15, ...	1.5	1.5	-	-	-	-	-	-	-	-	65°	63°
16, ...	3.0	3.1	-	-	-	-	-	-	-	-	66°	-
17, ...	-	0.6	-	-	-	-	-	-	-	-	-	-
18, ...	1.5	.7	4.70	26.70	.0160	.0050	.0210	6.75	.7700	.0140	68°	-
19, ...	1.5	1.5	-	-	-	-	-	-	-	-	68°	68°
20, ...	1.5	1.4	-	-	-	-	-	-	-	-	70°	68°
21, ...	1.5	1.6	8.80	25.20	.0130	.0092	.0222	6.42	.9000	.0080	69°	-
22, ...	1.5	1.5	-	-	-	-	-	-	-	-	69°	68°
23, ...	3.0	3.1	-	-	-	-	-	-	-	-	73°	73°
24, ...	-	0.5	-	-	-	-	-	-	-	-	-	-
25, ...	1.5	.6	10.60	33.30	.0212	.0088	.0300	11.50	1.0000	.0160	71°	68°
26, ...	1.5	.5	-	-	-	-	-	-	-	-	69°	67°
27, ...	1.5	-	-	-	-	-	-	-	-	-	69°	-
28, ...	1.5	1.3	10.60	27.90	.0100	.0124	.0224	8.10	1.1500	.0140	68°	-
29, ...	1.5	1.4	-	-	-	-	-	-	-	-	66°	63°
30, ...	3.0	3.0	-	-	-	-	-	-	-	-	67°	67°

Effluent clear and colorless and with little or no sediment.
June 27. — Trap put on outlet pipe. Outlet closed from 5.30 P.M., June 26, to 10.04 A.M., June 28.
Total effluent to end of month, 184.9 gallons.

Filter Tank No. 12 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	-	0.5	-	-	-	-	-	-	-	-	-	-	-
2, . .	1.5	.8	8.00	26.40	.0050	.0116	.0166	6.98	1.1000	.0120	-	65°	-
3, . .	1.5	1.6	-	-	-	-	-	-	-	-	-	65°	69°
4, . .	1.5	0.6	-	-	-	-	-	-	-	-	-	67°	69°
5, . .	1.5	2.5	6.60	25.20	.0056	.0098	.0154	6.62	.9500	.0080	-	68°	70°
6, . .	1.5	1.5	-	-	-	-	-	-	-	-	-	68°	69°
7, . .	3.0	2.8	-	-	-	-	-	-	-	-	-	70°	73°
8, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
9, . .	1.5	1.3	6.80	26.80	.0074	.0112	.0186	7.10	1.0000	.0090	-	69°	68°
10, . .	1.5	1.6	-	-	-	-	-	-	-	-	-	69°	69°
11, . .	1.5	0.7	-	-	-	-	-	-	-	-	-	69°	72°
12, . .	1.5	2.5	3.40	30.40	.0072	.0132	.0204	6.79	1.0000	.0060	-	69°	68°
13, . .	1.5	1.4	-	-	-	-	-	-	-	-	-	69°	66°
14, . .	3.0	3.2	-	-	-	-	-	-	-	-	-	69°	68°
15, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
16, . .	1.5	1.1	5.80	27.10	.0056	.0098	.0154	6.25	1.1000	.0055	-	69°	69°
17, . .	1.5	1.5	-	-	-	-	-	-	-	-	-	69°	68°
18, . .	1.5	0.5	-	-	-	-	-	-	-	-	-	71°	67°
19, . .	1.5	2.4	8.20	26.80	.0066	.0092	.0158	7.37	1.2000	.0020	-	71°	67°
20, . .	1.5	1.6	-	-	-	-	-	-	-	-	-	70°	72°
21, . .	3.0	3.0	-	-	-	-	-	-	-	-	-	71°	71°
22, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
23, . .	1.5	1.4	5.20	29.40	.0060	.0098	.0158	6.42	1.6200	.0045	-	72°	72°
24, . .	1.5	1.71	-	-	-	-	-	-	-	-	-	72°	-
25, . .	1.5	1.43	-	-	-	-	-	-	-	-	-	73°	70°
26, . .	1.5	1.31	11.30	25.50	.0060	.0098	.0158	6.95	1.2500	.0025	-	73°	71°
27, . .	23.0	-	-	-	-	-	-	-	-	-	24 h.	72°	-
28, . .	3.0	2.99	-	-	-	-	-	-	-	-	24 h.	72°	-
29, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
30, . .	1.5	1.24	8.10	29.00	.0044	.0278	.0322	7.53	1.0500	.0160	24 h.	71°	-
31, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	72°	-

Effluent colorless and generally clear and free from sediment.

July 27. — Outlet closed at 5.14 A.M., and tank filled with sewage. Thereafter outlet open only to draw effluent, generally 5 minutes 30 seconds daily.

Total effluent to end of month, 227.58 gallons.

Filter Tank No. 12 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	73°	-
2, . .	1.5	1.55	3.80	28.90	.0022	.0396	.0418	7.12	.7500	.0004	24 h.	73°	-
3, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	73°	-
4, . .	3.0	3.00	-	-	-	-	-	-	-	-	24 h.	74°	-
5, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
6, . .	1.5	1.57	1.90	29.60	.0034	.0222	.0256	7.15	.4000	.0120	24 h.	74°	-
7, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	72°	-
8, . .	3.0	1.50	-	-	-	-	-	-	-	-	24 h.	72°	-
9, . .	1.5	1.57	2.50	27.50	.0102	.0254	.0356	7.21	.2600	.0050	24 h.	73°	-
10, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	72°	-
11, . .	3.0	3.00	-	-	-	-	-	-	-	-	24 h.	73°	-
12, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
13, . .	1.5	1.61	3.00	34.20	.0056	.0244	.0300	7.70	.0600	.0035	24 h.	70°	-
14, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	-	-
15, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	69°	-
16, . .	1.5	1.56	4.40	40.30	.0046	.0216	.0262	8.14	.0200	.0010	24 h.	69°	-
17, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	70°	-
18, . .	3.0	3.00	-	-	-	-	-	-	-	-	24 h.	71°	-
19, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
20, . .	1.5	1.50	5.40	32.40	.0102	.0236	.0338	7.82	.0700	.0000	24 h.	71°	-
21, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	71°	-
22, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	70°	-
23, . .	1.5	1.57	5.50	28.80	.0120	.0240	.0360	6.30	.0070	.0000	24 h.	70°	-
24, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	70°	-
25, . .	3.0	3.00	-	-	-	-	-	-	-	-	24 h.	70°	-
26, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
27, . .	1.5	1.50	4.40	28.20	.0190	.0274	.0464	5.75	.0000	.0000	24 h.	71°	-
28, . .	3.0	1.50	-	-	-	-	-	-	-	-	24 h.	70°	-
29, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	69°	-
30, . .	1.5	1.50	4.60	26.00	.0208	.0236	.0444	5.47	.0050	.0000	24 h.	70°	-
31, . .	1.5	1.50	-	-	-	-	-	-	-	-	24 h.	70°	-

Effluent generally nearly clear or slightly milky, with little or no sediment and with color from 0 to 0.1.

After August 1, residue on evaporation obtained with sodium carbonate. Outlet generally open five minutes thirty seconds daily. August 28.—Surface not all covered with sewage applied.

Total effluent to end of month, 274.51 gallons.

Filter Tank No. 12 — Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	3.00	3.00	-	-	-	-	-	-	-	-	24 h.	71°	-
2, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
3, . .	1.50	1.50	2.00	27.80	.0494	.0270	.0764	5.39	.0070	.0000	24 h.	70°	-
4, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	71°	-
5, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	70°	-
6, . .	1.50	1.50	1.00	28.10	.0800	.0270	.1070	5.37	.0050	.0000	24 h.	68°	-
7, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	68°	-
8, . .	3.00	3.00	-	-	-	-	-	-	-	-	24 h.	66°	-
9, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
10, . .	1.50	1.50	3.40	28.20	.1600	.0374	.1974	7.06	.0070	.0000	24 h.	67°	-
11, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	67°	-
12, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	66°	-
13, . .	1.50	1.50	6.20	32.30	.5304	.0314	.5618	10.65	.0100	.0000	24 h.	66°	-
14, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	64°	-
15, . .	3.00	3.00	-	-	-	-	-	-	-	-	24 h.	64°	-
16, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
17, . .	1.50	1.50	3.70	39.60	.8000	.0480	.8480	13.70	.0100	.0000	24 h.	65°	-
18, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	65°	-
19, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	64°	-
20, . .	1.50	1.50	8.80	39.20	.8500	.0430	.8930	13.35	.0100	.0000	24 h.	64°	-
21, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	63°	-
22, . .	3.00	3.00	-	-	-	-	-	-	-	-	24 h.	61°	-
23, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
24, . .	1.50	1.50	3.80	39.00	.8000	.0440	.8440	13.35	.0100	.0000	24 h.	58°	-
25, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	58°	-
26, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	58°	-
27, . .	3.00	1.50	8.00	38.00	.9000	.0460	.9460	13.00	.0100	.0000	24 h.	58°	-
28, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	57°	-
29, . .	4.50	3.00	5.50	28.00	1.5100	.1300	1.6400	4.72	.0200	.0000	24 h.	55°	-
29, . .	-	-	5.10	23.40	1.7400	.0800	1.8200	5.88	.0150	.0000	24 h.	-	-
30, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-

Generally a distinct turbidity in effluent, little or no sediment and color from 0 to 0.2. September 17, 20 and 24. — Samples contained iron in solution. September 29, first sample from hole bored in side of tank one foot below top of standing sewage. Second sample from hole in middle of side of tank. Outlet generally open five minutes thirty seconds daily.

Total effluent to end of month, 319 51 gallons.

Filter Tank No. 12 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	1.50	1.50	8.00	31.80	1.0000	.0440	1.0440	9.45	.0100	.0000	24 h.	53°	-
2, . .	1.50	2.09	-	-	-	-	-	-	-	-	24 h.	53°	-
3, . .	1.50	1.50	5.20	31.20	1.9700	.2500	2.2200	5.77	-	-	24 h.	51°	-
4, . .	1.50	1.50	4.00	29.20	1.0400	.0280	1.0680	9.15	.0120	.0000	24 h.	50°	-
5, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	50°	-
6, . .	3.00	3.00	-	-	-	-	-	-	-	-	24 h.	50°	-
7, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
8, . .	1.50	1.50	5.20	24.40	1.0000	.0340	1.0340	6.60	.0050	.0000	24 h.	52°	-
9, . .	3.00	2.23	-	-	-	-	-	-	-	-	24 h.	51°	-
10, . .	1.50	1.58	-	-	-	-	-	-	-	-	24 h.	49°	-
11, . .	1.50	1.50	3.30	22.20	1.1300	.0320	1.1620	5.85	.0100	.0000	24 h.	49°	-
12, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	47°	-
13, . .	3.00	3.00	-	-	-	-	-	-	-	-	24 h.	47°	-
14, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
15, . .	1.50	1.50	4.50	23.60	1.2200	.0300	1.2500	7.51	.0100	.0000	24 h.	47°	-
16, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	47°	-
17, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	48°	-
18, . .	1.50	1.50	2.70	24.80	1.3300	.0270	1.3570	7.65	.0100	.0000	24 h.	47°	-
19, . .	1.50	1.50	-	-	1.9000	.6300	2.5300	-	-	-	24 h.	46°	-
20, . .	3.00	3.00	-	-	-	-	-	-	-	-	24 h.	47°	-
21, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
22, . .	1.50	1.50	5.10	24.90	1.5000	.0290	1.5290	8.40	.0070	.0000	24 h.	45°	-
23, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	45°	-
24, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	45°	-
25, . .	1.50	1.50	5.40	25.50	1.7500	.0290	1.7790	8.49	.0120	.0000	24 h.	45°	-
26, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	45°	-
27, . .	3.00	3.00	-	-	-	-	-	-	-	-	24 h.	46°	-
28, . .	-	-	-	-	-	-	-	-	-	-	24 h.	-	-
29, . .	1.50	1.50	4.90	22.90	1.3900	.0230	1.4130	6.50	.0070	.0000	24 h.	46°	-
29, . .	-	-	-	-	1.6500	.4300	2.0800	-	-	-	-	-	-
30, . .	3.00	2.56	-	-	-	-	-	-	-	-	24 h.	46°	-
31, . .	1.50	1.50	-	-	-	-	-	-	-	-	24 h.	45°	-

Effluent generally nearly clear with very little or no sediment and with color from 0 to 0.1.

Sample of October 3, of 19, and second of 29, from sewage in top of tank. October 3. — Much animal and vegetable growth in sewage standing on surface. October 9 and 30. — A part of surface uncovered after drawing effluent. Outlet generally open about four minutes fifteen seconds daily.

Total effluent to end of month, 368.47 gallons.

Filter Tank No. 12 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	1.50	1.50	4.10	22.10	1.7200	.0370	1.7570	5.87	.0090	.0000	24 h.	47°	–
2, . .	1.50	1.50	–	–	–	–	–	–	–	–	24 h.	46°	–
3, . .	3.00	3.00	–	–	–	–	–	–	–	–	24 h.	48°	–
4, . .	–	–	–	–	–	–	–	–	–	–	24 h.	–	–
5, . .	1.50	1.50	7.10	22.20	1.6600	.0420	1.7020	5.32	.0080	.0000	24 h.	48°	–
6, . .	1.50	1.50	–	–	–	–	–	–	–	–	24 h.	49°	–
7, . .	1.50	1.50	–	–	–	–	–	–	–	–	24 h.	50°	–
8, . .	1.50	1.50	2.90	22.20	1.6600	.0310	1.6910	5.10	.0100	.0000	24 h.	49°	–
9, . .	1.50	1.50	–	–	–	–	–	–	–	–	24 h.	49°	–
10, . .	3.00	3.00	–	–	–	–	–	–	–	–	24 h.	48°	–
11, . .	–	–	–	–	–	–	–	–	–	–	24 h.	–	–
12, . .	1.50	1.50	2.00	22.20	1.6900	.0300	1.7200	5.88	.0070	.0000	24 h.	45°	–
13, . .	1.50	1.50	–	–	–	–	–	–	–	–	24 h.	43°	–
14, . .	1.50	1.50	–	–	–	–	–	–	–	–	24 h.	43°	–
15, . .	1.50	1.50	2.30	24.00	1.9500	.0340	1.9840	7.23	.0100	.0000	24 h.	42°	–
16, . .	1.50	1.50	–	–	–	–	–	–	–	–	24 h.	42°	–
17, . .	3.00	3.00	–	–	–	–	–	–	–	–	24 h.	42°	–
18, . .	–	–	–	–	–	–	–	–	–	–	24 h.	–	–
19, . .	1.50	1.50	2.00	22.80	2.0000	.0320	2.0320	6.81	.0050	.0000	24 h.	40°	–
20, . .	1.50	1.50	–	–	–	–	–	–	–	–	24 h.	40°	–
21, . .	1.50	1.50	–	–	–	–	–	–	–	–	24 h.	38°	–
22, . .	1.50	1.50	3.10	23.90	1.8100	.0430	1.8530	6.96	.0050	.0000	24 h.	45°	–
23, . .	1.50	1.50	–	–	–	–	–	–	–	–	24 h.	44°	–
24, . .	3.00	3.00	–	–	–	–	–	–	–	–	24 h.	45°	–
25, . .	–	–	–	–	–	–	–	–	–	–	24 h.	–	–
26, . .	1.50	1.50	2.60	27.50	2.1700	.0500	2.2200	8.81	.0070	.0000	24 h.	45°	–
27, . .	1.50	4.55	–	–	2.3800	.0900	2.4700	5.30	.0200	.0000	–	45°	–
27, . .	–	–	–	–	2.4800	.0800	2.5600	7.64	.0200	.0000	–	–	–
27, . .	–	–	–	–	1.4200	.1400	1.5600	3.93	.0070	.0000	–	–	–
28, . .	1.50	21.55	–	–	–	–	–	–	–	–	–	44°	50°

Effluent very nearly clear and free from sediment and with color from 0. to 0.1.

Outlet generally open four minutes daily till November 26. November 27. — Effluent drawn till sewage just disappeared below surface. November 28. — Tank drained and outlet to be left open but closed at 8.54 P.M. owing to high river. November 27. — First sample, from hole bored ¾ way down tank, second, from ½ way down and third from top of tank.

Total effluent to end of month, 433.57 gallons.

Filter Tank No. 12 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	3.00	3.75	3.30	21.90	2.1000	.0300	2.1300	4.50	.0300	.0000	44°	43°
2, ...	-	0.70	-	-	-	-	-	-	-	-	-	-
3, ...	1.50	.62	3.10	21.20	2.1700	.0500	2.2200	4.31	.0500	.0000	44°	43°
4, ...	1.50	1.76	-	-	-	-	-	-	-	-	45°	43°
5, ...	1.50	1.43	-	-	-	-	-	-	-	-	44°	44°
6, ...	1.50	1.52	1.70	24.10	2.1500	.0300	2.1800	4.51	.1200	.0002	46°	44°
7, ...	1.50	1.57	-	-	-	-	-	-	-	-	45°	43°
8, ...	3.00	3.26	-	-	-	-	-	-	-	-	45°	-
9, ...	-	0.70	-	-	-	-	-	-	-	-	-	-
10, ...	1.50	.59	2.10	30.00	2.2200	.0350	2.2550	8.25	.2300	.0004	45°	44°
11, ...	1.50	1.64	-	-	-	-	-	-	-	-	45°	43°
12, ...	1.50	1.46	-	-	-	-	-	-	-	-	44°	40°
13, ...	1.50	1.34	2.10	28.90	2.0000	.0340	2.0340	6.00	.2000	.0002	44°	39°
14, ...	1.50	0.46	-	-	-	-	-	-	-	-	46°	35°
15, ...	3.00	4.48	-	-	-	-	-	-	-	-	45°	40°
16, ...	-	0.73	-	-	-	-	-	-	-	-	-	-
17, ...	1.50	.62	2.60	25.80	1.6600	.0310	1.6910	4.80	.2600	.0008	41°	48°
18, ...	1.50	.34	-	-	-	-	-	-	-	-	45°	-
19, ...	-	-	-	-	-	-	-	-	-	-	-	-
20, ...	-	-	-	-	-	-	-	-	-	-	-	-
21, ...	-	2.48	-	-	-	-	-	-	-	-	-	37°
22, ...	3.00	2.12	-	-	-	-	-	-	-	-	45°	-
23, ...	-	0.77	-	-	-	-	-	-	-	-	-	-
24, ...	1.50	.65	1.30	25.70	1.4300	.0450	1.4750	3.27	.4000	.0008	42°	45°
25, ...	1.50	1.78	-	-	-	-	-	-	-	-	45°	-
26, ...	1.50	1.33	-	-	-	-	-	-	-	-	45°	47°
27, ...	1.50	1.46	1.50	25.10	1.5800	.0270	1.6070	3.31	.4500	.0004	46°	46°
28, ...	1.50	1.48	-	-	-	-	-	-	-	-	45°	46°
29, ...	3.00	3.15	-	-	-	-	-	-	-	-	45°	45°
30, ...	-	0.70	-	-	-	-	-	-	-	-	-	-
31, ...	1.50	.57	1.40	29.20	1.3900	.0420	1.4320	3.85	1.0200	.0006	45°	46°

Effluent very nearly clear and free from sediment with color less than 0.1.

December 1. — Outlet opened at 8.18 A.M., but closed from 11.10 to 11.48 to replace broken trap. December 14. — Outlet thawed out at 3.30 P.M.; 15, at 8.20 A.M.; outlet closed from 3.40 P.M., December 18 to 1.59 P.M., December 21. River high. December 31. — Manganese in sample.

Total effluent to end of month, 477.03 gallons.

Filter Tank No. 12 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	1.50	1.62	-	-	-	-	-	-	-	-	45°	46°
2, ...	1.50	1.47	-	-	-	-	-	-	-	-	45°	46°
3, ...	1.50	1.46	0.90	36.70	1.4300	.0320	1.4620	5.50	1.4500	.0020	45°	46°
4, ...	1.50	1.53	-	-	-	-	-	-	-	-	45°	45°
5, ...	3.00	3.17	-	-	-	-	-	-	-	-	45°	43°
6, ...	-	.65	-	-	-	-	-	-	-	-	-	-
7, ...	1.50	.62	1.10	37.70	1.2500	.0250	1.2750	5.71	1.9000	.0020	45°	-
8, ...	1.50	1.69	-	-	-	-	-	-	-	-	45°	46°
9, ...	1.50	1.54	-	-	-	-	-	-	-	-	45°	45°
10, ...	1.50	1.49	0.60	37.30	1.0800	.0230	1.1030	4.96	1.5500	.0600	45°	47°
11, ...	1.50	1.48	-	-	-	-	-	-	-	-	45°	47°
12, ...	3.00	3.23	-	-	-	-	-	-	-	-	44°	45°
13, ...	-	.68	-	-	-	-	-	-	-	-	-	-
14, ...	1.50	.47	2.00	33.10	.6400	.0320	.6720	4.54	1.4000	.0004	44°	45°
15, ...	1.50	1.60	-	-	-	-	-	-	-	-	45°	44°
16, ...	1.50	1.49	-	-	-	-	-	-	-	-	44°	44°
17, ...	1.50	1.59	1.80	38.50	.5500	.0250	.5750	6.15	1.4700	.0400	46°	47°
18, ...	1.50	1.36	-	-	-	-	-	-	-	-	45°	48°
19, ...	3.00	3.23	-	-	-	-	-	-	-	-	44°	44°
20, ...	-	.54	-	-	-	-	-	-	-	-	-	-
21, ...	1.50	.46	1.70	34.00	.3300	.0180	.3480	5.18	1.5500	.0300	44°	43°
22, ...	1.50	1.64	-	-	-	-	-	-	-	-	44°	44°
23, ...	1.50	1.52	-	-	-	-	-	-	-	-	46°	44°
24, ...	1.50	1.58	2.00	34.40	.2560	.0166	.2726	4.67	2.0000	.0300	-	44°
25, ...	1.50	1.48	-	-	-	-	-	-	-	-	44°	46°
26, ...	3.00	3.29	-	-	-	-	-	-	-	-	44°	46°
27, ...	-	.64	-	-	-	-	-	-	-	-	-	-
28, ...	1.50	.46	0.40	33.00	.1500	.0060	.1560	4.17	2.3000	.0200	44°	46°
29, ...	1.50	1.65	-	-	-	-	-	-	-	-	45°	44°
30, ...	1.50	1.38	-	-	-	-	-	-	-	-	46°	43°
31, ...	1.50	1.65	1.40	30.90	.0920	.0110	.1030	4.18	1.8000	.0100	44°	-

Effluent very nearly clear and free from sediment with color less than 0.1.

Trap broken on the morning of January 6, and replaced in the forenoon of January 7. Outlet open in the mean time.

Total effluent to end of month, 523.69 gallons.

Filter Tank No. 12 — Continued.

February, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage	Effluent.
1, ...	1.50	1.42	–	–	–	–	–	–	–	–	45°	44°
2, ...	3.00	3.24	–	–	–	–	–	–	–	–	44°	43°
3, ...	–	.67	–	–	–	–	–	–	–	–	–	–
4, ...	1.50	.47	1.60	30.40	.0520	.0140	.0660	4.10	1.6000	.0075	44°	42°
5, ...	1.50	1.78	–	–	–	–	–	–	–	–	46°	43°
6, ...	1.50	1.42	–	–	–	–	–	–	–	–	44°	44°
7, ...	1.50	1.40	2.40	28.80	.0290	.0160	.0450	3.85	1.9000	.0065	45°	42°
8, ...	1.50	1.52	–	–	–	–	–	–	–	–	44°	40°
9, ...	3.00	3.37	–	–	–	–	–	–	–	–	45°	42°
10, ...	–	.65	–	–	–	–	–	–	–	–	–	–
11, ...	1.50	.38	1.30	27.70	.0270	.0120	.0390	4.30	1.7000	.0060	44°	–
12, ...	1.50	1.79	–	–	–	–	–	–	–	–	46°	44°
13, ...	1.50	1.50	–	–	–	–	–	–	–	–	46°	43°
14, ...	1.50	1.45	1.40	27.60	.0200	.0130	.0330	4.40	1.4000	.0045	45°	44°
15, ...	1.50	1.52	–	–	–	–	–	–	–	–	45°	45°
16, ...	3.00	3.25	–	–	–	–	–	–	–	–	45°	45°
17, ...	–	.65	–	–	–	–	–	–	–	–	–	–
18, ...	1.50	.45	0.70	25.70	.0104	.0088	.0192	4.02	1.0000	.0050	35°	42°
19, ...	1.50	1.69	–	–	–	–	–	–	–	–	34°	43°
20, ...	1.50	1.43	–	–	–	–	–	–	–	–	35°	43°
21, ...	1.50	1.51	1.00	27.20	.0096	.0134	.0230	4.17	1.2000	.0040	34°	43°
22, ...	1.50	1.53	–	–	–	–	–	–	–	–	35°	44°
23, ...	3.00	3.20	–	–	–	–	–	–	–	–	35°	43°
24, ...	–	.69	–	–	–	–	–	–	–	–	–	–
25, ...	1.50	.43	1.40	25.90	.0078	.0118	.0196	3.80	1.4000	.0030	35°	39°
26, ...	1.50	1.78	–	–	–	–	–	–	–	–	35°	42°
27, ...	1.50	1.46	–	–	–	–	–	–	–	–	34°	42°
28, ...	1.50	1.52	1.00	27.10	.0070	.0124	.0194	4.22	1.4000	.0030	33°	45°

Effluent colorless, clear or nearly so, and with very little or no sediment.

February 5.— Trap taken from outlet pipe. February 18 and after.— Sewage applied without heating.

Total effluent to end of month, 565.86 gallons.

Filter Tank No. 12 — Continued.

March, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	1.50	1.48	-	-	-	-	-	-	-	-	35°	45°
2, ...	3.00	3.20	-	-	-	-	-	-	-	-	36°	-
3, ...	-	.62	-	-	-	-	-	-	-	-	-	-
4, ...	1.50	.47	0.70	25.00	.0072	.0132	.0204	3.42	1.4000	.0035	35°	47°
5, ...	1.50	1.61	-	-	-	-	-	-	-	-	35°	45°
6, ...	1.50	1.58	-	-	-	-	-	-	-	-	35°	43°
7, ...	1.50	1.57	1.00	25.30	.0052	.0102	.0154	3.17	1.1500	.0040	36°	44°
8, ...	1.50	1.44	-	-	-	-	-	-	-	-	36°	44°
9, ...	3.00	3.21	-	-	-	-	-	-	-	-	34°	41°
10, ...	-	.68	-	-	-	-	-	-	-	-	-	-
11, ...	1.50	.44	1.40	24 90	.0038	.0102	.0140	3.29	1.2000	.0030	35°	43°
12, ...	1.50	1.73	-	-	-	-	-	-	-	-	34°	43°
13, ...	1.50	1.52	-	-	-	-	-	-	-	-	36°	43°
14, ...	1.50	1.51	0.80	26.00	.0042	.0112	.0154	3.40	1.3000	.0030	37°	45°
15, ...	1.50	1.48	-	-	-	-	-	-	-	-	36°	44°
16, ...	3.00	3.22	-	-	-	-	-	-	-	-	37°	45°
17, ...	-	.52	-	-	-	-	-	-	-	-	-	-
18, ...	1.50	.44	0.80	28.80	.0044	.0104	.0148	3.56	1.5000	.0035	37°	43°
19, ...	1.50	1.78	-	-	-	-	-	-	-	-	38°	44°
20, ...	1.50	1.40	-	-	-	-	-	-	-	-	39°	43°
21, ...	1.50	1.50	1.80	28.30	.0022	.0108	.0130	3.60	1.5000	.0040	38°	44°
22, ...	1.50	1.57	-	-	-	-	-	-	-	-	38°	46°
23, ...	3.00	3.08	-	-	-	-	-	-	-	-	40°	47°
24, ...	-	.74	-	-	-	-	-	-	-	-	-	-
25, ...	1.50	.42	1.40	28.80	.0036	.0120	.0156	3.51	1.6000	.0040	41°	47°
26, ...	1.50	1.66	-	-	-	-	-	-	-	-	41°	47°
27, ...	1.50	1.58	-	-	-	-	-	-	-	-	40°	46°
28, ...	1.50	1.42	0.70	27.10	.0022	.0098	.0120	4.90	1.6000	.0030	41°	46°
29, ...	1.50	1.52	-	-	-	-	-	-	-	-	42°	48°
30, ...	3.00	3.16	-	-	-	-	-	-	-	-	41°	45°
31, ...	-	.65	-	-	-	-	-	-	-	-	-	-

Effluent generally clear and colorless, with very little or no sediment.
Total effluent to end of month, 613.06 gallons.

Filter Tank No. 12 — Continued.

April, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	1.50	.45	1.20	33.00	.0040	.0096	.0136	5.37	2.0000	.0050	39°	42°
2, ...	1.50	1.75	-	-	-	-	-	-	-	-	39°	43°
3, ...	1.50	1.49	-	-	-	-	-	-	-	-	39°	44°
4, ...	1.50	1.47	0.50	31.60	.0042	.0118	.0160	4.30	2.4000	.0035	40°	46°
5, ...	1.50	1.54	-	-	-	-	-	-	-	-	40°	46°
6, ...	3.00	3.22	-	-	-	-	-	-	-	-	42°	46°
7, ...	-	.65	-	-	-	-	-	-	-	-	-	-
8, ...	1.50	.47	1.60	32.40	.0044	.0090	.0134	6.27	1.8000	.0040	42°	47°
9, ...	1.50	1.71	-	-	-	-	-	-	-	-	43°	50°
10, ...	1.50	1.42	-	-	-	-	-	-	-	-	45°	50°
11, ...	1.50	1.55	1.10	30.50	.0038	.0102	.0140	4.91	1.8000	.0040	46°	-
12, ...	1.50	1.57	-	-	-	-	-	-	-	-	47°	54°
13, ...	3.00	3.07	-	-	-	-	-	-	-	-	47°	54°
14, ...	-	.62	-	-	-	-	-	-	-	-	-	-
15, ...	1.50	.44	1.10	33.50	.0056	.0088	.0144	4.44	2.6000	.0070	47°	50°
16, ...	1.50	1.69	-	-	-	-	-	-	-	-	46°	49°
17, ...	1.50	1.38	-	-	-	-	-	-	-	-	47°	49°
18, ...	1.50	1.54	1.50	32.00	.0028	.0118	.0146	4.04	2.2000	.0040	46°	49°
19, ...	1.50	1.59	-	-	-	-	-	-	-	-	53°	56°
20, ...	1.50	1.46	-	-	-	-	-	-	-	-	45°	-
21, ...	-	1.29	-	-	-	-	-	-	-	-	-	-
22, ...	1.50	.54	0.50	25.60	.0030	.0098	.0128	2.16	2.0000	.0030	48°	52°
23, ...	1.50	1.51	-	-	-	-	-	-	-	-	48°	51°
24, ...	1.50	1.51	-	-	-	-	-	-	-	-	47°	54°
25, ...	1.50	1.69	2.20	21.80	.0024	.0090	.0114	1.02	1.6000	.0020	52°	57°
26, ...	1.50	1.47	-	-	-	-	-	-	-	-	52°	56°
27, ...	1.50	1.53	-	-	-	-	-	-	-	-	51°	58°
28, ...	-	.80	-	-	-	-	-	-	-	-	-	-
29, ...	1.50	.69	1.20	21.00	.0016	.0080	.0096	0.70	1.8000	.0040	54°	-
30, ...	1.50	1.57	-	-	-	-	-	-	-	-	53°	57°

Effluent colorless, and generally clear and with very slight or no sediment.

Beginning April 16, city water and insoluble egg albumen applied instead of sewage. The mixture contained 2.8 parts per 100,000 nitrogen equivalent to 1.7 parts albuminoid ammonia.

Total effluent to end of month, 654.74 gallons.

Filter Tank No. 12 — Continued.

May, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	1.50	1.45	-	-	-	-	-	-	-	-	51°	53°
2, ...	1.50	1.49	1.70	19.80	.0010	.0058	.0068	.53	1.7000	.0015	52°	56°
3, ...	1.50	1.42	-	-	-	-	-	-	-	-	50°	-
4, ...	1.50	1.50	-	-	-	-	-	-	-	-	52°	55°
5, ...	-	.78	-	-	-	-	-	-	-	-	-	-
6, ...	1.50	.74	-	-	.0050	.0058	.0108	.49	1.7000	.0030	56°	58°
7, ...	1.50	1.51	-	-	-	-	-	-	-	-	51°	58°
8, ...	1.50	1.54	-	-	-	-	-	-	-	-	52°	60°
9, ...	1.50	1.59	1.00	18.00	.0012	.0064	.0076	.51	1.8000	.0020	54°	63°
10, ...	1.50	1.51	-	-	-	-	-	-	-	-	57°	65°
11, ...	1.50	1.04	-	-	-	-	-	-	-	-	54°	64°
12, ...	-	1.10	-	-	-	-	-	-	-	-	-	-
13, ...	1.50	.68	.60	18.30	.0200	.0060	.0260	.62	1.8000	.0020	56°	62°
14, ...	1.50	1.54	-	-	-	-	-	-	-	-	55°	61°
15, ...	1.50	1.54	-	-	-	-	-	-	-	-	58°	63°
16, ...	1.50	1.50	-	-	.0160	.0040	.0200	.67	1.8000	.0012	58°	63°
17, ...	1.50	1.52	-	-	-	-	-	-	-	-	59°	66°
18, ...	1.50	1.54	-	-	-	-	-	-	-	-	63°	70°
19, ...	-	.70	-	-	-	-	-	-	-	-	-	-
20, ...	1.50	.61	1.60	17.50	.0024	.0070	.0094	.47	1.7000	.0014	58°	65°
21, ...	1.50	1.63	-	-	-	-	-	-	-	-	60°	65°
22, ...	1.50	1.51	-	-	-	-	-	-	-	-	62°	66°
23, ...	1.50	1.44	-	-	-	-	-	-	-	-	60°	63°
24, ...	1.50	1.48	-	-	-	-	-	-	-	-	60°	63°
25, ...	1.50	1.57	-	-	-	-	-	-	-	-	60°	64°
26, ...	-	.65	-	-	-	-	-	-	-	-	-	-
27, ...	1.50	.66	-	-	.0012	.0090	.0102	.42	1.6000	.0007	57°	54°
28, ...	1.50	1.66	-	-	-	-	-	-	-	-	61°	63°
29, ...	1.50	1.47	-	-	-	-	-	-	-	-	59°	61°
30, ...	1.50	1.45	-	-	.0020	.0076	.0096	.37	1.6000	.0006	59°	60°
31, ...	1.50	1.59	-	-	-	-	-	-	-	-	62°	66°

Effluent generally clear and colorless and with very slight or no sediment.

The mixture applied contained 2.8 parts per 100,000 nitrogen, equivalent to 1.7 parts albuminoid ammonia.

Total effluent to end of month, 695.15 gallons.

Filter Tank No. 12 — Continued.

June, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	1.50	1.46	-	-	-	-	-	-	-	-	61°	66°
2, ...	-	.70	-	-	-	-	-	-	-	-	-	-
3, ...	1.50	.77	-	-	-	-	-	-	-	-	60°	67°
4, ...	1.50	1.60	-	-	-	-	-	-	-	-	60°	66°
5, ...	1.50	1.48	-	-	-	-	-	-	-	-	62°	65°
6, ...	1.50	1.48	1.50	16.30	.0026	.0126	.0152	.42	1.6000	.0005	61°	67°
7, ...	1.50	1.53	-	-	-	-	-	-	-	-	61°	65°
8, ...	1.50	1.43	-	-	-	-	-	-	-	-	60°	65°
9, ...	0	.72	-	-	-	-	-	-	-	-	-	-
10, ...	1.50	.80	3.20	15.60	.0016	.0056	.0072	.42	1.7000	.0003	65°	73°
11, ...	-	.74	-	-	-	-	-	-	-	-	-	71°
12, ...	1.50	.81	-	-	-	-	-	-	-	-	64°	69°
13, ...	1.50	1.58	-	-	-	-	-	-	-	-	71°	72°
14, ...	1.50	1.54	-	-	-	-	-	-	-	-	66°	74°
15, ...	1.50	1.45	-	-	-	-	-	-	-	-	64°	74°
16, ...	-	.69	-	-	-	-	-	-	-	-	-	-
17, ...	1.50	.75	-	-	-	-	-	-	-	-	69°	71°
18, ...	1.50	1.41	-	-	-	-	-	-	-	-	63°	65°
19, ...	1.50	1.43	-	-	-	-	-	-	-	-	63°	64°
20, ...	2.70	3.22	2.60	14.40	.0002	.0064	.0066	.42	1.7000	.0002	65°	70°
21, ...	1.50	1.12	-	-	-	-	-	-	-	-	67°	74°
22, ...	1.50	1.44	-	-	-	-	-	-	-	-	66°	73°
23, ...	-	.68	-	-	-	-	-	-	-	-	-	-
24, ...	1.50	.74	1.20	27.90	.0032	.0072	.0104	5.44	2.3000	.0004	65°	68°
25, ...	1.50	1.53	-	-	-	-	-	-	-	-	66°	68°
26, ...	1.50	1.51	-	-	-	-	-	-	-	-	67°	68°
27, ...	1.50	1.51	3.20	44.20	.0036	.0064	.0100	8.36	3.1000	.0009	71°	72°
28, ...	1.50	1.51	-	-	-	-	-	-	-	-	69°	75°
29, ...	1.50	1.53	-	-	-	-	-	-	-	-	70°	76°
30, ...	-	.67	-	-	-	-	-	-	-	-	-	-

Effluent clear and colorless and generally free from sediment.

The mixture applied contained 2.8 parts nitrogen, equivalent to 1.7 parts albuminoid ammonia.

June 20.—By mistake 1.2 gallons of the solution, intended for Tank No. 13, was applied to this tank.

Total effluent to end of month, 732.98 gallons.

Filter Tank No. 12 — Continued.

July, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	1.50	.73	1.60	37.20	.0026	.0064	.0090	4.27	3.1000	.0003	71°	76°
2, ...	1.50	1.46	-	-	-	-	-	-	-	-	69°	73°
3, ...	1.50	1.50	-	-	-	-	-	-	-	-	70°	73°
4, ...	1.50	1.55	-	-	-	-	-	-	-	-	72°	-
5, ...	1.50	1.43	2.60	23.70	.0020	.0076	.0096	1.82	2.7000	.0002	71°	72°
6, ...	1.50	1.48	-	-	-	-	-	-	-	-	71°	74°
7, ...	-	.69	-	-	-	-	-	-	-	-	-	-
8, ...	1.50	.82	1.50	22.00	.0022	.0074	.0096	1.35	2.6000	.0000	72°	72°
9, ...	1.50	1.43	-	-	-	-	-	-	-	-	70°	69°
10, ...	3.00	3.23	-	-	-	-	-	-	-	-	68°	68°
11, ...	3.00	2.92	-	-	-	-	-	-	-	-	67°	67°
12, ...	3.00	3.06	-	-	-	-	-	-	-	-	71°	70°
13, ...	3.00	3.03	-	-	-	-	-	-	-	-	73°	73°
14, ...	-	.50	-	-	-	-	-	-	-	-	-	-
15, ...	3.00	2.40	1.80	15.60	.0014	.0070	.0084	.73	1.9000	.0000	65°	66°
16, ...	3.00	3.03	1.40	15.60	.0010	.0110	.0120	.72	1.7000	.0000	67°	66°
17, ...	3.00	2.97	-	-	-	-	-	-	-	-	69°	67°
18, ...	3.00	3.00	1.80	14.60	.0010	.0082	.0092	.62	1.5000	.0000	70°	70°
19, ...	3.00	2.99	-	-	-	-	-	-	-	-	70°	71°
20, ...	3.00	3.04	-	-	-	-	-	-	-	-	67°	69°
21, ...	-	.50	-	-	-	-	-	-	-	-	-	-
22, ...	3.00	2.48	2.20	13.40	.0014	.0082	.0096	.57	1.3000	.0000	70°	71°
23, ...	3.00	2.97	-	-	-	-	-	-	-	-	69°	70°
24, ...	3.00	2.96	-	-	-	-	-	-	-	-	68°	70°
25, ...	3.00	2.95	-	-	-	-	-	-	-	-	70°	69°
26, ...	3.00	2.98	1.40	12.60	.0004	.0054	.0058	.54	1.2000	.0000	70°	71°
27, ...	3.00	2.87	-	-	-	-	-	-	-	-	69°	68°
28, ...	-	.55	-	-	-	-	-	-	-	-	-	-
29, ...	3.00	2.61	-	-	-	-	-	-	-	-	72°	75°
30, ...	3.00	2.97	-	-	-	-	-	-	-	-	72°	75°
31, ...	3.00	2.99	-	-	-	-	-	-	-	-	70°	74°

Effluent colorless and generally clear and free from sediment.

July 1 to 9. — The mixture of egg albumen applied contained 2.8 parts per 100,000 nitrogen, equivalent to 1.7 parts albuminoid ammonia. July 10 to 31. — Pulverized baked blood albumen in city water was applied, and the mixture contained 1.4 parts nitrogen, equivalent to 0.85 parts albuminoid ammonia.

Total effluent to end of month, 801.07 gallons.

Filter Tank No. 12 — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	3.00	2.93	3.40	12.80	.0004	.0066	.0070	.50	1.3000	.0000	71°	–
2, ...	3.00	3.02	–	–	–	–	–	–	–	–	70°	75°
3, ...	3.00	2.92	–	–	–	–	–	–	–	–	70°	74°
4, ...	–	.50	–	–	–	–	–	–	–	–	–	–
5, ...	3.00	2.42	–	–	–	–	–	–	–	–	69°	69°
6, ...	3.00	3.00	–	–	–	–	–	–	–	–	70°	70°
7, ...	3.00	3.10	–	–	–	–	–	–	–	–	70°	70°
8, ...	3.00	2.56	3.00	10.70	.0026	.0770	.0796	.94	1.3000	.0005	69°	70°
9, ...	3.00	2.95	–	–	–	–	–	–	–	–	69°	71°
10, ...	3.00	2.96	–	–	–	–	–	–	–	–	70°	72°
11, ...	–	.47	–	–	–	–	–	–	–	–	–	–
12, ...	3.00	2.38	–	–	–	–	–	–	–	–	68°	67°
13, ...	3.00	2.98	–	–	–	–	–	–	–	–	69°	69°
14, ...	3.00	2.92	–	–	–	–	–	–	–	–	66°	66°
15, ...	3.00	2.96	–	–	–	–	–	–	–	–	66°	65°
16, ...	3.00	2.96	–	–	–	–	–	–	–	–	68°	68°
17, ...	3.00	3.00	–	–	–	–	–	–	–	–	68°	68°
18, ...	–	.49	–	–	–	–	–	–	–	–	–	–
19, ...	3.00	2.46	–	–	.0018	.0052	.0070	3.47	1.8000	.0005	68°	69°
20, ...	3.00	3.00	–	–	–	–	–	–	–	–	69°	68°
21, ...	3.00	2.93	–	–	–	–	–	–	–	–	68°	68°
22, ...	3.00	3.00	–	–	–	–	–	–	–	–	70°	72°
23, ...	3.00	2.99	–	–	.0008	.0054	.0062	2.27	1.4000	.0000	69°	69°
24, ...	3.00	2.89	–	–	–	–	–	–	–	–	67°	69°
25, ...	–	.49	–	–	–	–	–	–	–	–	–	–
26, ...	3.00	2.46	–	–	.0004	.0050	.0054	1.66	1.2500	.0000	68°	68°
27, ...	3.00	2.96	–	–	–	–	–	–	–	–	68°	67°
28, ...	3.00	2.83	–	–	–	–	–	–	–	–	68°	66°
29, ...	3.00	2.94	–	–	–	–	–	–	–	–	67°	66°
30, ...	3.00	2.96	–	–	–	–	–	–	–	–	69°	69°
31, ...	3.00	2.90	–	–	–	–	–	–	–	–	69°	71°

Effluent clear and colorless and free from sediment.

August 1 to 18. — The mixture applied contained 1.4 parts nitrogen, equivalent to 0.85 parts albuminoid ammonia. August 7. — A culture of Bacillus prodigiosus applied. August 19 to 31. — City water alone applied.

Total effluent to end of month, 880.40 gallons.

Filter Tank No. 12 — Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	–	.52	–	–	–	–	–	–	–	–	–	–
2, ...	3.00	2.70	1.00	9.50	.0006	.0058	.0064	.63	.9000	.0001	67°	69°
3, ...	3.00	2.95	–	–	–	–	–	–	–	–	69°	69°
4, ...	3.00	2.91	–	–	–	–	–	–	–	–	69°	70°
5, ...	3.00	2.93	–	–	.0002	.0080	.0082	.32	.6000	.0007	69°	69°
6, ...	3.00	2.95	–	–	–	–	–	–	–	–	70°	72°
7, ...	3.00	2.89	–	–	–	–	–	–	–	–	68°	70°
8, ...	–	.49	–	–	–	–	–	–	–	–	–	–
9, ...	3.00	2.41	–	–	.0012	.0058	.0070	.28	.5000	.0002	67°	69°
10, ...	3.00	2.96	–	–	–	–	–	–	–	–	68°	67°
11, ...	3.00	2.93	–	–	–	–	–	–	–	–	66°	65°
12, ...	3.00	2.94	–	–	–	–	–	–	–	–	67°	66°
13, ...	3.00	2.95	–	–	–	–	–	–	–	–	67°	65°
14, ...	3.00	2.97	–	–	–	–	–	–	–	–	67°	66°
15, ...	–	.49	–	–	–	–	–	–	–	–	–	–
16, ...	3.00	2.51	1.80	9.00	.0012	.0072	.0084	.44	.4000	.0000	70°	71°
17, ...	3.00	2.96	–	–	–	–	–	–	–	–	69°	72°
18, ...	3.00	2.89	–	–	–	–	–	–	–	–	68°	69°
19, ...	3.00	2.89	–	–	–	–	–	–	–	–	64°	62°
20, ...	3.00	3.21	–	–	–	–	–	–	–	–	65°	62°
21, ...	3.00	2.81	–	–	–	–	–	–	–	–	66°	62°
22, ...	–	.53	–	–	–	–	–	–	–	–	–	–
23, ...	3.00	2.43	–	–	.0260	.0200	.0460	5.51	.6000	.0000	62°	59°
24, ...	3.00	2.95	–	–	–	–	–	–	–	–	62°	61°
25, ...	3.00	2.99	–	–	–	–	–	–	–	–	64°	61°
26, ...	3.00	2.92	–	–	.0010	.0100	.0110	2.00	1.0500	.0000	64°	64°
27, ...	3.00	2.90	–	–	–	–	–	–	–	–	63°	61°
28, ...	3.00	2.91	–	–	.0056	.0068	.0124	1.00	.5600	.0001	61°	58°
29, ...	–	.50	–	–	–	–	–	–	–	–	–	–
30, ...	3.00	2.43	–	–	–	–	–	–	–	–	62°	60°

Effluent clear and colorless and free from sediment.

City water alone applied. September 2. — A culture of Bacillus prodigiosus applied. September 20. — A sterilized solution of peptone applied.

Total effluent to end of month, 954.22 gallons.

Filter Tank No. 12 — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	3.00	3.00	-	-	-	-	-	-	-	-	63°	62°
2, ...	3.00	2.92	-	-	-	-	-	-	-	-	62°	62°
3, ...	3.00	2.85	-	-	-	-	-	-	-	-	60°	59°
4, ...	3.00	3.08	-	-	.0028	.0100	.0128	1.27	.3800	.0000	62°	59°
5, ...	3.00	2.90	-	-	.0030	.0176	.0206	5.80	.6000	.0002	59°	56°
6, ...	-	.55	-	-	-	-	-	-	-	-	-	-
7, ...	3.00	2.41	-	-	-	-	-	-	-	-	58°	57°
8, ...	3.00	2.90	-	-	-	-	-	-	-	-	58°	55°
9, ...	3.00	2.93	-	-	-	-	-	-	-	-	58°	54°
10, ...	3.00	2.90	-	-	-	-	-	-	-	-	57°	53°
11, ...	3.00	2.96	-	-	-	-	-	-	-	-	55°	53°
12, ...	3.00	2.93	-	-	.0008	.0078	.0086	.97	.4500	.0000	57°	54°
13, ...	-	.48	-	-	-	-	-	-	-	-	-	-
14, ...	3.00	2.35	-	-	-	-	-	-	-	-	54°	49°
15, ...	3.00	3.03	-	-	-	-	-	-	-	-	56°	52°
16, ...	3.00	2.91	-	-	-	-	-	-	-	-	55°	52°
17, ...	3.00	2.95	-	-	-	-	-	-	-	-	55°	52°
18, ...	3.00	2.96	-	-	-	-	-	-	-	-	55°	54°
19, ...	3.00	2.94	-	-	.0000	.0062	.0062	.40	.2200	.0000	54°	52°
20, ...	-	.53	-	-	-	-	-	-	-	-	-	-
21, ...	3.00	2.29	-	-	-	-	-	-	-	-	54°	51°
22, ...	3.00	2.95	-	-	-	-	-	-	-	-	53°	50°
23, ...	3.00	2.96	-	-	-	-	-	-	-	-	52°	49°
24, ...	3.00	2.93	-	-	-	-	-	-	-	-	52°	46°
25, ...	3.00	2.96	-	-	-	-	-	-	-	-	53°	49°
26, ...	3.00	2.92	58.00	5.00	-	-	-	.28	.0500	.0000	53°	50°
27, ...	-	.52	-	-	-	-	-	-	-	-	-	-
28, ...	3.00	2.40	-	-	-	-	-	-	-	-	54°	52°
29, ...	3.00	2.92	-	-	-	-	-	-	-	-	53°	52°
30, ...	3.00	2.94	53.20	7.60	.0040	-	-	.29	.0200	-	51°	49°
31, ...	3.00	2.97	-	-	-	-	-	-	-	-	53°	51°

Effluent colorless, free from sediment and generally clear.

October 1 to 22. — City water alone applied. October 3. — A culture of Bacillus prodigiosus applied. October 23 to 31. — 100 parts per 100,000 of granulated sugar in city water applied.

Total effluent to end of month, 1,033.46 gallons.

Filter Tank No. 12 — Continued.

November, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	3.00	2.94	-	-	-	-	-	-	-	-	52°	52°
2, ...	3.00	2.97	37.50	28.00	.0026	-	-	.22	.1800	.0000	53°	53°
3, ...	-	.51	-	-	-	-	-	-	-	-	-	-
4, ...	3.00	2.39	-	-	-	-	-	-	-	-	53°	53°
5, ...	3.00	2.93	-	-	-	-	-	-	-	-	51°	48°
6, ...	3.00	2.93	-	-	-	-	-	-	-	-	52°	48°
7, ...	3.00	3.01	-	-	-	-	-	-	-	-	50°	49°
8, ...	3.00	2.97	-	-	-	-	-	-	-	-	53°	53°
9, ...	3.00	2.93	66.60	6.80	.0200	-	-	.24	.0200	.0000	53°	52°
10, ...	-	.50	-	-	-	-	-	-	-	-	-	-
11, ...	3.00	2.39	-	-	-	-	-	-	-	-	53°	52°
12, ...	3.00	3.03	-	-	-	-	-	-	-	-	54°	53°
13, ...	3.00	2.96	-	-	-	-	-	-	-	-	53°	54°
14, ...	3.00	2.98	-	-	-	-	-	-	-	-	56°	57°
15, ...	3.00	2.84	-	-	-	-	-	-	-	-	51°	51°
16, ...	3.00	2.90	55.20	13.50	.0024	-	-	.23	.0600	.0000	49°	48°
17, ...	-	.52	-	-	-	-	-	-	-	-	-	-
18, ...	3.00	2.43	-	-	-	-	-	-	-	-	50°	47°
19, ...	3.00	3.01	-	-	-	-	-	-	-	-	50°	49°
20, ...	3.00	3.11	-	-	-	-	-	-	-	-	51°	51°
21, ...	3.00	2.99	-	-	-	-	-	-	-	-	51°	52°
22, ...	3.00	3.23	-	-	-	-	-	-	-	-	50°	50°
23, ...	3.00	2.92	70.80	6.20	.0010	-	-	.26	.0000	.0000	50°	51°
24, ...	-	.52	-	-	-	-	-	-	-	-	-	-
25, ...	3.00	2.35	-	-	-	-	-	-	-	-	50°	50°
26, ...	3.00	2.97	-	-	-	-	-	-	-	-	48°	47°
27, ...	3.00	2.99	-	-	-	-	-	-	-	-	45°	46°
28, ...	3.00	3.15	-	-	-	-	-	-	-	-	49°	47°
29, ...	3.00	2.98	-	-	-	-	-	-	-	-	47°	49°
30, ...	3.00	2.92	71.20	7.80	-	-	-	.32	.0000	.0000	46°	45°

Effluent colorless, clear or nearly so, and free from sediment.
One hundred parts per 100,000 of granulated sugar in city water applied.
Total effluent to end of month, 1,110.73 gallons.

Filter Tank No. 12 — Continued.

December, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	–	.52	–	–	–	–	–	–	–	–	–	–
2, ...	3.00	2.42	–	–	–	–	–	–	–	–	46°	45°
3, ...	3.00	2.95	–	–	–	–	–	–	–	–	47°	46°
4, ...	3.00	2.13	–	–	–	–	–	–	–	–	42°	40°
5, ...	3.00	3.01	–	–	–	–	–	–	–	–	44°	41°
6, ...	3.00	3.04	–	–	–	–	–	–	–	–	44°	42°
7, ...	3.00	2.96	74.60	6.40	.0020	–	–	.37	.0000	.0000	44°	45°
8, ...	–	.52	–	–	–	–	–	–	–	–	–	–
9, ...	3.00	2.37	–	–	–	–	–	–	–	–	37°	49°
10, ...	3.00	3.11	–	–	–	–	–	–	–	–	38°	46°
11, ...	3.00	3.20	–	–	–	–	–	–	–	–	–	47°
12, ...	3.00	2.91	–	–	–	–	–	–	–	–	37°	44°
13, ...	3.00	3.10	–	–	–	–	–	–	–	–	–	43°
14, ...	3.00	2.86	4.40	16.50	.0014	.0368	.0382	4.05	.2200	.0030	37°	40°
15, ...	–	.70	–	–	–	–	–	–	–	–	–	–
16, ...	3.00	2.52	–	–	–	–	–	–	–	–	45°	42°
17, ...	3.00	3.07	–	–	–	–	–	–	–	–	–	43°
18, ...	3.00	3.10	–	–	–	–	–	–	–	–	–	43°
19, ...	3.00	3.22	–	–	–	–	–	–	–	–	44°	48°
20, ...	3.00	3.12	–	–	–	–	–	–	–	–	45°	46°
21, ...	3.00	3.04	–	–	.0032	.0270	.0302	6.85	.8600	.0004	45°	48°
22, ...	–	.59	–	–	–	–	–	–	–	–	–	–
23, ...	3.00	2.45	–	–	–	–	–	–	–	–	44°	44°
24, ...	3.00	3.08	–	–	–	–	–	–	–	–	45°	42°
25, ...	3.00	3.22	–	–	–	–	–	–	–	–	–	–
26, ...	3.00	2.89	–	–	–	–	–	–	–	–	44°	45°
27, ...	3.00	3.00	–	–	–	–	–	–	–	–	44°	43°
28, ...	3.00	2.95	3.00	43.60	.0064	.0192	.0256	16.40	.8000	.0005	45°	42°
29, ...	–	.65	–	–	–	–	–	–	–	–	–	–
30, ...	3.00	2.42	–	–	–	–	–	–	–	–	45°	44°
31, ...	3.00	3.08	–	–	–	–	–	–	–	–	–	41°

Effluent colorless, generally clear or nearly so, and free from sediment.

December 1 to 8. — One hundred parts per 100,000 of granulated sugar in city water applied. December 9 to 31. — Sewage applied. December 12 and 16. — A culture of Bacillus prodigiosus put on.

Total effluent to end of month, 1,188.93 gallons.

Filter Tank No. 12 — Continued.

January, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	3.00	2.99	-	-	-	-	-	-	-	-	-	42°
2, ...	3.00	3.15	-	-	-	-	-	-	-	-	45°	48°
3, ...	3.00	2.95	-	-	-	-	-	-	-	-	46°	47°
4, ...	3.00	2.93	2.60	30.50	.0052	.0182	.0234	8.50	.6000	.0003	44°	44°
5, ...	-	.63	-	-	-	-	-	-	-	-	-	-
6, ...	3.00	2.43	-	-	-	-	-	-	-	-	44°	43°
7, ...	3.00	3.04	-	-	-	-	-	-	-	-	-	45°
8, ...	3.00	3.01	-	-	-	-	-	-	-	-	46°	44°
9, ...	3.00	2.93	-	-	-	-	-	-	-	-	44°	40°
10, ...	3.00	2.95	-	-	-	-	-	-	-	-	44°	36°
11, ...	3.00	3.00	4.70	23.60	.0028	.0158	.0186	5.27	.4400	.0002	45°	36°
12, ...	-	.69	-	-	-	-	-	-	-	-	-	-
13, ...	3.00	2.48	-	-	-	-	-	-	-	-	44°	43°
14, ...	3.00	3.04	-	-	-	-	-	-	-	-	-	43°
15, ...	3.00	3.00	-	-	-	-	-	-	-	-	44°	40°
16, ...	3.00	3.10	-	-	-	-	-	-	-	-	44°	44°
17, ...	3.00	2.64	-	-	-	-	-	-	-	-	-	38°
18, ...	3.00	3.14	2.90	21.10	.0034	.0166	.0200	4.07	.3400	.0000	44°	40°
19, ...	-	.73	-	-	-	-	-	-	-	-	-	-
20, ...	3.00	2.45	-	-	-	-	-	-	-	-	-	47°
21, ...	3.00	2.97	-	-	-	-	-	-	-	-	43°	45°
22, ...	3.00	3.00	-	-	-	-	-	-	-	-	44°	39°
23, ...	3.00	3.02	-	-	-	-	-	-	-	-	42°	37°
24, ...	3.00	2.99	-	-	-	-	-	-	-	-	42°	39°
25, ...	3.00	3.08	4.20	21.80	.0022	.0138	.0160	4.72	.3000	.0000	40°	37°
26, ...	-	.64	-	-	-	-	-	-	-	-	-	-
27, ...	3.00	2.42	-	-	-	-	-	-	-	-	43°	41°
28, ...	3.00	2.97	-	-	-	-	-	-	-	-	46°	37°
29, ...	3.00	3.02	-	-	-	-	-	-	-	-	44°	40°
30, ...	3.00	3.02	-	-	-	-	-	-	-	-	44°	40°
31, ...	3.00	3.00	4.50	25.20	.0052	.0170	.0222	5.07	.0800	.0003	42°	39°

Effluent clear and colorless and free from sediment.

January 1 to 12. — Ten parts per 100,000 of granulated sugar added to sewage applied. January 13 to 31. — Twenty parts.

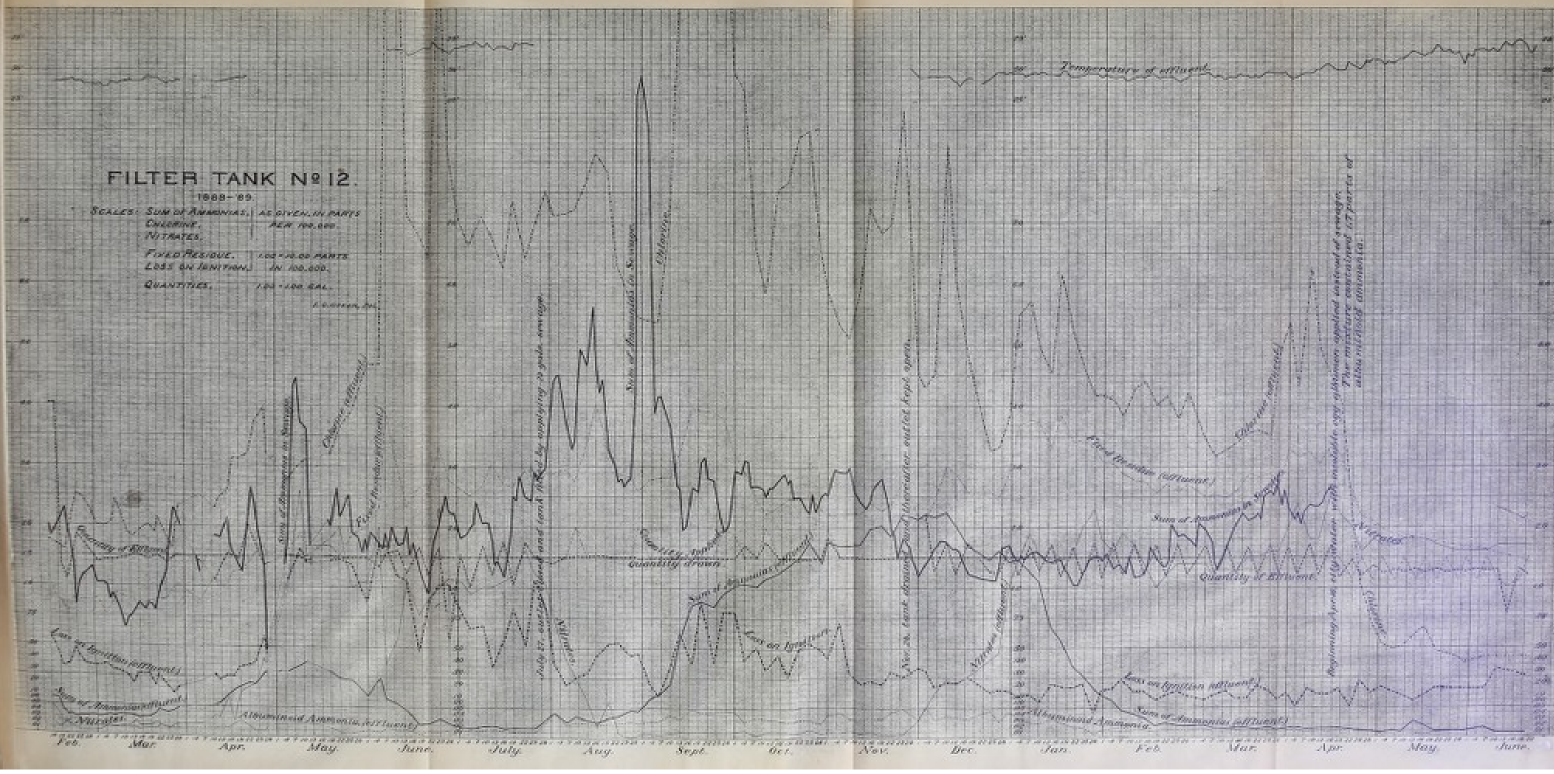
Total effluent to end of month, 1,270.34 gallons.

Filter Tank No. 12 — Continued.

February, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	3.00	3.04	-	-	-	-	-	-	-	-	44°	41°
2, ...	-	.56	-	-	-	-	-	-	-	-	-	-
3, ...	3.00	2.39	-	-	-	-	-	-	-	-	44°	42°
4, ...	3.00	3.08	-	-	-	-	-	-	-	-	-	43°
5, ...	3.00	3.02	-	-	-	-	-	-	-	-	46°	46°
6, ...	3.00	2.89	-	-	-	-	-	-	-	-	45°	42°
7, ...	3.00	3.01	-	-	.0044	.0184	.0228	5.35	.2200	.0001	-	38°
8, ...	3.00	3.07	-	-	-	-	-	-	-	-	45°	43°
9, ...	-	.65	-	-	-	-	-	-	-	-	-	-
10, ...	3.00	2.32	-	-	-	-	-	-	-	-	44°	-
11, ...	3.00	3.10	-	-	-	-	-	-	-	-	-	41°
12, ...	3.00	3.04	-	-	-	-	-	-	-	-	44°	42°
13, ...	3.00	3.05	-	-	-	-	-	-	-	-	44°	43°
14, ...	3.00	3.03	-	-	.0052	.0176	.0228	6.46	.4500	.0022	-	43°
15, ...	3.00	2.96	-	-	-	-	-	-	-	-	45°	46°
16, ...	-	.68	-	-	-	-	-	-	-	-	-	-
17, ...	3.00	2.40	-	-	-	-	-	-	-	-	44°	43°
18, ...	3.00	2.95	-	-	-	-	-	-	-	-	-	42°
19, ...	3.00	3.02	-	-	-	-	-	-	-	-	46°	41°
20, ...	3.00	2.99	-	-	-	-	-	-	-	-	45°	40°
21, ...	3.00	2.96	-	-	.0066	.0192	.0258	6.30	.6200	.0008	-	37°
22, ...	3.00	2.96	-	-	-	-	-	-	-	-	44°	37°
23, ...	-	.74	-	-	-	-	-	-	-	-	-	-
24, ...	3.00	2.44	-	-	-	-	-	-	-	-	44°	42°
25, ...	3.00	3.08	-	-	-	-	-	-	-	-	-	42°
26, ...	3.00	3.19	-	-	-	-	-	-	-	-	46°	45°
27, ...	3.00	2.99	-	-	-	-	-	-	-	-	45°	45°
28, ...	3.00	2.99	-	-	.0060	.0190	.0250	4.59	1.1000	.0004	-	45°

Effluent clear and colorless and free from sediment.
Twenty parts per 100,000 of granulated sugar added to sewage applied.
Total effluent to end of month, 1,342.94 gallons.


FILTER TANK No 12.
1888–89.
SCALES: SUM OF AMMONIAS, CHLORINE, NITRATES. AS GIVEN, IN PARTS PER 100,000.
FIXED RESIDUE. LOSS ON IGNITION. 1.00 = 10.00 PARTS IN 100,000.
QUANTITIES. 1.00 = 100 GAL.
Temperature of effluent.
Chlorine.
Sum of Ammonias in Sewage.
Fixed Residue (effluent.)
Quantity drawn.
Quantity of Effluent.
Nitrates.
Loss on Ignition (effluent.)
Albuminoid Ammonia (effluent.)
Sum of Ammonias (effluent.)
Feb. Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May. June.

Filter Tank No. 12—Concluded.

March, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	3.00	2.88	-	-	-	-	-	-	-	-	44°	45°
2, ...	-	.68	-	-	-	-	-	-	-	-	-	-
3, ...	3.00	2.33	-	-	-	-	-	-	-	-	36°	39°
4, ...	3.00	3.11	-	-	-	-	-	-	-	-	-	41°
5, ...	3.00	3.02	-	-	-	-	-	-	-	-	40°	43°
6, ...	3.00	2.99	-	-	-	-	-	-	-	-	40°	39°
7, ...	3.00	2.97	-	-	.0064	.0188	.0252	6.87	.8000	.0002	38°	38°
8, ...	3.00	2.95	-	-	-	-	-	-	-	-	38°	40°
9, ...	-	.71	-	-	-	-	-	-	-	-	-	-
10, ...	3.00	2.42	-	-	-	-	-	-	-	-	40°	43°
11, ...	3.00	3.07	-	-	-	-	-	-	-	-	41°	43°
12, ...	3.00	3.07	-	-	-	-	-	-	-	-	44°	46°
13, ...	3.00	3.08	-	-	-	-	-	-	-	-	48°	48°
14, ...	3.00	2.96	-	-	.0162	.0204	.0366	11.85	2.2000	.0024	41°	45°
15, ...	3.00	2.99	-	-	-	-	-	-	-	-	41°	43°
16, ...	-	.68	-	-	-	-	-	-	-	-	-	-
17, ...	3.00	2.43	-	-	-	-	-	-	-	-	40°	42°
18, ...	3.00	3.23	-	-	-	-	-	-	-	-	43°	44°
19, ...	3.00	2.91	-	-	-	-	-	-	-	-	38°	40°
20, ...	3.00	3.08	-	-	-	-	-	-	-	-	41°	42°
21, ...	3.00	3.08	-	-	.0124	.0192	.0316	11.10	2.4000	.0080	42°	44°
22, ...	8.00	2.99	-	-	-	-	-	-	-	-	43°	44°
23, ...	-	.66	-	-	-	-	-	-	-	-	-	-
24, ...	3.00	2.45	-	-	-	-	-	-	-	-	39°	43°
25, ...	3.00	3.06	-	-	-	-	-	-	-	-	41°	41°
26, ...	3.00	3.10	-	-	-	-	-	-	-	-	43°	46°
27, ...	3.00	3.07	-	-	-	-	-	-	-	-	44°	45°
28, ...	3.00	2.97	-	-	.0040	.0148	.0188	10.89	2.5000	.0002	42°	41°
29, ...	3.00	2.99	-	-	-	-	-	-	-	-	40°	41°
30, ...	-	.66	-	-	-	-	-	-	-	-	-	-
31, ...	3.00	2.42	-	-	-	-	-	-	-	-	41°	46°

Effluent colorless, free from sediment and generally clear.

March 1 to 4.—Twenty parts per 100,000 of granulated sugar added to sewage applied. March 5 to 31.—Twenty parts per 100,000 of sugar and common chloride, equal to 4 parts nitrogen, applied in city water.

Total effluent to end of month, 1,421.95 gallons.

FILTER TANK No. 13.

February and March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
29, . .	6.0	6.2	0.90	3.10	.0090	.0040	.0130	.36	.0150	.0008	-	44°	36°
March, 1888.													
1, . .	3.0	2.1	-	-	-	-	-	-	-	-	-	44°	42°
2, . .	3.0	3.8	2.90	7.60	.0106	.0098	.0204	2.08	.0080	.0009	-	44°	-
3, . .	3.0	2.1	-	-	-	-	-	-	-	-	-	44°	40°
4, . .	3.0	3.8	-	-	-	-	-	-	-	-	-	44°	40°
5, . .	3.0	2.3	2.60	8.00	.0146	.0104	.0250	2.34	.0150	.0026	-	44°	40°
6, . .	3.0	3.6	-	-	-	-	-	-	-	-	-	43°	-
7, . .	3.0	2.0	2.40	8.00	.0172	.0104	.0276	2.40	.0100	.0020	-	42°	39°
8, . .	3.0	3.1	-	-	-	-	-	-	-	-	-	44°	-
9, . .	3.0	3.8	2.60	8.50	.0216	.0108	.0324	2.00	.0100	.0033	-	42°	44°
10, . .	3.0	3.2	-	-	-	-	-	-	-	-	-	44°	40°
11, . .	3.0	2.7	-	-	-	-	-	-	-	-	-	44°	44°
12, . .	3.0	3.0	2.80	8.20	.0294	.0078	.0372	1.98	.0300	.0050	-	44°	42°
13, . .	3.0	2.9	-	-	-	-	-	-	-	-	-	44°	40°
14, . .	3.0	2.1	2.30	7.60	.0366	.0070	.0436	1.98	.0250	.0020	-	44°	40°
15, . .	3.0	3.9	-	-	-	-	-	-	-	-	-	44°	-
16, . .	3.0	2.9	2.50	8.00	.0344	.0066	.0410	2.08	.0200	.0100	-	43°	-
17, . .	3.0	2.1	-	-	-	-	-	-	-	-	-	43°	42°
18, . .	3.0	3.8	-	-	-	-	-	-	-	-	-	44°	-
19, . .	3.0	2.7	2.80	9.70	.0634	.0108	.0742	2.10	.0250	.0020	-	43°	43°
20, . .	3.0	2.0	-	-	-	-	-	-	-	-	-	44°	-
21, . .	3.0	3.2	2.20	8.70	.0656	.0078	.0734	2.20	.0250	.0010	-	44°	-
22, . .	3.0	3.9	-	-	-	-	-	-	-	-	-	40°	-
23, . .	3.0	2.9	1.30	8.50	.0608	.0062	.0670	1.76	.0200	.0007	-	44°	40°
24, . .	3.0	2.0	-	-	-	-	-	-	-	-	30 s.	44°	38°
25, . .	3.0	4.1	-	-	-	-	-	-	-	-	-	44°	41°
26, . .	3.0	2.9	2.90	8.50	.0920	.0086	.1006	1.80	.0120	.0004	30 s.	44°	41°
27, . .	3.0	2.0	-	-	-	-	-	-	-	-	0 s.	44°	42°
28, . .	5.0	4.1	1.20	11.60	.1320	.0140	.1460	3.00	.0200	.0008	-	44°	44°
29, . .	3.0	2.9	-	-	-	-	-	-	-	-	-	43°	44°
30, . .	3.0	3.0	1.80	11.80	.1720	.0110	.1830	2.80	.0250	.0008	30 s.	44°	40°
31, . .	3.0	.1	-	-	-	-	-	-	-	-	-	44°	-

Effluent colorless, generally clear or nearly so, and with very little or no sediment.
February 29. — First sewage applied. March 31. — Outlet closed at 10.41 A.M. River high.
Total effluent to end of month, 95.2 gallons.

Filter Tank No. 13 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
2, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
3, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
4, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
5, . .	3.00	5.76	1.90	10.20	.1520	.0120	.1640	2.20	.0800	.0010	45 s.	43°	39°
6, . .	3.00	2.31	-	-	-	-	-	-	-	-	25 s.	46°	-
7, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
8, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
9, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
10, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
11, . .	3.00	3.73	2.90	10.60	.1160	.0070	.1230	2.52	.0800	.0015	1 m. 15 s.	44°	39°
12, . .	3.00	3.10	-	-	-	-	-	-	-	-	35 s.	40°	-
13, . .	3.00	2.90	1.60	10.80	.1760	.0170	.1930	2.75	.1400	.0008	30 s.	-	-
14, . .	3.00	2.90	-	-	-	-	-	-	-	-	-	45°	-
15, . .	3.00	3.00	-	-	-	-	-	-	-	-	1 m. 10 s.	45°	43°
16, . .	3.00	2.60	3.00	13.30	.2280	.0100	.2380	3.26	.0800	.0000	1 m.	42°	43°
17, . .	3.00	3.00	-	-	-	-	-	-	-	-	1 m. 5 s.	42°	-
18, . .	3.00	2.90	2.70	13.60	.2400	.0120	.2520	3.32	.0800	.0006	1 m.	45°	-
19, . .	3.00	3.00	-	-	-	-	-	-	-	-	-	42°	45°
20, . .	3.00	3.00	1.30	13.30	.3080	.0070	.3150	2.75	.1500	.0007	1 m.	43°	44°
21, . .	6.00	4.90	-	-	-	-	-	-	-	-	1 m. 5 s.	42°	-
22, . .	-	.70	-	-	-	-	-	-	-	-	-	-	-
23, . .	3.00	1.70	3.50	17.20	.4000	.0090	.4090	4.07	.0900	.0008	-	43°	-
24, . .	3.00	3.00	-	-	-	-	-	-	-	-	-	42°	-
25, . .	3.00	3.10	4.30	16.90	.5150	.0100	.5250	4.40	.0950	.0006	-	42°	-
26, . .	3.00	3.00	-	-	-	-	-	-	-	-	-	46°	-
27, . .	3.00	3.00	4.00	15.80	.4500	.0120	.4620	2.93	.1800	.0014	-	44°	-
28, . .	6.00	5.90	-	-	-	-	-	-	-	-	-	46°	-
29, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
30, . .	-	-	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless and generally clear or nearly so, and with very little sediment.

April 5. — Outlet opened at 7.36 A.M. Outlet closed from 5.11 P.M., April 6, to 7.49 A.M., April 11. River high. April 29. — Outlet closed at 6.40 P.M. River high.

Total effluent to end of month, 158.70 gallons.

Filter Tank No. 13 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	-	-	-	-	-	-	-	-	-	-	-	-
2, ...	-	-	-	-	-	-	-	-	-	-	-	-
3, ...	-	-	-	-	-	-	-	-	-	-	-	-
4, ...	3.0	2.7	8.10	13.90	.3200	.0040	.3240	2.64	.5500	.0033	45°	-
5, ...	6.0	5.8	-	-	-	-	-	-	-	-	45°	-
6, ...	-	.6	-	-	-	-	-	-	-	-	-	-
7, ...	3.0	2.6	6.30	22.90	.3400	.0150	.3550	3.20	1.4000	.0070	50°	-
8, ...	3.0	2.6	-	-	-	-	-	-	-	-	48°	-
9, ...	3.0	3.0	-	-	-	-	-	-	-	-	50°	-
10, ...	3.0	3.0	11.40	17.10	.2300	.0080	.2380	3.16	1.5000	.0063	51°	-
11, ...	3.0	2.9	-	-	-	-	-	-	-	-	51°	-
12, ...	6.0	5.1	-	-	-	-	-	-	-	-	49°	-
13, ...	-	-	-	-	-	-	-	-	-	-	-	-
14, ...	-	-	-	-	-	-	-	-	-	-	-	-
15, ...	-	-	-	-	-	-	-	-	-	-	-	-
16, ...	-	-	-	-	-	-	-	-	-	-	-	-
17, ...	3.0	3.8	13.10	16.10	.0520	.0110	.0630	3.06	1.8000	.0067	49°	-
18, ...	3.0	3.1	-	-	-	-	-	-	-	-	49°	-
19, ...	6.0	5.8	-	-	-	-	-	-	-	-	50°	-
20, ...	-	.6	-	-	-	-	-	-	-	-	-	-
21, ...	3.0	2.6	11.20	16.00	.0240	.0070	.0310	3.84	.8000	.0029	51°	-
22, ...	3.0	3.0	-	-	-	-	-	-	-	-	52°	-
23, ...	3.0	3.0	-	-	-	-	-	-	-	-	53°	-
24, ...	3.0	3.1	4.70	23.30	.0056	.0088	.0144	3.86	1.2000	.0011	55°	-
25, ...	3.0	2.9	-	-	-	-	-	-	-	-	56°	-
26, ...	6.0	5.7	-	-	-	-	-	-	-	-	57°	-
27, ...	-	.5	-	-	-	-	-	-	-	-	-	-
28, ...	3.0	2.6	9.50	19.80	.0012	.0102	.0114	2.57	.9000	.0003	57°	-
29, ...	3.0	3.0	-	-	-	-	-	-	-	-	56°	-
30, ...	3.0	3.0	-	-	-	-	-	-	-	-	57°	-
31, ...	3.0	3.0	9.40	21.70	.0008	.0094	.0102	5.32	1.0000	.0003	57°	-

Effluent colorless and generally clear and nearly free from sediment.

May 4. — Outlet opened at 9.38 A.M. Outlet closed from 8.38 P.M., May 12, to 8.09 A.M., May 17. River high. May 17 and 21. — Sand in sample.

Total effluent to end of month, 232.7 gallons.

Filter Tank No. 13 — Continued.

June, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	3.0	3.0	-	-	-	-	-	-	-	-	58°	-
2, ...	6.0	5.7	-	-	-	-	-	-	-	-	60°	-
3, ...	-	.5	-	-	-	-	-	-	-	-	-	-
4, ...	3.0	1.9	7.70	21.20	.0014	.0094	.0108	4.40	1.2000	.0003	59°	-
5, ...	3.0	3.0	-	-	-	-	-	-	-	-	61°	-
6, ...	3.0	2.9	-	-	-	-	-	-	-	-	61°	-
7, ...	3.0	3.0	7.30	18.60	.0016	.0094	.0110	4.10	1.1000	.0016	64°	67°
8, ...	3.0	3.0	-	-	-	-	-	-	-	-	64°	65°
9, ...	6.0	5.7	-	-	-	-	-	-	-	-	66°	65°
10, ...	-	.6	-	-	-	-	-	-	-	-	-	-
11, ...	3.0	2.6	10.20	19.60	.0012	.0110	.0122	6.42	.8000	.0009	68°	66°
12, ...	3.0	2.9	-	-	-	-	-		-	-	65°	65°
13, ...	3.0	2.9	-	-	-	-	-	-	-	-	64°	64°
14, ...	3.0	2.9	8.60	23.80	.0022	.0096	.0118	5.60	.9500	.0004	65°	62°
15, ...	3.0	3.3	-	-	-	-	-	-	-	-	65°	62°
16, ...	6.0	5.8	-	-	-	-	-	-	-	-	66°	-
17, ...	-	.6	-	-	-	-	-	-	-	-	-	-
18, ...	3.0	2.5	4.20	29.00	.0018	.0116	.0134	7.45	.9700	.0012	68°	71°
19, ...	3.0	2.9	-	-	-	-	-	-	-	-	68°	68°
20, ...	3.0	2.9	-	-	-	-	-	-	-	-	70°	68°
21, ...	3.0	2.9	15.00	34.30	.0020	.0090	.0110	11.97	.7000	.0005	69°	65°
22, ...	3.0	3.1	-	-	-	-	-	-	-	-	69°	67°
23, ...	6.0	5.8	-	-	-	-	-	-	-	-	73°	71°
24, ...	-	.5	-	-	-	-	-	-	-	-	-	-
25, ...	3.0	2.5	3.50	35.10	.0028	.0104	.0132	7.78	1.2500	.0014	71°	67°
26, ...	3.0	3.0	-	-	-	-	-	-	-	-	69°	67°
27, ...	3.0	3.0	-	-	-	-	-	-	-	-	69°	69°
28, ...	3.0	2.9	6.80	24.60	.0014	.0104	.0118	5.12	1.3000	.0004	68°	62°
29, ...	3.0	3.0	-	-	-	-	-	-	-	-	66°	63°
30, ...	6.0	5.7	-	-	-	-	-	-	-	-	68°	65°

Effluent colorless and generally clear and very nearly free from sediment.
Total effluent to end of month, 323.7 gallons.

Filter Tank No. 13 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	–	0.6	–	–	–	–	–	–	–	–	–	–
2, ...	3.0	2.6	4.90	24.90	.0010	.0094	.0104	6.60	1.0500	.0004	65°	68°
3, ...	3.0	3.0	–	–	–	–	–	–	–	–	65°	67°
4, ...	3.0	3.0	–	–	–	–	–	–	–	–	67°	68°
5, ...	3.0	3.0	5.20	26.00	.0006	.0104	.0110	6.90	1.0500	.0002	68°	70°
6, ...	3.0	2.9	–	–	–	–	–	–	–	–	68°	70°
7, ...	6.0	5.7	–	–	–	–	–	–	–	–	70°	72°
8, ...	–	.6	–	–	–	–	–	–	–	–	–	–
9, ...	3.00	2.53	4.70	27.70	.0018	.0104	.0122	7.10	1.0500	.0006	69°	67°
10, ...	3.00	2.96	–	–	–	–	–	–	–	–	69°	70°
11, ...	3.00	3.01	–	–	–	–	–	–	–	–	69°	72°
12, ...	3.00	2.79	3.60	28.70	.0020	.0116	.0136	7.10	1.1500	.0004	69°	67°
13, ...	3.00	2.91	–	–	–	–	–	–	–	–	69°	66°
14, ...	6.00	5.98	–	–	–	–	–	–	–	–	69°	67°
15, ...	–	.32	–	–	–	–	–	–	–	–	–	–
16, ...	3.00	2.48	4.50	26.30	.0004	.0086	.0090	6.42	1.1000	.0004	69°	68°
17, ...	3.00	3.00	–	–	–	–	–	–	–	–	69°	67°
18, ...	3.00	2.94	–	–	–	–	–	–	–	–	71°	68°
19, ...	3.00	2.87	11.30	24.80	.0012	.0094	.0106	7.66	1.4500	.0003	71°	66°
20, ...	3.00	3.03	–	–	–	–	–	–	–	–	70°	71°
21, ...	6.00	5.85	–	–	–	–	–	–	–	–	71°	71°
22, ...	–	.23	–	–	–	–	–	–	–	–	–	–
23, ...	3.00	2.82	6.70	27.10	.0028	.0088	.0116	5.88	1.7200	.0020	72°	72°
24, ...	3.00	3.01	–	–	–	–	–	–	–	–	72°	–
25, ...	3.00	2.95	–	–	–	–	–	–	–	–	73°	69°
26, ...	3.00	3.02	5.30	31.30	.0010	.0112	.0122	7.24	1.2000	.0004	73°	71°
27, ...	3.00	2.89	–	–	–	–	–	–	–	–	72°	–
28, ...	6.00	5.72	–	–	–	–	–	–	–	–	72°	65°
29, ...	–	.63	–	–	–	–	–	–	–	–	–	–
30, ...	3.00	2.57	1.80	29.80	.0002	.0120	.0122	5.90	1.3300	.0006	71°	69°
31, ...	–	3.07	–	–	–	–	–	–	–	–	72°	–

Effluent colorless and generally clear and free from sediment.
Total effluent to end of month, 412.68 gallons.

Filter Tank No. 13 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	3.00	2.87	–	–	–	–	–	–	–	–	73°	71°
2, ...	3.00	3.00	3.60	34.60	.0006	.0122	.0128	8.48	1.7000	.0005	73°	71°
3, ...	3.00	2.99	–	–	–	–	–	–	–	–	73°	72°
4, ...	6.00	5.70	–	–	–	–	–	–	–	–	74°	72°
5, ...	–	.59	–	–	–	–	–	–	–	–	–	–
6, ...	3.00	2.27	–	–	–	–	–	–	–	–	74°	71°
7, ...	3.00	3.04	1.20	30.80	.0016	.0120	.0136	5.15	1.7000	.0008	72°	69°
8, ...	3.00	3.06	–	–	–	–	–	–	–	–	72°	68°
9, ...	3.00	2.97	4.40	27.00	.0016	.0108	.0124	5.66	1.7500	.0005	73°	72°
0, ...	3.00	2.96	–	–	–	–	–	–	–	–	72°	73°
1, ...	6.00	5.83	–	–	–	–	–	–	–	–	73°	69°
2, ...	–	.55	–	–	–	–	–	–	–	–	–	–
3, ...	3.00	2.85	2.40	31.60	.0014	.0086	.0100	5.37	1.8000	.0004	70°	66°
4, ...	3.00	3.10	–	–	–	–	–	–	–	–	–	67°
5, ...	3.00	3.04	–	–	–	–	–	–	–	–	69°	67°
6, ...	3.00	3.09	4.50	31.90	.0006	.0098	.0104	5.49	1.4000	.0004	69°	72°
7, ...	3.00	2.94	–	–	–	–	–	–	–	–	70°	72°
8, ...	6.00	5.93	–	–	–	–	–	–	–	–	71°	73°
9, ...	–	.54	–	–	–	–	–	–	–	–	–	–
0, ...	3.00	2.46	6.50	29.30	.0024	.0116	.0140	5.68	1.3400	.0008	71°	–
1, ...	3.00	2.96	–	–	–	–	–	–	–	–	71°	69°
2, ...	3.00	3.03	–	–	–	–	–	–	–	–	70°	69°
3, ...	3.00	2.95	4.80	27.70	.0016	.0094	.0110	5.50	1.8000	.0040	70°	68°
4, ...	3.00	3.04	–	–	–	–	–	–	–	–	70°	69°
5, ...	6.00	4.67	–	–	–	–	–	–	–	–	70°	74°
6, ...	–	.56	–	–	–	–	–	–	–	–	–	–
7, ...	3.00	2.42	4.90	34.40	.0026	.0114	.0140	8.37	1.6670	.0016	71°	74°
8, ...	3.00	2.93	–	–	–	–	–	–	–	–	70°	68°
9, ...	3.00	3.41	–	–	–	–	–	–	–	–	69°	69°
0, ...	3.00	3.07	7.10	41.30	.0020	.0120	.0140	12.60	1.6630	.0004	70°	69°
1, ...	3.00	3.02	–	–	–	–	–	–	–	–	70°	72°

Effluent colorless and generally clear and free from sediment.
After August 1 residue on evaporation obtained with sodium carbonate.
Total effluent to end of month, 504.52 gallons.

Filter Tank No. 13 — Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	6.00	5.87	–	–	–	–	–	–	–	–	71°	72°
2, ...	–	.53	–	–	–	–	–	–	–	–	–	–
3, ...	3.00	2.45	3.40	56.80	.0034	.0126	.0160	17.21	1.4000	.0016	70°	68°
4, ...	3.00	3.01	–	–	–	–	–	–	–	–	71°	67°
5, ...	3.00	2.96	–	–	–	–	–	–	–	–	70°	67°
6, ...	3.00	2.88	2.20	49.60	.0042	.0120	.0162	15.07	1.2500	.0004	68°	62°
7, ...	3.00	2.99	–	–	–	–	–	–	–	–	68°	–
8, ...	6.00	5.97	–	–	–	–	–	–	–	–	66°	61°
9, ...	–	.62	–	–	–	–	–	–	–	–	–	–
10, ...	3.00	2.53	3.20	46.30	.0024	.0100	.0124	13.95	1.3000	.0014	67°	69°
11, ...	3.00	2.93	–	–	–	–	–	–	–	–	67°	67°
12, ...	3.00	3.02	–	–	–	–	–	–	–	–	66°	–
13, ...	3.00	2.96	3.00	41.40	–	–	–	10.65	1.4000	.0004	66°	67°
14, ...	3.00	3.02	–	–	–	–	–	–	–	–	64°	65°
15, ...	6.00	5.78	–	–	–	–	–	–	–	–	64°	64°
16, ...	–	.59	–	–	–	–	–	–	–	–	–	–
17, ...	3.00	2.48	1.90	31.10	.0018	.0116	.0134	7.80	1.2000	.0004	65°	67°
18, ...	3.00	3.12	–	–	–	–	–	–	–	–	65°	–
19, ...	3.00	3.02	–	–	–	–	–	–	–	–	64°	64°
20, ...	3.00	3.46	2.10	36.00	.0004	.0108	.0112	7.90	1.3500	.0001	64°	62°
21, ...	3.00	3.01	–	–	–	–	–	–	–	–	63°	62°
22, ...	6.00	5.91	–	–	–	–	–	–	–	–	61°	61°
23, ...	–	.55	–	–	–	–	–	–	–	–	–	–
24, ...	3.00	2.50	1.60	29.80	.0006	.0098	.0104	5.71	1.4300	.0002	58°	61°
25, ...	3.00	3.02	–	–	–	–	–	–	–	–	58°	60°
26, ...	3.00	3.06	–	–	–	–	–	–	–	–	58°	58°
27, ...	3.00	3.10	1.70	29.90	.0006	.0118	.0124	5.40	1.4300	.0001	58°	61°
28, ...	3.00	2.99	–	–	–	–	–	–	–	–	57°	–
29, ...	6.00	5.74	–	–	–	–	–	–	–	–	55°	56°
30, ...	–	.59	–	–	–	–	–	–	–	–	–	–

Effluent clear and colorless and generally free from sediment.
September 27. — Hole drilled about the middle of side of tank and plugged.
Total effluent to end of month, 595.18 gallons.

Filter Tank No. 13 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	3.00	2.49	3.00	32.30	.0004	.0112	.0116	10.20	1.0500	.0002	53°	-
2, ...	3.00	3.02	-	-	-	-	-	-	-	-	53°	-
3, ...	3.00	2.96	-	-	-	-	-	-	-	-	51°	55°
4, ...	3.00	3.04	0.40	33.90	.0000	.0092	.0092	6.85	1.2500	.0001	50°	57°
5, ...	3.00	3.01	-	-	-	-	-	-	-	-	50°	60°
6, ...	6.00	5.81	-	-	-	-	-	-	-	-	50°	-
7, ...	-	.58	-	-	-	-	-	-	-	-	-	-
8, ...	3.00	2.48	3.20	35.30	.0020	.0100	.0120	10.40	1.1500	.0004	52°	55°
9, ...	3.00	3.05	-	-	-	-	-	-	-	-	51°	-
10, ...	3.00	2.98	-	-	-	-	-	-	-	-	49°	53°
11, ...	3.00	3.04	1.30	33.10	.0014	.0102	.0116	7.17	1.1700	.0001	49°	55°
12, ...	3.00	2.96	-	-	-	-	-	-	-	-	47°	55°
13, ...	6.00	5.87	-	-	-	-	-	-	-	-	47°	-
14, ...	-	.52	-	-	-	-	-	-	-	-	-	-
15, ...	3.00	2.49	2.00	28.30	.0000	.0098	.0098	5.38	1.1500	.0000	47°	54°
16, ...	3.00	3.04	-	-	-	-	-	-	-	-	47°	55°
17, ...	3.00	2.99	-	-	-	-	-	-	-	-	48°	56°
18, ...	3.00	2.99	.80	29.90	.0004	.0092	.0096	4.91	1.4900	.0000	47°	55°
19, ...	3.00	2.93	-	-	-	-	-	-	-	-	46°	54°
20, ...	6.00	5.89	-	-	-	-	-	-	-	-	47°	56°
21, ...	-	.56	-	-	-	-	-	-	-	-	-	-
22, ...	3.00	2.48	1.10	27.40	.0004	.0100	.0104	4.80	1.0000	.0000	45°	53°
23, ...	3.00	2.66	-	-	-	-	-	-	-	-	45°	53°
24, ...	3.00	2.99	-	-	-	-	-	-	-	-	45°	55°
25, ...	3.00	3.04	3.70	26.80	.0004	.0128	.0132	5.00	1.5700	.0000	45°	55°
26, ...	3.00	3.01	-	-	-	-	-	-	-	-	45°	-
27, ...	6.00	5.86	-	-	-	-	-	-	-	-	46°	55°
28, ...	-	.57	-	-	-	-	-	-	-	-	-	-
29, ...	3.00	2.41	2.60	28.30	.0010	.0096	.0106	7.14	1.2000	.0000	46°	55°
30, ...	3.00	2.81	-	-	-	-	-	-	-	-	46°	55°
31, ...	3.00	2.96	-	-	-	-	-	-	-	-	45°	55°

Effluent clear and colorless and generally free from sediment.

October 10. — Faucets put in side of tank, one-quarter, one-half and three-quarters way down and 2 inches from bottom.

Total effluent to end of month, 686.67 gallons.

Filter Tank No. 13 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	3.00	3.01	2.40	35.00	.0014	.0134	.0148	8.90	1.2200	.0005	47°	59°
2, ...	3.00	3.04	-	-	-	-	-	-	-	-	46°	59°
3, ...	6.00	5.84	-	-	-	-	-	-	-	-	48°	61°
4, ...	-	.55	-	-	-	-	-	-	-	-	-	-
5, ...	3.00	2.42	1.30	29.90	.0024	.0100	.0124	5.04	1.4800	.0006	48°	53°
6, ...	3.00	3.13	-	-	-	-	-	-	-	-	49°	58°
7, ...	3.00	2.98	-	-	-	-	-	-	-	-	50°	56°
8, ...	3.00	2.99	1.70	42.00	.0006	.0118	.0124	11.10	1.8200	.0002	49°	53°
9, ...	5.00	3.02	-	-	-	-	-	-	-	-	49°	56°
10, ...	6.00	5.87	-	-	-	-	-	-	-	-	48°	55°
11, ...	-	.58	-	-	-	-	-	-	-	-	-	-
12, ...	3.00	2.45	1.00	36.70	.0002	.0116	.0118	11.00	1.2500	.0001	45°	52°
13, ...	3.00	2.99	-	-	-	-	-	-	-	-	43°	50°
14, ...	3.00	3.07	-	-	-	-	-	-	-	-	43°	53°
15, ...	3.00	2.98	.70	31.30	.0002	.0100	.0102	5.97	1.2500	.0001	42°	52°
16, ...	3.00	3.01	-	-	-	-	-	-	-	-	42°	54°
17, ...	6.00	5.84	-	-	-	-	-	-	-	-	42°	51°
18, ...	-	.57	-	-	-	-	-	-	-	-	-	-
19, ...	3.00	2.45	2.80	28.80	.0002	.0090	.0092	13.04	1.2000	.0002	40°	49°
20, ...	3.00	3.02	-	-	-	-	-	-	-	-	40°	48°
21, ...	3.00	3.00	-	-	-	-	-	-	-	-	38°	45°
22, ...	3.00	2.95	1.40	30.50	.0000	.0088	.0088	6.10	1.1800	.0000	45°	46°
23, ...	3.00	2.98	-	-	-	-	-	-	-	-	44°	43°
24, ...	6.00	5.90	-	-	-	-	-	-	-	-	45°	45°
25, ...	-	.58	-	-	-	-	-	-	-	-	-	-
26, ...	3.00	2.54	1.40	27.40	.0006	.0100	.0106	5.61	1.0000	.0002	45°	46°
27, ...	3.00	2.42	-	-	-	-	-	-	-	-	45°	46°
28, ...	3.00	2.31	-	-	-	-	-	-	-	-	44°	50°
29, ...	-	-	-	-	-	-	-	-	-	-	-	-
30, ...	-	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, generally clear and with very little or no sediment.
November 28. — Outlet closed at 8.55 P.M. River high.
Total effluent to end of month, 769.16 gallons.

Filter Tank No. 13 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	6.00	6.40	2.20	21.70	.0004	.0104	.0108	3.75	.8000	.0000	44°	42°
2, ...	-	.58	-	-	-	-	-	-	-	-	-	-
3, ...	3.00	2.46	2.90	19.80	.0004	.0082	.0086	4.42	.7700	.0000	44°	42°
4, ...	3.00	3.11	-	-	-	-	-	-	-	-	45°	43°
5, ...	3.00	2.99	-	-	-	-	-	-	-	-	44°	43°
6, ...	3.00	2.99	1.30	24.30	.0002	.0088	.0090	4.86	1.0500	.0001	46°	44°
7, ...	3.00	3.00	-	-	-	-	-	-	-	-	45°	43°
8, ...	6.00	5.89	-	-	-	-	-	-	-	-	45°	44°
9, ...	-	.61	-	-	-	-	-	-	-	-	-	-
10, ...	3.00	2.48	1.60	30.40	.0002	.0110	.0112	7.57	.7500	.0000	45°	43°
11, ...	3.00	2.98	-	-	-	-	-	-	-	-	45°	42°
12, ...	3.00	3.04	-	-	-	-	-	-	-	-	44°	41°
13, ...	3.00	2.92	1.80	24.90	.0002	.0094	.0096	4.69	.7500	.0000	44°	39°
14, ...	3.00	2.50	-	-	-	-	-	-	-	-	46°	34°
15, ...	6.00	6.61	-	-	-	-	-	-	-	-	45°	37°
16, ...	-	.68	-	-	-	-	-	-	-	-	-	-
17, ...	3.00	2.56	3.10	23.40	.0000	.0100	.0100	4.01	.7000	.0006	41°	47°
18, ...	3.00	1.66	-	-	-	-	-	-	-	-	45°	-
19, ...	-	-	-	-	-	-	-	-	-	-	-	-
20, ...	-	-	-	-	-	-	-	-	-	-	-	-
21, ...	-	2.57	-	-	-	-	-	-	-	-	-	38°
22, ...	6.00	5.31	-	-	-	-	-	-	-	-	45°	-
23, ...	-	.67	-	-	-	-	-	-	-	-	-	-
24, ...	3.00	3.32	.80	18.40	.0018	.0116	.0134	2.70	.5500	.0000	42°	42°
25, ...	3.00	3.15	-	-	-	-	-	-	-	-	45°	-
26, ...	3.00	2.92	-	-	-	-	-	-	-	-	45°	39°
27, ...	3.00	3.00	.90	21.40	.0006	.0106	.0112	3.49	.7500	.0000	46°	48°
28, ...	3.00	2.99	-	-	-	-	-	-	-	-	45°	47°
29, ...	6.00	5.84	-	-	-	-	-	-	-	-	45°	46°
30, ...	-	.61	-	-	-	-	-	-	-	-	-	-
31, ...	3.00	2.43	.70	23.60	.0006	.0112	.0118	4.21	.7800	.0000	45°	47°

Effluent colorless, generally clear and with very little or no sediment.

December 1. — Outlet opened at 8.19 A.M. December 14. — Outlet thawed out at 3.15 P.M.; December 15, at 8.22 A.M. Outlet closed from 3.40 P.M., December 18, to 2.00 P.M., December 21.

Total effluent to end of month, 855.43 gallons.

Filter Tank No. 13 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Alkalinity.	Temperature. Sewage.	Temperature. Effluent.
1, . .	3.00	3.05	-	-	-	-	-	-	-	-	-	45°	47°
2, . .	3.00	2.95	-	-	-	-	-	-	-	-	-	45°	47°
3, . .	3.00	2.97	.60	29.70	.0008	.0090	.0098	8.26	.6200	.0000	-	45°	45°
4, . .	3.00	3.01	-	-	-	-	-	-	-	-	-	45°	45°
5, . .	6.00	5.93	-	-	-	-	-	-	-	-	-	45°	43°
6, . .	-	.58	-	-	-	-	-	-	-	-	-	-	-
7, . .	3.00	2.58	1.00	25.00	.0006	.0102	.0108	5.11	.7000	.0000	-	45°	43°
8, . .	3.00	3.04	-	-	-	-	-	-	-	-	-	45°	45°
9, . .	3.00	3.04	-	-	-	-	-	-	-	-	-	45°	45°
10, . .	3.00	2.96	1.10	23.20	.0004	.0098	.0102	4.12	.7000	.0000	-	45°	46°
11, . .	3.00	2.96	-	-	-	-	-	-	-	-	-	45°	46°
12, . .	6.00	5.60	-	-	-	-	-	-	-	-	-	44°	44°
13, . .	-	.65	-	-	-	-	-	-	-	-	-	-	-
14, . .	3.00	2.45	1.10	23.80	.0014	.0076	.0090	4.74	.8300	.0000	-	-	44°
15, . .	3.00	3.01	-	-	-	-	-	-	-	-	-	49°	43°
16, . .	3.00	3.02	-	-	-	-	-	-	-	-	-	49°	43°
17, . .	3.00	3.14	1.40	24.60	.0012	.0092	.0104	5.33	.7000	.0000	-	-	47°
18, . .	3.00	2.98	-	-	-	-	-	-	-	-	-	48°	48°
19, . .	6.00	5.78	-	-	-	-	-	-	-	-	-	46°	44°
20, . .	-	.49	-	-	-	-	-	-	-	-	-	-	-
21, . .	3.00	2.50	.90	18.40	.0006	.0058	.0064	2.52	.8000	.0002	.092	48°	42°
22, . .	3.00	3.05	-	-	-	-	-	-	-	-	-	46°	43°
23, . .	3.00	3.07	-	-	-	-	-	-	-	-	-	46°	43°
24, . .	3.00	3.04	1.80	15.70	.0000	.0054	.0054	2.49	.9000	.0000	.078	48°	45°
25, . .	3.00	3.01	-	-	-	-	-	-	-	-	-	45°	45°
26, . .	6.00	5.86	-	-	-	-	-	-	-	-	-	46°	45°
27, . .	-	.62	-	-	-	-	-	-	-	-	-	-	-
28, . .	3.00	2.49	.80	15.80	.0004	.0030	.0034	2.53	1.0000	.0002	.071	48°	46°
29, . .	3.00	3.05	-	-	-	-	-	-	-	-	-	48°	46°
30, . .	3.00	3.00	-	-	-	-	-	-	-	-	-	47°	42°
31, . .	3.00	3.09	.80	18.50	.0020	.0082	.0102	3.68	1.2000	.0001	-	47°	-

Effluent colorless, clear or nearly so and with very little or no sediment.

Beginning January 14, a solution of ammonium chloride and sodium carbonate in city water applied instead of sewage. January 14 to 27.—The solution contained 1.00 part per 100,000 of free ammonia. January 28 to 31.—It contained 2.00 parts.

Total effluent to end of month, 948.40 gallons.

Filter Tank No. 13 — Continued.

February, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Alkalinity.	Temperature. Sewage.	Temperature. Effluent.
1, . .	3.00	3.00	-	-	-	-	-	-	-	-	-	48°	44°
2, . .	6.00	5.86	-	-	-	-	-	-	-	-	-	46°	43°
3, . .	-	.55	-	-	-	-	-	-	-	-	-	-	-
4, . .	3.00	2.48	1.40	21.30	.0074	.0040	.0114	4.48	1.3000	.0003	-	47°	42°
5, . .	3.00	3.11	-	-	-	-	-	-	-	-	-	47°	42°
6, . .	3.00	3.48	-	-	-	-	-	-	-	-	-	47°	45°
7, . .	3.00	2.98	2.10	29.70	.0460	.0062	.0522	7.12	1.5000	.0018	-	48°	41°
8, . .	3.00	3.04	-	-	-	-	-	-	-	-	-	46°	39°
9, . .	6.00	5.98	-	-	-	-	-	-	-	-	-	46°	41°
10, . .	-	.63	-	-	-	-	-	-	-	-	-	-	-
11, . .	3.00	3.08	.90	33.20	.1160	.0160	.1320	8.40	1.8000	.0050	-	47°	-
12, . .	3.00	3.13	-	-	-	-	-	-	-	-	-	46°	43°
13, . .	3.00	3.10	-	-	-	-	-	-	-	-	-	46°	43°
14, . .	3.00	3.04	1.00	38.70	.1800	.0090	.1890	8.52	2.8000	.0200	-	46°	44°
15, . .	3.00	3.02	-	-	-	-	-	-	-	-	-	45°	45°
16, . .	6.00	5.92	-	-	-	-	-	-	-	-	-	46°	45°
17, . .	-	.97	-	-	-	-	-	-	-	-	-	-	-
18, . .	3.00	3.18	.70	42.20	.1760	.0060	.1820	8.47	3.0000	.1200	-	46°	43°
19, . .	3.00	3.03	-	-	-	-	-	-	-	-	-	45°	44°
20, . .	3.00	2.99	-	-	-	-	-	-	-	-	-	46°	42°
21, . .	3.00	3.01	2.10	40.20	.2120	.0060	.2180	8.30	3.0000	.1200	.075	46°	42°
22, . .	3.00	3.04	-	-	-	-	-	-	-	-	-	44°	43°
23, . .	6.00	5.83	-	-	-	-	-	-	-	-	-	45°	42°
24, . .	-	.63	-	-	-	-	-	-	-	-	-	-	-
25, . .	3.00	2.45	1.70	38.20	.1040	.0050	.1090	8.50	3.0000	.1670	-	45°	40°
26, . .	3.00	3.06	-	-	-	-	-	-	-	-	-	46°	41°
27, . .	3.00	3.02	-	-	-	-	-	-	-	-	-	46°	41°
28, . .	3.00	3.02	.70	39.90	.0600	.0030	.0630	8.50	3.0000	.2000	-	45°	44°

Effluent colorless, clear or nearly so and with very little sediment.

February 1 to 3. — The solution applied contained 2.00 parts per 100,000 of free ammonia. February 4 to 28. — It contained 4.00 parts.

Total effluent to end of month, 1035.03 gallons.

Filter Tank No. 13 — Continued.

March, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Alkalinity.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	3.00	2.99	-	-	-	-	-	-	-	-	-	46°	44°
2, . .	6.00	5.80	-	-	-	-	-	-	-	-	-	46°	-
3, . .	-	.61	-	-	-	-	-	-	-	-	-	-	-
4, . .	3.00	2.49	.80	40.30	.0130	.0070	.0200	8.47	3.1000	.1500	-	45°	46°
5, . .	3.00	2.98	-	-	-	-	-	-	-	-	-	46°	46°
6, . .	3.00	3.08	-	-	-	-	-	-	-	-	-	45°	43°
7, . .	3.00	3.09	2.80	40.20	.0110	.0050	.0160	8.35	3.2500	.0100	-	51°	44°
8, . .	3.00	2.98	-	-	-	-	-	-	-	-	-	54°	43°
9, . .	3.00	2.96	-	-	-	-	-	-	-	-	-	52°	41°
10, . .	-	.58	-	-	-	-	-	-	-	-	-	-	-
11, . .	3.00	2.40	1.30	40.10	.0012	.0038	.0050	8.55	3.1000	.0012	-	46°	43°
12, . .	3.00	3.02	-	-	-	-	-	-	-	-	-	56°	42°
13, . .	3.00	3.10	-	-	-	-	-	-	-	-	-	56°	43°
14, . .	3.00	2.99	.90	40.30	.0004	.0060	.0064	8.60	3.0000	.0005	.072	56°	46°
15, . .	3.00	3.00	-	-	-	-	-	-	-	-	-	53°	45°
16, . .	3.00	3.02	-	-	-	-	-	-	-	-	-	53°	44°
17, . .	-	.56	-	-	-	-	-	-	-	-	-	-	-
18, . .	3.00	2.39	1.40	41.80	.0022	.0062	.0084	8.50	3.0000	.0005	-	50°	44°
19, . .	3.00	3.06	-	-	-	-	-	-	-	-	-	55°	44°
20, . .	3.00	2.96	-	-	-	-	-	-	-	-	-	58°	44°
21, . .	3.00	2.98	1.60	55.10	.0010	.0058	.0068	13.50	3.2500	.0007	-	54°	44°
22, . .	3.00	3.07	-	-	-	-	-	-	-	-	-	52°	46°
23, . .	3.00	2.98	2.00	68.10	.0010	.0068	.0078	15.87	6.0000	.0090	-	59°	47°
24, . .	-	.62	-	-	-	-	-	-	-	-	-	-	-
25, . .	3.00	2.33	1.80	70.50	.0016	.0078	.0094	16.25	6.0000	.0050	-	54°	47°
26, . .	3.00	3.04	-	-	-	-	-	-	-	-	-	48°	46°
27, . .	3.00	3.02	-	-	-	-	-	-	-	-	-	55°	45°
28, . .	3.00	2.96	1.70	76.40	.0038	.0062	.0100	16.65	6.0000	.0030	-	65°	47°
29, . .	3.00	3.04	-	-	-	-	-	-	-	-	-	54°	48°
30, . .	3.00	2.94	-	-	-	-	-	-	-	-	-	52°	46°
31, . .	-	.57	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, clear or very nearly so, and generally with very little sediment.

March 1 to 17. — The solution applied contained 4.00 parts per 100,000 of free ammonia. March 18 to 31. — It contained 8.00 parts. Beginning March 7, the water to be applied was boiled and allowed to cool before the ammonium chloride and sodium carbonate were added.

Total effluent to end of month, 1116.64 gallons.

Filter Tank No. 13 — Continued.

April, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Alkalinity.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	3.00	2.38	1.70	76.60	.0024	.0058	.0082	17.00	5.5000	.0014	.105	48°	43°
2, . .	3.00	3.10	-	-	-	-	-	-	-	-	-	58°	43°
3, . .	3.00	3.04	-	-	-	-	-	-	-	-	-	56°	44°
4, . .	3.00	2.98	.60	74.80	.0016	.0060	.0076	17.13	6.0000	.0008	-	57°	45°
5, . .	3.00	3.02	-	-	-	-	-	-	-	-	-	54°	46°
6, . .	3.00	2.98	-	-	-	-	-	-	-	-	-	56°	46°
7, . .	-	.57	-	-	-	-	-	-	-	-	-	-	-
8, . .	3.00	2.43	1.50	79.50	.0022	.0064	.0086	16.60	5.5000	.0004	-	50°	48°
9, . .	3.00	3.08	-	-	-	-	-	-	-	-	-	58°	49°
10, . .	3.00	2.96	-	-	-	-	-	-	-	-	-	58°	50°
11, . .	3.00	3.04	2.20	73.70	.0018	.0064	.0082	16.76	6.0000	.0006	-	56°	-
12, . .	3.00	3.01	-	-	-	-	-	-	-	-	-	68°	53°
13, . .	3.00	2.90	-	-	-	-	-	-	-	-	-	63°	53°
14, . .	-	.56	-	-	-	-	-	-	-	-	-	-	-
15, . .	3.00	2.38	3.80	95.80	.0010	.0068	.0078	23.65	10.0000	.0020	.120	45°	49°
16, . .	3.00	3.03	-	-	-	-	-	-	-	-	-	52°	49°
17, . .	3.00	2.95	-	-	-	-	-	-	-	-	-	52°	49°
18, . .	3.00	3.05	7.20	132.00	.0040	.0092	.0132	32.55	10.0000	.0030	-	54°	49°
19, . .	3.00	3.06	-	-	-	-	-	-	-	-	-	62°	54°
20, . .	3.00	3.09	-	-	-	-	-	-	-	-	-	62°	-
21, . .	-	.96	-	-	-	-	-	-	-	-	-	-	-
22, . .	3.00	2.20	1.60	148.40	.0118	.0092	.0210	34.40	12.0000	.0250	.255	52°	53°
23, . .	3.00	3.00	-	-	-	-	-	-	-	-	-	50°	52°
24, . .	3.00	3.01	-	-	-	-	-	-	-	-	-	56°	52°
25, . .	3.00	3.04	5.60	184.60	.8200	.0180	.8380	53.40	12.0000	.0450	-	64°	56°
26, . .	3.00	2.95	-	-	-	-	-	-	-	-	-	64°	57°
27, . .	3.00	3.03	-	-	-	-	-	-	-	-	-	60°	54°
28, . .	-	.64	-	-	-	-	-	-	-	-	-	-	-
29, . .	3.00	2.41	10.40	249.80	3.5700	.0510	3.6210	67.30	15.0000	.2000	.557	54°	56°
30, . .	3.00	3.07	-	-	-	-	-	-	-	-	-	53°	56°

Effluent generally clear and colorless and with very slight sediment.

April 1 to 11.—The solution applied contained 8.00 parts per 100,000 of free ammonia. April 12 to 22.—It contained 16.00 parts. April 23 to 30.—It contained 34.00 parts. Until about April 17, the ammonium chloride and sodium carbonate were added together, but afterwards separately.

April 29 to August 29.—The water to be applied was not boiled.

Total effluent to end of month, 1194.56 gallons.

Filter Tank No. 13 — Continued.

May, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Alkalinity.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	3.00	2.96	-	-	-	-	-	-	-	-	-	51°	54°
2, . .	3.00	3.02	23.00	276.00	4.0900	.0100	4.1000	70.20	20.0000	.2600	-	52°	55°
3, . .	3.00	2.98	-	-	-	-	-	-	-	-	-	50°	-
4, . .	3.00	2.97	-	-	-	-	-	-	-	-	-	52°	55°
5, . .	-	.57	-	-	-	-	-	-	-	-	-	-	-
6, . .	3.00	2.43	-	-	2.5500	.0700	2.6200	71.20	22.0000	.2300	.405	56°	59°
7, . .	3.00	2.97	-	-	-	-	-	-	-	-	-	51°	58°
8, . .	3.00	3.03	-	-	-	-	-	-	-	-	-	52°	59°
9, . .	3.00	3.07	12.00	304.00	1.6900	.0200	1.7100	72.20	26.0000	.1000	-	54°	63°
10, . .	3.00	2.83	-	-	-	-	-	-	-	-	-	67°	66°
11, . .	3.00	3.02	-	-	-	-	-	-	-	-	-	54°	64°
12, . .	-	.44	-	-	-	-	-	-	-	-	-	-	-
13, . .	3.00	2.34	8.00	306.80	.4100	.0240	.4340	72.30	24.0000	.0260	.215	56°	62°
14, . .	3.00	2.95	-	-	-	-	-	-	-	-	-	55°	61°
15, . .	3.00	3.05	-	-	-	-	-	-	-	-	-	58°	64°
16, . .	3.00	2.98	-	-	.2520	.0140	.2660	72.40	24.0000	.0010	.150	58°	64°
17, . .	3.00	3.10	-	-	-	-	-	-	-	-	-	59°	66°
18, . .	3.00	2.99	-	-	-	-	-	-	-	-	-	63°	69°
19, . .	-	.55	-	-	-	-	-	-	-	-	-	-	-
20, . .	3.00	2.35	12.00	314.00	.0520	.0170	.0690	73.00	26.0000	.0008	-	58°	66°
21, . .	3.00	3.01	-	-	-	-	-	-	-	-	-	60°	65°
22, . .	3.00	3.04	-	-	-	-	-	-	-	-	-	62°	66°
23, . .	3.00	2.94	-	-	-	-	-	-	-	-	-	60°	63°
24, . .	3.00	3.02	-	-	-	-	-	-	-	-	-	60°	62°
25, . .	3.00	3.00	-	-	-	-	-	-	-	-	-	60°	63°
26, . .	-	.50	-	-	-	-	-	-	-	-	-	-	-
27, . .	3.00	2.33	1.00	308.00	.0840	.0120	.0960	72.80	24.0000	.0020	.170	57°	55°
28, . .	3.00	3.06	-	-	-	-	-	-	-	-	-	61°	61°
29, . .	3.00	2.99	-	-	-	-	-	-	-	-	-	59°	61°
30, . .	3.00	2.98	-	-	.4440	.0250	.4690	72.90	25.0000	.0200	-	59°	60°
31, . .	3.00	3.13	-	-	-	-	-	-	-	-	-	62°	66°

Effluent clear or nearly so, with very slight sediment, and with color from 0 to 0.1.
The solution applied contained 34.00 parts per 100,000 of free ammonia throughout the month.
Total effluent to end of month, 1275.16 gallons.

Filter Tank No. 13 — Continued.

June, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Alkalinity.	Temperature. Sewage.	Temperature. Effluent.
1, . .	3.00	3.05	-	-	-	-	-	-	-	-	-	61°	66°
2, . .	-	.54	-	-	-	-	-	-	-	-	-	-	-
3, . .	3.00	2.47	-	-	-	-	-	-	-	-	-	60°	65°
4, . .	3.00	3.08	-	-	-	-	-	-	-	-	-	60°	65°
5, . .	3.00	3.14	-	-	-	-	-	-	-	-	-	62°	65°
6, . .	3.00	3.01	7.00	301.00	.0280	.0150	.0430	70.50	24.0000	.0004	-	61°	66°
7, . .	3.00	2.94	-	-	-	-	-	-	-	-	-	61°	65°
8, . .	3.00	2.91	-	-	-	-	-	-	-	-	-	60°	64°
9, . .	-	.52	-	-	-	-	-	-	-	-	-	-	-
10, . .	3.00	2.48	16.00	298.00	.0400	.0140	.0540	71.40	25.0000	.0018	-	65°	70°
11, . .	3.00	3.02	-	-	-	-	-	-	-	-	-	69°	72°
12, . .	3.00	2.89	-	-	-	-	-	-	-	-	-	64°	70°
13, . .	3.00	2.96	-	-	-	-	-	-	-	-	-	71°	72°
14, . .	3.00	3.06	-	-	-	-	-	-	-	-	-	66°	72°
15, . .	3.00	2.95	-	-	-	-	-	-	-	-	-	64°	73°
16, . .	-	.58	-	-	-	-	-	-	-	-	-	-	-
17, . .	3.00	2.34	-	-	-	-	-	-	-	-	-	69°	74°
18, . .	3.00	2.91	-	-	-	-	-	-	-	-	-	63°	66°
19, . .	3.00	2.92	-	-	-	-	-	-	-	-	-	63°	64°
20, . .	3.00	3.34	3.00	284.00	3.0000	.0380	3.0380	68.50	26.0000	.0060	.370	65°	69°
21, . .	3.00	2.92	-	-	-	-	-	-	-	-	-	67°	72°
22, . .	3.00	2.89	-	-	-	-	-	-	-	-	-	66°	72°
23, . .	-	.52	-	-	-	-	-	-	-	-	-	-	-
24, . .	3.00	2.36	12.00	313.00	1.0000	.0700	1.0700	71.10	28.0000	.0040	.342	65°	70°
25, . .	3.00	2.95	-	-	-	-	-	-	-	-	-	66°	67°
26, . .	3.00	2.97	-	-	-	-	-	-	-	-	-	67°	69°
27, . .	3.00	2.97	20.00	338.00	1.4000	.1300	1.5300	70.60	27.0000	.0009	.615	71°	72°
28, . .	3.00	2.95	-	-	-	-	-	-	-	-	-	69°	75°
29, . .	3.00	2.95	-	-	-	-	-	-	-	-	-	70°	76°
30, . .	-	.50	-	-	-	-	-	-	-	-	-	-	-

Effluent nearly clear and with very slight sediment, and with color from 0 to 0.2.
The solution applied contained 34.00 parts per 100,000 of free ammonia.
June 17. — Samples of sand taken.
Total effluent to end of month, 1350.25 gallons.

Filter Tank No. 13 — Continued.

July, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Alkalinity.	Temperature. Sewage.	Temperature. Effluent.
1, . .	3.00	2.38	38.00	366.00	.3120	.0440	.3560	71.20	28.0000	.0060	.710	71°	76°
2, . .	3.00	3.50	-	-	-	-	-	-	-	-	-	69°	79°
3, . .	3.00	2.99	-	-	-	-	-	-	-	-	-	70°	73°
4, . .	3.00	3.01	-	-	-	-	-	-	-	-	-	72°	-
5, . .	3.00	2.91	8.00	352.00	1.3600	.0720	1.4320	71.40	25.0000	.0225	.860	71°	72°
6, . .	3.00	2.92	-	-	-	-	-	-	-	-	-	71°	-
7, . .	-	.55	-	-	-	-	-	-	-	-	-	-	-
8, . .	3.00	2.42	10.00	314.00	1.4400	.0700	1.5100	61.20	22.0000	.0200	.720	72°	73°
9, . .	3.00	3.01	-	-	-	-	-	-	-	-	-	70°	-
10, . .	1.50	1.41	-	-	-	-	-	-	-	-	-	68°	67°
11, . .	1.50	1.42	-	-	-	-	-	-	-	-	-	67°	67°
12, . .	1.50	1.59	-	-	-	-	-	-	-	-	-	71°	70°
13, . .	1.50	1.51	-	-	-	-	-	-	-	-	-	73°	74°
14, . .	-	.55	-	-	-	-	-	-	-	-	-	-	-
15, . .	1.50	.91	36.00	536.00	.6000	.0740	.6740	109.30	30.0000	.0200	1.305	65°	65°
16, . .	1.50	1.46	-	-	-	-	-	-	-	-	-	67°	66°
17, . .	1.50	1.51	-	-	-	-	-	-	-	-	-	69°	68°
18, . .	1.50	1.43	28.00	660.00	2.0000	.0740	2.0740	123.70	34.0000	.2600	1.800	70°	-
19, . .	1.50	1.53	-	-	-	-	-	-	-	-	-	70°	71°
20, . .	1.50	1.51	-	-	-	-	-	-	-	-	-	67°	69°
21, . .	-	.53	-	-	-	-	-	-	-	-	-	-	-
22, . .	1.50	1.04	29.00	619.00	1.6000	.0700	1.6700	106.60	43.0000	.0160	2.000	70°	71°
23, . .	1.50	1.41	-	-	-	-	-	-	-	-	-	69°	70°
24, . .	1.50	1.42	-	-	-	-	-	-	-	-	-	68°	69°
25, . .	1.50	1.44	-	-	-	-	-	-	-	-	-	70°	68°
26, . .	1.50	1.47	26.00	722.00	3.4800	.0700	3.5500	143.70	40.0000	.9000	2.100	70°	71°
27, . .	1.50	1.39	-	-	-	-	-	-	-	-	-	69°	67°
28, . .	-	.53	-	-	-	-	-	-	-	-	-	-	-
29, . .	1.50	1.24	18.00	722.00	2.3200	.1300	2.4500	143.20	45.0000	.5000	1.865	72°	-
30, . .	1.50	1.53	-	-	-	-	-	-	-	-	-	72°	75°
31, . .	1.50	1.49	-	-	-	-	-	-	-	-	-	70°	74°

Average color of effluent 0.3. From very slightly milky to distinct turbidity and from no sediment to considerable.

July 2 to 9. — The solution applied contained 34 parts per 100,000 of free ammonia and 50 per cent. more soda than required to form nitrate with the nitrogen present. July 10 to 31. — It contained 68 parts per 100,000 of free ammonia and soda as before. July 2, 6, 9, 18 and 29. — Bottom of tank sterilized by forcing in hot water.

Total effluent to end of month, 1402.26 gallons.

Filter Tank No. 13 — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Alkalinity.	Temperature. Sewage.	Temperature. Effluent.
1, . .	1.50	1.94	10.00	674.00	1.4000	.0900	1.4900	136.70	50.0000	1.0000	-	71°	-
2, . .	1.50	1.25	-	-	-	-	-	-	-	-	-	70°	-
3, . .	1.50	1.56	-	-	-	-	-	-	-	-	-	70°	74°
4, . .	-	.50	-	-	-	-	-	-	-	-	-	-	-
5, . .	1.50	.95	34.00	676.00	1.5000	.0270	1.5270	137.90	48.0000	1.2000	1.725	69°	69°
6, . .	1.50	1.44	-	-	-	-	-	-	-	-	-	70°	70°
7, . .	1.50	1.42	-	-	-	-	-	-	-	-	-	70°	70°
8, . .	1.50	1.39	36.00	716.00	.6000	.0320	.6320	142.20	57.0000	1.0000	1.720	69°	69°
9, . .	1.50	1.45	-	-	-	-	-	-	-	-	-	69°	71°
10, . .	1.50	1.45	-	-	-	-	-	-	-	-	-	70°	73°
11, . .	-	.59	-	-	-	-	-	-	-	-	-	-	-
12, . .	1.50	.77	-	-	-	-	-	-	-	-	-	68°	67°
13, . .	1.50	1.01	-	-	-	-	-	-	-	-	-	69°	-
14, . .	1.50	1.72	-	-	.1520	.0200	.1720	105.30	55.0000	.0400	.585	66°	68°
15, . .	1.50	1.48	-	-	-	-	-	-	-	-	-	66°	65°
16, . .	1.50	1.48	-	-	-	-	-	-	-	-	-	68°	69°
17, . .	1.50	1.51	-	-	-	-	-	-	-	-	-	68°	69°
18, . .	-	.52	-	-	-	-	-	-	-	-	-	-	-
19, . .	1.50	.73	-	-	.2480	.0260	.2740	140.80	48.0000	.4000	.940	68°	71°
20, . .	1.50	1.48	-	-	-	-	-	-	-	-	-	69°	69°
21, . .	1.50	1.46	-	-	-	-	-	-	-	-	-	68°	70°
22, . .	1.50	1.14	-	-	-	-	-	-	-	-	-	70°	-
23, . .	1.50	1.67	-	-	-	-	-	-	-	-	-	69°	70°
24, . .	1.50	1.11	-	-	-	-	-	-	-	-	-	67°	70°
25, . .	-	.61	-	-	-	-	-	-	-	-	-	-	-
26, . .	1.50	.84	-	-	.1540	.0120	.1660	146.50	46.0000	.5500	-	68°	68°
27, . .	1.50	1.39	-	-	-	-	-	-	-	-	-	68°	66°
28, . .	1.50	1.56	-	-	-	-	-	-	-	-	-	68°	66°
29, . .	1.50	1.45	-	-	-	-	-	-	-	-	-	67°	67°
30, . .	1.50	1.47	-	-	-	-	-	-	-	-	-	-	69°
31, . .	1.50	1.29	-	-	-	-	-	-	-	-	-	79°	72°

Effluent generally clear and free from sediment with color from 0 to 0.15.

August 1 to 5.— The solution applied contained 68 parts per 100,000 of free ammonia and 50 per cent. more soda than required to form nitrate with the nitrogen present. August 6 to 31.— It contained free ammonia as before but soda was reduced to just form nitrate with the nitrogen present. August 2, 13 and 22.— Bottom of tank sterilized by forcing in hot water. After August 30.— Water applied to tank was boiled one hour and allowed to cool.

Total effluent to end of month, 1440.89 gallons.

Filter Tank No. 13 — Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Alkalinity.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	–	.55	–	–	–	–	–	–	–	–	–	–	–
2, . .	1.50	1.00	24.00	668.00	7.0000	–	–	165.40	30.0000	16.0000	.820	81°	70°
3, . .	1.50	1.51	–	–	–	–	–	–	–	–	–	70°	70°
4, . .	1.50	1.37	–	–	–	–	–	–	–	–	–	70°	71°
5, . .	1.50	2.07	–	–	–	–	–	–	–	–	–	70°	70°
6, . .	1.50	1.42	–	–	5.0000	–	–	158.20	40.0000	9.0000	.835	73°	73°
7, . .	1.50	1.39	–	–	–	–	–	–	–	–	–	74°	70°
8, . .	–	.50	–	–	–	–	–	–	–	–	–	–	–
9, . .	1.50	.97	–	–	1.9000	–	–	152.90	45.0000	5.0000	–	67°	69°
10, . .	1.50	1.19	–	–	–	–	–	–	–	–	–	81°	67°
11, . .	1.50	1.56	–	–	1.1700	.0200	1.1900	153.00	45.0000	2.5000	.500	70°	65°
12, . .	1.50	1.44	–	–	–	–	–	–	–	–	–	69°	66°
13, . .	1.50	1.43	–	–	1.4000	.0300	1.4300	150.10	40.0000	4.0000	.575	69°	66°
14, . .	1.50	1.43	–	–	–	–	–	–	–	–	–	69°	68°
15, . .	–	.51	–	–	–	–	–	–	–	–	–	–	–
16, . .	1.50	1.01	18.00	600.00	.5000	.0400	.5400	147.20	50.0000	.3000	.425	72°	72°
17, . .	1.50	1.40	–	–	–	–	–	–	–	–	–	78°	72°
18, . .	1.50	1.42	–	–	.3300	.0500	.3800	145.30	45.0000	.8500	.465	73°	69°
19, . .	1.50	1.48	–	–	–	–	–	–	–	–	–	62°	63°
20, . .	1.50	1.42	–	–	–	–	–	–	–	–	–	61°	62°
21, . .	1.50	1.41	–	–	–	–	–	–	–	–	–	65°	62°
22, . .	–	.49	–	–	–	–	–	–	–	–	–	–	–
23, . .	1.50	.95	–	–	.3000	.0800	.3800	143.00	40.0000	.9000	–	52°	60°
24, . .	1.50	1.42	–	–	–	–	–	–	–	–	–	57°	62°
25, . .	1.50	1.45	–	–	–	–	–	–	–	–	–	61°	62°
26, . .	1.50	1.44	–	–	.2000	.0500	.2500	142.10	37.0000	3.0000	–	65°	64°
27, . .	1.50	1.39	–	–	–	–	–	–	–	–	–	63°	61°
28, . .	1.50	1.40	–	–	.8000	.0600	.8600	141.70	42.0000	1.0000	–	55°	57°
29, . .	–	.50	–	–	–	–	–	–	–	–	–	–	–
30, . .	1.50	.80	–	–	–	–	–	–	–	–	–	82°	61°

Effluent generally clear and free from sediment, with color from 0 to 0.1.

The solution applied contained 68 parts per 100,000 of free ammonia, and enough soda to just form nitrate with the nitrogen present.

Total effluent to end of month, 1477.21 gallons.

Filter Tank No. 13 — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Alkalinity.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, . .	1.50	1.47	-	-	-	-	-	-	-	-	-	64°	62°
2, . .	1.50	1.43	-	-	-	-	-	-	-	-	-	64°	62°
3, . .	1.50	1.44	-	-	-	-	-	-	-	-	-	54°	61°
4, . .	1.50	1.42	-	-	-	-	-	-	-	-	-	62°	60°
5, . .	1.50	1.01	-	-	.2300	.0600	.2900	140.00	45.0000	.7000	.465	57°	56°
6, . .	-	.55	-	-	-	-	-	-	-	-	-	-	-
7, . .	1.50	.90	-	-	-	-	-	-	-	-	-	56°	59°
8, . .	1.50	1.38	-	-	-	-	-	-	-	-	-	58°	55°
9, . .	1.50	1.43	-	-	-	-	-	-	-	-	-	53°	54°
10, . .	1.50	1.40	-	-	-	-	-	-	-	-	-	55°	53°
11, . .	1.50	1.46	-	-	-	-	-	-	-	-	-	54°	54°
12, . .	1.50	1.47	-	-	10.0000	-	-	142.30	38.0000	.0240	.155	52°	55°
13, . .	-	.55	-	-	-	-	-	-	-	-	-	-	-
14, . .	1.50	.87	-	-	-	-	-	-	-	-	-	44°	49°
15, . .	1.50	1.49	-	-	-	-	-	-	-	-	-	52°	53°
16, . .	1.50	1.42	-	-	-	-	-	-	-	-	-	51°	52°
17, . .	1.50	1.45	-	-	-	-	-	-	-	-	-	48°	53°
18, . .	1.50	1.46	-	-	-	-	-	-	-	-	-	54°	53°
19, . .	1.50	1.45	-	-	37.0000	-	-	143.00	4.2000	.0080	.045	48°	54°
20, . .	-	.60	-	-	-	-	-	-	-	-	-	-	-
21, . .	1.50	.88	-	-	-	-	-	-	-	-	-	53°	50°
22, . .	1.50	1.33	-	-	-	-	-	-	-	-	-	53°	50°
23, . .	1.50	1.46	-	-	42.0000	-	-	143.10	13.0000	.0150	.085	47°	48°
24, . .	1.50	1.44	-	-	-	-	-	-	-	-	-	45°	46°
25, . .	1.50	1.48	-	-	-	-	-	-	-	-	-	48°	49°
26, . .	1.50	1.51	-	-	34.0000	-	-	140.00	15.0000	6.0000	.310	51°	52°
27, . .	-	.55	-	-	-	-	-	-	-	-	-	-	-
28, . .	1.50	1.01	-	-	-	-	-	-	-	-	-	52°	53°
29, . .	1.50	1.44	-	-	-	-	-	-	-	-	-	55°	51°
30, . .	1.50	1.45	-	-	-	-	-	-	-	-	-	51°	50°
31, . .	1.50	1.47	-	-	-	-	-	-	-	-	-	53°	52°

Effluent colorless, free from sediment and generally clear.

October 1 to 7.—The solution applied contained 68 parts per 100,000 of free ammonia and enough soda to just form nitrate with the nitrogen present. October 8 to 31. —It contained free ammonia as before, but the soda was reduced to just enough to form nitrate with one-half of nitrogen present.

Total effluent to end of month, 1515.88 gallons.

Filter Tank No. 13 — Continued.

November, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Alkalinity.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	1.50	1.45	–	–	–	–	–	–	–	–	–	53°	52°
2, .	1.50	1.51	–	–	30.0000	–	–	140.00	17.0000	3.5000	.380	54°	53°
3, .	–	.54	–	–	–	–	–	–	–	–	–	–	–
4, .	1.50	1.00	–	–	–	–	–	–	–	–	–	50°	53°
5, .	1.50	1.35	–	–	–	–	–	–	–	–	–	51°	48°
6, .	1.50	1.43	–	–	–	–	–	–	–	–	–	49°	48°
7, .	1.50	1.51	–	–	–	–	–	–	–	–	–	48°	51°
8, .	1.50	1.48	–	–	–	–	–	–	–	–	–	56°	52°
9, .	1.50	1.46	21.00	429.00	26.0000	–	–	140.00	30.0000	9.0000	.480	58°	53°
10, .	–	.52	–	–	–	–	–	–	–	–	–	–	–
11, .	1.50	1.00	–	–	–	–	–	–	–	–	–	51°	51°
12, .	1.50	1.45	–	–	–	–	–	–	–	–	–	59°	53°
13, .	1.50	1.49	–	–	–	–	–	–	–	–	–	60°	54°
14, .	1.50	1.51	–	–	–	–	–	–	–	–	–	60°	67°
15, .	1.50	1.35	–	–	–	–	–	–	–	–	–	56°	50°
16, .	1.50	1.39	–	–	21.0000	–	–	141.00	22.0000	9.0000	.380	50°	49°
17, .	–	.52	–	–	–	–	–	–	–	–	–	–	–
18, .	1.50	1.03	–	–	–	–	–	–	–	–	–	46°	47°
19, .	1.50	1.56	–	–	–	–	–	–	–	–	–	54°	50°
20, .	1.50	1.55	–	–	–	–	–	–	–	–	–	61°	52°
21, .	1.50	1.51	–	–	–	–	–	–	–	–	–	62°	52°
22, .	1.50	1.49	–	–	–	–	–	–	–	–	–	62°	51°
23, .	1.50	1.46	–	–	19.0000	–	–	142.00	25.0000	9.0000	.470	60°	52°
24, .	–	.52	–	–	–	–	–	–	–	–	–	–	–
25, .	1.50	1.02	–	–	–	–	–	–	–	–	–	55°	50°
26, .	1.50	1.43	–	–	–	–	–	–	–	–	–	52°	47°
27, .	1.50	1.49	–	–	–	–	–	–	–	–	–	50°	45°
28, .	1.50	1.56	–	–	–	–	–	–	–	–	–	54°	47°
29, .	1.50	1.49	–	–	–	–	–	–	–	–	–	52°	49°
30,	1.50	1.48	–	–	19.0000	–	–	140.00	17.0000	17.0000	.550	50°	44°

Effluent colorless and generally clear and free from sediment.

The solution applied contained 68 parts per 100,000 of free ammonia and enough soda to form nitrate with one-half of the nitrogen present.

Total effluent to end of month, 1554.43 gallons.

Filter Tank No 13 — Continued.

December, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Alkalinity.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1,	-	.51	-	-	-	-	-	-	-	-	-	-	-
2,	1.50	1.07	-	-	-	-	-	-	-	-	-	46°	45°
3,	1.50	1.39	-	-	-	-	-	-	-	-	-	46°	45°
4,	1.50	2.15	-	-	-	-	-	-	-	-	-	44°	41°
5,	1.50	1.46	-	-	-	-	-	-	-	-	-	45°	41°
6,	1.50	1.49	-	-	-	-	-	-	-	-	-	51°	44
7,	1.50	1.57	-	-	10.2000	-	-	102.00	13.7000	15.0000	1.230	50°	47°
8,	-	.52	-	-	-	-	-	-	-	-	-	-	-
9,	1.50	1.12	-	-	-	-	-	-	-	-	-	54°	49°
10,	1.50	1.43	-	-	-	-	-	-	-	-	-	49°	47°
11,	1.50	1.11	-	-	20.5000	-	-	142.00	15.3000	20.0000	-	53°	45°
12,	1.50	1.44	-	-	-	-	-	-	-	-	-	49°	44°
13,	1.50	1.50	-	-	-	-	-	-	-	-	-	46°	44°
14,	1.50	1.40	-	-	23.0000	-	-	142.00	12.0000	20.0000	1.010	38°	39°
15,	-	.52	-	-	-	-	-	-	-	-	-	-	-
16,	1.50	1.10	-	-	-	-	-	-	-	-	-	43°	43°
17,	1.50	1.45	-	-	-	-	-	-	-	-	-	44°	43°
18,	1.50	1.51	-	-	-	-	-	-	-	-	-	47°	43°
19,	1.50	1.55	-	-	-	-	-	-	-	-	-	50°	49°
20,	1.50	1.51	-	-	-	-	-	-	-	-	-	50°	46°
21,	1.50	1.54	-	-	19.5000	-	-	139.50	19.0000	10.0000	.950	55°	49°
22,	-	.48	-	-	-	-	-	-	-	-	-	-	-
23,	1.50	1.03	-	-	-	-	-	-	-	-	-	45°	44°
24,	1.50	1.48	-	-	-	-	-	-	-	-	-	45°	43°
25,	1.50	1.60	-	-	-	-	-	-	-	-	-	50°	-
26,	1.50	1.41	-	-	-	-	-	-	-	-	-	51°	46°
27,	1.50	1.44	-	-	-	-	-	-	-	-	-	47°	44°
28,	1.50	1.45	-	-	18.5000	-	-	145.00	13.0000	30.0000	1.040	44°	44°
29,	-	.52	-	-	-	-	-	-	-	-	-	-	-
30,	1.50	.97	-	-	-	-	-	-	-	-	-	46°	45°
31,	1.50	1.63	-	-	-	-	-	-	-	-	-	44°	41°

Effluent colorless or nearly so, clear or slightly turbid and free from sediment.

The solution applied contained 68 parts per 100,000 of free ammonia and enough soda to just form nitrate with one-half of the nitrogen present.

Total effluent to end of month, 1593.78 gallons.

Filter Tank No. 13 — Continued.

January, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Alkalinity.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1,	1.50	1.47	-	-	-	-	-	-	-	-	-	47°	42°
2,	1.50	1.57	-	-	-	-	-	-	-	-	-	54°	49°
3,	1.50	1.45	-	-	-	-	-	-	-	-	-	56°	47°
4,	1.50	1.43	76.00	420.00	32.0000	-	-	143.00	7.3000	21.0000	1.100	46°	44°
5,	-	.50	-	-	-	-	-	-	-	-	-	-	-
6,	1.50	1.09	-	-	-	-	-	-	-	-	-	45°	44°
7,	1.50	1.45	-	-	-	-	-	-	-	-	-	54°	45°
8,	1.50	1.48	-	-	-	-	-	-	-	-	-	46°	45°
9,	1.50	1.43	-	-	-	-	-	-	-	-	-	42°	40°
10,	1.50	1.37	-	-	-	-	-	-	-	-	-	40°	36°
11,	1.50	1.46	-	-	26.0000	-	-	143.00	9.0000	20.0000	1.300	42°	37°
12,	-	.54	-	-	-	-	-	-	-	-	-	-	-
13,	1.50	1.14	-	-	-	-	-	-	-	-	-	45°	44°
14,	1.50	1.45	-	-	-	-	-	-	-	-	-	46°	44°
15,	1.50	1.48	-	-	-	-	-	-	-	-	-	42°	41°
16,	1.50	1.54	-	-	-	-	-	-	-	-	-	50°	44°
17,	1.50	1.36	-	-	-	-	-	-	-	-	-	38°	39°
18,	1.50	1.57	-	-	24.5000	-	-	143.00	7.0000	15.0000	1.150	40°	41°
19,	-	.59	-	-	-	-	-	-	-	-	-	-	-
20,	1.50	1.06	-	-	-	-	-	-	-	-	-	50°	47°
21,	1.50	1.40	-	-	-	-	-	-	-	-	-	49°	46°
22,	1.50	1.39	-	-	-	-	-	-	-	-	-	-	38°
23,	1.50	1.54	-	-	-	-	-	-	-	-	-	34°	37°
24,	1.50	1.54	-	-	-	-	-	-	-	-	-	38°	38°
25,	1.50	1.44	-	-	28.0000	-	-	139.00	8.4000	18.0000	1.290	37°	38°
26,	-	.52	-	-	-	-	-	-	-	-	-	-	-
27,	1.50	1.10	-	-	-	-	-	-	-	-	-	43°	40°
28,	1.50	1.43	-	-	-	-	-	-	-	-	-	43°	37°
29,	1.50	1.52	-	-	-	-	-	-	-	-	-	43°	42°
30,	1.50	1.60	-	-	-	-	-	-	-	-	-	48°	40°
31,	1.50	1.52	-	-	17.0000	-	-	124.00	10.0000	15.0000	-	42°	39°

Effluent free from sediment clear, or nearly so, and with color from 0 to 0.1.

The solution applied contained 68 parts per 100,000 of free ammonia and enough soda to just form nitrate with one half of the nitrogen present.

Total effluent to end of month, 1,634.21 gallons.

Filter Tank No. 13 — Continued.

February, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Alkalinity.	Temperature. Sewage.	Temperature. Effluent.
1,	1.50	1.63	-	-	-	-	-	-	-	-	-	47°	41°
2,	-	.47	-	-	-	-	-	-	-	-	-	-	-
3,	1.50	1.12	-	-	-	-	-	-	-	-	-	42°	43°
4,	1.50	1.52	-	-	-	-	-	-	-	-	-	52°	44°
5,	1.50	1.52	-	-	-	-	-	-	-	-	-	53°	47°
6,	1.50	1.45	-	-	-	-	-	-	-	-	-	42°	42°
7,	1.50	1.53	-	-	18.0000	-	-	135.56	8.0000	20.0000	.920	38°	38°
8,	1.50	1.55	-	-	-	-	-	-	-	-	-	46°	43°
9,	-	.52	-	-	-	-	-	-	-	-	-	-	-
10,	1.50	1.08	-	-	-	-	-	-	-	-	-	37°	-
11,	1.50	1.50	-	-	-	-	-	-	-	-	-	45°	41°
12,	1.50	1.55	-	-	-	-	-	-	-	-	-	46°	44°
13,	1.50	1.56	-	-	-	-	-	-	-	-	-	45°	44°
14,	1.50	1.49	-	-	23.0000	-	-	135.00	8.7000	20.0000	.800	51°	44°
15,	1.50	1.47	-	-	-	-	-	-	-	-	-	53°	46°
16,	-	.56	-	-	-	-	-	-	-	-	-	-	-
17,	1.50	1.08	-	-	-	-	-	-	-	-	-	43°	44°
18,	1.50	1.45	-	-	-	-	-	-	-	-	-	49°	40°
19,	1.50	1.54	-	-	-	-	-	-	-	-	-	44°	41°
20,	1.50	1.52	-	-	-	-	-	-	-	-	-	43°	41°
21,	1.50	1.47	-	-	23.0000	-	-	139.00	11.0000	24.0000	1.050	38°	37°
22,	1.50	1.51	-	-	-	-	-	-	-	-	-	38°	37°
23,	-	.58	-	-	-	-	-	-	-	-	-	-	-
24,	1.50	1.15	-	-	-	-	-	-	-	-	-	43°	43°
25,	1.50	1.48	-	-	-	-	-	-	-	-	-	48°	42°
26,	1.50	1.60	-	-	-	-	-	-	-	-	-	51°	46°
27,	1.50	1.54	-	-	-	-	-	-	-	-	-	51°	45°
28,	1.50	1.49	-	-	21.0000	-	-	139.00	10.5000	24.0000	.900	51°	45°

Effluent free from sediment and generally clear, with color from 0.1 to 0.2.

The solution applied contained 68 parts per 100,000 of free ammonia and enough soda to just form nitrate with one half of the nitrogen present.

Total effluent to end of month, 1,671.14 gallons.

Filter Tank No. 13 — Concluded.

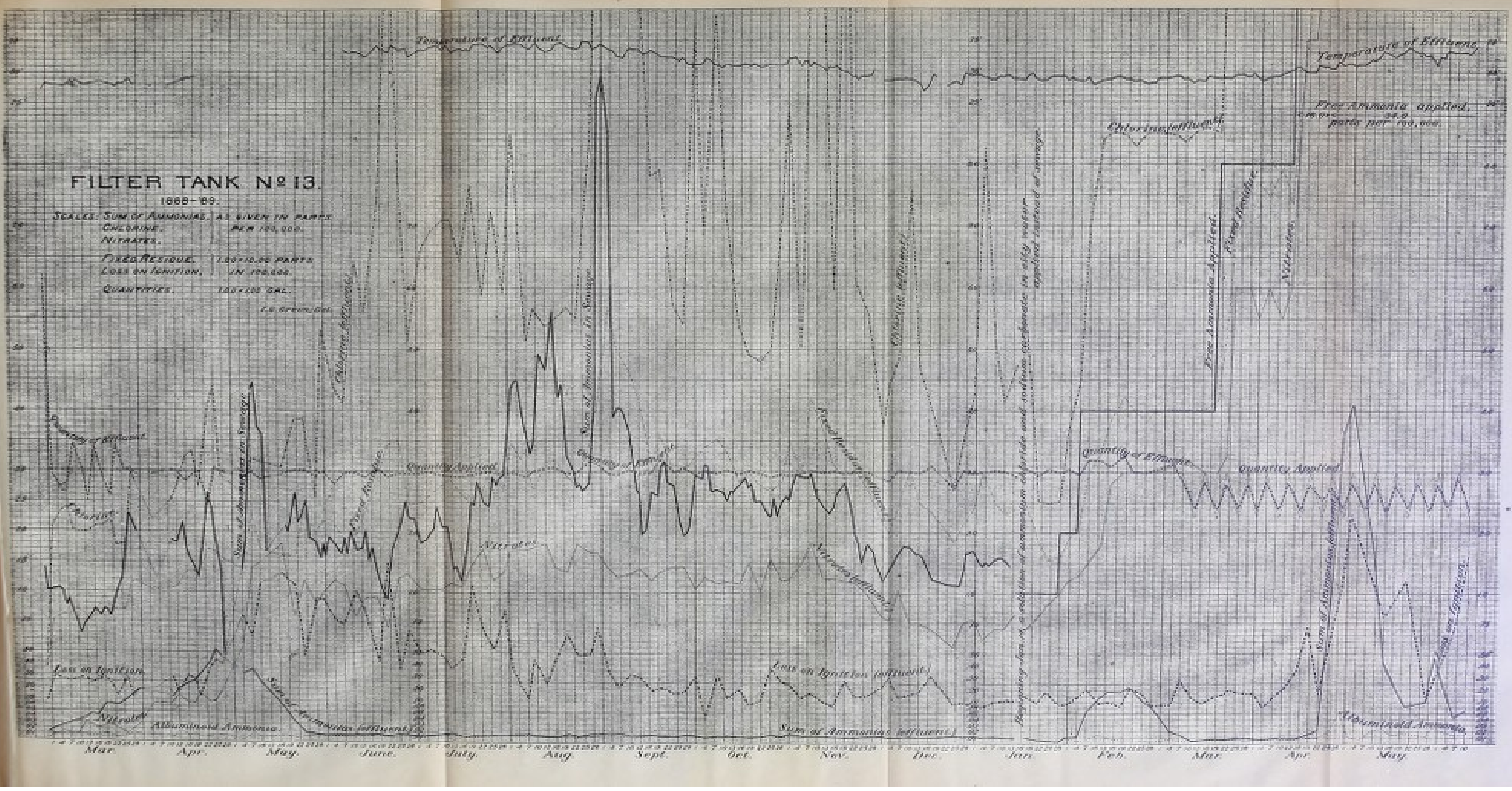
March, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Alkalinity.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	1.50	1.54	–	–	–	–	–	–	–	–	–	50°	46°
2, .	–	.52	–	–	–	–	–	–	–	–	–	–	–
3, .	1.50	1.05	–	–	–	–	–	–	–	–	–	50°	39°
4, .	1.50	1.51	–	–	–	–	–	–	–	–	–	40°	42°
5, .	1.50	1.51	–	–	–	–	–	–	–	–	–	45°	44°
6, .	1.50	1.48	–	–	–	–	–	–	–	–	–	45°	39°
7, .	1.50	1.48	–	–	24.0000	–	–	140.00	13.0000	16.0000	2.000	42°	38°
8, .	1.50	1.54	–	–	–	–	–	–	–	–	–	41°	40°
9, .	–	.56	–	–	–	–	–	–	–	–	–	–	–
10, .	1.50	1.13	–	–	–	–	–	–	–	–	–	36°	43°
11, .	1.50	1.48	–	–	–	–	–	–	–	–	–	50°	43°
12, .	1.50	1.58	–	–	–	–	–	–	–	–	–	48°	47°
13, .	1.50	1.54	–	–	–	–	–	–	–	–	–	54°	48°
14, .	1.50	1.50	–	–	14.5000	–	–	141.00	15.0000	24.0000	1.400	55°	45°
15, .	1.50	1.49	–	–	–	–	–	–	–	–	–	45°	43°
16, .	–	.55	–	–	–	–	–	–	–	–	–	–	–
17, .	1.50	1.10	–	–	–	–	–	–	–	–	–	39°	43°
18, .	1.50	1.51	–	–	–	–	–	–	–	–	–	51°	45°
19, .	1.50	1.45	–	–	–	–	–	–	–	–	–	44°	40°
20, .	1.50	1.54	–	–	–	–	–	–	–	–	–	44°	43°
21, .	1.50	1.57	–	–	15.0000	–	–	141.00	18.0000	22.0000	1.900	52°	45°
22, .	1.50	1.50	–	–	–	–	–	–	–	–	–	50°	44°
23, .	–	.53	–	–	–	–	–	–	–	–	–	–	–
24, .	1.50	1.05	–	–	–	–	–	–	–	–	–	41°	43°
25, .	1.50	1.49	–	–	–	–	–	–	–	–	–	44°	42°
26, .	1.50	1.58	–	–	–	–	–	–	–	–	–	50°	47°
27, .	1.50	1.54	–	–	–	–	–	–	–	–	–	52°	45°
28, .	1.50	1.51	–	–	13.0000	–	–	141.00	17.0000	25.0000	1.500	46°	41°
29, .	1.50	1.51	–	–	–	–	–	–	–	–	–	40°	41°
30, .	–	.55	–	–	–	–	–	–	–	–	–	–	–
31, .	1.50	1.08	–	–	–	–	–	–	–	–	–	45°	47°

Generally a slight turbidity and sediment in effluent, with color from 0.2 to 0.3.

March 1 to 4. — The solution applied contained 68 parts per 100,000 of free ammonia, and enough soda to just form nitrate with one half of nitrogen present. March 5 to 31. — It contained free ammonia as before, but the soda was increased to just form nitrate with all the nitrogen present.

Total effluent to end of month, 1,711.11 gallons.



FILTER TANK No 13.
1888-'89.
SCALES: SUM OF AMMONIAS, AS GIVEN IN PARTS
CHLORINE, PER 100,000.
NITRATES.
FIXED RESIDUE. 1.00=10.00 PARTS
LOSS ON IGNITION. IN 100,000.
QUANTITIES. 1.00=100 GAL.
Temperature of Effluent.
Quantity Applied.
Quantity of Effluent.
Nitrates.
Nitrates (effluent).
Chlorine (effluent).
Fixed Residue.
Sum of Ammonias in Sewage.
Sum of Ammonias (effluent).
Loss on Ignition.
Loss on Ignition (effluent).
Albuminoid Ammonia.
Free Ammonia Applied.
Free Ammonia applied, parts per 100,000.
Mar.
Apr.
May.
June.
July.
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May.

FILTER TANK No. 14.

February and March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
29, . .	12.00	12.10	2.10	7.30	.0394	.0138	.0532	1.08	.0120	.0005	-	44°	36°
March, 1888.													
1, . .	6.00	6.00	4.90	10.10	.0672	.0140	.0812	2.38	.0080	.0014	-	44°	40°
2, . .	6.00	5.90	-	-	-	-	-	-	-	-	-	44°	40°
3, . .	6.00	5.90	-	-	-	-	-	-	-	-	-	44°	42°
4, . .	6.00	5.90	4.10	10.30	.1000	.0168	.1168	2.36	.0200	.0035	-	44°	37°
5, . .	6.00	5.90	-	-	-	-	-	-	-	-	-	44°	37°
6, . .	6.00	5.50	2.30	11.40	.1200	.0160	.1360	2.44	.0120	.0033	-	43°	40°
7, . .	6.00	5.60	-	-	-	-	-	-	-	-	-	42°	36°
8, . .	6.00	5.90	2.60	9.40	.0960	.0130	.1090	1.80	.0120	.0023	-	44°	-
9, . .	6.00	5.90	-	-	-	-	-	-	-	-	-	42°	43°
10, . .	6.00	5.80	-	-	-	-	-	-	-	-	-	44°	39°
11, . .	6.00	5.60	2.20	9.50	.1280	.0210	.1490	1.82	.0450	.0055	-	44°	40°
12, . .	6.00	5.80	-	-	-	-	-	-	-	-	-	44°	-
13, . .	6.00	5.90	1.50	10.00	.1520	.0110	.1630	1.95	.0250	.0020	-	44°	-
14, . .	6.00	5.10	-	-	-	-	-	-	-	-	-	44°	42°
15, . .	6.00	6.80	2.20	9.80	.1880	.0800	.2680	1.93	.0150	.0014	1 m.	44°	42°
16, . .	6.00	5.90	-	-	-	-	-	-	-	-	-	43°	44°
17, . .	6.00	5.10	-	-	-	-	-	-	-	-	-	43°	43°
18, . .	6.00	6.70	2.30	10.60	.2040	.0120	.2160	2.08	.0200	.0022	-	44°	-
19, . .	6.00	6.00	-	-	-	-	-	-	-	-	-	43°	41°
20, . .	6.00	3.90	1.80	10.90	.2200	.0100	.2300	2.13	.0350	.0020	-	44°	-
21, . .	6.00	5.99	-	-	-	-	-	-	-	-	-	44°	44°
22, . .	6.00	6.70	0.90	9.90	.2520	.0210	.2730	1.44	.0420	.0022	-	40°	44°
23, . .	6.00	5.90	-	-	-	-	-	-	-	-	1m.15s.	44°	44°
24, . .	6.00	5.20	-	-	-	-	-	-	-	-	1m.25s.	44°	38°
25, . .	6.00	6.70	1.60	10.80	.2800	.0190	.2990	1.72	.0250	.0058	-	44°	40°
26, . .	6.00	6.00	-	-	-	-	-	-	-	-	50 s.	44°	40°
27, . .	6.00	6.00	1.60	14.60	.4880	.0170	.5050	2.94	.0550	.0016	-	44°	41°
28, . .	6.00	5.20	-	-	-	-	-	-	-	-	-	44°	43°
29, . .	6.00	7.00	2.60	14.20	.5600	.0220	.5820	3.02	.0550	.0036	-	43°	43°
30, . .	6.00	4.80	-	-	-	-	-	-	-	-	1m 35s.	44°	43°
31, . .	6.00	2.10	-	-	-	-	-	-	-	-	-	44°	-

Effluent colorless, generally slightly turbid and with little or no sediment.
February 29. — First sewage applied. February 29, March 2, 3, 4, 5, 7, 8 and 12 — After sewage applied, effluent came out in a stream for one or two minutes. March 31. — Outlet closed at 10.28 A.M. River high.
Total effluent to end of month, 188.89 gallons.

Filter Tank No. 14 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
2, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
3, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
4, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
5, . .	6.00	9.93	1.60	14.40	.4440	.0160	.4600	2.08	.2000	.0022	50 s.	43°	39°
6, . .	6.00	4.89	-	-	-	-	-	-	-	-	-	46°	-
7, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
8, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
9, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
10, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
11, . .	6.00	6.60	3.90	17.50	.5900	.0180	.6080	3.40	.3500	.0033	50 s.	44°	40°
12, . .	6.00	5.50	-	-	-	-	-	-	-	-	1m.25s.	40°	43°
13, . .	6.00	11.10	-	-	-	-	-	-	-	-	1m.20s.	42°	41°
14, . .	6.00	6.00	-	-	-	-	-	-	-	-	1m.25s.	45°	-
15, . .	6.00	6.00	3.00	16.80	.6400	.0290	.6690	3.50	.2000	.0017	2m.10s.	45°	43°
16, . .	6.00	6.00	-	-	-	-	-	-	-	-	2 m.	42°	44°
17, . .	6.00	4.80	2.70	17.00	.5800	.0110	.5910	2.98	.1600	.0022	2m.15s.	42°	45°
18, . .	6.00	6.00	-	-	-	-	-	-	-	-	2m.10s.	45°	44°
19, . .	6.00	6.20	3.30	16.00	.4300	.0180	.4480	2.87	.3250	.0020	2m.15s.	42°	46°
20, . .	6.00	6.50	-	-	-	-	-	-	-	-	2m.15s.	43°	43°
21, . .	12.00	11.80	3.70	22.00	.4760	.0110	.4810	4.26	.3500	.0025	2 m.	42°	-
22, . .	-	0.80	-	-	-	-	-	-	-	-	-	-	-
23, . .	6.00	5.70	-	-	-	-	-	-	-	-	-	43°	-
24, . .	6.00	5.80	6.20	21.70	.4300	.0130	.4430	4.68	.7000	.0036	-	42°	-
25, . .	6.00	6.10	-	-	-	-	-	-	-	-	-	42°	-
26, . .	6.00	6.00	3.90	17.20	.2900	.0070	.2970	2.64	.7000	.0025	-	46°	-
27, . .	6.00	6.00	-	-	-	-	-	-	-	-	-	44°	-
28, . .	12.00	6.30	6.20	16.60	.1880	.0210	.2090	2.48	1.0000	.0080	-	46°	-
29, . .	-	0.43	-	-	-	-	-	-	-	-	-	-	-
30, . .	-	-	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, and generally nearly clear and nearly free from sediment.

April 5. — Outlet opened at 7.38 A.M. Outlet closed from 5.13 P.M., April 6, to 8.08 A.M., April 11. River high. April 29. — Outlet closed at 6.38 P.M. River high.

Total effluent to end of month, 317.34 gallons.

Filter Tank No. 14 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	-	-	-	-	-	-	-	-	-	-	-	-
2, ...	-	-	-	-	-	-	-	-	-	-	-	-
3, ...	-	-	-	-	-	-	-	-	-	-	-	-
4, ...	6.00	5.90	-	-	-	-	-	-	-	-	45°	-
5, ...	12.00	11.40	11.50	28.50	.0520	.0140	.0660	3.32	3.0000	.0111	45°	-
6, ...	-	0.70	-	-	-	-	-	-	-	-	-	-
7, ...	6.00	5.30	-	-	-	-	-	-	-	-	50°	-
8, ...	6.00	6.00	11.00	19.80	.0360	.0230	.0590	3.42	1.5000	.0050	48°	-
9, ...	6.00	5.90	-	-	-	-	-	-	-	-	50°	-
10, ...	6.00	6.00	-	-	-	-	-	-	-	-	51°	-
11, ...	6.00	5.90	7.50	15.90	.0080	.0070	.0150	2.78	.8000	.0020	51°	-
12, ...	12.00	10.80	-	-	-	-	-	-	-	-	49°	-
13, ...	-	-	-	-	-	-	-	-	-	-	-	-
14, ...	-	-	-	-	-	-	-	-	-	-	-	-
15, ...	-	-	-	-	-	-	-	-	-	-	-	-
16, ...	-	-	-	-	-	-	-	-	-	-	-	-
17, ...	6.00	6.90	-	-	-	-	-	-	-	-	49°	-
18, ...	6.00	5.90	9.80	22.80	.0008	.0250	.0258	4.00	1.5000	.0020	49°	-
19, ...	12.00	11.70	-	-	-	-	-	-	-	-	50°	-
20, ...	-	0.60	-	-	-	-	-	-	-	-	-	-
21, ...	6.00	5.70	-	-	-	-	-	-	-	-	51°	-
22, ...	6.00	6.00	7.60	22.30	.0020	.0132	.0152	4.20	2.0000	.0010	52°	-
23, ...	6.00	5.90	-	-	-	-	-	-	-	-	53°	-
24, ...	6.00	6.00	-	-	-	-	-	-	-	-	55°	-
25, ...	6.00	5.90	6.90	23.50	.0004	.0212	.0216	3.54	.8000	.0010	56°	-
26, ...	12.00	10.70	-	-	-	-	-	-	-	-	57°	-
27, ...	-	0.60	-	-	-	-	-	-	-	-	-	-
28, ...	6.00	5.60	-	-	-	-	-	-	-	-	57°	-
29, ...	6.00	6.00	-	-	-	-	-	-	-	-	56°	-
30, ...	6.00	4.80	-	-	-	-	-	-	-	-	57°	-
31, ...	6.00	6.00	6.60	28.10	.0002	.0198	.0200	5.94	.9000	.0010	57°	-

Effluent colorless, generally nearly clear and nearly free from sediment.
May 4. — Outlet opened at 9.43 A.M. Outlet closed from 8.37 P.M., May 12, to 8.10 A.M., May 17.
Total effluent to end of month, 463.54 gallons.

Filter Tank No. 14 — Continued.

June. 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	6.00	6.00	–	–	–	–	–	–	–	–	58°	–
2, ...	12.00	10.70	–	–	–	–	–	–	–	–	60°	–
3, ...	–	0.60	–	–	–	–	–	–	–	–	–	–
4, ...	6.00	5.60	9.50	26.00	.0030	.0180	.0210	4.56	1.3500	.0010	59°	–
5, ...	6.00	6.10	–	–	–	–	–	–	–	–	61°	–
6, ...	6.00	5.60	–	–	–	–	–	–	–	–	61°	–
7, ...	6.00	5.70	4.30	23.00	.0022	.0162	.0184	3.80	1.2500	.0022	64°	67°
8, ...	6.00	5.90	–	–	–	–	–	–	–	–	64°	65°
9, ...	12.00	11.20	–	–	–	–	–	–	–	–	66°	65°
10, ...	–	0.70	–	–	–	–	–	–	–	–	–	–
11, ...	6.00	5.60	8.20	26.20	.0042	.0210	.0252	6.39	1.0000	.0020	68°	67°
12, ...	6.00	5.80	–	–	–	–	–	–	–	–	65°	65°
13, ...	6.00	5.90	–	–	–	–	–	–	–	–	64°	64°
14, ...	6.00	6.00	6.80	26.00	.0018	.0274	.0292	5.75	.7500	.0009	65°	61°
15, ...	6.00	5.50	–	–	–	–	–	–	–	–	65°	62°
16, ...	12.00	11.70	–	–	–	–	–	–	–	–	66°	–
17, ...	–	0.70	–	–	–	–	–	–	–	–	–	–
18, ...	6.00	5.60	5.40	33.20	.0066	.0202	.0268	7.95	1.3300	.0043	68°	68°
19, ...	6.00	6.00	–	–	–	–	–	–	–	–	68°	68°
20, ...	6.00	5.50	–	–	–	–	–	–	–	–	70°	68°
21, ...	6.00	5.80	10.60	62.00	.0032	.0246	.0278	24.25	.7000	.0022	69°	66°
22, ...	6.00	6.00	–	–	–	–	–	–	–	–	69°	67°
23, ...	12.00	11.60	–	–	–	–	–	–	–	–	73°	72°
24, ...	–	0.60	–	–	–	–	–	–	–	–	–	–
25, ...	6.00	5.50	7.10	35.10	.0100	.0222	.0322	6.05	1.4000	.0029	71°	67°
26, ...	6.00	5.10	–	–	–	–	–	–	–	–	69°	67°
27, ...	6.00	–	–	–	–	–	–	–	–	–	69°	–
28, ...	6.00	1.30	12.00	29.00	.0042	.0118	.0160	4.90	1.7500	.0080	68°	–
29, ...	6.00	13.90	–	–	–	–	–	–	–	–	66°	61°
30, ...	12.00	11.30	–	–	–	–	–	–	–	–	67°	65°

Effluent colorless, generally nearly clear and nearly free from sediment.

June 27. — Trap put on outlet pipe. Outlet closed from 5.30 P.M., June 26, to about 2.25 P.M., June 29, except for 5 minutes on June 28. June 29. — Some effluent lost.

Total effluent to end of month, 641.04 gallons.

Filter Tank No. 14 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	-	0.60	-	-	-	-	-	-	-	-	-	-
2, ...	6.00	5.80	7.80	26.00	.0034	.0238	.0272	7.13	.9500	.0056	65°	65°
3, ...	6.00	6.00	-	-	-	-	-	-	-	-	65°	67°
4, ...	6.00	6.00	-	-	-	-	-	-	-	-	67°	69°
5, ...	6.00	5.90	6.30	29.70	.0044	.0230	.0274	7.70	.9000	.0105	68°	71°
6, ...	6.00	5.50	-	-	-	-	-	-	-	-	68°	70°
7, ...	12.00	10.80	-	-	-	-	-	-	-	-	70°	72°
8, ...	-	0.60	-	-	-	-	-	-	-	-	-	-
9, ...	6.00	5.60	5.10	29.00	.0090	.0198	.0288	7.33	1.0200	.0200	69°	68°
10, ...	6.00	5.97	-	-	-	-	-	-	-	-	69°	70°
11, ...	6.00	6.01	-	-	-	-	-	-	-	-	69°	75°
12, ...	6.00	5.79	6.00	29.20	.0076	.0236	.0312	7.80	.9300	.0100	69°	67°
13, ...	6.00	5.92	-	-	-	-	-	-	-	-	69°	65°
14, ...	12.00	11.70	-	-	-	-	-	-	-	-	69°	68°
15, ...	-	0.36	-	-	-	-	-	-	-	-	-	-
16, ...	6.00	5.32	8.00	34.30	.0078	.0250	.0328	11.35	1.1000	.0040	69°	69°
17, ...	6.00	6.00	-	-	-	-	-	-	-	-	69°	67°
18, ...	6.00	5.92	-	-	-	-	-	-	-	-	71°	67°
19, ...	6.00	5.90	8.60	24.10	.0040	.0196	.0236	5.12	1.2200	.0040	71°	66°
20, ...	6.00	6.04	-	-	-	-	-	-	-	-	70°	71°
21, ...	12.00	11.62	-	-	-	-	-	-	-	-	71°	72°
22, ...	-	0.59	-	-	-	-	-	-	-	-	-	-
23, ...	6.00	5.69	8.30	29.30	.0210	.0200	.0410	8.56	1.4300	.0225	72°	72°
24, ...	6.00	5.92	-	-	-	-	-	-	-	-	72°	-
25, ...	6.00	6.73	-	-	-	-	-	-	-	-	73°	70°
26, ...	6.00	6.03	7.40	28.90	.0064	.0204	.0268	5.90	1.2500	.0120	73°	[illegible]
27, ...	6.00	5.90	-	-	-	-	-	-	-	-	72°	-
28, ...	12.00	11.51	-	-	-	-	-	-	-	-	72°	65°
29, ...	-	0.67	-	-	-	-	-	-	-	-	-	-
30, ...	6.00	5.81	1.40	26.90	.0064	.0238	.0302	6.32	.9500	.0200	71°	70°
31, ...	6.00	5.77	-	-	-	-	-	-	-	-	72°	-

Effluent colorless and generally clear, or nearly so, and free from sediment.
Total effluent to end of month, 819.01 gallons.

Filter Tank No. 14 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	6.00	6.00	-	-	-	-	-	-	-	-	73°	72°
2, ...	6.00	5.94	2.40	35.80	.0008	.0416	.0424	6.90	1.7600	.0060	73°	71°
3, ...	6.00	5.98	-	-	-	-	-	-	-	-	73°	72°
4, ...	12.00	9.65	-	-	-	-	-	-	-	-	74°	73°
5, ...	-	0.62	-	-	-	-	-	-	-	-	-	-
6, ...	6.00	5.53	3.30	28.30	.0238	.0410	.0648	5.10	1.5000	.0350	74°	71°
7, ...	6.00	5.97	-	-	-	-	-	-	-	-	72°	69°
8, ...	6.00	6.06	-	-	-	-	-	-	-	-	72°	69°
9, ...	6.00	5.99	2.40	25.00	.0344	.0306	.0650	5.91	1.6500	.0200	73°	71°
10, ...	6.00	5.96	-	-	-	-	-	-	-	-	72°	73°
11, ...	12.00	11.78	-	-	-	-	-	-	-	-	73°	69°
12, ...	-	0.59	-	-	-	-	-	-	-	-	-	-
13, ...	6.00	5.52	3.40	28.90	.0336	.0462	.0798	5.41	1.5500	.0320	70°	66°
14, ...	6.00	6.07	-	-	-	-	-	-	-	-	-	67°
15, ...	6.00	5.99	-	-	-	-	-	-	-	-	69°	68°
16, ...	6.00	5.62	2.20	32.00	.0104	.0326	.0430	5.20	1.4000	.0080	69°	72°
17, ...	6.00	5.94	-	-	-	-	-	-	-	-	70°	72°
18, ...	12.00	11.44	-	-	-	-	-	-	-	-	71°	73°
19, ...	-	0.60	-	-	-	-	-	-	-	-	-	-
20, ...	6.00	5.61	6.80	30.80	.0424	.0396	.0820	6.52	1.2500	.0300	71°	-
21, ...	6.00	5.78	-	-	-	-	-	-	-	-	71°	69°
22, ...	6.00	6.12	-	-	-	-	-	-	-	-	70°	69°
23, ...	9.00	9.18	4.40	26.40	.0150	.0254	.0404	4.39	1.4700	.0240	70°	68°
24, ...	9.00	8.87	-	-	-	-	-	-	-	-	70°	65°
25, ...	18.00	16.41	-	-	-	-	-	-	-	-	70°	73°
26, ...	-	0.63	-	-	-	-	-	-	-	-	-	-
27, ...	9.00	8.45	6.40	39.40	.0552	.0566	.1118	12.10	1.2500	.0100	71°	72°
28, ...	9.00	8.78	-	-	-	-	-	-	-	-	70°	68°
29, ...	9.00	8.48	-	-	-	-	-	-	-	-	69°	69°
30, ...	9.00	8.94	5.90	54.10	.1914	.0234	.2148	16.70	1.2500	.0100	70°	69°
31, ...	9.00	9.13	-	-	-	-	-	-	-	-	70°	71°

Effluent from very slightly milky to distinctly turbid, with very little or no sediment and with color from 0 to 0.2.

After August 1 residue on evaporation obtained with sodium carbonate. August 11. — Outlet closed 1 hour 46 minutes, to replace broken trap.

Total effluent to end of month, 1,026 64 gallons.

Filter Tank No. 14 — Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	18.00	17.06	-	-	-	-	-	-	-	-	71°	72°
2, ...	-	0.58	-	-	-	-	-	-	-	-	-	-
3, ...	9.00	8.53	3.80	38.60	.0520	.0300	.0820	11.04	.8300	.0080	70°	68°
4, ...	9.00	8.83	-	-	-	-	-	-	-	-	71°	67°
5, ...	9.00	9.02	-	-	-	-	-	-	-	-	70°	67°
6, ...	9.00	8.76	1.10	37.30	.0280	.0212	.0492	9.33	1.3000	.0060	68°	63°
7, ...	9.00	9.02	-	-	-	-	-	-	-	-	68°	-
8, ...	18.00	17.84	-	-	-	-	-	-	-	-	66°	62°
9, ...	-	0.67	-	-	-	-	-	-	-	-	-	-
10, ...	9.00	8.54	4.30	48.40	.1536	.0356	.1892	15.85	1.1500	.0200	67°	69°
11, ...	9.00	8.87	-	-	-	-	-	-	-	-	67°	68°
12, ...	9.00	8.98	-	-	-	-	-	-	-	-	66°	-
13, ...	9.00	8.96	4.10	24.00	.0800	.0202	.1002	4.04	1.3500	.0060	66°	67°
14, ...	9.00	8.96	-	-	-	-	-	-	-	-	64°	65°
15, ...	18.00	17.36	-	-	-	-	-	-	-	-	64°	64°
16, ...	-	0.68	-	-	-	-	-	-	-	-	-	-
17, ...	9.00	8.69	3.70	35.30	.1200	.0428	.1628	11.45	.7000	.0300	65°	67°
18, ...	9.00	8.57	-	-	-	-	-	-	-	-	65°	-
19, ...	9.00	9.00	-	-	-	-	-	-	-	-	64°	63°
20, ...	9.00	9.08	2.80	29.50	.0200	.0230	.0430	6.10	.6600	.0010	64°	62°
21, ...	9.00	8.83	-	-	-	-	-	-	-	-	63°	62°
22, ...	18.00	17.83	-	-	-	-	-	-	-	-	61°	61°
23, ...	-	0.62	-	-	-	-	-	-	-	-	-	-
24, ...	9.00	8.57	2.50	26.10	.0140	.0260	.0400	4.78	1.0000	.0030	58°	61°
25, ...	9.00	8.93	-	-	-	-	-	-	-	-	58°	60°
26, ...	9.00	8.74	-	-	-	-	-	-	-	-	58°	58°
27, ...	9.00	9.13	0.70	21.30	.0080	.0240	.0320	2.75	1.0000	.0050	58°	61°
28, ...	9.00	8.99	-	-	-	-	-	-	-	-	57°	-
29, ...	18.00	17.16	-	-	-	-	-	-	-	-	55°	56°
30, ...	-	0.67	-	-	-	-	-	-	-	-	-	-

Effluent colorless, free from sediment and nearly clear.

September 15. — Some effluent lost. September 21. — After sewage applied, air from within forced the effluent out in jets at short intervals for three minutes, when all flow ceased. After eight minutes the flow was as usual. September 25. — Hole drilled in middle of side of tank.

Total effluent to end of month, 1,294.11 gallons.

Filter Tank No. 14 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	9.00	8.60	3.40	40.30	.0510	.0284	.0794	11.95	1.1700	.0070	53°	–
2, ...	9.00	8.72	–	–	–	–	–	–	–	–	53°	–
3, ...	9.00	8.98	–	–	–	–	–	–	–	–	51°	56°
4, ...	9.00	9.06	2.10	29.70	.0100	.0220	.0320	5.74	1.0800	.0030	50°	56°
5, ...	9.00	8.97	–	–	–	–	–	–	–	–	50°	58°
6, ...	18.00	17.71	–	–	–	–	–	–	–	–	50°	–
7, ...	–	0.79	–	–	–	–	–	–	–	–	–	–
8, ...	9.00	8.42	3.70	35.70	.0200	.0250	.0450	10.45	.8000	.0100	52°	55°
9, ...	9.00	8.86	–	–	–	–	–	–	–	–	51°	–
10, ...	9.00	8.70	–	–	–	–	–	–	–	–	49°	53°
11, ...	9.00	8.86	2.60	28.30	.0224	.0208	.0432	5.45	1.2000	.0010	49°	54°
12, ...	9.00	9.02	–	–	–	–	–	–	–	–	47°	55°
13, ...	18.00	17.66	–	–	–	–	–	–	–	–	47°	–
14, ...	–	0.62	–	–	–	–	–	–	–	–	–	–
15, ...	9.00	8.50	3.50	26.10	.0094	.0218	.0312	4.90	1.0000	.0022	47°	54°
16, ...	9.00	9.00	–	–	–	–	–	–	–	–	47°	55°
17, ...	9.00	8.96	–	–	–	–	–	–	–	–	48°	55°
18, ...	9.00	8.92	1.10	29.60	.0036	.0094	.0130	4.70	1.2700	.0022	47°	56°
19, ...	9.00	8.89	–	–	–	–	–	–	–	–	46°	54°
20, ...	18.00	17.29	–	–	–	–	–	–	–	–	47°	–
21, ...	–	1.10	–	–	–	–	–	–	–	–	–	–
22, ...	9.00	8.05	2.10	19.50	.0018	.0204	.0222	4.62	.6800	.0016	45°	53°
23, ...	9.00	8.96	–	–	–	–	–	–	–	–	45°	55°
24, ...	9.00	8.81	–	–	–	–	–	–	–	–	45°	55°
25, ...	9.00	9.06	2.60	20.90	.0018	.0292	.0310	3.82	1.2000	.0006	45°	55°
26, ...	9.00	9.00	–	–	–	–	–	–	–	–	45°	–
27, ...	18.00	17.90	–	–	–	–	–	–	–	–	46°	55°
28, ...	–	0.70	–	–	–	–	–	–	–	–	–	–
29, ...	9.00	8.39	3.90	37.20	.0076	.0252	.0328	13.92	.7000	.0030	46°	55°
30, ...	9.00	8.91	–	–	–	–	–	–	–	–	46°	55°
31, ...	9.00	8.96	–	–	–	–	–	–	–	–	45°	55°

Effluent generally nearly clear and free from sediment, and with color from 0 to 0.1.

October 5. — Faucet put in side of tank midway. October 10. — Faucets put in one-quarter, three-quarters, and seven-eighths way down, and eight inches from bottom. Results of observations on samples from side of tank and on series of samples of regular effluent given in the text.

Total effluent to end of month, 1,570.48 gallons.

Filter Tank No. 14 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	9.00	8.95	2.80	30.60	.0036	.0230	.0266	6.85	1.2500	.0012	47°	59°
2, ...	9.00	9.01	-	-	-	-	-	-	-	-	46°	59°
3, ...	18.00	17.72	-	-	-	-	-	-	-	-	48°	61°
4, ...	-	0.68	-	-	-	-	-	-	-	-	-	-
5, ...	9.00	8.48	1.60	29.10	.0072	.0188	.0260	5.03	.8500	.0012	48°	53°
6, ...	9.00	9.00	-	-	-	-	-	-	-	-	49°	57°
7, ...	9.00	8.83	-	-	-	-	-	-	-	-	50°	56°
8, ...	9.00	9.01	2.90	40.10	.0026	.0200	.0226	10.73	1.3000	.0016	49°	53°
9, ...	9.00	8.97	-	-	-	-	-	-	-	-	49°	56°
10, ...	18.00	17.64	-	-	-	-	-	-	-	-	48°	54°
11, ...	-	0.61	-	-	-	-	-	-	-	-	-	-
12, ...	9.00	8.32	2.10	29.70	.0010	.0222	.0232	8.50	.6700	.0024	45°	52°
13, ...	9.00	8.84	-	-	-	-	-	-	-	-	43°	51°
14, ...	9.00	9.06	-	-	-	-	-	-	-	-	43°	53°
15, ...	9.00	8.94	2.20	28.20	.0136	.0182	.0318	5.00	1.3000	.0012	42°	52°
16, ...	9.00	8.84	-	-	-	-	-	-	-	-	42°	53°
17, ...	18.00	17.55	-	-	-	-	-	-	-	-	42°	51°
18, ...	-	0.75	-	-	-	-	-	-	-	-	-	-
19, ...	9.00	8.41	2.40	29.90	.0032	.0182	.0214	14.90	.7500	.0026	40°	49°
20, ...	9.00	8.64	-	-	-	-	-	-	-	-	40°	48°
21, ...	9.00	9.14	-	-	-	-	-	-	-	-	38°	45°
22, ...	9.00	8.80	2.40	26.00	.0006	.0150	.0156	3.87	1.1000	.0007	45°	45°
23, ...	9.00	9.02	-	-	-	-	-	-	-	-	44°	43°
24, ...	18.00	17.52	-	-	-	-	-	-	-	-	45°	45°
25, ...	-	0.75	-	-	-	-	-	-	-	-	-	-
26, ...	9.00	8.42	1.90	24.90	.0042	.0158	.0200	4.34	.8000	.0024	45°	46°
27, ...	9.00	9.01	-	-	-	-	-	-	-	-	45°	46°
28, ...	9.00	8.71	-	-	-	-	-	-	-	-	44°	51°
29, ...	-	-	-	-	-	-	-	-	-	-	-	-
30, ...	-	-	-	-	-	-	-	-	-	-	-	-

Effluent nearly clear with very little or no sediment, and with color less than 0.1.

November 1. — Aspirator attached to cock 4 feet below top of tank October 18, removed. November 26. — It required 25 minutes for the tank to take the applied sewage. Effluent running more slowly than usual. November 28. — Outlet closed at 8.56 P.M. River high.

Total effluent to end of month, 1,820.08 gallons.

Filter Tank No. 14 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	18.00	18.27	1.80	18.70	.0010	.0148	.0158	3.49	.7500	.0014	44°	43°
2, ...	-	0.75	-	-	-	-	-	-	-	-	-	-
3, ...	9.00	8.54	2.50	18.40	.0238	.0264	.0502	4.94	1.0000	.0006	44°	42°
4, ...	9.00	8.93	-	-	-	-	-	-	-	-	45°	43°
5, ...	9.00	9.07	-	-	-	-	-	-	-	-	44°	42°
6, ...	9.00	8.92	1.90	27.40	.0186	.0174	.0360	4.70	.8500	.0008	46°	44°
7, ...	9.00	9.13	-	-	-	-	-	-	-	-	45°	42°
8, ...	18.00	17.59	-	-	-	-	-	-	-	-	45°	43°
9, ...	-	0.77	-	-	-	-	-	-	-	-	-	-
10, ...	9.00	8.17	1.20	28.40	.0372	.0170	.0542	4.70	.6000	.0060	45°	43°
11, ...	9.00	8.93	-	-	-	-	-	-	-	-	45°	42°
12, ...	9.00	8.90	-	-	-	-	-	-	-	-	44°	41°
13, ...	9.00	8.82	2.60	25.50	.0140	.0170	.0310	4.15	.7000	.0002	44°	39°
14, ...	9.00	8.82	-	-	-	-	-	-	-	-	46°	32°
15, ...	18.00	18.72	-	-	-	-	-	-	-	-	45°	36°
16, ...	-	0.85	-	-	-	-	-	-	-	-	-	-
17, ...	9.00	8.60	1.40	22.30	.0388	.0208	.0596	3.05	.5500	.0020	41°	48°
18, ...	9.00	6.65	-	-	-	-	-	-	-	-	45°	-
19, ...	-	-	-	-	-	-	-	-	-	-	-	-
20, ...	-	-	-	-	-	-	-	-	-	-	-	-
21, ...	-	2.63	-	-	-	-	-	-	-	-	-	36°
22, ...	13.00	16.97	-	-	-	-	-	-	-	-	45°	-
23, ...	-	0.81	-	-	-	-	-	-	-	-	-	-
24, ...	9.00	8.24	1.80	24.20	.0152	.0202	.0354	4.01	.7000	.0008	42°	43°
25, ...	9.00	9.02	-	-	-	-	-	-	-	-	45°	-
26, ...	9.00	8.72	-	-	-	-	-	-	-	-	45°	47°
27, ...	9.00	8.98	1.80	25.00	.0040	.0152	.0192	4.00	.7000	.0000	46°	49°
28, ...	9.00	8.92	-	-	-	-	-	-	-	-	45°	47°
29, ...	18.00	16.69	-	-	-	-	-	-	-	-	45°	47°
30, ...	-	0.79	-	-	-	-	-	-	-	-	-	-
31, ...	9.00	8.33	1.40	25.20	.0360	.0164	.0524	3.88	.5000	.0014	45°	-

Effluent nearly clear with very little or no sediment, and with color less than 0.1.

December 1. — Outlet opened at 8.19 A.M. Effluent running slowly and 39 minutes was required for tank to take sewage applied; December 8, 2 hours 6 minutes required. December 14. — Outlet thawed out at 3 20 P.M.; December 15, at 8.24 A.M; December 18, 3.40 P.M., to December 21, 2.01 P.M. Outlet closed. River high. December 18 and 29. — Some effluent lost. December 31. — No manganese in sample.

Total effluent to end of month, 2,070.61 gallons.

Filter Tank No. 14 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	9.00	8.96	–	–	–	–	–	–	–	–	45°	47°
2, ...	9.00	8.86	–	–	–	–	–	–	–	–	45°	47°
3, ...	9.00	8.87	1.80	32.90	.0168	.0164	.0332	8.71	.7000	.0003	45°	45°
4, ...	9.00	9.02	–	–	–	–	–	–	–	–	45°	44°
5, ...	18.00	17.67	–	–	–	–	–	–	–	–	45°	43°
6, ...	–	.84	–	–	–	–	–	–	–	–	–	–
7, ...	9.00	8.29	1.50	25.10	.0008	.0180	.0188	4.59	.4000	.0002	45°	43°
8, ...	9.00	8.76	–	–	–	–	–	–	–	–	45°	45°
9, ...	9.00	6.78	–	–	–	–	–	–	–	–	45°	45°
10, ...	9.00	9.04	1.40	25.00	.0012	.0166	.0178	3.91	.6500	.0008	45°	47°
11, ...	9.00	9.00	–	–	–	–	–	–	–	–	45°	46°
12, ...	18.00	17.67	–	–	–	–	–	–	–	–	44°	44°
13, ...	–	.89	–	–	–	–	–	–	–	–	–	–
14, ...	9.00	8.39	2.30	30.00	.0104	.0136	.0240	7.25	.5000	.0008	44°	43°
15, ...	9.00	8.92	–	–	–	–	–	–	–	–	45°	44°
16, ...	9.00	8.95	–	–	–	–	–	–	–	–	44°	43°
17, ...	9.00	8.70	2.80	27.20	.0022	.0166	.0188	5.60	.5000	.0024	46°	47°
18, ...	9.00	9.12	–	–	–	–	–	–	–	–	45°	48°
19, ...	18.00	17.60	–	–	–	–	–	–	–	–	44°	45°
20, ...	–	.89	–	–	–	–	–	–	–	–	–	–
21, ...	9.00	8.09	2.00	23.10	.0030	.0114	.0144	3.95	.3300	.0050	44°	42°
22, ...	9.00	8.70	–	–	–	–	–	–	–	–	44°	42°
23, ...	9.00	8.72	–	–	–	–	–	–	–	–	46°	44°
24, ...	9.00	9.05	2.50	25.50	.0060	.0132	.0192	4.00	1.0000	.0020	–	45°
25, ...	9.00	8.84	–	–	–	–	–	–	–	–	44°	46°
26, ...	9.00	8.51	–	–	–	–	–	–	–	–	44°	46°
27, ...	–	1.06	–	–	–	–	–	–	–	–	–	–
28, ...	9.00	7.89	2.50	26.30	.0178	.0136	.0314	4.00	.6000	.0200	44°	47°
29, ...	9.00	8.36	–	–	–	–	–	–	–	–	45°	46°
30, ...	9.00	9.01	–	–	–	–	–	–	–	–	46°	42°
31, ...	9.00	10.07	2.50	22.70	.1280	.0410	.1690	3.98	.4200	.0080	44°	–

Effluent generally clear, or nearly so, with very little or no sediment, and with color less than 0.1.

January 30. — Some effluent lost. January 31. — Surface levelled. January 21 to 30. — Surface continually covered with sewage.

Total effluent to end of month, 2,336.13 gallons.

Filter Tank No. 14 — Continued.

February, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	9.00	9.04	–	–	–	–	–	–	–	–	45°	44°
2, ...	18.00	17.71	–	–	–	–	–	–	–	–	44°	43°
3, ...	–	.80	–	–	–	–	–	–	–	–	–	–
4, ...	9.00	8.45	2.10	20.30	.1400	.0240	.1640	3.83	.5000	.0170	44°	42°
5, ...	9.00	9.03	–	–	–	–	–	–	–	–	46°	42°
6, ...	9.00	8.96	–	–	–	–	–	–	–	–	44°	45°
7, ...	9.00	8.90	2.90	23.10	.0280	.0320	.0600	4.75	.7000	.0025	45°	41°
8, ...	9.00	8.96	–	–	–	–	–	–	–	–	44°	39°
9, ...	18.00	17.80	–	–	–	–	–	–	–	–	45°	41°
10, ...	–	.75	–	–	–	–	–	–	–	–	–	–
11, ...	9.00	8.42	1.80	24.10	.0760	.0260	.1020	5.08	.6000	.0070	47°	–
12, ...	9.00	9.08	–	–	–	–	–	–	–	–	46°	43°
13, ...	9.00	8.95	2.00	13.50	.0114	.0154	.0268	1.20	.5000	.0028	46°	44°
14, ...	9.00	9.05	1.40	9.20	.0056	.0122	.0178	.50	.3500	.0010	46°	44°
15, ...	9.00	9.00	–	–	–	–	–	–	–	–	46°	45°
16, ...	18.00	17.73	–	–	–	–	–	–	–	–	45°	45°
17, ...	–	.74	–	–	–	–	–	–	–	–	–	–
18, ...	9.00	8.46	1.20	7.00	.0012	.0096	.0108	.23	.3000	.0008	46°	43°
19, ...	9.00	8.95	–	–	–	–	–	–	–	–	45°	44°
20, ...	9.00	8.93	–	–	–	–	–	–	–	–	46°	42°
21, ...	9.06	8.02	1.00	7.00	.0002	.0192	.0194	.44	.3200	.0002	45°	42°
22, ...	9.00	9.11	–	–	–	–	–	–	–	–	46°	43°
23, ...	18.00	17.30	–	–	–	–	–	–	–	–	45°	42°
24, ...	–	.84	–	–	–	–	–	–	–	–	–	–
25, ...	9.00	8.42	2.50	19.60	.0132	.0168	.0300	3.83	.6000	.0010	45°	40°
26, ...	9.00	6.62	–	–	–	–	–	–	–	–	45°	42°
27, ...	9.00	9.98	–	–	–	–	–	–	–	–	45°	40°
28, ...	9.00	8.12	3.00	21.90	.0042	.0174	.0216	3.80	1.0000	.0030	45°	44°

Effluent nearly clear and generally free from sediment, and with color less than 0.1.

February 11 to 20. — City water applied instead of sewage. February 21. — Some effluent lost. Cover with mercury seal put on tank. Did not exclude air at first, owing to a leak. Sewage to be applied through a funnel with a stop cock in top of cover.

Total effluent to end of month, 2,584.25 gallons.

Filter Tank No. 14 — Continued.

March, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	9.00	8.34	-	-	-	-	-	-	-	-	44°	44°
2, ...	9.00	9.05	-	-	-	-	-	-	-	-	35°	-
3, ...	-	.94	-	-	-	-	-	-	-	-	-	-
4, ...	9.00	8.08	2.80	21.90	.0840	.0550	.1390	4.27	.3200	.0250	35°	46°
5, ...	9.00	9.65	-	-	-	-	-	-	-	-	35°	46°
6, ...	9.00	8.52	-	-	-	-	-	-	-	-	35°	43°
7, ...	9.00	8.72	5.80	17.30	.2640	.1080	.3720	2.77	.0150	.0000	35°	43°
8, ...	9.00	9.84	-	-	-	-	-	-	-	-	34°	44°
9, ...	9.00	7.86	-	-	-	-	-	-	-	-	33°	41°
10, ...	-	1.31	-	-	-	-	-	-	-	-	-	-
11, ...	9.00	8.06	3.00	17.80	.5800	.0540	.6340	2.93	.0050	.0025	33°	43°
12, ...	9.00	8.42	-	-	-	-	-	-	-	-	33°	43°
13, ...	9.00	9.14	-	-	-	-	-	-	-	-	35°	43°
14, ...	9.00	9.08	2.80	19.90	.9000	.0790	.9790	3.65	.0250	.0060	36°	46°
15, ...	9.00	7.73	-	-	-	-	-	-	-	-	35°	45°
16, ...	9.00	12.49	-	-	-	-	-	-	-	-	36°	45°
17, ...	-	.84	-	-	-	-	-	-	-	-	-	-
18, ...	9.00	7.08	4.00	19.60	1.2900	.0880	1.3780	3.62	.0150	.0005	36°	43°
19, ...	9.00	8.72	-	-	-	-	-	-	-	-	37°	45°
20, ...	9.00	8.89	-	-	-	-	-	-	-	-	38°	44°
21, ...	9.00	8.25	3.50	21.20	1.4000	.0710	1.4710	3.70	.0800	.0180	37°	43°
22, ...	9.00	7.28	-	-	-	-	-	-	-	-	37°	47°
23, ...	9.00	9.04	-	-	-	-	-	-	-	-	39°	46°
24, ...	-	2.85	-	-	-	-	-	-	-	-	-	-
25, ...	9.00	5.38	3.70	21.70	1.1600	.0860	1.2460	3.66	.0100	.0010	41°	47°
26, ...	9.00	10.06	-	-	-	-	-	-	-	-	-	45°
27, ...	4.80	6.19	-	-	-	-	-	-	-	-	41°	46°
28, ...	3.00	2.44	5.40	29.50	1.5200	.1010	1.6210	6.95	.0050	.0008	41°	47°
29, ...	3.00	2.45	-	-	-	-	-	-	-	-	39°	47°
30, ...	-	2.28	-	-	-	-	-	-	-	-	-	46°
31, ...	-	.57	-	-	-	-	-	-	-	-	-	-

Effluent decidedly turbid, nearly free from sediment, and with color averaging 0.14.

March 1. — Tank made tight to exclude air. March 15 and 26. — Some effluent lost. March 16 to 26. — Air let into tank at the top. March 27. — Cover removed from top of tank and trap from outlet pipe. The tank would not take the usual amount of sewage. March 28 and 29. — Surface covered with sewage. March 28. — Air from tank contained 1.8 per cent. oxygen, 1.1 carbonic acid and 97.1 nitrogen. March 29. — The corresponding per cents. were 0.7, 0.9 and 98.4.

Total effluent to end of month, 2,793.80 gallons.

Filter Tank No. 14 — Continued.

April, 1889.

Date.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Analyses of Air from the Tank.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Oxygen.	Carbonic Acid.	Nitrogen.
1, . .	.57	4.90	28.10	1.4700	.0650	1.5350	4.73	.0100	.0050	-	-	-
2, . .	5.20	-	-	-	-	-	-	-	-	2.6	.5	96.9
3, . .	8.10	-	-	-	-	-	-	-	-	-	-	-
4, . .	8.96	2.40	33.00	1.4300	.0620	1.4920	9.10	1.2000	.0200	-	-	-
5, . .	8.98	-	-	-	-	-	-	-	-	-	-	-
6, . .	8.95	-	-	-	-	-	-	-	-	-	-	-
7, . .	.61	-	-	-	-	-	-	-	-	-	-	-
8, . .	8.47	1.00	28.00	.3800	.0320	.4120	4.44	1.4000	.0240	-	-	-
9, . .	8.98	-	-	-	-	-	-	-	-	20.7	.3	79.0
10, . .	8.95	-	-	-	-	-	-	-	-	19.7	.9	79.4
11, . .	9.04	1.60	28.10	.0680	.0250	.0930	4.17	2.3000	.0080	-	-	-
12, . .	8.97	-	-	-	-	-	-	-	-	-	-	-
13, . .	8.87	-	-	-	-	-	-	-	-	-	-	-
14, . .	.59	-	-	-	-	-	-	-	-	-	-	-
15, . .	8.10	1.40	27.70	.0400	.0460	.0860	3.66	1.6000	.0030	-	-	-
16, . .	8.71	-	-	-	-	-	-	-	-	-	-	-
17, . .	8.80	-	-	-	-	-	-	-	-	-	-	-
18, . .	9.37	2.40	31.60	.0720	.0290	.1010	7.52	1.8000	.0040	19.7	1.2	79.1
19, . .	8.95	-	-	-	-	-	-	-	-	14.3	3.4	82.3
20, . .	8.81	-	-	-	-	-	-	-	-	7.4	5.4	87.2
21, . .	.82	-	-	-	-	-	-	-	-	-	-	-
22, . .	8.00	2.10	33.20	.0400	.0320	.0720	4.12	1.6000	.0080	-	-	-
23, . .	8.94	-	-	-	-	-	-	-	-	-	-	-
24, . .	8.96	-	-	-	-	-	-	-	-	-	-	-
25, . .	8.96	7.20	28.40	.4800	.1140	.5940	4.02	.0600	.0020	.6	6.2	93.2
26, . .	8.84	-	-	-	-	-	-	-	-	-	-	-
27, . .	8.77	-	-	-	-	-	-	-	-	-	-	-
28, . .	.86	-	-	-	-	-	-	-	-	-	-	-
29, . .	2.84	7.80	32.60	.7840	.0960	.8800	6.13	-	.0004	20.6	.5	78.9
30, . .	3.12	-	-	-	-	-	-	-	-	-	-	-

From very slight to decided turbidity and very little sediment in effluent, with color averaging 0.14.

April 1. — No sewage on surface. April 2. — Surface levelled and scraped and 7 pounds of material removed. April 2 and 3. — Some effluent lost. April 2 to 17. — Air drawn continuously from near the bottom of tank. April 17. — Cover replaced on tank. April 27 to 30. — Air drawn as before. Cock in top of cover left open.

Total effluent to end of month, 3,001.89 gallons.

Filter Tank No. 14 — Continued.

May, 1889.

Date.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Analyses of Air from the Tank.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Oxygen.	Carbonic Acid.	Nitrogen.
1, . .	3.01	-	-	-	-	-	-	-	-	-	-	-
2, . .	3.00	3.40	40.00	.1440	.0080	.1520	5.33	4.5000	.0200	-	-	-
3, . .	2.96	-	-	-	-	-	-	-	-	-	-	-
4, . .	3.02	-	-	-	-	-	-	-	-	-	-	-
5, . .	.68	-	-	-	-	-	-	-	-	-	-	-
6, . .	2.11	-	-	.0900	.0250	.1150	3.86	3.8000	.0200	20.6	.3	79.1
7, . .	2.95	-	-	-	-	-	-	-	-	16.4	2.0	81.6
8, . .	3.07	-	-	-	-	-	-	-	-	-	-	-
9, . .	3.06	2.30	32.30	.0240	.0220	.0460	4.77	5.0000	.0060	7.3	5.6	87.1
10, . .	2.84	-	-	-	-	-	-	-	-	-	-	-
11, . .	2.82	-	-	-	-	-	-	-	-	.6	9.7	89.7
12, . .	.65	-	-	-	-	-	-	-	-	-	-	-
13, . .	2.09	5.00	48.00	.0600	.0230	.0830	4.79	2.0000	.0040	-	-	-
14, . .	3.13	-	-	-	-	-	-	-	-	-	-	-
15, . .	2.90	-	-	-	-	-	-	-	-	-	-	-
16, . .	2.97	-	-	.0560	.0730	.1290	5.12	.1600	.0100	.2	7.8	92.0
17, . .	3.36	-	-	-	-	-	-	-	-	-	-	-
18, . .	3.25	-	-	-	-	-	-	-	-	-	-	-
19, . .	.67	-	-	-	-	-	-	-	-	-	-	-
20, . .	2.31	7.60	36.20	.2200	.0430	.2630	4.67	2.2000	.0350	-	-	-
21, . .	3.13	-	-	-	-	-	-	-	-	-	-	-
22, . .	2.94	-	-	-	-	-	-	-	-	-	-	-
23, . .	2.96	6.80	45.30	.0640	.0150	.0790	3.93	3.2000	.0018	7.0	.8	92.2
24, . .	2.95	-	-	-	-	-	-	-	-	-	-	-
25, . .	3.02	-	-	-	-	-	-	-	-	-	-	-
26, . .	.59	-	-	-	-	-	-	-	-	-	-	-
27, . .	2.37	-	-	.0440	.0200	.0640	4.62	3.7000	.0325	-	-	-
28, . .	2.54	-	-	-	-	-	-	-	-	-	-	-
29, . .	3.01	-	-	-	-	-	-	-	-	-	-	-
30, . .	3.06	-	-	.0240	.0280	.0520	4.67	3.4000	.0120	-	-	-
31, . .	3.14	-	-	-	-	-	-	-	-	-	-	-

Effluent nearly clear and free from sediment, with color from 0 to 0.2.

May 1 to 6. — Air drawn continuously from near bottom of tank. Cock in top of cover left open. May 6 to 20. — Air excluded from tank. May 20 to December 7. — Aspirator with a return current run continuously to keep the air mixed. Air accidentally admitted several times till June 6.

Total effluent to end of month, 3,082.45 gallons.

Filter Tank No. 14 — Continued.

June, 1889.

Date.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Analyses of Air from the Tank.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Oxygen.	Carbonic Acid.	Nitrogen.
1, . .	2.91	–	–	–	–	–	–	–	–	–	–	–
2, . .	.71	–	–	–	–	–	–	–	–	–	–	–
3, . .	2.42	2.00	36.30	.0400	.0210	.0610	5.03	3.4000	.0250	–	–	–
4, . .	3.00	–	–	–	–	–	–	–	–	–	–	–
5, . .	2.80	–	–	–	–	–	–	–	–	–	–	–
6, . .	2.71	2.10	25.70	.0240	.0270	.0510	5.85	3.0000	.0080	–	–	–
7, . .	3.06	–	–	–	–	–	–	–	–	–	–	–
8, . .	3.69	–	–	–	–	–	–	–	–	–	–	–
9, . .	.74	–	–	–	–	–	–	–	–	–	–	–
10, . .	1.76	1.60	35.60	.0480	.0140	.0620	5.86	3.3000	.0250	–	–	–
11, . .	3.01	–	–	–	–	–	–	–	–	–	–	–
12, . .	2.83	–	–	–	–	–	–	–	–	1.7	.9	97.6
13, . .	3.01	3.00	35.00	.0320	.0240	.0560	5.11	3.0000	.0200	–	–	–
14, . .	2.95	–	–	–	–	–	–	–	–	.8	1.4	97.7
15, . .	2.90	–	–	–	–	–	–	–	–	–	–	–
16, . .	.83	–	–	–	–	–	–	–	–	–	–	–
17, . .	2.36	–	–	–	–	–	–	–	–	–	–	–
18, . .	2.77	–	–	–	–	–	–	–	–	–	–	–
19, . .	3.04	–	–	–	–	–	–	–	–	–	–	–
20, . .	2.81	1.50	31.30	.0160	.0180	.0340	5.07	2.8000	.0070	6.5	.8	92.7
21, . .	3.23	–	–	–	–	–	–	–	–	–	–	–
22, . .	2.83	–	–	–	–	–	–	–	–	–	–	–
23, . .	.65	–	–	–	–	–	–	–	–	–	–	–
24, . .	2.73	1.60	31.70	.0280	.0220	.0500	5.48	2.4000	.0220	–	–	–
25, . .	2.43	–	–	–	–	–	–	–	–	–	–	–
26, . .	3.18	–	–	–	–	–	–	–	–	–	–	–
27, . .	2.90	3.00	32.80	.0300	.0220	.0520	5.27	2.8000	.0010	–	–	–
28, . .	2.96	–	–	–	–	–	–	–	–	–	–	–
29, . .	2.86	–	–	–	–	–	–	–	–	–	–	–
30, . .	.58	–	–	–	–	–	–	–	–	–	–	–

Effluent very slightly turbid, free from sediment or nearly so, and with color from 0 to 0.1.
June 15 to 19. — Air admitted 15 minutes daily. June 20 to 30. — Five minutes daily.
Total effluent to end of month, 3,157.11 gallons.

Filter Tank No. 14—Continued.

July, 1889.

Date.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Analyses of Air from the Tank.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Oxygen.	Carbonic Acid.	Nitrogen.
1,	2.53	-	-	-	-	-	-	-	-	-	-	-
2,	2.75	2.00	30.90	.0360	.0190	.0550	6.70	2.1000	.0100	-	-	-
3,	2.95	-	-	-	-	-	-	-	-	-	-	-
4,	2.86	-	-	-	-	-	-	-	-	-	-	-
5,	2.90	2.10	32.60	.0320	.0110	.0430	7.82	2.0000	.0200	-	-	-
6,	2.97	-	-	-	-	-	-	-	-	-	-	-
7,	.75	-	-	-	-	-	-	-	-	-	-	-
8,	2.54	2.40	29.60	.0360	.0200	.0560	7.15	1.8000	.0175	-	-	-
9,	2.71	-	-	-	-	-	-	-	-	-	-	-
10,	2.92	-	-	-	-	-	-	-	-	-	-	-
11,	2.95	-	-	.0265	.0190	.0455	-	2.1000	.0113	-	-	-
12,	2.98	-	-	-	-	-	-	-	-	-	-	-
13,	2.96	-	-	-	-	-	-	-	-	-	-	-
14,	.58	-	-	-	-	-	-	-	-	-	-	-
15,	2.43	2.60	24.30	.0290	.0290	.0580	6.44	.9000	.0180	-	-	-
16,	2.82	-	-	-	-	-	-	-	-	-	-	-
17,	2.87	-	-	-	-	-	-	-	-	-	-	-
18,	3.46	1.50	27.80	.0230	.0210	.0440	5.52	1.6000	.0060	-	-	-
19,	3.02	-	-	-	-	-	-	-	-	-	-	-
20,	2.86	-	-	-	-	-	-	-	-	-	-	-
21,	.62	-	-	-	-	-	-	-	-	-	-	-
22,	2.81	2.80	25.40	.0250	.0220	.0470	5.82	1.5000	.0180	-	-	-
23,	2.72	-	-	-	-	-	-	-	-	-	-	-
24,	2.90	-	-	-	-	-	-	-	-	-	-	-
25,	3.07	-	-	-	-	-	-	-	-	-	-	-
26,	3.06	3.40	24.80	.0024	.0138	.0162	4.39	1.8000	.0050	-	-	-
27,	2.90	-	-	-	-	-	-	-	-	-	-	-
28,	.74	-	-	-	-	-	-	-	-	-	-	-
29,	2.73	-	-	-	-	-	-	-	-	-	-	-
30,	2.38	-	-	-	-	-	-	-	-	-	-	-
31,	3.04	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, clear or slightly milky and free from sediment or very nearly so. Air admitted to tank 5 minutes daily.

Total effluent to end of month, 3,236.89 gallons.

Filter Tank No. 14 — Continued.

August, 1889.

Date.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Analyses of Air from the Tank.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Oxygen.	Carbonic Acid.	Nitrogen.
1, . .	2.98	-	-	-	-	-	-	-	-	1.9	.7	97.4
2, . .	2.95	3.80	27.20	.0040	.0130	.0170	5.10	2.2000	.0110	-	-	-
3, . .	2.95	-	-	-	-	-	-	-	-	-	-	-
4, . .	.69	-	-	-	-	-	-	-	-	-	-	-
5, . .	2.39	2.10	23.90	.0056	.0166	.0222	4.51	1.9000	.0110	-	-	-
6, . .	2.87	-	-	-	-	-	-	-	-	-	-	-
7, . .	2.90	-	-	-	-	-	-	-	-	-	-	-
8, . .	3.01	1.20	28.00	.0016	.0128	.0144	5.20	2.2000	.0060	3.5	.6	95.9
9, . .	3.00	-	-	-	-	-	-	-	-	-	-	-
10, . .	2.87	-	-	-	-	-	-	-	-	-	-	-
11, . .	.52	-	-	-	-	-	-	-	-	-	-	-
12, . .	2.53	-	-	-	-	-	-	-	-	-	-	-
13, . .	3.08	-	-	-	-	-	-	-	-	-	-	-
14, . .	2.99	-	-	.0010	.0118	.0128	4.86	1.8000	.0018	4.1	.7	95.2
15, . .	2.92	-	-	-	-	-	-	-	-	-	-	-
16, . .	2.92	-	-	-	-	-	-	-	-	-	-	-
17, . .	3.02	-	-	-	-	-	-	-	-	-	-	-
18, . .	.59	-	-	-	-	-	-	-	-	-	-	-
19, . .	2.60	-	-	.0040	.0132	.0172	4.52	2.0000	.0100	-	-	-
20, . .	2.84	-	-	-	-	-	-	-	-	-	-	-
21, . .	3.10	-	-	-	-	-	-	-	-	-	-	-
22, . .	2.91	-	-	-	-	-	-	-	-	-	-	-
23, . .	3.45	-	-	.0030	.0146	.0176	4.60	1.8000	.0090	-	-	-
24, . .	2.26	-	-	-	-	-	-	-	-	-	-	-
25, . .	.59	-	-	-	-	-	-	-	-	-	-	-
26, . .	2.52	-	-	.0048	.0146	.0194	5.00	1.7000	.0200	-	-	-
27, . .	2.92	-	-	-	-	-	-	-	-	-	-	-
28, . .	2.92	-	-	-	-	-	-	-	-	-	-	-
29, . .	3.10	-	-	.0026	.0116	.0142	8.10	1.7000	.0050	-	-	-
30, . .	2.92	-	-	-	-	-	-	-	-	-	-	-
31, . .	2.74	-	-	-	-	-	-	-	-	-	-	-

Effluent clear and colorless and generally free from sediment.
August 1 to 14. — Air admitted to tank 5 minutes daily. August 15 to 31. — Three minutes daily.
Total effluent to end of month, 3,316.94 gallons.

Filter Tank No. 14 — Continued.

September, 1889.

Date.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Analyses of Air from the Tank.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Oxygen.	Carbonic Acid.	Nitrogen.
1, . .	.59	-	-	-	-	-	-	-	-	-	-	-
2, . .	2.83	2.10	31.40	.0044	.0106	.0150	6.94	2.0000	.0100	-	-	-
3, . .	2.68	-	-	-	-	-	-	-	-	-	-	-
4, . .	2.80	-	-	-	-	-	-	-	-	1.0	.9	98.1
5, . .	2.99	-	-	-	-	-	-	-	-	3.3	.5	96.2
6, . .	2.94	-	-	-	-	-	-	-	-	-	-	-
7, . .	2.78	-	-	-	-	-	-	-	-	-	-	-
8, . .	.52	-	-	-	-	-	-	-	-	-	-	-
9, . .	2.82	-	-	.0048	.0140	.0188	4.94	.9000	.0200	-	-	-
10, . .	2.75	-	-	-	-	-	-	-	-	-	-	-
11, . .	3.17	-	-	-	-	-	-	-	-	-	-	-
12, . .	2.54	-	-	-	-	-	-	-	-	-	-	-
13, . .	3.02	-	-	-	-	-	-	-	-	-	-	-
14, . .	3.07	-	-	-	-	-	-	-	-	-	-	-
15, . .	.66	-	-	-	-	-	-	-	-	-	-	-
16, . .	2.55	2.00	30.40	.0034	.0130	.0164	7.99	1.2000	.0085	-	-	-
17, . .	2.76	-	-	-	-	-	-	-	-	-	-	-
18, . .	2.97	-	-	-	-	-	-	-	-	-	-	-
19, . .	2.78	-	-	-	-	-	-	-	-	-	-	-
20, . .	3.10	-	-	-	-	-	-	-	-	-	-	-
21, . .	2.74	-	-	-	-	-	-	-	-	-	-	-
22, . .	.68	-	-	-	-	-	-	-	-	-	-	-
23, . .	2.62	-	-	.0020	.0158	.0178	4.16	1.0600	.0024	-	-	-
24, . .	2.73	-	-	-	-	-	-	-	-	-	-	-
25, . .	3.14	-	-	-	-	-	-	-	-	-	-	-
26, . .	2.77	-	-	-	-	-	-	-	-	-	-	-
27, . .	2.73	-	-	-	-	-	-	-	-	-	-	-
28, . .	2.98	-	-	.0012	.0128	.0140	4.40	1.3500	.0016	-	-	-
29, . .	.76	-	-	-	-	-	-	-	-	-	-	-
30, . .	2.80	-	-	-	-	-	-	-	-	-	-	-

Effluent clear and colorless and generally free from sediment.
Air admitted to tank 3 minutes daily.
Total effluent to end of month, 3,391.21 gallons.

Filter Tank No. 14 — Continued.

October, 1889.

Date.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Analyses of Air from the Tank.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Oxygen.	Carbonic Acid.	Nitrogen.
1, . .	2.45	-	-	-	-	-	-	-	-	-	-	-
2, . .	2.74	-	-	-	-	-	-	-	-	-	-	-
3, . .	3.10	-	-	-	-	-	-	-	-	-	-	-
4, . .	2.90	-	-	-	-	-	-	-	-	-	-	-
5, . .	3.12	-	-	.0014	.0132	.0146	4.72	1.8000	.0012	-	-	-
6, . .	.80	-	-	-	-	-	-	-	-	-	-	-
7, . .	2.05	-	-	-	-	-	-	-	-	1.5	1.4	97.1
8, . .	2.87	-	-	-	-	-	-	-	-	-	-	-
9, . .	2.90	-	-	-	-	-	-	-	-	-	-	-
10, . .	2.77	-	-	-	-	-	-	-	-	1.8	.8	97.9
11, . .	3.08	-	-	-	-	-	-	-	-	-	-	-
12, . .	2.95	-	-	.0010	.0122	.0132	5.00	1.3000	.0014	-	-	-
13, . .	.68	-	-	-	-	-	-	-	-	-	-	-
14, . .	2.52	-	-	-	-	-	-	-	-	-	-	-
15, . .	2.63	-	-	-	-	-	-	-	-	-	-	-
16, . .	3.01	-	-	-	-	-	-	-	-	-	-	-
17, . .	3.09	-	-	-	-	-	-	-	-	-	-	-
18, . .	2.69	-	-	-	-	-	-	-	-	-	-	-
19, . .	3.31	-	-	.0016	.0144	.0160	5.00	1.3400	.0070	-	-	-
20, . .	.50	-	-	-	-	-	-	-	-	-	-	-
21, . .	2.29	-	-	-	-	-	-	-	-	-	-	-
22, . .	2.73	-	-	-	-	-	-	-	-	-	-	-
23, . .	2.87	-	-	-	-	-	-	-	-	-	-	-
24, . .	3.19	-	-	-	-	-	-	-	-	-	-	-
25, . .	2.42	-	-	-	-	-	-	-	-	-	-	-
26, . .	2.97	-	-	.0008	.0120	.0128	4.60	1.6000	.0018	-	-	-
27, . .	.80	-	-	-	-	-	-	-	-	-	-	-
28, . .	2.28	-	-	-	-	-	-	-	-	-	-	-
29, . .	2.80	-	-	-	-	-	-	-	-	-	-	-
30, . .	3.06	-	-	-	-	-	-	-	-	-	-	-
31, . .	3.01	-	-	-	-	-	-	-	-	-	-	-

Effluent clear and colorless and free from sediment.
October 1 to 6.— Air admitted to tank 3 minutes daily. October 7 to 31.— One minute daily.
Total effluent to end of month, 3,469.79 gallons.

Filter Tank No. 14 — Continued.

November, 1889.

Date.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Analyses of Air from the Tank. Oxygen.	Analyses of Air from the Tank. Carbonic Acid.	Analyses of Air from the Tank. Nitrogen.
1, . . .	2.88	-	-	-	-	-	-	-	-	-	-	-
2, . . .	3.19	-	-	.0036	.0150	.0186	4.45	1.2500	.0012	-	-	-
3, . . .	.17	-	-	-	-	-	-	-	-	-	-	-
4, . . .	2.60	-	-	-	-	-	-	-	-	-	-	-
5, . . .	2.92	-	-	-	-	-	-	-	-	-	-	-
6, . . .	2.70	-	-	-	-	-	-	-	-	-	-	-
7, . . .	3.20	-	-	-	-	-	-	-	-	-	-	-
8, . . .	3.16	-	-	-	-	-	-	-	-	-	-	-
9, . . .	2.92	2.50	27.10	.0008	.0156	.0164	4.77	1.3000	.0016	-	-	-
10, . . .	.39	-	-	-	-	-	-	-	-	-	-	-
11, . . .	2.80	-	-	-	-	-	-	-	-	-	-	-
12, . . .	2.95	-	-	-	-	-	-	-	-	-	-	-
13, . . .	3.05	-	-	-	-	-	-	-	-	-	-	-
14, . . .	2.63	-	-	-	-	-	-	-	-	-	-	-
15, . . .	2.27	-	-	-	-	-	-	-	-	3.1	.7	96.2
16, . . .	3.16	-	-	.0024	.0140	.0164	5.86	1.6000	.0014	-	-	-
17, . . .	.85	-	-	-	-	-	-	-	-	-	-	-
18, . . .	2.89	-	-	-	-	-	-	-	-	-	-	-
19, . . .	2.84	-	-	-	-	-	-	-	-	-	-	-
20, . . .	2.68	-	-	-	-	-	-	-	-	-	-	-
21, . . .	3.38	-	-	-	-	-	-	-	-	-	-	-
22, . . .	2.56	-	-	-	-	-	-	-	-	-	-	-
23, . . .	2.74	-	-	.0006	.0148	.0154	4.74	1.5400	.0008	-	-	-
24, . . .	.80	-	-	-	-	-	-	-	-	-	-	-
25, . . .	2.45	-	-	-	-	-	-	-	-	-	-	-
26, . . .	2.72	-	-	-	-	-	-	-	-	-	-	-
27, . . .	3.18	-	-	-	-	-	-	-	-	9.9	.3	89.8
28, . . .	2.73	-	-	-	-	-	-	-	-	-	-	-
29, . . .	2.90	-	-	-	-	-	-	-	-	-	-	-
30, . . .	2.93	-	-	.0012	.0130	.0142	5.30	1.6000	.0004	-	-	-

Effluent clear and colorless and free from sediment.
November 1 to 3. — Air admitted to tank 1 minute daily. November 4 to 30. — No air admitted.
Total effluent to end of month, 3,546.43 gallons.

Filter Tank No. 14 — Continued.

December, 1889.

Date.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Analyses of Air from the Tank.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Oxygen.	Carbonic Acid.	Nitrogen.
1, . .	.99	-	-	-	-	-	-	-	-	-	-	-
2, . .	2.96	-	-	-	-	-	-	-	-	-	-	-
3, . .	2.02	-	-	-	-	-	-	-	-	-	-	-
4, . .	3.20	-	-	-	-	-	-	-	-	-	-	-
5, . .	3.43	-	-	-	-	-	-	-	-	-	-	-
6, . .	2.54	-	-	-	-	-	-	-	-	-	-	-
7, . .	2.98	-	-	.0024	.0140	.0164	4.70	1.4000	.0002	-	-	-
8, . .	.76	-	-	-	-	-	-	-	-	-	-	-
9, . .	2.69	-	-	-	-	-	-	-	-	-	-	-
10, . .	3.05	-	-	.0016	.0154	.0170	4.40	1.4800	.0000	-	-	-
11, . .	2.62	-	-	.0002	.0130	.0132	4.10	1.4600	.0002	-	-	-
12, . .	2.92	-	-	-	-	-	-	-	-	-	-	-
13, . .	2.79	-	-	.0006	.0160	.0166	3.70	1.3400	.0020	-	-	-
14, . .	2.85	-	-	.0024	.0144	.0168	4.02	1.3400	.0003	-	-	-
15, . .	.65	-	-	-	-	-	-	-	-	-	-	-
16, . .	2.86	-	-	-	-	-	-	-	-	-	-	-
17, . .	2.84	-	-	.0020	.0156	.0176	4.14	1.3000	.0002	-	-	-
18, . .	3.34	-	-	-	-	-	-	-	-	-	-	-
19, . .	2.72	-	-	-	-	-	-	-	-	-	-	-
20, . .	3.17	-	-	.0030	.0170	.0200	5.80	.7500	.0014	-	-	-
21, . .	2.46	-	-	.0040	.0218	.0258	5.95	.6000	.0060	-	-	-
22, . .	.52	-	-	-	-	-	-	-	-	-	-	-
23, . .	2.64	-	-	-	-	-	-	-	-	-	-	-
24, . .	3.47	-	-	-	-	-	-	-	-	-	-	-
25, . .	2.91	-	-	-	-	-	-	-	-	-	-	-
26, . .	2.48	-	-	-	-	-	-	-	-	-	-	-
27, . .	2.64	-	-	-	-	-	-	-	-	-	-	-
28, . .	2.96	-	-	.1570	.0626	.2196	5.02	.0700	.0008	-	-	-
29, . .	.82	-	-	-	-	-	-	-	-	-	-	-
30, . .	2.08	-	-	-	-	-	-	-	-	-	-	-
31, . .	3.19	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless and generally clear and free from sediment.

December 1 to 6. — No air admitted to tank. December 7. — The aspirator put on May 20 removed. All air excluded from tank.

Total effluent to end of month, 3,623.98 gallons.

Filter Tank No. 14 — Continued.

January, 1890.

Date.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Analyses of Air from the Tank.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Oxygen.	Carbonic Acid.	Nitrogen.
1, . .	3.80	-	-	.3600	.1000	.4600	7.37	.0100	.0002	-	-	-
2, . .	2.69	-	-	-	-	-	-	-	-	-	-	-
3, . .	2.54	-	-	-	-	-	-	-	-	-	-	-
4, . .	3.31	5.50	34.20	.3700	.1200	.4900	5.70	.0000	.0000	-	-	-
5, . .	.61	-	-	-	-	-	-	-	-	-	-	-
6, . .	2.45	-	-	-	-	-	-	-	-	-	-	-
7, . .	2.71	-	-	-	-	-	-	-	-	-	-	-
8, . .	3.16	-	-	.4500	.0900	.5400	6.16	.0000	.0000	-	-	-
9, . .	2.34	-	-	-	-	-	-	-	-	-	-	-
10, . .	2.87	-	-	-	-	-	-	-	-	-	-	-
11, . .	3.55	-	-	.5700	.1100	.6800	4.82	.0000	.0002	-	-	-
12, . .	.74	-	-	-	-	-	-	-	-	-	-	-
13, . .	2.66	-	-	-	-	-	-	-	-	-	-	-
14, . .	2.63	-	-	-	-	-	-	-	-	-	-	-
15, . .	3.52	-	-	-	-	-	-	-	-	-	-	-
16, . .	2.14	-	-	-	-	-	-	-	-	-	-	-
17, . .	1.70	-	-	-	-	-	-	-	-	-	-	-
18, . .	3.49	-	-	.5700	.1300	.7000	4.27	.0000	.0000	-	-	-
19, . .	1.35	-	-	-	-	-	-	-	-	-	-	-
20, . .	2.83	-	-	-	-	-	-	-	-	-	-	-
21, . .	2.72	-	-	-	-	-	-	-	-	-	-	-
22, . .	2.53	-	-	.6500	.0600	.7100	3.60	.0000	.0000	-	-	-
23, . .	3.62	-	-	-	-	-	-	-	-	-	-	-
24, . .	2.54	-	-	-	-	-	-	-	-	-	-	-
25, . .	3.55	-	-	.7500	.1200	.8700	3.94	.0000	.0000	-	-	-
26, . .	.62	-	-	-	-	-	-	-	-	-	-	-
27, . .	2.29	-	-	-	-	-	-	-	-	-	-	-
28, . .	2.92	-	-	-	-	-	-	-	-	-	-	-
29, . .	3.16	-	-	-	-	-	-	-	-	-	-	-
30, . .	2.66	-	-	-	-	-	-	-	-	-	-	-
31, . .	3.20	-	-	1.0000	.0700	1.0700	4.97	.0000	.0000	-	-	-

Effluent very turbid, with from no sediment to much, and from no color to a brown, due to suspended matter. All air excluded from tank.

Total effluent to end of month, 3,704.88 gallons.

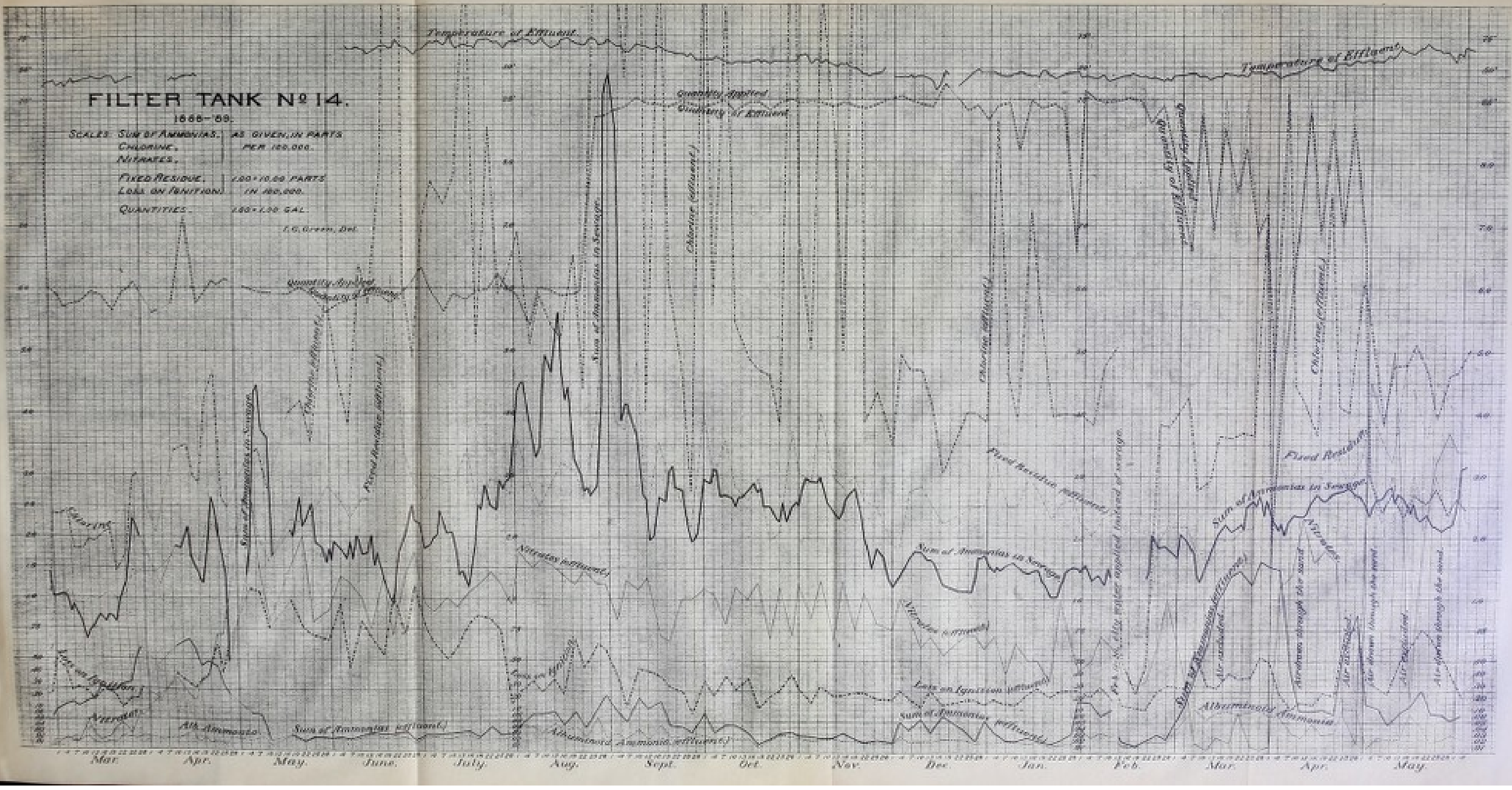
Filter Tank No. 14 — Concluded.

February, 1890.

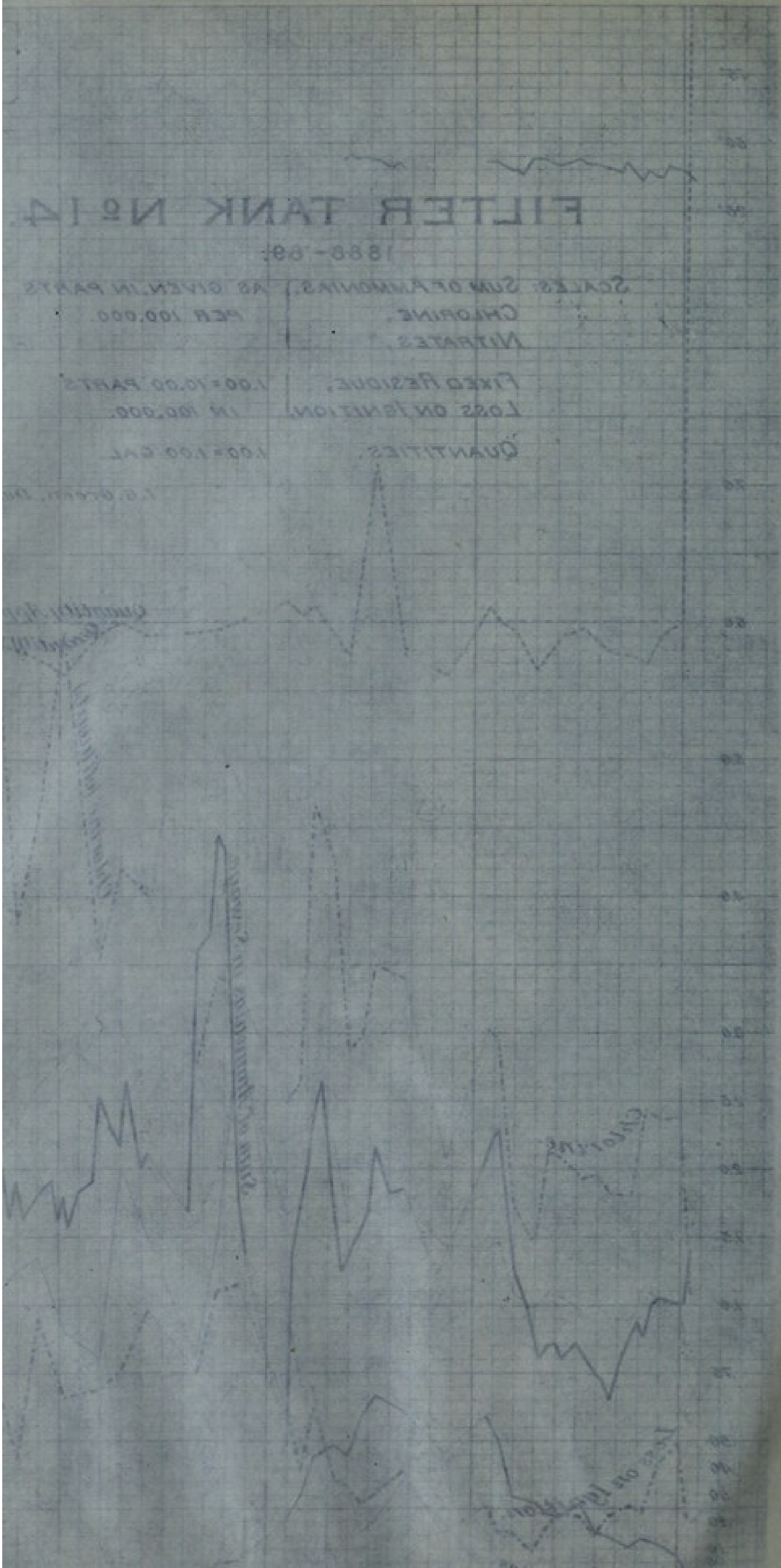
Date.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Analyses of Air from the Tank.		
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Oxygen.	Carbonic Acid.	Nitrogen.
1, . .	2.71	-	-	-	-	-	-	-	-	-	-	-
2, . .	.88	-	-	-	-	-	-	-	-	-	-	-
3, . .	2.64	-	-	-	-	-	-	-	-	-	-	-
4, . .	3.34	-	-	-	-	-	-	-	-	-	-	-
5, . .	1.99	-	-	-	-	-	-	-	-	-	-	-
6, . .	2.65	-	-	-	-	-	-	-	-	-	-	-
7, . .	4.25	-	-	1.0500	.1300	1.1800	4.55	.0000	.0000	-	-	-
8, . .	2.53	-	-	-	-	-	-	-	-	-	-	-
9, . .	.08	-	-	-	-	-	-	-	-	-	-	-
10, . .	3.11	-	-	-	-	-	-	-	-	-	-	-
11, . .	3.14	-	-	-	-	-	-	-	-	-	-	-
12, . .	3.58	-	-	-	-	-	-	-	-	-	-	-
13, . .	3.07	-	-	-	-	-	-	-	-	-	-	-
14, . .	3.10	-	-	1.4000	.1000	1.5000	3.72	.0000	.0000	-	-	-
15, . .	2.67	-	-	-	-	-	-	-	-	-	-	-

Effluent from slightly to distinctly turbid, with from no sediment to much, and with a brown color. All air excluded from tank.

Total effluent to February 15, 3,744.62 gallons.



FILTER TANK No 14.
1888–'89.
SCALES. SUM OF AMMONIAS, CHLORINE, NITRATES. AS GIVEN, IN PARTS PER 100,000.
FIXED RESIDUE, LOSS ON IGNITION. 1.00 = 10.00 PARTS IN 100,000.
QUANTITIES. 1.00 = 1.00 GAL.
Temperature of Effluent.
Quantity Applied
Quantity of Effluent
Sum of Ammonias in Sewage
Chlorine (effluent)
Fixed Residue (effluent)
Nitrates (effluent)
Loss on Ignition (effluent)
Sum of Ammonias (effluent)
Albuminoid Ammonia (effluent)
Alb. Ammonia
Fixed Residue
Nitrates
Air drawn through the sand
Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May.



General Results with Coarse Sand Filters.

By experimenting with four filters made of clean, sharp, coarse, mortar sand, — 76 per cent. of which is of particles having diameters from 0.02 of an inch to 0.09 of an inch, 5 per cent. between 0.01 and 0.02 of an inch, and about 1 per cent. finer, — we have learned that 60,000 gallons of sewage may be filtered daily on an acre, removing from 97 to 99 per cent. of the organic matter of the sewage, and giving an effluent always colorless and generally clear, with very little or no sediment.

Larger quantities, up to 180,000 gallons per acre per day, may be purified by the removal of 97 per cent. of the organic impurities for several months at a time; but we have not yet learned how to continue this indefinitely. We have also found that this material, when filtering 60,000 gallons per day, will remove an average of .999 of the bacteria applied in the sewage, but that there is a time soon after the application of sewage when the number may for an hour amount to from 1 to 5 per cent. of the number applied. During the same hour purification from other organic matter is not so complete as at other hours.

We have now to learn what results we may obtain by filtering through finer sand; and for this purpose select a sand 90 per cent. of whose particles have diameters less than 0.01 of an inch.

FILTER TANK No. 2.

Physical Characteristics.

This tank is filled, above the underdrains and their adjacent layers of coarse and fine gravel and coarse sand, with five feet in depth of clean fine sand of quite even grain. The following is the result of a mechanical analysis: —

	Approximate Diameter of Grains, in Inches.	Percentage of Whole Quantity.
Between sieve No. 20 and No. 40,	0.020 to 0.040	1
Between sieve No. 40 and No. 55,	0.012 to 0.020	4
Between sieve No. 55 and No. 70,	0.010 to 0.012	5
Between sieve No. 70 and No. 100,	0.008 to 0.010	19
Between sieve No. 100 and No. 140,	0.005 to 0.008	28
	0.003 to 0.005	33
	0.001 to 0.003	9
	0.000 to 0.001	1

This sand is nearly white and appears to be nearly all of angular grains of quartz. The grains insoluble in strong acid in two hours formed 97.74 per cent. The soluble portion yielded 0.84 of one per cent., of the whole, of alumina, and 0.069 of one per cent. of oxide of iron and manganese. About one-third of one per cent. was lost on heating to redness; this loss was from the three finer grades given in the table.

The specific gravity of the solid particles is 2.65; and of the mass, when closely packed dry, 1.55, — giving an air space of 42 per cent. of the volume. The open space varies with the method of packing and is found to be in this tank about 40 per cent. of the volume.

Quantity of Liquid ordinarily held by the Sand.

The lower foot of this filtering material, although drained by gravel under its whole area, remains completely saturated all of the time, and the second foot from the bottom is continually about three-quarters saturated. The third foot is generally about one-half saturated. The fourth foot varies from two-thirds saturated, an hour after sewage has been applied, to one-third saturated on the following day; and the upper foot varies from five-sixths saturated, as sewage disappears from the surface, to about one-third saturated the following day. Generally, when sewage is applied, the tank averages about five-eighths saturated, or contains about one-quarter of its volume of liquid. From examinations made by taking out samples of the sand from different depths, — from which these results are obtained, — and from comparing the changes in chlorine in the effluent which follow the marked changes in chlorine of the applied sewage, it was determined that liquid, from any sewage applied over the surface, reached the outlet after pushing before it 2,275 gallons. Consequently the constituents of the effluent are compared with those of the sewage applied just before the beginning of the last 2,275 gallons which have flowed out.

Previous to the application of sewage 1,000 gallons of water had been applied in three or four hours of each day. This flowed through the filter at the maximum rate of 120 gallons per hour.

Effect of applying Sewage at a very low Temperature to Sand containing Frost.

Sewage was first applied on Dec. 19, 1887. The quantity was, the first five days, 136 gallons daily, and its temperature was 35° Fahr. This temperature was about ten degrees lower than the temperature of sewage in the main sewer, being cooled by flowing about 3,000 feet in an iron pipe through the water of the river.

The 136 gallons spread over the surface and went down with regularity, with no obstruction from frost.

On December 23 the minimum temperature of the air fell to 8°; rose to 19° on December 25; and then fell daily to 2° below zero on December 31.

On December 25 the surface of the sand appears to have been slightly frozen, and, two days later, to have been frozen nearly all over, — enough to check the flow to a maximum rate of about ten gallons per hour; which rate continued three days, and then grew less, until on January 1 the maximum flow was but one and a half gallons per hour.

On December 24 the quantity of sewage applied was increased to 272 gallons, and this amount was applied daily for three days; after which, snow falling upon the tank, a less quantity would run out over the top of the tank; and on the last day of the month, there being three inches of ice on the surface, only 40 gallons could be applied, as this filled the tank.

From these facts it is probable that the sewage settled quite evenly through the sand for the first week, when 1,300 gallons of water had been pushed through and the sewage was about two-thirds of the way down the tank. After this the applied sewage must have found passage through the frost in the upper layers of the sand at certain points, and not over the whole area. Some of these points were probably where the sewage entered the tank from the hose, which was shifted from point to point when discharging; here the sewage was a little warmer than where, after spreading over the surface, it came in contact with ice and snow. Under these points the entering sewage would push the water beneath the sewage farther down than in other parts, until the descending sewage would first meet the underdraining gravel at points beneath those where it passed through the frost most freely. By the chemical analysis we see that liquid from the sewage reached the bottom at one or more of these points on December 29, when 1,837 gallons had passed through after the first application of sewage; for on that day the chlorine, which previously had been 0.22 parts per 100,000, — the same as when water had been filtering, — rose to 0.36 parts; after which it increased daily. It appears, however, that with this sand some chlorine was at first held back in the filter; for when the 2,275 gallons of water, which this filter is estimated to hold when drained, had passed out, the chlorine had increased to only 0.72 parts, at which time the chlorine of the applied sewage was about four times this amount; and the chlorine of the effluent did not reach that of the sewage until January 17, when over 4,000 gallons had passed out, of which not more than 10 per cent. could have come from rain or snow.

By careful comparison of the amount of chlorine that came off with that put on, it would appear that, when 4,000 gallons of effluent had come off, 2,800 gallons were of water and 1,200 gallons were of sewage. When 4,800 gallons had come off, 2,815 were of water and 2,000 were of sewage. When 5,279 had come off, 2,587 were of water and 2,692 were of sewage; and when 5,800 gallons had come off, 2,323 gallons were of water and 3,477 gallons were of sewage; indicating that the chlorine was held back, to some degree, for the first month only, and then passed through as applied.

The rain of January 1–2, coming upon the three inches of ice and one inch of snow on the tank, thawed these to some extent, leaving but two inches of ice; and the rain and applied sewage thawed some of the frost in the tank, so that the quantity flowing through increased from 32 gallons on the day before the rain to 79 gallons and 113 gallons on the two following days. But the weather growing colder, and the temperature of the sewage being 35° when applied, the quantity flowing decreased, in the next week, to less than 50 gallons, the space from the top of sand to top of tank nearly filled with ice, and it was found impracticable to continue intermittent filtration with sewage at this low temperature, upon a level surface of fine sand when it was exposed to so low a temperature and to the cooling effect of snow falling into it.

It must be borne in mind that this sewage was about ten degrees colder than sewage is generally found to be in such weather at the outlet of separate sewerage systems.

Before abandoning experiments with sewage at this temperature, it was thought best to try the effect of getting the sewage below the surface more quickly; and on January 11 two rings one foot wide were cut through the ice and one foot deep into the sand. One of these rings went around in the tank one foot and a half from the outside, and the other five feet from the outside. These rings were filled with coarse sand, like that of Tank No. 1, which, when dry, would receive about 170 gallons of water and would allow about 115 gallons to drain out of it.

In cutting these rings the frost in the sand was found to be one foot deep; and the three inches of ice above was in some places frozen to the sand. The top of the rings of coarse sand was even with the original surface, so that the applied sewage covered the whole area, when not obstructed by ice.

The quantity of sewage applied during the next nine days averaged 265 gallons per day, and the effluent averaged 192 gallons. The minimum daily temperature of the air averaged 5° Fahr. and ice accumulated to the depth of four inches. After the fourth day the quantity of effluent decreased. On the ninth day it was 112 gallons, and three days later only 12 gallons. The surface was again frozen up.

On January 23 four holes were cut through the ice and frost of the tank. The ice was about six inches thick, and the frost in the sand fifteen inches deep. The minimum temperature of that day was 14° below zero; and the average minimum daily temperature for the last eleven days of January was 5° below zero. After January 23, for five days, 150 gallons of sewage, at temperature of 35° to 39°, were daily poured into the four holes, and an average of 95 gallons passed through the tank; but in the next two days the quantity of effluent decreased to 38 gallons. Then two new holes were cut through the ice and frost; and the frost was found to be two feet deep under six inches of ice.

With the six holes — 150 gallons being applied daily — the quantity flowing through averaged 125 gallons for the next eight days, — the least quantity being 106 gallons. The temperature of applied sewage was 37° and of the effluent 36°; and the average minimum daily temperature of the air was 8° above zero, and one day it was 5° below.

During the extremely cold weather the four holes, less than a foot square, which received 150 gallons of sewage at 37° temperature daily, grew smaller by a lining of ice.

On February 7 a new hole was cut through the frost, which was found to be 27 inches deep. The flow through the former holes was much checked by frost, and a large part of the 150 gallons applied entered the tank through this new hole, the bottom of which was but three feet above the bottom of the filtering material.

Although sewage had been entering the filter for seven weeks, and for the past month had been entering through a few holes cut in the frost, nearly all of its organic impurities had been retained by the filter. The effluent at this time contained but one per cent. as much ammonia as the sewage. It was concluded to be of no advantage to continue applying sewage at a temperature eight or ten degrees lower than that of the sewage within the sewer, and a hot-water pipe was run through the tank into which the sewage was pumped, and for the remainder of the winter the sewage was raised to a temperature as high as or higher than its temperature in the sewer.

From February 12 to 16 the sewage was applied at 44°, — the same temperature it had in the sewer, — and the quantity passing through the filter was the same as the quantity applied.

Removal of Frost by applying Heated Sewage.

On February 17 the ice was cleared from the surface of the tank, and a ring one foot and one-half wide and one foot from outside of the tank was cut two inches deep into the sand. The sand from this ring was filled into the holes previously cut. Seventy-five gallons of sewage, heated to 68°, were poured into this ring and settled one-quarter of an inch in two and a half hours.

The large amount of frost which had accumulated in the sand during the extremely cold winter, and the application of sewage at the temperature of eight or ten degrees below that in the sewer, was so much of an obstruction to the entrance of sewage over the whole surface and the consequent general distribution of sewage throughout the whole mass of the filter, that it was desirable to remove this frost as promptly as practicable. To accomplish this object, sewage was applied during the next three weeks, or until March 10, at an increased temperature averaging 55° ; and many holes were melted through the frost by pressing the end of the hose, through which sewage was brought from the measuring tank, against the frost at one point until a hole was melted through by the warm sewage. One hundred and fifty gallons were applied daily and seven-eighths as much came through ; but it came through at the temperature of 35° and 36° and the frost still was found over nearly the whole area of the tank.

On March 10 an attempt was made to thaw out the tank ; and during the next thirteen days 5,350 gallons of sewage were applied at 64° ; which all came through at 35°. At the end of this time there was still much frost in the tank, appearing, by examination with sounding rod, to cover nearly one-half of the area a little below the surface ; but the passage for sewage was quite free. One hundred gallons placed on the surface disappeared in about an hour. The temperature of the effluent increased only two degrees in the next ten days, and reached 39° on April 9 ; the applied sewage being, after April 1, at about 44°.

Tables and Diagram of Results.

At the end of this section on Tank No. 2 may be found the results of each of the 235 chemical analyses of the effluent ; the daily quantity applied and drawn off ; the temperature of the sewage and effluent ; and other daily observations concerning this tank. The quality of the sewage applied may be found in tables accompanying Tank No. 1.

Near the tables for Tank No. 2 may be found the daily results of chemical examinations of the effluent and the sum of ammonias of the sewage presented upon a diagram, having the scales described under Tank No. 1.

Dissolved Organic Matter held back by the Sand.

From the preceding account of the frost in the tank it is evident that, from December 27 to March 10, the applied sewage passed through the upper two feet in depth of the sand in a few places of small area, except during the ten days from January 11 to 21, after the rings were cut through the frost and filled with coarse sand, and then the area was not more than one-third of the whole area of the tank ; and it is remarkable that for more than six weeks after sewage was first applied, and for three weeks after the chlorine indicated the effluent to be undiluted by water previously in the tank or from other source, the ammonias of the effluent were but seven-tenths of one per cent. of those of the applied sewage. Experiments in the laboratory indicate that during this time ammonia was being stored up in the sand, and that it was gradually working its way down through the sand, being abundant near the top, growing less from point to point downward and disappearing before reaching the bottom. At the end of this time some ammonia was reaching the bottom. In the next two weeks it appeared in the effluent, increasing from 0.0146 parts in 100,000 to 0.2500 parts; or, from less than one per cent. to 15 per cent. of the ammonias of the applied sewage. The quantity of effluent continued to be about 135 gallons per day.

During the next nineteen days, — from February 22 to March 12, — with the same quantity flowing, the ammonias of the effluent remained nearly constant, averaging 0.2691 parts, or 18 per cent. of those of the sewage.

From March 12 to 22 5,000 gallons of sewage passed through the tank, which was at the rate of 90,000 gallons per acre per day. The filtration during this time was not intermittent but was continuous; and the ammonias of the effluent increased from 0.2470 parts to 0.6790 parts per 100,000, which, as the sewage was then weaker than formerly, owing to great dilution by rainfall, was about 90 per cent. of the ammonias of the sewage.

From March 24 the quantity of sewage applied was 150 gallons daily; and the effluent was in the next month about 6 per cent. more, being increased by the rain which fell upon the tank.

Beginning of Nitrification.

The temperature of the sewage applied was, during the last week of March, 60°; and in April, 44°. The temperature of the effluent rose, in this time, about one degree a week, — from 36° to 42°. When it was 39°, the nitrates of the effluent, which for the previous month had averaged 0.007 parts in 100,000, rose to 0.012 on April 10, followed in succeeding analyses by 0.025, 0.030 and 0.035 parts. This was the beginning of the rise in the nitrates, which continued through the spring, — rising slowly to the middle of May, and then very rapidly reaching 2.900 parts in the middle of June.

This rise in the nitrates began at the same temperature of the effluent as in tanks No. 1, No. 12, No. 13 and No. 14, and indicates that, when liquid in the tank is below the temperature of 39° Fahr., the conditions are not favorable for nitrification to begin; although, by the experience of the next winter, it becomes evident that nitrification, being in progress, will continue at a lower temperature.

It is, moreover, true that in tanks No. 1, No. 2, No. 4, No. 6 and No. 7 — as will be seen by referring to the diagram of nitrates given with account of Tank No. 12 — the nitrates increased about the middle of January, 1888, soon after sewage first came through, when it was being applied at temperatures from 35° to 40°, and came out, in the only two cases when temperature was observed in that month, at 35° and 36°. This increase in nitrates reached in No. 6, where it was the greatest, 0.110 parts; and in No. 2 it reached 0.030 parts, and soon fell to the amount found in the sewage. This increase in nitrates appeared in the effluent very soon after sewage had displaced water which was previously in the tank, — which water had been applied at 45°; and it is probable that this nitrification took place in the upper layers of the sand, when sewage at 35° to 40° was replacing water at 45°, and appeared later, after it had been cooled to below 39° by mingling with colder liquid from sewage coming down upon it.

The nitrates in the effluent of No. 2 rose from 0.012 to 0.035 parts from April 10 to 20, when the temperature of the effluent was 39° and 40°. They continued with but little increase until May 19, when the temperature of the effluent had reached 49°, at which time the increase in the nitrates became rapid and very marked, rising from 0.065 on May 19 to 2.700 on June 6, when the temperature had reached 58°; and continuing from June 6 to June 23 at an average of 2.383 parts in 100,000.

In this period of rapid nitrification the amount of nitrogen which came off as nitrates was greater than all of the nitrogen that was, in the same time, applied in the sewage.

By referring to the Diagram of Nitrates it will be seen that this rapid nitrification in Tank No. 2 occurred at a later period than in any of the other tanks, being five weeks later than in Tank No. 1. At the rate sewage was being applied it would take about nine days longer for any sewage applied to reach the bottom in this tank than in No. 1.

The rapid increase of ammonias in the effluent that occurred in March, when 500 gallons of sewage were applied daily, and the method of filtration was changed from intermittent to continuous, caused them to average, from March 19 to April 1, 0.6560 parts per 100,000, — the highest they have attained. This increase was all in the free ammonia, which averaged 0.6323 parts, while the albuminoid ammonia remained as before, 0.0237 parts. After this with 150 gallons applied daily and intermittent filtration resumed, the ammonias decreased slowly, until a month after nitrification had begun to increase rapidly. The average sum of ammonias for April was 0.5763 parts or 33 per cent. of that of the sewage; of which 0.5571 parts were free ammonia, and 0.0192 parts were albuminoid ammonia, — the latter being but 3 per cent. of the albuminoid ammonia of the sewage.

For readily seeing the more general changes and results of filtration of sewage in Tank No. 2, during the past two years, the following table of monthly averages has been arranged from the tables of daily observations: —

Monthly Averages of Daily Results with Tank No. 2.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888.												
Dec. 19–Jan. 13,	Sewage, .	–	22.78	22.83	1.3100	.5187	2.8287	3.17	.006	–	–	–
January, . .	Effluent, .	108	2.61	6.88	.0029	.0097	.0126	2.44	.014	–	36°	10,433
	Per cent.,	–	11	30	.2of1	1.9	.7of1	–	–	–	–	–
Jan. 14–Feb. 15,	Sewage, .	–	34.67	18.49	.9465	.6482	1.5947	2.34	.007	–	–	–
February, . .	Effluent, .	142	2.03	10.74	.0832	.0155	.0987	2.63	.013	–	35°	721
	Per cent.,	–	6	58	9	2.4	6	–	–	–	–	–
Feb. 16–Mar. 19,	Sewage, .	–	15.29	16.50	.7229	.3767	1.0996	2.34	.007	–	–	–
March, . .	Effluent, .	251	2.09	12.02	.4597	.0250	.4847	2.53	.006	.0004	35°	2,779
	Per cent.,	–	14	73	64	7	44	–	–	–	–	–
Mar. 20–Apr. 10,	Sewage, .	–	38.57	46.76	1.0553	.6760	1.7313	2.81	.008	–	–	–
April, . .	Effluent, .	158	1.61	11.28	.5571	.0192	.5763	2.39	.018	.0003	39°	1,092
	Per cent.,	–	4	24	53	3	33	–	–	–	–	–
Apr. 11–May 12,	Sewage, .	–	36.14	43.18	1.0295	1.1528	2.1823	3.37	.007	–	–	–
May, . . .	Effluent, .	153	3.33	13.86	.5100	.0157	.5257	3.47	.116	.0026	49°	170
	Per cent.,	–	9	32	50	1.4	24	–	–	–	–	–
May 13–June 8,	Sewage, .	–	27.93	33.92	1.2894	.5975	1.8869	4.31	.008	.0006	–	–
June, . . .	Effluent, .	117	13.62	21.34	.3778	.0145	.3923	4.67	2.056	.0499	61°	151
	Per cent.,	–	49	63	29	3	21	–	–	–	–	–
June 9–30, . .	Sewage, .	–	17.51	26.09	1.4844	.3425	1.8269	4.77	.007	.0003	–	–
July, . . .	Effluent, .	85	8.04	26.79	.1550	.0117	.1667	7.59	1.319	.0388	68°	222
	Per cent.,	–	46	103	10	3	9	–	–	–	–	–
July 1–Aug. 4, .	Sewage, .	–	21.62	27.46	2.0752	.5576	2.6328	6.56	.009	.0001	–	–
August, . .	Effluent, .	97	2.39	26.87	.0422	.0149	.0571	8.17	1.156	.0086	70°	157
	Per cent.,	–	11	98	2	3	2	–	–	–	–	–
Aug. 5–Sept. 7,	Sewage, .	–	75.44	82.60	2.8100	1.9217	4.7317	8.40	–	.0000	–	–
September, .	Effluent, .	95	1.13	28.82	.0012	.0080	.0092	8.76	.818	.0000	67°	368
	Per cent.,	–	1.6	35	.04of1	.4of1	.2of1	–	–	–	–	–
Sept. 8–Oct. 5, .	Sewage, .	–	26.11	44.73	1.8979	.6736	2.5715	7.82	–	.0000	–	–
October, . .	Effluent, .	93	1.06	25.60	.0003	.0072	.0075	6.95	.792	.0000	57°	39
	Per cent.,	–	4	57	.02of1	1.1	.3of1	–	–	–	–	–
October 6–25, .	Sewage, .	–	18.65	29.73	2.2488	.4537	2.7025	5.05	–	.0000	–	–
November, .	Effluent, .	69	1.25	22.13	.0003	.0072	.0075	4.47	.863	.0000	51°	11
	Per cent.,	–	7	74	.01of1	1.6	.3of1	–	–	–	–	–
Oct. 26–Nov. 19,	Sewage, .	–	19.06	29.46	2.2600	.4590	2.7190	4.84	–	.0000	–	–
December, .	Effluent, .	59	.70	21.29	.0005	.0064	.0069	4.12	.784	.0000	43°	5
	Per cent.,	–	4	72	.02of1	1.4	.3of1	–	–	–	–	–

Monthly Averages of Daily Results with Tank No. 2.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1889.												
Nov. 20-Dec. 26,	Sewage, .	–	15.13	30.55	1.0977	.3331	1.4308	4.52	.011	.0000	–	–
January, . .	Effluent, .	63	.62	20.62	.0008	.0060	.0068	4.19	.762	.0000	40°	12
	Per cent.,	–	4	67	.07of1	1.8	.5of1	–	–	–	–	–
Dec. 27-Jan. 20,	Sewage, .	–	11.66	25.92	1.1940	.2720	1.4660	4.36	.020	.0004	–	–
February, . .	Effluent, .	57	1.03	18.46	.0008	.0059	.0067	4.00	.736	.0000	39°	23
	Per cent.,	–	9	71	.07of1	2.2	.5of1	–	–	–	–	–
Jan. 21-Mar. 15,	Sewage, .	–	10.39	19.83	1.1871	.2871	1.4742	3.64	.022	.0127	–	–
March, . .	Effluent, .	129	1.08	18.79	.0009	.0077	.0086	3.62	.651	.0001	38°	28
	Per cent.,	–	10	95	.08of1	2.7	.6of1	–	–	–	–	–
Mar. 16-Apr. 19,	Sewage, .	–	13.03	27.07	1.8320	.4507	2.2827	5.98	.008	.0011	–	–
April, . .	Effluent, .	198	1.34	28.07	.0201	.0095	.0296	6.06	1.713	.0081	45°	7
	Per cent.,	–	10	104	1.1	2.1	1.3	–	–	–	–	–
Apr. 20-May 12,	Sewage, .	–	14.53	23.16	2.1567	.4211	2.5778	4.36	.004	.0000	–	–
May, . . .	Effluent, .	137	1.09	30.54	.0019	.0098	.0117	4.80	2.256	.0010	58°	57
	Per cent.,	–	8	132	.1of1	2.3	.5of1	–	–	–	–	–
May 13-June 10,	Sewage, .	–	17.56	24.93	2.0311	.4633	2.4944	4.33	.000	.0000	–	–
June, . . .	Effluent, .	113	1.89	27.26	.0020	.0104	.0124	4.63	1.638	.0002	64°	38
	Per cent.,	–	11	109	.1of1	2.2	.5of1	–	–	–	–	–
June 11-July 17,	Sewage, .	–	26.04	27.70	2.5040	.6400	3.1440	5.74	.000	.0000	–	–
July, . . .	Effluent, .	135	2.36	24.10	.0020	.0094	.0114	5.96	1.000	.0000	68°	57
	Per cent.,	–	9	87	.1of1	1.5	.4of1	–	–	–	–	–
July 18-Aug. 12,	Sewage, .	–	23.25	39.82	2.1018	.5800	2.6818	4.97	.000	.0000	–	–
August, . .	Effluent, .	120	.83	19.93	.0008	.0074	.0082	4.48	.504	.0000	68°	6
	Per cent.,	–	3.6	50	.04of1	1.3	.3of1	–	–	–	–	–
Aug. 13-Sept. 19,	Sewage, .	–	29.16	36.13	1.7433	.7300	2.4733	6.28	.000	.0002	-	–
September, .	Effluent, .	167	1.80	26.40	.0013	.0078	.0091	7.77	.864	.0000	66°	8
	Per cent.,	–	6	73	.07of1	1.1	.4of1	–	–	–	-	–
Sept. 20-Oct. 17,	Sewage, .	–	26.07	29.89	1.9545	.7818	2.7363	4.85	.001	.0002	–	–
October, . .	Effluent, .	189	–	–	.0044	.0090	.0134	5.18	1.376	.0005	56°	7
	Per cent.,	–	–	–	.2of1	1.2	.5of1	–	–	–	–	–

This table gives for each month the mean daily quantity of effluent, the mean of the chemical analyses of the effluent and of the sewage from which the effluent for each month was derived, and the percentage which the former is of the latter. The average number of bacteria found in a cubic centimeter of the effluent, by semi-weekly observations for each month, is also given.

The daily quantity which, at the same rate, would have been filtered upon an acre may be determined by multiplying the daily quantity by two hundred.

The time from the application of sewage to its appearance at the outlet may be determined by dividing 2,275 by the daily quantity filtered. This varied, in the last year, from 40 days in February to 12 days in April and October.

In May, 1888, the sum of ammonias of the effluent averaged 0.5257 parts, which was 24 per cent. of those of the sewage, the free ammonia being 0 5100 and the albuminoid ammonia 0.0157 parts, the former 50 per cent. and the latter 1.4 per cent. of those of the sewage. In this month the nitrates increased a little and averaged 0.116 parts.

Ammonias continued High for Three Weeks after Nitrification was Active and then rapidly decreased.

In June the quantity of sewage applied was 150 gallons daily until June 17, after which it was 100 gallons. The ammonias continued nearly constant for three weeks, while the nitrates increased to their highest point. The ammonias in this time averaged 0.4626 parts, and afterwards fell to 0.2460 parts, at the end of the month, — averaging for the month 0.3923 parts, or 21 per cent. of those of the sewage; and the nitrates averaged 2.056 parts and the nitrites 0.0499 parts.

In this month the total amount of nitrogen in the effluent, determined as for Tank No. 1, exceeded the total amount of nitrogen applied in the sewage by 9 per cent., — this excess being derived from nitrogenous matter previously stored in the sand. In this month 94 per cent. of as much nitrogen as was applied came away in the effluent as nitrates. After this remarkably complete nitrification, the ammonias of the effluent grew less month by month, for the next four months, — July to October, — during which the amount filtered daily was nearly constant and averaged 18,500 gallons per acre. The free ammonia in the successive months was as follows: July, 0.1550 parts, or 10 per cent. of that of the sewage; August, 0.0422 parts, or 2 per cent.; September, 0.0012 parts, or one twenty-fifth of one per cent.; and in October, 0.0003 parts, or one-fiftieth of one per cent. of that of the sewage.

The albuminoid ammonia was as follows: July, 0.0117 parts, or 3 per cent. of that of the sewage; August, 0.0149 parts, or 3 per cent.; September, 0.0080, or 0.4 of one per cent.; and October, 0.0072, or 1.1 per cent. of that of the sewage.

Influence of the Condition of the Surface upon Nitrification.

During these four months, while the ammonias were growing rapidly less, — until the nitrogenous organic matter in the effluent became less than in most of the drinking waters in the State, — the nitrates were decreasing. They were in July 1.319 parts per 100,-000; in August, 1.156 parts; in September, 0.818 parts; and in October, 0.792 parts. These were generally lower than the nitrates of Tank No. 1, especially in September. This was probably due to the choking up of the surface of the tank, by which the sewage remained longer upon the surface after it was applied. From the middle of July to the middle of August the time which the sewage remained on the surface increased from 2 hours to 24 hours, much rain falling upon the tank in the latter month; and about the middle of September, after heavy rains, the surface was kept covered with water for several days.

To change this condition the application of sewage was changed, after September 15, from 100 gallons applied daily to 200 gallons applied every second day, except when this day was Sunday the application was made on the third day. This gave more time for the surface to dry between applications and allowed more air to enter the sand, but before the end of October sewage and rain-water were standing upon the surface of the tank all of the time, and in the first four days of November no sewage was applied; and after this 150 gallons were applied until the 4th of March, 1889, with the same intervals with which 200 gallons had been previously applied.

The following table contains the percentage of nitrogen applied in the sewage, which appears in the effluent as nitrates from June, 1888, — the first month after nitrification began, — through October, 1889. The total nitrogen of the sewage was determined by taking 0.82 of the free ammonia, plus two times 0.82 of the albuminoid ammonia, plus the nitrates; and the readings of nitrates in the effluent are corrected for the variation between the quantities of liquid applied and liquid drawn off, due to variations in rainfall and evaporation.

Percentage of Nitrogen applied in the Sewage that appears in the Effluent as Nitrates.

Date.	Nitrogen applied in Sewage.	Nitrates in Effluent corrected for Quantity.	Per Cent. of Nitrogen applied.	Average daily Quantity. Gallons.	Temperature.	
					Sewage.	Effluent.
1888.						
June,	2.0452	1.919	94	117	56°	61°
July,	1.7859	1.212	68	85	68°	68°
August,	2.6242	1.021	39	97	70°	70°
September,	5.4558	.776	14	95	70°	67°
October,	2.6610	.912	34	93	61°	57°
November,	2.5881	.999	39	69	47°	51°
December,	2.6060	.750	29	59	45°	43°
1889.						
January,	1.4574	.705	48	63	44°	40°
February,	1.4456	.788	55	57	45°	39°
March,	1.4790	.607	41	129	42°	38°
April,	2.2505	1.654	73	198	41°	45°
May,	2.4631	2.364	96	137	54°	58°
June,	2.4253	1.760	73	113	63°	64°
July,	3.1029	.871	28	135	71°	68°
August,	2.6747	.570	21	120	71°	68°
September,	2.6269	.835	32	167	70°	66°
October,	2.8860	1.345	47	189	57°	56°

The percentage of nitrates in September, 1888, as well as the percentage of ammonias of this month previously given, are smaller than they would have been but that two or three samples of the sewage applied were very much higher in nitrogenous matter than usual, and a filter cannot quickly adapt itself to exceptional conditions.

Other conditions that may have affected the nitrification are the following: In July, 1888, there were ten small tufts of grass growing on this tank, and the surface became greenish to the depth of one-sixteenth to one-eighth of an inch. This was not a covering upon the sand that would curl up when dry, as in some of the tanks, but was in the sand to this depth.

Obstruction of the Surface removed by Oxidation upon reducing the Quantity of Sewage.

The surface of the filter had not been disturbed since the ice was cut from it in February, and it was left undisturbed for the year following to demonstrate whether it would clear itself of any obstructions that might accumulate under peculiar circumstances. The unusual rainfall of 13.66 inches in September and October, 1888, helped to keep the surface continually wet, and interfered with intermittent action of the filter, and prevented the removal of obstructions by oxidation. The resulting effluent was, however, remarkably pure during all this time; but the quantity to which it was found necessary, with this condition of the surface, to reduce the amount filtered was smaller than desirable. It averaged for the next four months — November to February — 12,400 gallons per acre per day.

Quantity of Sewage increased.

At the end of February, 1889, the tank had cleared itself of obstructions at the surface so completely, and the effluent was so pure, that on March 6 the quantity was doubled, and averaged for March 25,800 gallons per acre per day; and was still further increased on the 27th of March, and averaged for April 39,600 gallons per acre per day, — the quantities applied being 450 gallons on every other day except Sunday. This quantity at first disappeared readily, but was at last found to keep the surface covered with water all of the time when accompanied by rain; and after May 15 was reduced to 300 gallons, — the average quantity filtered for May being 27,400 gallons per acre per day. This quantity applied was continued for four months, till the middle of September, when it was increased to 500 gallons applied on three days in each week; and this quantity was continued through October, making the average quantity filtered in June, July and August, 1889, 24,500 gallons per acre per day; in September, 33,400 gallons; and in October, 37,800 gallons per acre per day.

In June, 1889, a green slime was observed on the surface of the sand, which in July curled up in places when dry. This was, in the following months, somewhat of an obstruction to the entrance of sewage; but, without any disturbance of the surface or removal of deposit, this tank filtered three times as much sewage at the end of the second year as at the end of the first, with, as will be seen, nearly as satisfactory purification.

Early in June, 1889, about one-tenth of the surface was covered with grass; by the first of July about three-quarters of the surface was covered; and by the last of August the whole surface was covered with rank, tall grass. This was cut from one-half of the surface on October 26.

Nitrification active through the Winter.

Referring to the table, we see the percentage of nitrogen applied in the sewage that appears in the effluent as nitrates decreased from 94 per cent. in June, 1888, to 39 per cent. in August. The percentage in September was exceptionally low, — 14 per cent., — for the reason previously given. It then continued through October and November at 34 and 39 per cent. In the four cold months, December to March, the percentages were 29, 48, 55 and 41, averaging 43, — which is higher than for any of the previous four months.

As stated in giving an account of Tank No. 1, the winter of 1888–89 was not as cold as usual; and this tank, like No. 1, was covered with canvas to keep out the snow from November 22 to March 13. The sewage was applied for three months at a temperature but one or two degrees below that in the sewer, and the effluent averaged 41°; but in the fourth month the temperature of applied sewage was from 33° to 41°, and that of the effluent from 37° to 40°, averaging 38°, — which was lower than the temperature at which in the previous winter nitrification began. Still, nitrification being in progress, we find that it continued efficiently with the sewage and the effluent at as low temperatures as they are ever likely to be found in sewage fields in this climate, provided snow is kept from the surface. The nitrogen as nitrates in the effluent at this very low temperature of 38° averaged for the month of March 0.661 parts in 100,000, and amounted to 41 per cent. of the total nitrogen applied; and the ammonias amounted to but six-tenths of one per cent. of the ammonias of the sewage.

Nitrification increases in the Spring.

With the opening of spring the nitrates of the effluent increased, and their percentage of the total nitrogen applied rose as follows: in April, nitrates, 1.713 parts per 100,000 or 73 per cent.; in May, 2.256 parts or 96 per cent.; and in June, 1.638 parts or 73 per cent., of the total nitrogen applied in the sewage.

In July the rainfall amounted to 7.04 inches; and the green slime upon the surface, being thus kept wet between applications of sewage, interfered with the entrance of air into the sand and with the completeness of nitrification. The nitrates decreased from July 3 to August 3, 1889, from 1.5000 parts to 0.2700 parts per 100,000, — averaging, for the month of July, 1.0000 parts, — and were 28 per cent. of the total nitrogen of the sewage applied.

In the three following months, with the increasing quantities filtered, viz., 120, 167 and 189 gallons per day, the nitrates increased as follows: 0 504 parts, 0.864 parts and 1.376 parts, — which were 21, 32 and 47 per cent. of the total nitrogen of the applied sewage. In these three months, with from 30 per cent. to 100 per cent. more sewage filtering, the nitrification was more complete than in the corresponding months of the previous year.

For the year, November, 1888, through October, 1889, the nitrogen in the nitrates of the effluent averaged 1.104 parts per 100,000, — which was 48 per cent. of the total nitrogen of the sewage.

Purification during the Second Year.

The ammonias of the effluent of Tank No. 2 have been very low during the second year of its use, from Nov. 1, 1888, to Nov. 1, 1889. The free ammonia by monthly averages has varied from one one-hundredth of one per cent. to one and one-tenth per cent. of that of the sewage, and averaged for the year but 0.0030 parts per 100,000, or one-sixth of one per cent. of that of the sewage. The albuminoid ammonia varied from 1.1 per cent. to 2.7 per cent., and averaged for the year 0.0080 parts per 100,000, or 1.8 per cent. of that of the sewage; and the sum of the ammonias averaged but one-half of one per cent. of the sum of the ammonias of the sewage.

This tank of fine sand, after it had filtered 40,000 gallons of sewage, or the equivalent of 8,000,000 gallons on an acre, filtered in the second year 44,000 gallons of sewage, or the equivalent of 8,800,000 gallons on an acre, and removed therefrom 99½ per cent. of all of the organic matter as indicated by the ammonias without having the sand of the filter disturbed, or sediment removed from the surface, or in any way cleaned except the cleaning produced by oxidation and nitrification.

Purification during the Winter, 1888–89.

During the cold months of the year, — December, 1888, to March, 1889, — the free ammonia averaged 0.0007 parts, or one-sixteenth of one per cent. of that of the sewage; the albuminoid ammonia averaged 0 0065 parts, or 2 per cent. of that of the sewage; and the nitrogen of the nitrates 0.736 parts, or 41 per cent. of the total nitrogen of the applied sewage.

The purification from nitrogenous organic matter was, during these cold months, such as to leave the effluent containing less of such matter than the waters of Lake Winnipiseogee.

The loss on ignition obtained during May, June and July, 1888, was of no significance for reasons given in considering Tank No. 1. During the last year the loss on ignition has varied from 0.62 parts per 100,000 to 2.36 parts, and has averaged 1.27 parts, — which is 7 per cent. of that of the sewage. If from this average loss on ignition we should deduct, as appears proper from Mr. Hazen's report appended, 0.60 parts per 100,000 there would remain 0.67 parts, — which is 4 per cent. of that of the sewage, and is 2.2 times the percentage which the albuminoid ammonia of the effluent is of the albuminoid ammonia of the sewage. Since Aug. 1, 1888, the losses on ignition in the effluent from all of the tanks, as well as of the sewage, have been determined with sodium carbonate, as described under Tank No. 1. During the cold months the loss on ignition of the effluent as determined was 0.86 parts per 100,000, or 6 per cent. of that of the sewage. Deducting as before 0.60 parts, it would be 0.26 parts or 2 per cent. of that of the sewage.

Summary of Results in the Cold Months of 1888-89 compared with the Year.

	For the Year.		For the Cold Months.	
	Parts per 100,000.	Percentage of the Same in the Sewage.	Parts per 100,000.	Percentage of the Same in the Sewage.
Loss on ignition, ...	1.27	7.	0.86	6.
Loss on ignition corrected, ...	0.67	4.	0.26	2.
Free ammonia, ...	0.0030	0.16	0.0007	0.06
Albuminoid ammonia, ...	0.0080	1.8	0.0065	2.
Sum of ammonias, ...	0.0110	0.5	0.0072	0.4
		Percentage of Total Nitrogen in the Sewage		Percentage of Total Nitrogen in the Sewage.
Nitrogen as nitrates, ...	1.1040	48.	0.7120	43.

The effluent from the filter contained less impurities in the winter months than the average for the year, but the sewage during the winter also contained less impurity than through the year; still, the degree of purification was nearly as great through the winter — when more than 99½ per cent. of all of the nitrogenous organic matter was removed — as during the year.

This result confirms the conclusion made with Tank No. 1, that purification by nitrification with intermittent filtration is entirely practicable in this climate, if snow is kept from the filtering area.

The fixed residue of the effluent increases with the nitrification; becoming at times of greatest nitrification larger in amount than in the sewage. It has varied during the last year from 18.46 parts to 30.54 parts, — averaging 23.42 parts, or 82 per cent. of that of the sewage.

The chlorine in the sewage has varied by monthly averages from 2.34 to 8.40 parts per 100,000; and the variations at different hours in the same day have been even wider than this. The average for the past year has been 4.91 parts, and the average chlorine of the effluent for the same time has been 4.94 parts. From this it will be seen that, though this sand retained some chlorine for a time when it first came through, there is no reason to think that any of the chlorine now applied is retained in the sand; in fact, if we multiply the average chlorine observed each month in the sewage and in the effluent by the quantity of sewage applied and by the quantity of effluent respectively, it will appear that about 2 per cent. more chlorine came away from the tank than was applied to it during the past year. We can safely conclude that no change in the quantity of chlorine is caused by this filter.

The Amount of Nitrogen stored in the Filter and the Amount lost.

We have found that, during the last year, 48 per cent. of the nitrogen of the sewage appears in solution in the effluent; and there is about 1 per cent. more of nitrogen indicated by the ammonias. We have now to seek for the remaining 51 per cent. to determine under what conditions and how much of it has been stored in the sand, and how much has been lost.

The total nitrogen applied to the tank, and the amounts found in the effluent and in the sand, have been determined as described under Tank No. 1.

The quantities of nitrogen found at different dates, stored in the sand at several points from top to bottom, have been plotted and the total quantity in the tank determined. From these plottings the following table has been made, giving the quantity of nitrogen in parts per 100,000 of the weight of the dry sand for the different dates at the several depths: —

Distance below Surface. (Inches.)	December, 1888.	February, 1889.	June, 1889.	November, 1889.	Distance below Surface. (Inches.)	December, 1888.	February, 1889.	June, 1889.	November, 1889.
0 to ¼, . . .	86.80?	–	130.80?	598.60?	18, ...	2.05	1.55	1.15	.60
1, ...	11.00	24.85	28.60	33.95	24, ...	1.95	1.40	.85	.45
2, ...	7.65	14.10	19.95	21.20	36, ...	1.85	1.10	.80	.40
4, ...	4.30	6.15	6.35	7.05	48, ...	1.55	.80	.80	.35
8, ...	2.40	3.05	2.65	2.75	60, ...	1.20	.50	.80	.30
12, ...	2.25	1.95	1.80	1.35					

From the plottings the total quantity stored in the tank at different dates has been determined, and the results together with the amounts applied and the amounts that came off in the effluent are placed in the following table: —

Summary of total nitrogen applied to Tank No. 2 for several periods between Jan. 1, 1888, and Nov. 1. 1889; the amount which came off in the effluent and the amount stored in the tank; together with a balance unaccounted for.

	From Jan. 1, 1888, to Dec. 1, 1888. Pounds.	Per Cent. of Nitrogen applied.	From Dec. 1, 1888, to June 1, '89. Pounds.	Per Cent. of Nitrogen applied.	From June 1, 1889, to Nov. 1, 1889. Pounds.	Per Cent. of Nitrogen applied.	From June 1, 1888, to Nov. 1, 1889. Pounds.	Per Cent. of Nitrogen applied.
Amount of nitrogen applied,	7.88	–	3.34	–	5.20	–	16.42	–
Amount came off in effluent,	2.54	32	2.24	67	2.03	39	6.81	41
Difference, ...	5.34	–	1.10	–	3.17	–	9.61	–
Amount stored in tank, .	2.94	37	.41	12	1.25	24	4.60	28
Amount not accounted for, .	2.40	31	.69	21	1.92	37	5.01	31

In the year 1888, 32 per cent. of the nitrogen applied in the sewage came off in the effluent; in 1889, 51 per cent. thus came off; and, in the whole time, 41 per cent. During the six months, including the spring nitrification, 67 per cent. came off; and in the month of highest nitrification — May — 97 per cent. came off.

The amount stored in the tank the first year was 37 per cent. of the whole amount applied; in the second year, 20 per cent.; and, in the whole time, 28 per cent. During the six months including the spring the amount stored was but 12 per cent. of the amount applied.

The amount unaccounted for the first year was 31 per cent. of the amount applied. It was the same percentage in the second year;

and, consequently, for the whole time. It was but 21 per cent. during the six months including the most complete nitrification.

Until we learn better we shall regard this quantity of nitrogen as having escaped into the air.

Where in the Filter is the Stored Nitrogen?

By examining the table of total nitrogen found in the sand, and the diagrams from which it was made, we find that above a depth of nine inches the amount stored has continually increased during the second year, and that below this depth the amount has as steadily decreased.

The cleansing process goes on more efficiently in the lower four feet of the tank than in the upper nine inches. Three-quarters of all the nitrogen that was stored in the sand in the lower four feet, at the end of the first year, has been removed by the cleansing process of nitrification during the second year. There has also been a decrease, in the last eight months, in the amount stored at eight inches below the surface; and an increase of only one-sixth at a depth of four inches; but above this, and particularly in the upper inch, there has been a decided increase.

It must be borne in mind that the surface of this tank has not been raked over, or in any way disturbed, during the past eighteen months, in which 70,000 gallons of sewage, the equivalent of 14,000,000 gallons on an acre, have been poured on this surface.

The amount of nitrogen applied here in the sewage, during the ten months of 1889, has been 8.49 pounds; and 2.13 pounds, or one-quarter as much, still remains on the surface and in the upper inch in depth of the sand.

Below a plane five-eighths of an inch under the surface there is no more nitrogen stored in the sand than there was at the end of the first year; and, if the upper five-eighths of an inch of sand were taken away and replaced once in two years, it is evident that this filter would continue indefinitely to filter as efficiently as during the past twelve months the equivalent of 8,800,000 gallons of sewage on an acre in a year. But there are indications that it can do better than this. It is evident, from the data presented, that the cleansing process of oxidation goes on more completely in the lower part of this tank than in the upper few inches; and it is probable that, if the upper six inches be occasionally worked over and the surface turned under by plowing, the organic matter deposited on the surface will be more completely burned up than if allowed to remain upon the surface. It will also be seen that in September, 1889, the purification by this filter was nearly as complete, when 60 per cent. more sewage was filtering, as in September, 1888. The comparison in October cannot be justly made, because after Oct. 11, 1889, a trap was on the outlet drain, which appears to have interfered with action in the lower layer of the sand which ordinarily receives air from the outlet.

The effluent from Tank No. 2 has, for the seventeen months since nitrification began, generally been clear, bright, colorless water, looking like an excellent quality of spring water.

The chemist's notes indicate, on one or two days of some months, a very slight turbidity and very slight sediment, but no color.

Microscopical Examination of the Effluent of Tank No. 2.

From June to December, 1888, the number of organisms found at different times upon a fine cloth, through which five gallons of effluent had been strained, was counted. On one-half of the days when examinations were made no organisms were found. On two occasions, Leptothrix was found to the number of 4 and 5; Crenothrix was found once to the number of 5; Synedra once to the number of 5, and once a pair of yeast cells was found. These are the only vegetable forms that were found. Of the animal forms, Monas was found four times, the number averaging 42. Other animal forms were found but once each, and were Trachelomonas 10, Leganella 10, Actinophrys 10, Arcella 3, and Monostyla 2.

Since December, 1888, no vegetable forms have been found except at one time a few spores, which at that time seemed to pervade all of our liquids, and zoöglœa found on three occasions. But one animal form, an infusorian, was once found. From the extremely small numbers of microscopic organisms found, and the long intervals when none were observed in the effluent, it is not probable that they are carried through the filter. Upon examining samples of the sand taken at different depths from top to bottom on Nov. 7, 1889, no microscopic organisms were found below the surface; but clots of bacterial zoöglœa were found in slowly diminishing numbers, but quite abundant at five feet below the top. Every sand grain examined appeared spotted or coated with zoöglœa.

Bacteria in Effluent from Tank No. 2.

By referring to the table of Monthly Averages of Daily Results with Tank No. 2, we get a general view of the number of bacteria found in this effluent at different times in the past two years. The largest numbers, averaging 10,433 per cubic centimeter, were found in the first month, January, 1888. They decreased to 1,092 in April; and after nitrification began the numbers were much smaller, being between 100 and 200; and after the ammonia of the effluent was reduced to that of good drinking water the numbers became less than 100; and for the last twelve months have averaged 21 per cubic centimeter. In five of these months they averaged but 7.

Looking for the conditions under which changes occurred, we must turn to the table of daily records of bacteria and of daily chemical analyses to be found at the end of this section.

The number of bacteria found in the sewage may be seen with tables of Tank No. 1.

The number of bacteria found in the effluent of No. 2 has varied as follows: When water containing 54 bacteria per cubic centimeter was, in December, 1887, filtering through this tank at the rate of 1,000 gallons a day, the number of bacteria in the effluent was 6 per cubic centimeter. When sewage, with its half a million bacteria, more or less, in a cubic centimeter, began to reach the outlet, the number of bacteria increased from 3, on December 30, to 6,618, on January 3; and, while sewage was mingling with the original water in the sand, the number increased to 16,000 by January 11; after which it fell, slowly at first and then more rapidly, till February 2, when the number was but 10.

Such a rise in the number of bacteria, followed by a marked fall, is to be found in nearly all of the tanks which have filtered sewage; and the most reasonable explanation that has been found is in the fact that the rise occurred when sewage was mingling with the water previously in the tank, and the fall began when sewage had taken full possession of the tank. When the number was rising, the sewage, bringing large numbers of bacteria, mingled with water containing absorbed oxygen and oxygen brought down from the surface, which served to prevent the death of all of the bacteria and allowed four per cent. of them to live through the passage of the sand; but when the water had been expelled, and some of the oxygen entering the tank from the top was used in forming nitrates, the bacteria could no longer survive the passage, and they almost entirely disappeared from the effluent.

The reduction of the number to so near annihilation is, however, peculiar to tanks of fine sand, and also to the circumstances of this time.

The sand of this tank contains 71 per cent. of its weight finer than the holes of a sieve having 100 meshes on each side of a square inch; and 43 per cent. will pass through a sieve of 140 meshes. The lower foot of the five feet in depth, when completely drained, is found to be saturated; no air can consequently rise up through the tank from the underdrains. During the time of increase of numbers of bacteria it required about two weeks for any sewage applied to the top to reach the bottom of the tank; hence we see that it is mechanically possible for bacteria in large numbers to pass through the sand of this tank, and that under favorable circumstances 4 per cent. of those applied may survive when two weeks are required for the passage; but, as after this the number has never exceeded one per cent., and has generally been a very small fraction of one per cent., we must regard these circumstances as exceptionally favorable. The exceptional condition is that which has been mentioned, the mingling of sewage with water containing absorbed oxygen, or having oxygen brought from the surface still associated with it.

The temperature of the applied sewage in January, and till February 12, was from 35° to 40°; after which it was generally as high as or higher than 44°. The temperature of the effluent in the latter part of January, and through February and March, was 35° or 36°; and higher afterwards.

During the rapid fall in the number of bacteria the tank contained sewage which could have had no free oxygen in the lower part of the tank; and it being extremely cold, — the average morning temperature from January 15 to February 2, during the rapid fall, being 1° below zero, and frost forming in the upper part of the tank to the depth of two feet, — very little oxygen could enter the top of the tank. Thus being nearly cut off from oxygen for the long time of the passage, which was nearly three weeks, — about one week of which was spent in the layer which was entirely saturated and must have contained no free oxygen, — the bacteria could not survive so long a passage; and but 10 out of 500,000 came through.

This extremely low number did not continue. In the next two weeks the number averaged 247, and for the remainder of February the number averaged 1,433. This increase may be due to the time of passage, in the latter part of the month, being reduced from three weeks to about two weeks.

In March the time of passage was but 10 days, and the number of bacteria varied from 787 to 8,422 per cubic centimeter, and averaged 2,779. At this time the number found in a cubic centimeter of the sewage applied was about 1,250,000.

In April the time of passage averaged two weeks, and the number decreased, averaging 1,092.

An uncertainty enters the computation of the time of passage during the months of January, February and March — and particularly in February — on account of the obstruction by frost. The time which probably controls the life of bacteria is the time of passing through the saturated layer in the lower foot of the filter, which generally requires one-third of the whole time of passage; and, however the time was hastened in the upper frost-bound layers, it is probable that — except in February, when sewage was entering principally through a few holes cut through the frost — the liquid passed through nearly the whole area of the lower saturated layer in about one-third of the time given for the full passage.

No observations were made, at the time of the rapid decrease in bacteria coming through in January, to determine how completely the oxygen in the tank, and that entering, was appropriated by the organic matter; but, from experiments made since, it is nearly certain that, at or near the entrance to the saturated layer, there was no longer any free oxygen that could be used to support bacteria; and the being deprived of oxygen during six or more days, while passing through the saturated layer, was probably the controlling cause of the reduction, and nearly, if not quite, prevented any bacteria from getting through alive.

When the time of passage through this layer decreased to about three days, in March, the number of bacteria increased much, and again decreased when the time was increased in April to about five days. In this month nitrification began, but progressed very slowly.

The free ammonia was highest for the year, and albuminoid ammonia was higher than for any month, except the next previous.

Bacteria decrease rapidly when Nitrification commences.

In May the time of passing the saturated layer was the same as in April. The ammonias were between eight and nine tenths as much, with but little change in the month; and the nitrates, though low in the first half of the month, increased quite rapidly in the latter part; and the bacteria decreased from 899, in the early part of the month, to 10 at the end; averaging 170 for the month. This marked decrease in bacteria as nitrification increased, while there was a large food supply as shown by the ammonias, indicates that the process of nitrification has a deleterious effect, — perhaps from its using up oxygen apart from its usually accompanying condition of a want of food.

Up to this time there has been no question but that bacteria come through this filter of fine sand; their numbers, though small compared with the numbers put upon the surface, being at the greatest but five per cent., have depended upon the oxygen they could obtain on the passage, and upon the time of the passage. Now that nitrification has commenced we find the number is very small, being but one-hundredth of one per cent. of the number applied; and that, for the next eighteen months, the number has averaged but 70, and in the last twelve of these months but 21; and that the number does not decrease with the length of time of passage, but is as small when the time of passing through one foot of saturated layer is four days as when it is thirteen days. The question now rises whether any of these bacteria that have been found in the effluent of this tank since nitrification began have come through the sand, or if all have grown in the gravel and underdrains and outlet pipe beneath the filter, where they are in contact with air entering the outlet pipe.

The daily quantity of effluent in gallons per acre, the average amounts of free and albuminoid ammonia and nitrates, the number of bacteria found in the effluent, and the time of passing through one foot of saturated layer are given for each month after nitrification commenced in the following table : —

Date.	Daily Quantity of Effluent in Gallons per Acre.	Ammonia. Free.	Ammonia. Albuminoid.	Nitrates.	Per Cent. of Nitrogen applied coming off as Nitrates. (Corrected for Quantity.)	Number of Bacteria per Cubic Centimeter.	Time of Passing through One Foot of Saturated Layer. Days.
1888.							
June,	23,400	0.3778	.0145	2.056	94	151	6.3
July,	17,000	0.1550	.0117	1.319	68	222	9.
August,	19,400	0.0422	.0149	1.156	39	157	7.7
September,	19,000	0.0012	.0080	0.818	14	368	8.
October,	18,600	0.0003	.0072	0.792	34	39	8.1
November,	13,800	0.0003	.0072	0.863	39	11	11.
December,	11,800	0.0005	.0064	0.784	29	5	13.
1889.							
January,	12,600	0.0008	.0060	0.762	48	12	10.7
February,	11,400	0.0008	.0059	0.736	55	23	13.
March,	25,800	0.0009	.0077	0.661	41	28	6.
April,	39,600	0.0201	.0095	1.713	73	7	4.
May,	27,400	0.0019	.0098	2.256	96	57	5.5
June,	22,600	0.0020	.0104	1.638	73	38	6.6
July,	27,000	0.0020	.0094	1.000	28	57	5.7
August,	24,000	0.0008	.0074	0.504	21	6	6.0
September,	33,400	0.0013	.0078	0.864	32	8	4.5
October,	37,800	0.0044	.0090	1.376	47	7	4.

The numbers of bacteria here given are averages of those obtained from observations taken at about the same hour on from four to nine days in a month, and are referred to as the semi-weekly observations.

If these bacteria no longer come through the filter, it would be expected that those which had come through would remain in considerable quantity in the underdrains as long as the conditions there were favorable for their growth. It appears that they remained there, in larger numbers than ever afterwards, through June, July, August and September, 1888; being in largest numbers in September, when the effluent was the warmest, — at about 70°. The number then fell off rapidly, as cold weather came on, until in December the number averaged but five per cubic centimeter, although the number in the sewage from which this effluent came was more than half a million per cubic centimeter.

In 1889 the semi-weekly observations, which were then being taken but once a week, were found to be inadequate to express the true number of bacteria that came in the effluent; and while these observations were continued, other and more extended observations were made in most of the months of 1889, which are given in tables of series after the table of regular counts. These series of observations will be taken into account in discussing the number of bacteria found in the second year; hence the consideration of the semi-weekly observations will be limited to those of the first year.

Irregularity in Numbers of Bacteria may be due to Rain.

Upon examining in detail the record of bacteria, we find marked variations in the numbers; for example, in June, 1888, the numbers on different days were as follows: —

Day of the Month.	Number of Bacteria.	Day of the Month.	Number of Bacteria.
5,	14	21,	53
9,	27	26,	89
14,	574		

Seeking a cause for the large number on the 14th, if it originated at the surface of the tank it would have occurred at the time since which about 2,275 gallons of effluent have come from the tank. This would have been on May 28, on which day rain began and 91 gallons fell into the tank. This was at a time when the 150 gallons of sewage applied disappeared from the surface in less than a hour. The rain-water, following after this and going down by itself, mingling to some extent with the liquid left among the particles of sand by the sewage, may have carried sufficient oxygen not reduced by organic matter to have kept alive a few of the bacteria — one in a thousand — and allowed this number to come through.

Selecting the numbers that are exceptionally high, and are above 100, we make the following comparisons: —

Date.	Number of Bacteria observed.	Date when the Previous 2,275 Gallons of Effluent began.	Date of Nearest Rain.	Number of Gallons of Rain which fell into Tank.
1888.				
June 14,	574	May 27,	May 28,	91
July 7,	183	June 14,	June 15,	99
July 13,	404	June 17,	June 20,	17
July 21,	576	June 25,	June 25,	52
Aug. 7,	301	July 13,	July 12,	87
Aug. 11,	195	July 19,	July 19,	98
Aug. 16,	107	July 24,	July 22,	91
Sept. 11,	745	Aug. 18,	Aug. 17,	77
Sept. 15,	997	Aug. 22,	Aug. 22,	196

We find that, within one or two days of the computed time when rain falling upon the surface would appear at the outlet, the number of bacteria found in the effluent is exceptionally large, being thirteen times the number found on other occasions in the same months.

Some of the numbers less than 100, that are larger than usual may also be traced to a similar relation with rainfall upon the tank. But, eliminating only those numbers greater than 100, which have been shown to have so distinct a relation with the rainfall, we have the following monthly averages remaining : —

June (1888), 46 ; July, 57 ; August, 26 ; September, 32 ; October, 39 ; November, 11 ; December, 5, — or an average for the seven months of 31 per cubic centimeter.

The smallest number was in December, 1888, when the tank was covered with canvas and no rain fell upon it. This tank was covered also in the three following months, and the average number for these four months was 16 per cubic centimeter.

Do any Bacteria ordinarily pass through this Filter when Nitrifying?

The average number in the seven months of 1888, after nitrification became active, — which is 31 per cubic centimeter, — may be taken as the number shown by the first year's work to be expected in the effluent of this tank when sewage alone is filtering ; and we are now to seek the probability of this number out of half a million living through the passage, or whether these come from a growth in the coarse gravel and underdrains, exposed to air entering from below, — permanently living there or planted there by the occasional passage of bacteria which come through, supported by oxygen accompanying rain water.

Besides the semi-weekly observations which have been under consideration, long series of observations, made once an hour or oftener, were continued through many days in the early months of 1889. A summary of these results will be stated.

On January 4, when 150 gallons of sewage were being applied every other day, sixteen observations were made upon the rate of flow and number of bacteria. The rates of flow varied from 78 cubic centimeters per minute before sewage was applied to 388 cubic centimeters per minute seven hours after its application. The average number of bacteria found was 6, with no variation attributable to increased flow except one count of 42 when the rate had risen to 108 cubic centimeters per minute. On January 5 five counts averaged 5 bacteria. The flow was then decreasing from the application of the previous day.

On January 9, with ten observations, the number increased from 9 before the flow to 40 during the three hours of most rapid flow. The next forenoon the average number was 14; but in the afternoon, with the rate still decreasing, the average number was 80.

On February 1, with eleven observations, the average number before the increased flow began was 2, and through the rapid flow was also 2. On the following day ten observations gave the same average number.

On February 14, with twelve observations, the average number was less than 2; and on the next day thirteen counts averaged 2 with no variation due to rate of flow. If there had been absolutely none in the effluent as it flowed from the tank, these small numbers would have been counted from bacteria entering the samples from the air.

On February 27, with twelve observations, the average number counted was 8; and on the next day, with higher rates, it was 4.

In March, series were counted on twenty-one days, making in all 129 counts and averaging 185 bacteria.

Beginning with the 6th of this month, the amount of sewage was doubled, the application being 300 gallons three times a week. The number of bacteria found was greater than in the previous months, and on nearly every application the number of bacteria increased, at one or more counts, while the rate of flow was increasing, — the average change being from 14 to 414: with one count, not included in the average, when the number reached 2,336. This high number was on the day when 2,275 gallons had flowed out after applying to one small area of the surface a litre of bouillon containing 1,000,000,000 of the bacterium Bacillus prodigiosus, and it is possible that some bacteria came through with the food supply thus provided, but none of the peculiar species applied, although readily recognizable by their color, were found in the effluent.

The increase in number, from 14 just before the increase in rate of flow to 414 at some observation during the rapid flow, may be attributed to the increased depth and velocity of the stream in the underdrains and over the floor of the tank floating and washing off bacteria growing there; but it is difficult to conceive of the reason why on seven different days, when the rate of flow was decreasing, the number of one count of each day averaged 1,354 bacteria. On one day not included, the number counted was 5,577. This was on the same day when, on the increasing rate of flow, 2,336 were counted; and is probably attributable to the same cause, — the accompaniment of specially prepared food for bacteria. In fact all of these high counts but two occurred when from 1,900 to 2,700 gallons of effluent had come from the tank after the Bacillus prodigiosus, with the food in which it was growing, was applied. No explanation appears for the other two exceptionally high counts. No rain could have come through the tank, as the canvas covering was on till the 13th. We must conclude that, with the increased quantity of sewage, bacteria came through the tank at certain times, though not continuously.

On March 27 the quantity of sewage applied three times a week was again increased to 450 gallons, and this quantity was continued through April and to the middle of May.

In April, series were counted on 26 days, making in all 130 counts and giving an average for the month of 69. If we omit two counts in which the number was extremely high, the average number for the month was 30.

There was generally one count or more, when the rate was rapid, which was higher than those before the increased flow began, in the average ratio of 471 to 9; or, if we omit two extremely high counts, in the ratio 99 to 9.

The increased number when the rate was decreasing noticed in March was not so general in April, there being but four days when it occured with an average number of 192.

On May 1 the number before the increased rate of flow was 6, and afterward it was 36.

The increase in number of bacteria accompanying increase in rate of flow has been as follows: —

Date.	Quantity applied. Gallons.	Number of Counts.	Number of Bacteria.	
			Before Increase in Flow.	Highest Number after Increase in Flow.
1889.				
January,	150	40	7	41
February,	150	67	4	3
March,	300	129	14	414
April,	450	130	9	99

This increase in number of bacteria, with the increase in rate of flow in this tank, has not been a general and sustained increase, nor has it been proportional to the rate of flow; but, some time during the more rapid flow, the number counted has been greater than during the previous time of slow flow. This increase has been attributed to the growth of bacteria in the outlet pipe and underdrains and on the gravel upon the floor of the tank, just above the level at which water stands during the low flow, which upon a rise of water would be floated from their resting places, and by the stronger current be carried to the outlet.

Bacteria Found Living in Large Numbers in Outlet Pipe.

To determine if such bacteria exist in the outlet pipe, it was on May 2 swabbed out, one foot in length at a time, with a sterilized sponge. The water flowing in the pipe before the commencement contained 20 bacteria per cubic cent meter; but, after rubbing the sponge over the first foot in length of the pipe, the water pressed from the sponge contained 13,000 bacteria per cubic centimeter. The water taken up by the sponge while rubbing the second foot contained somewhat more, and for each foot in length the number found was between 13,000 and 24,000 bacteria per cubic centimeter. These bacteria appear to grow more abundantly where the surface of the pipe is damp, just above the ordinary surface of the stream flowing in the bottom of the pipe, and where they are exposed to the air entering the outlet.

Immediately after swabbing out the pipe, hot water was run through the pipe for twenty minutes, at temperatures from 175° to 200°, in order to kill any bacteria remaining. In the next half hour the number in the effluent averaged 7, but six hours later the number was considerably higher. The average of counts for the next six days was 200, and on May 10 the outlet pipe was again scalded out by running through it for twenty minutes water at about 200°. Eight counts, taken on this day after the scalding, gave the average number of bacteria in the effluent, 11. On the next day the number found was 18. Two days later the number was 91. On May 15 it was 1,140; on the next day, 135; and at 10 A.M., May 17, was 760. Between 10.30 and 11.30, May 17, the outlet pipe was again swabbed out, as on May 2, with the following result: — In the first foot were found 4,896 per cubic centimeter of the water pressed from the sponge; in the second foot, 35,192; in the third foot, 56,000; in the fourth foot, 61,600; in the fifth foot, 12,642; and in the sixth foot, next to the tank, 7,310. The effluent flowing out while the sponge was rubbing the fifth foot contained 45,900 per cubic centimeter.

The swabbing did not appear to remove all from the pipe; for at 3.15 P.M. the number in the effluent was 10,622; and at 5 P.M. 3,842. On the next day the number was 6,804. On May 20, it was 110; and on May 22, 11.

These experiments show that, during this month, very large numbers of bacteria were growing in the outlet pipe, and that immediately after destroying these by hot water very few were found in the effluent; but in a day or two the number increased, — probably coming down from the underdrains and gravel and growing rapidly in the pipe. The small number following scalding of the pipe indicates that very few were coming through the sand at this time.

On July 1 the effluent that was slowly coming through the sand was backed up, by closing the outlet, till about forty gallons were upon the bottom of the tank. Upon letting this out at a slow rate the number of bacteria was 16; at higher rates the number increased to 80 and 162; and, when the cap was removed from the outlet and the water rushed out, it contained 1,872 per cubic centimeter. This increase was evidently due not to an increased number coming through the sand but to the washing out of the drains by the increased current.

Before examining other series of observations taken upon the effluent later in the year, we will turn to examinations of the sand of this tank taken at different points by boring a hole two inches in diameter from top to bottom.

Number of Bacteria found in One Gram of Sand taken from Tank No. 2 at Various Depths on Different Dates.

Distance from Surface.	December 19, 1888.	February 4, 1889.	May 24, 1889.	November 7, 1889.
0 to ¼ inch,	2,032,600	–	2,169,700	1,544,900
¼ to ½ inch,	–	65,500	–	–
½ inch,	–	–	1,421,100	271,867
1 inch,	–	6,900	594,000	431,680
2 inches,	–	7,300	1,087,100	201,102
3 inches,	7,300	–	147,200	143,900

Number of Bacteria found in One Gram of Sand taken from Tank No. 2 at Various Depths on Different Dates — Concluded.

Distance from Surface.	December 19, 1888.	February 4, 1889.	May 24, 1889.	November 7, 1889.
4 inches,	-	10,800	-	-
5 inches,	-	-	190,300	150,024
6 to 7 inches,	500	-	-	-
9 to 10 inches,	-	700	3,600	-
12 inches,	1,200	-	-	7,320
16 to 17 inches,	-	5,900	6,700	58,666
24 inches,	1,000	-	-	56,666
26 inches.	-	-	17,100	-
28 to 29 inches,	-	0	-	-
36 inches,	2,100	-	-	136,111
40 inches,	-	-	9,700	-
46 inches,	-	300	-	-
52 inches,	19,100	-	-	7,980
54 inches,	-	-	12,100	-
59 inches,	700	900	-	-
60 inches,	-	-	-	16,347
61 inches,	-	-	7,400	-

Much the larger numbers were found in the upper five inches. These increased and were higher than at either of the other dates on May 24; this is at the season when plant growth is most rapid and when we find nitrification most complete. The number in November, in the upper five inches, was but one-half of the number in the previous May; but in the lower four and a half feet of the tank the number in November was greater than ever before although but a small fraction of those in the upper five inches. It may be that some of the high numbers in the lower part of the tank in November are due to particles of sand falling from the top into the hole.

It is evident that some kinds of bacteria live in the lower part of this tank for many days, and perhaps continually, without light and with little or no oxygen. The trap being put on the outlet pipe of No 2, on October 11 it was found, that, no air entering from below, the absorbed oxygen in the effluent became less day by day, until on November 25 there was none, — indicating that none existed at this season in the saturated layer of sand in the lower part of the tank.

The microscopical examination of the samples of sand obtained Nov. 7, 1889, showed the surface to have large numbers of bacteria alive and in zoöglœa. Anguillula was abundant; also there were mites, lichen spores, monads and Ulothrix. Below the surface throughout there could be seen only bacterial zoöglœa in slowly diminishing numbers, though quite abundant at sixty inches from the surface. It may be that these bacterial clots called zoöglœa are bacteria in a torpid state, — in which they can survive for a season without oxygen, — which develop into growing colonies when they come into favorable conditions with suitable food and air; or they may be the remains of bacteria.

Resuming the examinations of the effluent, we find on Sept. 4, 1889, with 300 gallons of sewage applied three times a week, five observations indicate that there was no increase of bacteria with increased rate of flow; there being 14 before and 6 after flooding. On the next day, while the rate was decreasing, the number averaged 7 until the rate got to be very low, when the number rose to 109; and on the morning after, when the rate was still lower, the number was once 275. This rise may be due to a rain of 197 gallons, which fell upon the tank on August 14.

On September 9 water which had come down slowly through the sand on the previous day, and had been held back by closing the outlet, was let out slowly at first, giving 4 bacteria per cubic centimeter; upon increasing the rate of flow to the maximum daily rate, the number increased to 22 and afterward fell off to 9; but at the very slowest rate one count revealed 671. As the regular flow from sewage applied increased to nearly the maximum of the last experiment, — when effluent was held back and ran out rapidly, — the number of bacteria increased to 27 and 22.

On September 10, no sewage being applied, the number of bacteria coming out was 10. Thirty gallons of water from Tank No. 8, which contained 18 bacteria per cubic centimeter, were gently run in through the outlet pipe to the underdrains and gravel of this tank. When this water was allowed to run out at about ten times the maximum velocity of the regular effluent the number of bacteria was 51; with sixteen times the velocity the number was 17; with thirty times the velocity the number was 47; and with eighty times the velocity the number was 263; and finally, at the ordinary maximum velocity, the number was 16, — showing only a few organisms to be in the drains and gravel capable of being removed by a rapid current at this time. Chemical examination of the water before it was put in and after it came out showed no increase of organic matter from deposit in the underdrains at this time.

On September 11 and 12 the average number was 7, increasing from 6 to 9 on increased rate of flow.

On September 16 the quantity of sewage was increased to 500 gallons applied three times a week. This quantity was continued through October.

On September 16, 17 and 18 the average number of bacteria was 14; and, though the maximum rate of flow was doubled, there appears to be no increase of bacteria due to increased flow.

On September 19, 20 and 21 the average number of bacteria was 4 and no increase with increased rate of flow. With this small number the six feet in length of the outlet pipe were sponged out, as described in May, with, however, a very different result, — the numbers for different feet varied from 1 to 7; averaging 3 per cubic centimeter of water taken up.

At this time, with no increase of bacteria coming with increased rate of flow, we find extremely few bacteria living in the outlet pipe; while in May, with a marked increase with the increased flow, they were very abundant there.

On September 23, 24 and 25 the number of bacteria, at low rates of flow, averaged 2 or practically none; and at the highest, with rapid flow, the number was 10 and 19. A short portion of the length of the outlet pipe was divided into sections around the circumference, and washed with a sterilized sponge. The number of bacteria found in a cubic centimeter of water pressed from the sponge, varied from 1 to 16, — averaging 4. The highest number was from the side, a little above the water.

On September 26 and 27 the number, with low rates of flow, was 8; which increased to 15, at one count, at a high rate of flow.

On the 28th, as the rate fell, one count showed 72 followed by 15, 6 and 3. On September 30 the average number was 7, with no change due to rate.

Summarizing the results of September, 1889, we have: —

Day of the Month.	Number at Low Rates of Flow.	Number at High Rates of Flow.	Day of the Month.	Number at Low Rates of Flow.	Number at High Rates of Flow.
4, ...	14	6	16, 17 and 18, . . .	18	6
5, ...	7	7	19, 20 and 21, . . .	2	6
9 and 10, ...	19	16	23, 24 and 25, . . .	2	15
11 and 12, ...	6	8	26 and 27, . . .	8	11
13 and 14, ...	10	12	28 and 30, . . .	6	25

The number of bacteria in the sewage applied was about 700,000 per cubic centimeter, and the number in the effluent averaged 10 per cubic centimeter, of which the number at low rates of flow was 9 and at high rates of flow was 11. The increase was at any time hardly as great as when an increased velocity was given in the drains with no increased rate coming through the sand.

On October 1, 2, 3 and 5 the average number was 8, with no increase with the increased rate of flow.

It will be observed that sewage, applied to the surface since September 16, reaches the bottom in about eleven days, and is about four days passing through the saturated layer, — instead of seven days, as in the previous month.

Series were taken daily through the month of October, 1889, and the number of bacteria at low and high rates of flow are here summarized. —

Day of the Month.	Number at Low Rates of Flow.	Number at High Rates of Flow.	Highest Number at High Rates.	Day of the Month.	Number at Low Rates of Flow.	Number at High Rates of Flow.	Highest Number at High Rates.
1, 2 and 3,	7	7	12	11 and 12,	20	1,020	1,100
5,	14	6	7	14 and 15,	12	61	90
7 and 8,	15	395	1,271	16 and 17,	11	57	78
9 and 10,	88	181	265				

After October 17 there was very little change in rate of flow, as the sewage remained on the surface nearly all of the time. After the eleventh a trap was on the outlet, so that the outlet pipe was all of the time full.

From October 18 to the end of the month the number of bacteria averaged 24 including one unusually high number of 325, without which the average would have been 16.

Bringing together the results of 524 counts made in six months of 1889, we have the following summary: —

Date.	Quantity of Sewage applied Three Times a Week. Gallons.	Number of Counts.	Average Number of Bacteria per Cubic Centimeter.	Date.	Quantity of Sewage applied Three Times a Week. Gallons.	Number of Counts.	Average Number of Bacteria per Cubic Centimeter.
1889.							
January,	150	40	14	April,	450	128	30†
February,	150	66	3	September,	300 and 500	86	16
March,	300	121	67*	October,	500	83	36‡

* Omitting 8 counts above 1,000. † Omitting 2 counts above 1,000. ‡ Omitting 3 counts above 940.

In January the number was small, and there was noticeable an occasional increase in number at times of rapid flow, — indicating that bacteria were growing in the drains.

In February the average number in 66 counts was 3. This is the same average number that we have found by pouring boiled water containing no bacteria into a bottle placed by the side of the bottle receiving the effluent, this number coming from the air. Hence we have reason to conclude that during this month no bacteria came through this filter.

It is probable, too, that in January none came through, but that a few were living in the drains.

In March, however, with the change from 150 gallons to 300 gallons being applied three times a week, it is evident that some bacteria came through the filter, and that there was a great increase in the drains. On the same day that the increase in quantity was made, 1,000,000,000 Bacillus prodigiosus with their food were applied, and although none of this species were found in the effluent, their food may have been one of the occasions of the great increase; for on the days March 22 and 23, when we should expect this to reach the bottom, occurred the highest counts of the month, viz; 2,336 1,798 and 5,577. There were, however, two other counts between 1,000 and 1,600, before these dates, which cannot be attributed to this cause; nor are any attributable to rain, for the canvas covering was over the tank till March 13, and the rain coming after this could not reach the outlet in this month.

There are three conclusions that may be reached from the data presented: one is that bacteria came through the filter during this month; another is that they grew unusually in the underdrains; and the third is that, nitrification being less complete, more food material was stored in the sand, so that those which were already within the sand increased more than usual and some of them came out with the effluent.

The increased quantity of sewage applied, the less complete nitrification by which more nitrogenous matter must have been stored in the tank because the ammonias of the effluent were not increased, and the addition of the specially prepared food put on with Bacillus prodigiosus, would all tend to increase the number of bacteria in the effluent.

The most probable conclusion is that a few bacteria came through the filter from the surface in this month, and that they increased within the lower layer of open sand and in the underdrains by growth there; and from these causes about one-thousandth as many bacteria were found in the effluent as in the sewage.

In April, with a larger amount of sewage applied, — which was found to contain many times as many bacteria as the sewage of March, — the actual number of bacteria in the effluent was found to be less; and the number was but 1 in 22,000 of the number applied: still, it is most probable that some came through the whole or a part of the depth of the filter, to keep up the number in the underdrains.

The experiments of May and July show that very large numbers were living in the outlet pipe and underdrains, when but few came out with the effluent. Observations in May also show that an unusually large number of bacteria were then in the sand from the top to the bottom of the tank.

In September the number found in the regular effluent was small, and the number that could be washed out of the underdrains, either by holding back the effluent and letting it flow out rapidly or by forcing water in from the outside and letting it rush out, was small; and, consistent with this result, the outlet pipe was found to contain but one-thousandth as many as in May. The average number in the effluent, by 86 counts in the month, was but 16 when 300 and 500 gallons were applied three times a week; and the number was no greater after the amount was increased to 500 gallons.

On October 7, when about 5,000 gallons had flowed out after the beginning of the application of 500 gallons at a time, the number was the highest for the month, — reaching 1,271 at the time of rapid flow. No reason is apparent for high numbers at this time. The numbers next lower than this were 1,100 and 940, on October 11, — just after a trap had been put upon the outlet, by which the outlet pipe was kept filled with water. The effect of this, wherever tried, has been similar, — to increase the number at first, after which they settle back to the previous low numbers. This is probably due to floating off from their resting place some of the bacteria growing upon the pipe above the surface of the stream usually running. During the rest of the month, with the trap on and a marked increase in the free ammonia and nitrites of the effluent, the number of bacteria averaged 30.

Reviewing all of the results of observations on bacteria obtained with Tank No. 2 after purification by nitrification was established, we conclude that there are seasons in which no bacteria live to get through the filter when the equivalent of 30,000 gallons on an acre is applied in half an hour once in two days; there are other seasons when, with the same quantity, a few bacteria are found in the effluent, some of which may have come down from the surface. That, with two or three times the above quantity of sewage, we have been unable to trace any bacteria from the surface to the bottom as we did in the coarse sand; but we find certain kinds of bacteria in considerable numbers within the sand from top to bottom, and we find a number in the effluent equivalent to 1 in 10,000 of the number applied in the sewage, with occasionally a larger number. Some of these probably come down from the surface, but the larger part probably grow within the sand or in the underdrains. Their number in these places appears to depend upon the amount and quality of the food supplied to them; and the larger numbers are likely to be caused by some irregularity in the use of the filter, or they may result from rain falling upon the filtering area.

TABLES

OF

ANALYSES OF EFFLUENT AND OBSERVATIONS

UPON

Filter Tank No. 2.

December, 1887.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.*	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
19, ...	136	96	.50	2.10	.0004	.0053	.0057	.26	.0150	None.	–	–
20, ...	136	135	.60	1.90	.0000	.0030	.0030	.21	.0100	None.	–	–
21, ...	136	166	.65	1.95	.0000	.0020	.0020	.23	.0100	Present.	36°	–
22, ...	136	150	.55	2.20	.0002	.0016	.0018	.23	.0090	Present.	34°	–
23, ...	136	111	.60	1.85	.0000	.0048	.0048	.22	.0100	Present.	–	–
24, ...	272	200	–	–	–	–	–	–	–	–	35°	–
25, ...	272	237	–	–	–	–	–	–	–	–	35°	–
26, ...	272	228	–	–	–	–	–	–	–	–	36°	–
27, ...	240	147	–	–	–	–	–	–	–	–	–	–
28, ...	132	244	.70	2.25	.0000	.0046	.0046	.22	.0100	Present.	36°	–
29, ...	272	252	1.55	2.35	.0058	.0044	.0102	.36	.0200	Present.	35°	–
30, ...	150	123	–	–	–	–	–	–	–	–	34°	–
31, ...	40	52	–	–	–	–	–	–	–	–	34°	–

December 19. — First sewage applied. Snow and ice on surface as follows: December 19, 2 inches; December 20, 1 inch; December 22, 1 inch; December 23, 1½ inch; December 24, two-thirds of surface covered; December 25, ½ inch; December 26, 3-16 inch; December 28, 1¼ inch; December 29, 1 inch; December 30, 1¼ inch; December 31, 3 inches. December 28 and 31. — Quantities of sewage applied filled the tank.

Total effluent to end of month, 2,141 gallons.

Filter Tank No. 2 — Continued.

January, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	30	32	1.00	2.60	.0026	.0060	.0086	.49	.0100	Present.	–	–
2, ...	200	79	–	–	–	–	–	–	–	–	–	–
3, ...	155	113	1.00	2.95	.0018	.0072	.0090	72	.0090	Present.	–	–
4, ...	125	99	–	–	–	–	–	–	–	–	–	–
5, ...	78	71	2.40	3.10	.0052	.0104	.0156	.85	.0000	None.	–	–
6, ...	70	52	–	–	–	–	–	–	–	–	34°	–
7, ...	45	54	–	–	–	–	–	–	–	–	35°	–
8, ...	82	43	1.80	3.55	.0014	.0058	.0072	1.06	.0100	None.	35°	–
9, ...	40	44	–	–	–	–	–	–	–	–	35°	–
10, ...	95	53	1.50	3.70	.0004	.0076	.0080	1.16	.0150	Present.	37°	–
11, ...	200	107	–	–	–	–	–	–	–	–	37°	–
12, ...	300	220	3.10	4.75	.0008	.0086	.0094	1.76	.0100	None.	38°	–
13, ...	300	207	2.20	4.90	.0006	.0090	.0096	1.92	.0100	None.	40°	–
14, ...	300	278	–	–	–	–	–	–	–	–	40°	–
15, ...	300	277	–	–	–	–	–	–	–	–	40°	–
16, ...	300	229	3.35	7.05	.0004	.0142	.0146	2.77	.0010	None.	40°	–
17, ...	238	161	3.15	8.00	.0012	.0152	.0164	3.18	.0080	None.	39°	–
18, ...	265	138	3.45	8.35	.0007	.0108	.0115	3.44	.0180	Present.	39°	–
19, ...	195	112	–	–	–	–	–	–	–	–	40°	36°
20, ...	135	60	3.45	8.90	.0014	.0110	.0124	3.54	.0180	.0001	38°	–
21, ...	60	32	–	–	–	–	–	–	–	–	39°	–
22, ...	10	12	3.25	8.95	.0048	.0116	.0164	3.51	.0100	Present.	38°	–
23, ...	150	103	2.95	9.60	.0040	.0090	.0130	3.28	.0150	Present.	39°	–
24, ...	150	105	3.90	8.55	.0028	.0094	.0122	3.30	.0200	Present.	38°	–
25, ...	150	107	3.00	9.10	.0046	.0088	.0134	3.23	.0200	Present.	38°	–
26, ...	150	82	–	–	–	–	–	–	–	–	37°	–
27, ...	150	77	2.85	9.50	.0066	.0096	.0162	3.28	.0250	Present.	39°	–
28, ...	112	78	–	–	–	–	–	–	–	–	35°	36°
29, ...	92	38	–	–	–	–	–	–	–	–	35°	–
30, ...	190	143	2.35	10.20	.0090	.0116	.0206	3.26	.0200	.0006	36°	–
31, ...	150	151	2.30	10.10	.0032	.0098	.0130	3.12	.0250	.0005	36°	36°

Snow and ice on surface as follows: January 1, 3 inches ice, 1 inch snow; January 2, 2 inches ice; January 3, 2½ inches; January 4, 2 inches; January 5, 6, 7 and 8, 2¼ inches; January 9 and 10, 3 inches; January 17, 4 inches; January 30, 6 inches. Frost in tank: January 11, 12 inches; January 24, 15 inches; January 30, 2 feet.

January 11.—Two rings cut in surface and filled with coarse sand. January 23 to 27 and 30.—Sewage run into holes cut through ice and frost.

Total effluent to end of month, 5,498 gallons.

Filter Tank No. 2 — Continued.

February, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	150	137	2.90	10.25	.0046	.0092	.0138	3.15	.0300	.0010	35°	35°
2, ...	150	124	-	-	-	-	-	-	-	-	36°	36°
3, ...	150	110	2.00	10.00	.0068	.0098	.0166	2.76	.0280	.0012	35°	36°
4, ...	150	121	-	-	-	-	-	-	-	-	37°	36°
5, ...	130	106	1.60	10.20	.0058	.0112	.0170	2.59	.0250	.0008	39°	36°
6, ...	135	109	1.50	10.00	.0036	.0118	.0154	2.50	.0180	.0005	39°	36°
7, ...	150	153	1.75	10.20	.0044	.0082	.0126	2.72	.0150	Present.	38°	35°
8, ...	150	149	2.20	10.50	.0056	.0084	.0140	2.75	.0300	Present.	37°	-
9, ...	150	121	-	-	-	-	-	-	-	-	36°	36°
10, ...	150	130	2.00	10.10	.0144	.0110	.0254	2.52	.0250	None.	38°	-
11, ...	150	104	-	-	-	-	-	-	-	-	36°	36°
12, ...	150	108	1.80	10.30	.0336	.0114	.0450	2.58	.0050	None.	44°	-
13, ...	150	142	-	-	-	-	-	-	-	-	44°	-
14, ...	150	169	1.70	11.00	.0896	.0158	.1054	2.75	.0000	None.	44°	36°
15, ...	150	191	1.50	11.20	.1170	.0190	.1360	2.66	.0050	None.	44°	35°
16, ...	150	170	-	-	-	-	-	-	-	-	41°	35°
17, ...	125	119	1.90	10.50	.1290	.0190	.1480	2.50	.0050	None.	68°	35°
18, ...	150	118	-	-	-	-	-	-	-	-	64°	-
19, ...	150	140	-	-	-	-	-	-	-	-	54°	-
20, ...	150	152	2.70	11.80	.2140	.0170	.2310	2.95	.0050	None.	44°	36°
21, ...	150	153	-	-	-	-	-	-	-	-	45°	36°
22, ...	150	223	2.50	11.30	.2600	.0380	.2980	2.40	.0050	Present.	57°	35°
23, ...	150	77	-	-	-	-	-	-	-	-	65°	36°
24, ...	150	250	2.50	11.10	.1890	.0340	.2230	2.60	.0050	None.	56°	-
25, ...	150	208	-	-	-	-	-	-	-	-	56°	35°
26, ...	150	196	-	-	-	-	-	-	-	-	55°	35°
27, ...	150	132	2.00	11.40	.2050	.0260	.2310	2.42	.0020	None.	44°	36°
28, ...	150	101	-	-	-	-	-	-	-	-	54°	35°
29, ...	150	113	2.00	11.90	.2150	.0290	.2440	2.20	.0050	None.	63°	35°

February 7. — A new hole cut through 27½ inches of frost. February 15. — 4 inches of water standing in holes. February 17. — Trench cut through ice and 25 gallons of water siphoned from surface. February 20. — 2 inches of ice and water removed. February 23. — Holes cut through frost and boiling water put on. February 24. — Entrance made through frost by hot water and by holding end of hose against surface as sewage was applied.

Total effluent to end of month, 9,624 gallons.

Filter Tank No. 2 — Continued.

March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Fixed.	Ammonia. Free.	Albuminoid.	Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Effluent.
1, .	150	109	-	-	-	-	-	-	-	-	-	55°	35°
2, .	150	122	2.10	11.30	.2320	.0350	.2670	2.14	.0070	Present.	-	51°	-
3, .	150	140	-	-	-	-	-	-	-	-	-	58°	35°
4, .	150	122	-	-	-	-	-	-	-	-	-	57°	35°
5, .	150	120	2.30	11.40	.2960	.0260	.3220	2.02	.0050	.0001	-	55°	35°
6, .	150	98	-	-	-	-	-	-	-	-	-	61°	36°
7, .	150	139	2.00	11.80	.3000	.0240	.3240	2.40	.0050	.0002	-	59°	35°
8, .	150	141	-	-	-	-	-	-	-	-	-	47°	-
9, .	150	166	2.00	11.20	.2720	.0230	.2950	2.20	.0050	.0006	-	50°	35°
10, .	475	14	-	-	-	-	-	-	-	-	-	66°	-
11, .	400	151	-	-	-	-	-	-	-	-	-	65°	35°
12, .	150	151	1.00	12.60	.2200	.0270	.2470	2.20	.0080	.0004	-	75°	36°
13, .	150	150	-	-	-	-	-	-	-	-	-	75°	35°
14, .	475	150	-	-	-	-	-	-	-	-	-	63°	35°
15, .	200	800	-	-	-	-	-	-	-	-	-	68°	35°
16, .	500	589	2.20	12.30	.4200	.0310	.4510	2.88	.0050	.0006	-	58°	34°
17, .	500	486	-	-	-	-	-	-	-	-	-	58°	34°
18, .	500	463	-	-	-	-	-	-	-	-	-	61°	35°
19, .	500	546	2.90	12.40	.6400	.0300	.6700	2.80	.0020	.0001	-	63°	34°
20, .	500	483	-	-	-	-	-	-	-	-	-	58°	35°
21, .	500	672	2.50	12.20	.6360	.0230	.6590	2.70	.0090	.0015	-	68°	35°
22, .	500	499	-	-	-	-	-	-	-	-	2 h. 45 m.	49°	35°
23, .	-	118	1.90	12.70	.6600	.0190	.6790	2.98	.0040	.0003	-	-	37°
24, .	150	92	-	-	-	-	-	-	-	-	1 h. 32 m.	60°	37°
25, .	150	123	-	-	-	-	-	-	-	-	-	63°	37°
26, .	150	154	2.60	12.10	.5800	.0220	.6020	2.70	.0040	.0002	1 h. 52 m.	67°	36°
27, .	150	274	-	-	-	-	-	-	-	-	-	65°	36°
28, .	150	235	1.70	11.80	.6400	.0220	6620	2.74	.0070	.0003	-	53°	36°
29, .	150	184	-	-	-	-	-	-	-	-	1 h. 21 m.	52°	36°
30, .	150	153	1.90	12.40	.6200	.0190	.6390	2.60	.0060	.0002	1 h.	54°	36°
31, .	150	147	-	-	-	-	-	-	-	-	-	60°	37°

Effluent colorless and generally nearly clear and with slight sediment.

March 10, 9.44 A.M., to March 15, 5.20 P.M. — Outlet of tank closed except for about 40 minutes daily when effluent was drawn. March 11. — Applied sewage settled but .01 inches in 1.5 hours. March 14. — Snow all removed from surface. March 25. — Second 75 gallons sewage applied disappeared in 52 minutes; March 27, in 34 minutes.

Total effluent to end of month, 17,415 gallons.

Filter Tank No. 2 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	150	145	1.70	12.80	.6500	.0310	.6810	2.50	.0100	.0003	45 m.	46°	37°
2, .	150	318	0.80	11.30	.5800	.0220	.6020	2.20	.0080	.0002	-	43°	36°
3, .	150	156	1.50	10.90	.5500	.0300	.5800	2.30	.0080	.0001	52 m.	43°	37°
4, .	150	142	1.70	10.90	.6000	.0250	.6250	2.20	.0120	.0002	1 h. 24 m.	42°	37°
5, .	150	181	-	-	-	-	-	-	-	-	58 m.	44°	37°
6, .	150	211	1.40	10.90	.4800	.0100	.4900	2.02	.0100	.0002	2 h. 18 m.	46°	38°
7, .	150	70	-	-	-	-	-	-	-	-	-	45°	-
8, .	-	-	-	-	-	-	-	-	-	-	-	-	-
9, .	150	168	1.40	10.90	.6000	.0220	.6220	2.16	.0080	.0001	1 h. 9 m.	36°	39°
10, .	150	141	1.00	10.30	.4500	.0130	.4630	1.84	.0120	.0002	1 h.	45°	39°
11, .	150	232	-	-	-	-	-	-	-	-	1 h. 52 m.	44°	39°
12, .	150	151	-	-	-	-	-	-	-	-	-	43°	39°
13, .	150	140	1.40	11.60	.5600	.0190	.5790	2.18	.0250	.0007	1 h. 23 m.	42°	39°
14, .	150	148	-	-	-	-	-	-	-	-	1 h. 31 m.	45°	39°
15, .	150	146	-	-	-	-	-	-	-	-	2 h. 53 m.	45°	39°
16, .	150	123	1.70	10.50	.5000	.0160	.5160	2.33	.0300	.0003	1 h. 49 m.	42°	40°
17, .	150	129	-	-	-	-	-	-	-	-	1 h. 25 m.	45°	40°
18, .	150	143	1.90	10.20	.4800	.0160	.4960	2.26	.0300	.0005	1 h. 22 m.	45°	40°
19, .	150	137	-	-	-	-	-	-	-	-	-	42°	40°
20, .	150	136	1.90	10.20	.5800	.0160	.5960	2.36	.0350	.0005	-	43°	40°
21, .	300	303	-	-	-	-	-	-	-	-	-	44°	40°
22, .	-	69	-	-	-	-	-	-	-	-	-	-	-
23, .	150	106	2.30	12.80	.5500	.0190	.5690	2.88	.0250	.0005	-	42°	42°
24, .	150	129	-	-	-	-	-	-	-	-	-	43°	41°
25, .	150	131	1.20	12.20	.6500	.0130	.6630	3.28	.0150	.0004	-	42°	41°
26, .	150	139	-	-	-	-	-	-	-	-	-	46°	42°
27, .	150	133	2.50	12.40	.5700	.0170	.5870	3.00	.0200	.0004	-	44°	42°
28, .	300	250	-	-	-	-	-	-	-	-	-	46°	42°
29, .	-	65	-	-	-	-	-	-	-	-	-	-	-
30, .	-	-	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless and generally clear, or very nearly so, and with very little or no sediment.

Organisms visible to the naked eye in samples throughout the month. April 7, 9.22 A.M., to April 9, 8.27, A.M. — Outlet closed. River high. April 30, 6.30 A.M. — Outlet closed. River high.

Total effluent to end of month, 21,757 gallons.

Filter Tank No. 2 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
2, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
3, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
4, . .	150	100	3.80	14.00	.4800	.0240	.5040	3.00	.0450	.0015	48 m.	45°	46°
5, . .	300	257	-	-	-	-	-	-	-	-	-	45°	45°
6, . .	-	71	-	-	-	-	-	-	-	-	-	-	-
7, . .	150	90	2.50	13.60	.5500	.0210	.5710	3.22	.0400	.0010	53 m.	50°	-
8, . .	150	95	-	-	-	-	-	-	-	-	-	48°	47°
9, . .	150	222	2.70	12.40	.5800	.0120	.5920	3.41	.0400	.0012	-	50°	47°
10, . .	150	177	-	-	-	-	-	-	-	-	-	51°	47°
11, . .	150	137	-	-	-	-	-	-	-	-	-	51°	47°
12, . .	300	443	3.30	15.30	.5700	.0160	.5860	3.90	.0200	.0011	-	49°	48°
13, . .	-	46	-	-	-	-	-	-	-	-	-	-	-
14, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
15, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
16, . .	-	-	-	-	-	-	-	-	-	-	-	-	-
17, . .	150	231	-	-	-	-	-	-	-	-	-	49°	49°
18, . .	150	125	-	-	-	-	-	-	-	-	-	49°	49°
19, . .	300	280	3.00	14.50	.5000	.0120	.5120	3.22	.0650	.0020	-	50°	49°
20, . .	-	66	-	-	-	-	-	-	-	-	-	-	-
21, . .	150	90	-	-	-	-	-	-	-	-	-	51°	50°
22, . .	150	120	-	-	-	-	-	-	-	-	-	52°	50°
23, . .	150	119	3.20	13.30	.4700	.0090	.4790	3.28	.1400	.0028	-	53°	51°
24, . .	150	127	-	-	-	-	-	-	-	-	-	55°	50°
25, . .	150	128	-	-	-	-	-	-	-	-	-	56°	51°
26, . .	300	237	5.10	13.30	.5000	.0140	.5140	3.06	.2300	.0069	-	57°	52°
27, . .	-	64	-	-	-	-	-	-	-	-	-	-	-
28, . .	150	111	-	-	-	-	-	-	-	-	-	57°	52°
29, . .	150	194	-	-	-	-	-	-	-	-	-	56°	53°
30, . .	150	147	3.00	14.50	.4300	.0180	.4480	4.64	.3500	.0044	-	57°	54°
31, . .	150	133	-	-	-	-	-	-	-	-	-	57°	53°

Effluent colorless and generally clear, or very nearly so, and with very little or no sediment.

Organisms visible to naked eye in samples of first half of month. May 4. — Outlet opened at 7.40 A.M. May 13, 12.06 P.M., to 17, 7.40 A.M. — Outlet closed. River high.

Total effluent to end of month, 25,567 gallons.

Filter Tank No. 2 — Continued.

June, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	150	125	-	-	-	-	-	-	-	-	58°	54°
2, ...	300	227	6.50	15.30	.4300	.0070	.4370	2.78	.8000	.0050	60°	55°
3, ...	-	60	-	-	-	-	-	-	-	-	-	-
4, ...	150	90	-	-	-	-	-	-	-	-	59°	55°
5, ...	150	121	-	-	-	-	-	-	-	-	61°	56°
6, ...	150	138	9.60	17.80	.4500	.0140	.4640	3.60	2.7000	.0180	61°	58°
7, ...	150	137	-	-	-	-	-	-	-	-	64°	58°
8, ...	150	129	-	-	-	-	-	-	-	-	64°	59°
9, ...	300	222	16.10	18.50	.4500	.0190	.4690	4.60	1.9000	.0130	66°	59°
10, ...	-	54	-	-	-	-	-	-	-	-	-	-
11, ...	150	92	-	-	-	-	-	-	-	-	68°	60°
12, ...	150	118	-	-	-	-	-	-	-	-	65°	60°
13, ...	150	112	20.60	25.50	.4500	.0090	.4590	5.25	2.3000	.0240	64°	60°
14, ...	150	185	-	-	-	-	-	-	-	-	65°	60°
15, ...	150	163	-	-	-	-	-	-	-	-	65°	61°
16, ...	300	232	12.20	26.80	.4700	.0140	.4840	5.22	2.9000	.0440	66°	62°
17, ...	-	88	-	-	-	-	-	-	-	-	-	-
18, ...	100	69	-	-	-	-	-	-	-	-	68°	64°
19, ...	100	67	-	-	-	-	-	-	-	-	68°	64°
20, ...	100	89	16.60	20.60	.3300	.0140	.3440	4.65	2.2000	.0750	70°	63°
21, ...	100	91	-	-	-	-	-	-	-	-	69°	63°
22, ...	100	100	-	-	-	-	-	-	-	-	69°	65°
23, ...	200	153	22.40	20.50	.2500	.0200	.2700	4.85	2.3000	.1200	73°	67°
24, ...	-	62	-	-	-	-	-	-	-	-	-	-
25, ...	100	77	-	-	-	-	-	-	-	-	71°	66°
26, ...	100	120	-	-	-	-	-	-	-	-	69°	65°
27, ...	100	125	8.40	24.00	.3500	.0080	.3580	5.20	1.8000	.0700	69°	66°
28, ...	100	65	-	-	-	-	-	-	-	-	68°	63°
29, ...	100	78	-	-	-	-	-	-	-	-	66°	66°
30, ...	200	111	10.20	23.10	.2200	.0260	.2460	5.87	1.6000	.0800	67°	66°

Effluent colorless, generally clear, and with very little sediment.
Total effluent to end of month, 29,067 gallons.

Filter Tank No. 2 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1,	-	74	-	-	-	-	-	-	-	-	-	-	-
2,	100	63	-	-	-	-	-	-	-	-	-	65°	66°
3,	100	67	-	-	-	-	-	-	-	-	-	65°	67°
4,	100	69	3.60	32.30	.1900	.0120	.2020	6.42	1.6700	.0800	-	67°	69°
5,	100	70	-	-	-	-	-	-	-	-	-	68°	68°
6,	100	65	-	-	-	-	-	-	-	-	-	68°	67°
7,	200	92	12.80	21.70	.1900	.0060	.1960	6.84	1.4500	.0500	-	70°	69°
8,	-	70	-	-	-	-	-	-	-	-	-	-	-
9,	100	57	-	-	-	-	-	-	-	-	-	69°	67°
10,	100	67	-	-	-	-	-	-	-	-	-	69°	69°
11,	100	65	7.40	26.50	.1500	.0140	.1640	7.52	1.3000	.0450	-	69°	69°
12,	100	123	-	-	-	-	-	-	-	-	-	69°	67°
13,	100	85	-	-	-	-	-	-	-	-	-	69°	66°
14,	200	114	10.70	26.30	.2000	.0120	.2120	8.85	1.2700	.0350	-	69°	68°
15,	-	80	-	-	-	-	-	-	-	-	-	-	-
16,	100	65	-	-	-	-	-	-	-	-	1h.57m.	69°	68°
17,	100	71	-	-	-	-	-	-	-	-	-	69°	67°
18,	100	34	8.20	29.30	.1600	.0100	.1700	8.28	1.3300	.0300	-	71°	68°
19,	100	86	-	-	-	-	-	-	-	-	-	71°	-
20,	100	176	-	-	-	-	-	-	-	-	-	70°	68°
21,	200	144	5.10	29.90	.1500	.0110	.1610	7.58	1.3300	.0300	-	71°	69°
22,	-	97	-	-	-	-	-	-	-	-	-	-	-
23,	100	107	-	-	-	-	-	-	-	-	-	72°	69°
24,	100	98	-	-	-	-	-	-	-	-	-	72°	70°
25,	100	80	8.30	24.70	.1100	.0170	.1270	7.33	1.1500	.0225	-	73°	70°
26,	100	72	-	-	-	-	-	-	-	-	-	73°	70°
27,	100	71	-	-	-	-	-	-	-	-	-	72°	69°
28,	200	131	8.20	23.60	.0900	.0120	.1020	7.90	1.0500	.0175	-	71°	68°
29,	-	88	-	-	-	-	-	-	-	-	-	-	-
30,	100	65	-	-	-	-	-	-	-	-	-	71°	70°
31,	100	72	-	-	-	-	-	-	-	-	-	72°	70°

Effluent colorless, and generally clear, and free from sediment.

July 19, 11.14 A.M., to 20, 2 P.M. — Outlet closed on account of leak in measuring basin. July 21. — Organisms visible to naked eye in sample.

Total effluent to end of month, 31,685 gallons.

Filter Tank No. 2 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	100	96	.00	31.00	.1000	.0110	.1110	8.91	1.4000	.0200	-	73°	70°
2, .	100	80	-	-	-	-	-	-	-	-	-	73°	71°
3, .	100	76	-	-	-	-	-	-	-	-	-	73°	71°
4, .	200	113	.30	30.00	.1800	.0560	.2360	9.01	1.1200	.0180	-	74°	71°
5, .	-	89	-	-	-	-	-	-	-	-	-	-	-
6, .	100	79	-	-	-	-	-	-	-	-	-	74°	70°
7, .	100	149	-	-	-	-	-	-	-	-	-	72°	70°
8, .	100	108	1.80	24.90	.0480	.0120	.0600	8.48	1.2500	.0160	-	72°	70°
9, .	100	102	-	-	-	-	-	-	-	-	-	73°	71°
10, .	100	98	-	-	-	-	-	-	-	-	-	72°	71°
11, .	200	129	.50	28.60	.0164	.0098	.0262	7.90	1.3000	.0060	-	73°	69°
12, .	-	78	-	-	-	-	-	-	-	-	-	-	-
13, .	100	138	-	-	-	-	-	-	-	-	-	70°	69°
14, .	100	118	-	-	-	-	-	-	-	-	24 h.	-	69°
15, .	100	93	3.00	27.70	.0136	.0078	.0214	8.00	1.2000	.0080	24 h.	69°	70°
16, .	100	94	-	-	-	-	-	-	-	-	23h.30m.	69°	72°
17, .	100	96	-	-	-	-	-	-	-	-	24 h.	70°	70°
18, .	200	149	5.10	25.00	.0096	.0090	.0186	8.30	1.1500	.0050	24 h.	70°	70°
19, .	-	82	-	-	-	-	-	-	-	-	24 h.	-	-
20, .	100	66	-	-	-	-	-	-	-	-	23 h.	71°	71°
21, .	100	70	-	-	-	-	-	-	-	-	24 h.	71°	71°
22, .	100	174	4.40	25.00	.0084	.0110	.0194	8.25	1.0000	.0030	22h.17m.	70°	69°
23, .	100	98	-	-	-	-	-	-	-	-	-	70°	69°
24, .	100	82	-	-	-	-	-	-	-	-	5h.41m.	70°	71°
25, .	200	132	2.90	25.80	.0022	.0100	.0122	7.90	1.1600	.0008	19h.53m.	70°	72°
26, .	-	65	-	-	-	-	-	-	-	-	-	-	-
27, .	100	60	-	-	-	-	-	-	-	-	-	71°	71°
28, .	100	66	-	-	-	-	-	-	-	-	3h.39m.	70°	69°
29, .	100	71	3.40	23.80	.0012	.0080	.0092	6.80	.8200	.0002	5h.28m.	69°	70°
30, .	100	78	-	-	-	-	-	-	-	-	-	70°	70°
31, .	100	74	-	-	-	-	-	-	-	-	-	70°	71°

Effluent clear and colorless and with very little or no sediment.

After August 1 residue on evaporation obtained with sodium carbonate. August 22. — 100 gallons water siphoned from surface. August 23. — Sewage applied did not disappear till night.

Total effluent to end of month, 34,688 gallons.

Filter Tank No. 2 — Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	200	140	1.30	23.90	.0022	.0114	.0136	6.00	.8000	.0001	27h.44m.	71°	70°
2, .	-	89	-	-	-	-	-	-	-	-	-	-	-
3, .	100	58	-	-	-	-	-	-	-	-	-	70°	71°
4, .	100	76	-	-	-	-	-	-	-	-	-	71°	68°
5, .	100	74	.80	22.30	.0014	.0098	.0112	5.13	.7000	.0001	-	70°	70°
6, .	100	66	-	-	-	-	-	-	-	-	-	68°	69°
7, .	100	53	-	-	-	-	-	-	-	-	-	68°	67°
8, .	200	288	.70	22.30	.0014	.0088	.0102	5.20	.6300	.0000	48h.10m.	66°	69°
9, .	-	131	-	-	-	-	-	-	-	-	-	-	-
10, .	100	89	-	-	-	-	-	-	-	-	21h.39m.	67°	69°
11, .	100	74	-	-	-	-	-	-	-	-	-	67°	69°
12, .	100	113	2.60	22.30	.0016	.0068	.0084	5.53	.8000	.0000	24 h.	66°	67°
13, .	100	100	-	-	-	-	-	-	-	-	24 h.	66°	69°
14, .	100	72	-	-	-	-	-	-	-	-	44 h.	64°	68°
15, .	-	59	1.00	27.20	.0014	.0070	.0084	6.94	.7500	.0000	-	-	68°
16, .	-	38	-	-	-	-	-	-	-	-	-	-	-
17, .	200	71	-	-	-	-	-	-	-	-	-	65°	68°
18, .	-	155	-	-	-	-	-	-	-	-	-	-	66°
19, .	200	147	1.10	31.90	.0012	.0078	.0090	12.60	1.0500	.0000	24h.59m.	64°	66°
20, .	-	76	-	-	-	-	-	-	-	-	-	-	67°
21, .	200	141	-	-	-	-	-	-	-	-	27h.48m.	63°	65°
22, .	-	137	.80	36.80	.0004	.0068	.0072	12.52	.8000	.0000	-	-	67°
23, .	-	32	-	-	-	-	-	-	-	-	-	-	-
24, .	200	99	-	-	-	-	-	-	-	-	-	58°	64°
25, .	-	63	-	-	-	-	-	-	-	-	-	-	65°
26, .	200	146	1.20	35.90	.0008	.0064	.0072	12.62	.9600	.0000	-	58°	64°
27, .	-	67	-	-	-	-	-	-	-	-	-	-	65°
28, .	200	111	-	-	-	-	-	-	-	-	5h.52m.	57°	63°
29, .	-	62	.70	36.80	.0000	.0076	.0076	12.30	.8700	.0000	-	-	61°
30, .	-	18	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless and generally clear and free from sediment.

September 5, 6 and 24. — Sewage applied disappeared during the night. September 18. — 135 gallons siphoned off and the rest disappeared during the night. September 21. — Water on surface in morning. September 22. — 110 gallons siphoned off; September 26. — 270 gallons. Some left on surface.

Total effluent to end of month, 37,533 gallons.

Filter Tank No. 2 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	200	119	-	-	-	-	-	-	-	-	-	53°	61°
2, .	-	118	-	-	-	-	-	-	-	-	-	-	62°
3, .	200	123	.50	35.30	.0000	.0086	.0086	11.86	.8500	.0000	-	51°	62°
4, .	-	101	-	-	-	-	-	-	-	-	-	-	61°
5, .	200	105	-	-	-	-	-	-	-	-	22h.18m.	50°	61°
6, .	-	95	1.90	31.80	.0004	.0082	.0086	10.10	.8200	.0000	-	-	60°
7, .	-	99	-	-	-	-	-	-	-	-	-	-	-
8, .	200	160	-	-	-	-	-	-	-	-	-	52°	59°
9, .	-	107	-	-	-	-	-	-	-	-	-	-	58°
10, .	200	69	.60	28.80	.0006	.0066	.0072	8.75	.8000	.0000	-	49°	58°
11, .	-	95	-	-	-	-	-	-	-	-	-	-	59°
12, .	200	81	-	-	-	-	-	-	-	-	-	47°	57°
13, .	-	116	.20	25.00	.0004	.0084	.0088	6.65	.7300	.0000	-	-	57°
14, .	-	64	-	-	-	-	-	-	-	-	-	-	-
15, .	200	64	-	-	-	-	-	-	-	-	-	47°	57°
16, .	-	82	-	-	-	-	-	-	-	-	-	-	57°
17, .	200	87	1.50	23.30	.0002	.0074	.0076	5.80	.6800	.0000	-	48°	55°
18, .	-	120	-	-	-	-	-	-	-	-	-	-	55°
19, .	200	107	-	-	-	-	-	-	-	-	48h.54m.	46°	56°
20, .	-	70	1.20	22.40	.0004	.0084	.0088	5.00	.6200	.0000	-	-	55°
21, .	-	99	-	-	-	-	-	-	-	-	-	-	-
22, .	200	56	-	-	-	-	-	-	-	-	-	45°	56°
23, .	-	100	-	-	-	-	-	-	-	-	-	-	54°
24, .	200	67	1.00	21.90	.0006	.0058	.0064	5.05	.8400	.0000	-	45°	53°
25, .	-	107	-	-	-	-	-	-	-	-	-	-	53°
26, .	200	93	-	-	-	-	-	-	-	-	-	45°	-
27, .	-	95	1.30	20.80	.0002	.0046	.0048	4.88	.9400	.0000	-	-	53°
28, .	-	76	-	-	-	-	-	-	-	-	-	-	-
29, .	200	72	-	-	-	-	-	-	-	-	6 dys.	46°	54°
30, .	-	67	-	-	-	-	-	-	-	-	-	-	54°
31, .	200	64	1.30	21.10	.0002	.0064	.0066	4.50	.8500	.0000	-	45°	54°

Effluent clear and colorless and generally free from sediment.

October 8. — 25 gallons water siphoned from surface; October 18. — 85 gallons. Some water left; October 25. — 115 gallons. October 10 and 17. — Sewage applied disappeared during second night after. — October 17, 24 and 29. — Some water on surface before sewage was applied.

Total effluent to end of month, 40,411 gallons.

Filter Tank No. 2 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	–	79	–	–	–	–	–	–	–	–	–	–	55°
2, .	–	58	–	–	–	–	–	–	–	–	–	–	55°
3, .	–	57	1.00	21.90	.0000	.0070	.0070	4.49	.8500	.0000	–	–	55°
4, .	–	37	–	–	–	–	–	–	–	–	–	–	–
5, .	150	43	–	–	–	–	–	–	–	–	29h.20m.	48°	54°
6, .	–	69	–	–	–	–	–	–	–	–	–	–	54°
7, .	150	50	.30	22.80	.0004	.0072	.0076	4.59	.8700	.0000	24h.19m.	50°	54°
8, .	–	46	–	–	–	–	–	–	–	–	–	–	54°
9, .	150	57	–	–	–	–	–	–	–	–	–	49°	55°
10, .	–	94	.80	21.10	.0006	.0070	.0076	4.51	.8300	.0000	–	–	54°
11, .	–	65	–	–	–	–	–	–	–	–	–	–	–
12, .	150	89	–	–	–	–	–		–	–	46h.16m.	45°	53°
13, .	–	90	–	–	–	–	–	–	–	–	–	–	53°
14, .	150	89	1.50	21.80	.0004	.0080	.0084	4.53	.8500	.0000	–	43°	53°
15, .	–	100	–	–	–	–	–	–	–	–	–	–	52°
16, .	150	130	–	–	–	–	–	–	–	–	21h.55m.	42°	52°
17, .	–	90	1.90	21.70	.0000	.0068	.0068	4.70	.8500	.0000	–	–	51°
18, .	–	25	–	–	–	–	–	–	–	–	–	–	–
19, .	150	95	–	–	–	–	–	–	–	–	–	40°	51°
20, .	–	83	–	–	–	–	–	–	–	–	–	–	51°
21, .	150	71	.70	22.40	.0004	.0070	.0074	4.16	1.0000	.0000	–	38°	49°
22, .	–	48	–	–	–	–	–	–	–	–	–	–	49°
23, .	150	50	–	–	–	–	–	–	–	–	–	44°	48°
24, .	–	53	1.00	22.80	.0006	.0082	.0088	4.38	.9500	.0001	–	–	48°
25, .	–	9	–	–	–	–	–	–	–	–	–	–	–
26, .	150	54	–	–	–	–	–	–	–	–	–	45°	48°
27, .	–	83	–	–	–	–	–	–	–	–	–	–	47°
28, .	150	126	2.80	22.50	.0000	.0066	.0066	4.43	.7000	.0000	–	44°	48°
29, .	–	62	–	–	–	–	–	–	–	–	–	–	46°
30, .	150	71	–	–	–	–	–	–	–	–	–	46°	47°

Effluent clear and colorless and with very little or no sediment.

Ice on surface: November 11, 1-16 inch; November 12, ¼ inch; November 22, ⅛ inch in spots; November 23 and 26, ⅛ inch; November 27, a few spots. November 12, 55 gallons water siphoned from surface. November 22, canvas cover put over tank. November 19, sewage applied disappeared during the night. November 26, during second night after application.

Total effluent to end of month, 42,484 gallons.

Filter Tank No. 2 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	–	75	.80	22.50	.0002	.0066	.0068	4.38	.8500	.0000	–	–	45°
2, .	–	27	–	–	–	–	–	–	–	–	–	–	–
3, .	150	85	–	–	–	–	–	–	–	–	2 h.	45°	45°
4, .	–	54	–	–	–	–	–	–	–	–	–	–	45°
5, .	150	83	.70	22.30	.0004	.0058	.0062	4.26	.8000	.0000	2 h. 32 m.	44°	44°
6, .	–	59	–	–	–	–	–	–	–	–	–	–	45°
7, .	150	78	–	–	–	–	–	–	–	–	–	45°	45°
8, .	–	59	1.10	22.50	.0004	.0078	.0082	4.13	.8000	.0000	–	–	45°
9, .	–	23	–	–	–	–	–	–	–	–	–	–	–
10, .	150	64	–	–	–	–	–	–	–	–	4 h.	45°	44°
11, .	–	46	–	–	–	–	–	–	–	–	–	–	43°
12, .	150	81	.50	20.60	.0002	.0062	.0064	4.14	.7000	.0000	5 h. 55 m.	44°	43°
13, .	–	55	–	–	–	–	–	–	–	–	–	–	42°
14, .	150	50	–	–	–	–	–	–	–	–	–	46°	39°
15, .	–	47	.80	21.10	.0002	.0056	.0058	4.00	.8000	.0000	–	–	43°
16, .	–	13	–	–	–	–	–	–	–	–	–	–	–
17, .	150	93	–	–	–	–	–	–	–	–	–	45°	44°
18, .	–	52	–	–	–	–	–	–	–	–	–	–	42°
19, .	–	–	–	–	–	–	–	–	–	–	–	–	–
20, .	–	–	–	–	–	–	–	–	–	–	–	–	–
21, .	150	114	–	–	–	–	–	–	–	–	6 h. 30 m.	46°	40°
22, .	–	36	.30	20.70	.0002	.0060	.0062	4.10	.7500	.0000	–	–	39°
23, .	–	11	–	–	–	–	–	–	–	–	–	–	–
24, .	150	47	–	–	–	–	–	–	–	–	–	42°	45°
25, .	–	46	–	–	–	–	–	–	–	–	–	–	–
26, .	150	104	.60	20.40	.0008	.0070	.0078	4.15	.8500	.0000	–	45°	41°
27, .	–	45	–	–	–	–	–	–	–	–	–	–	43°
28, .	150	105	–	–	–	–	–	–	–	–	3 h. 8 m.	45	40°
29, .	–	66	.80	20.20	.0020	.0062	.0082	3.80	.7200	.0000	–	–	42°
30, .	–	24	–	–	–	–	–	–	–	–	–	–	–
31, .	150	81	–	–	–	–	–	–	–	–	2 h. 42 m.	45°	41°

Effluent colorless, generally clear and with very little or no sediment.

December 15, ¼ inch ice on surface. December 18, 8.50 P.M., to December 21, 7.47 A.M. Outlet closed. River high. December 19, ⅝ inch frost in tank. December 21, 2 inches.

Total effluent to end of month, 44,207 gallons.

Filter Tank No. 2 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	52	-	-	-	-	-	-	-	-	-	-	41°
2, .	150	105	0.7	20.8	.0018	.0064	.0082	4.35	.7000	.0000	2 h. 17m.	45°	40°
3, .	-	57	-	-	-	-	-	-	-	-	-	-	41°
4, .	150	92	-	-	-	-	-	-	-	-	-	45°	40°
5, .	-	65	0.7	21.4	.0002	.0048	.0050	4.31	.7800	.0000	-	-	40°
6, .	-	22	-	-	-	-	-	-	-	-	-	-	-
7, .	150	74	-	-	-	-	-	-	-	-	2 h. 17m.	45°	40°
8, .	-	50	-	-	-	-	-	-	-	-	-	-	41°
9, .	150	96	0.9	22.3	.0006	.0072	.0078	4.24	.7800	.0000	2 h. 7m.	45°	40°
10, .	-	55	-	-	-	-	-	-	-	-	-	-	41°
11, .	150	90	-	-	-	-	-	-	-	-	2h. 3m.	45°	40°
12, .	-	56	0.3	22.4	.0010	.0060	.0070	4.31	1.0000	.0000	-	-	40°
13, .	-	24	-	-	-	-	-	-	-	-	-	-	-
14, .	150	64	-	-	-	-	-	-	-	-	2 h. 34m	44°	41°
15, .	-	48	-	-	-	-	-	-	-	-	-	-	41°
16, .	150	83	0.6	20.5	.0018	.0084	.0102	4.20	1.0000	.0000	-	44°	40°
17, .	-	59	-	-	-	-	-	-	-	-	-	-	42°
18, .	150	100	-	-	-	-	-	-	-	-	1 h. 50m.	45°	40°
19, .	-	61	0.3	20.0	.0006	.0058	.0064	4.15	.7000	.0000	-	-	40°
20, .	-	23	-	-	-	-	-	-	-	-	-	-	-
21, .	150	60	-	-	-	-	-	-	-	-	-	44°	40°
22, .	-	37	-	-	-	-	-	-	-	-	-	-	40°
23, .	150	85	1.2	19.1	.0002	.0050	.0052	4.18	.6500	.0001	6 h. 1m.	46°	40°
24, .	-	48	-	-	-	-	-	-	-	-	-	-	41°
25, .	150	94	-	-	-	-	-	-	-	-	8 h. 11m.	45°	40°
26, .	-	57	0.7	19.5	.0002	.0046	.0048	4.00	.6500	.0001	-	-	40°
27, .	-	22	-	-	-	-	-	-	-	-	-	-	-
28, .	150	79	-	-	-	-	-	-	-	-	-	44°	40°
29, .	-	55	-	-	-	-	-	-	-	-	-	-	40°
30, .	150	86	0.2	19.6	.0010	.0060	.0070	3.97	.6000	.0000	-	46°	39°
31, .	-	44	-	-	-	-	-	-	-	-	-	-	40°

Effluent colorless, generally clear and with very little or no sediment.
January 22, 1 inch of frost in tank; 26, ½ inch; January 29, none.
Total effluent to end of month, 46,150 gallons.

Filter Tank No. 2 — Continued.

February, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	150	98	-	-	-	-	-	-	-	-	-	45°	39°
2, .	-	47	1.6	18.0	.0002	.0052	.0054	4.05	.8000	.0000	-	-	39°
3, .	-	16	-	-	-	-	-	-	-	-	-	-	-
4, .	150	72	-	-	-	-	-	-	-	-	-	45°	40°
5, .	-	49	-	-	-	-	-	-	-	-	-	-	39°
6, .	150	100	0.9	19.5	.0006	.0050	.0056	4.12	.7000	.0000	-	44°	38°
7, .	-	43	-	-	-	-	-	-	-	-	-	-	38°
8, .	150	53	-	-	-	-	-	-	-	-	-	44°	38°
9, .	-	52	1.2	18.1	.0006	.0066	.0072	4.08	.7000	.0000	-	-	39°
10, .	-	15	-	-	-	-	-	-	-	-	-	-	-
11, .	150	37	-	-	-	-	-	-	-	-	-	44°	39°
12, .	-	68	-	-	-	-	-	-	-	-	-	-	38°
13, .	150	62	1.2	18.4	.0006	.0064	.0070	4.02	.8000	.0000	24 h.	46°	38°
14, .	-	76	-	-	-	-	-	-	-	-	24 h.	-	39°
15, .	150	55	-	-	-	-	-	-	-	-	-	45°	40°
16, .	-	77	1.0	18.2	.0004	.0046	.0050	4.03	.7500	.0000	-	-	39°
17, .	-	11	-	-	-	-	-	-	-	-	-	-	-
18, .	150	92	-	-	-	-	-	-	-	-	-	44°	39°
19, .	-	70	-	-	-	-	-	-	-	-	-	-	39°
20, .	150	101	0.6	18.6	.0026	.0062	.0088	3.86	.7000	.0000	-	46°	39°
21, .	-	50	-	-	-	-	-	-	-	-	-	-	39°
22, .	150	88	-	-	-	-	-	-	-	-	-	46°	40°
23, .	-	63	-	-	-	-	-	-	-	-	-	-	37°
24, .	-	19	-	-	-	-	-	-	-	-	-	-	-
25, .	150	25	-	-	-	-	-	-	-	-	-	45°	39°
26, .	-	48	-	-	-	-	-	-	-	-	-	-	38°
27, .	150	37	0.7	18.4	.0008	.0074	.0082	3.85	.7000	.0000	24 h.	45°	39°
28, .	-	82	-	-	-	-	-	-	-	-	-	-	39°

Effluent clear and colorless and with very little or no sediment.

February 2, 5, 7, 9, 11, 13, 14, 15, 18, 20, 21, 25, 27 and 28, thin ice on the whole or a part of the surface. — Frost in tank: February 2, 2 inches; 5, ½ inch; 7, 3½ inches; 9, 1 inch; 20, 3½ inches; 25, 4 inches. — February 20, Sewage applied disappeared during the night.

Total effluent to end of month, 47,756 gallons.

Filter Tank No. 2 — Continued.

March, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1,	150	134	-	-	-	-	-	-	-	-	-	44°	29°
2,	-	65	1.1	18.5	.0008	.0084	.0092	3.93	.5500	.0000	-	-	39°
3,	-	23	-	-	-	-	-	-	-	-	8 h. 16 m.	-	-
4,	150	113	-	-	-	-	-	-	-	-	-	35°	38°
5,	-	60	-	-	-	-	-	-	-	-	-	-	39°
6,	300	166	2.1	18.3	.0004	.0070	.0074	3.90	.6500	.0000	18 h. 59 m.	35°	38°
7,	-	107	-	-	-	-	-	-	-	-	-	-	38°
8,	300	215	-	-	-	-	-	-	-	-	-	34°	37°
9,	-	91	0.5	17.8	.0002	.0066	.0068	3.76	.6000	.0000	-	-	37°
10,	-	28	-	-	-	-	-	-	-	-	-	-	-
11,	300	189	-	-	-	-	-	-	-	-	-	33°	38°
12,	-	78	-	-	-	-	-	-	-	-	-	-	38°
13,	300	214	0.5	17.9	.0012	.0079	.0091	3.61	.5000	.0000	5 h. 29 m.	35°	37°
14,	-	93	-	-	-	-	-	-	-	-	-	-	38°
15,	300	205	-	-	-	-	-	-	-	-	3 h. 50 m.	35°	37°
16,	-	87	0.8	18.0	.0006	.0074	.0080	3.58	.6000	.0001	-	-	38°
17,	-	46	-	-	-	-	-	-	-	-	-	-	-
18,	300	240	-	-	-	-	-	-	-	-	4 h. 24 m.	36°	37°
19,	-	93	-	-	-	-	-	-	-	-	-	-	38°
20,	300	223	0.5	18.9	.0006	.0076	.0082	3.37	.5500	.0000	5 h. 15 m.	38°	37°
21,	-	91	-	-	-	-	-	-	-	-	-	-	38°
22,	300	197	-	-	-	-	-	-	-	-	3 h. 18 m.	37°	37°
23,	-	86	1.5	19.0	.0010	.0082	.0092	3.46	.7000	.0002	-	-	40°
24,	-	32	-	-	-	-	-	-	-	-	-	-	-
25,	300	160	-	-	-	-	-	-	-	-	2 h. 25 m.	41°	38°
26,	-	76	-	-	-	-	-	-	-	-	-	-	40°
27,	450	324	0.9	20.1	.0006	.0068	.0074	3.50	.8000	.0000	3 h. 23 m.	41°	39°
28,	-	102	-	-	-	-	-	-	-	-	-	-	40°
29,	450	328	-	-	-	-	-	-	-	-	4 h. 47 m.	39°	39°
30,	-	100	1.8	20.6	.0030	.0092	.0122	3.50	1.0000	.0006	-	-	40°
31,	-	31	-	-	-	-	-	-	-	-	-	-	-

Effluent clear and colorless and generally free from sediment.

March 1. — Surface covered with ice. March 4. — A little ice on surface and frost in one-half of tank at a depth of from 1 inch to 3 inches below surface. March 8. — Sewage applied disappeared at night. March 13. — Canvas cover removed.

Total effluent to end of month, 51,753 gallons.

Filter Tank No. 2 — Continued.

April, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	* Ammonia. Free.	* Ammonia. Albuminoid.	* Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	450	403	-	-	-	-	-	-	-	-	-	39°	40°
2, .	-	151	-	-	-	-	-	-	-	-	-	-	40°
3, .	450	363	0.7	22.5	.0060	.0078	.0138	3.53	1.2000	.0010	-	38°	40°
4, .	-	110	-	-	-	-	-	-	-	-	-	-	40°
5, .	450	314	-	-	-	-	-	-	-	-	-	39°	41°
6, .	-	125	1.6	28.8	.0186	.0104	.0290	6.47	1.4000	.0040	-	-	41°
7, .	-	38	-	-	-	-	-	-	-	-	-	-	-
8, .	450	293	-	-	-	-	-	-	-	-	6h.40m.	41°	41°
9, .	-	102	-	-	-	-	-	-	-	-	-	-	42°
10, .	450	317	0.8	27.9	.0212	.0086	.0298	6.00	1.4000	.0030	6h.11m.	44°	41°
11, .	-	102	-	-	-	-	-	-	-	-	-	-	43°
12, .	450	327	-	-	-	-	-	-	-	-	7h.54m.	46°	43°
13, .	-	112	0.7	24.7	.0226	.0100	.0326	5.14	1.2000	.0030	-	-	44°
14, .	-	11	-	-	-	-	-	-	-	-	-	-	-
15, .	450	272	-	-	-	-	-	-	-	-	-	45°	45°
16, .	-	109	-	-	-	-	-	-	-	-	-	-	45°
17, .	450	338	2.6	27.2	.0162	.0084	.0246	6.12	1.2000	.0060	-	47°	45°
18, .	-	136	-	-	-	-	-	-	-	-	-	-	45°
19, .	450	285	-	-	-	-	-	-	-	-	-	49°	48°
20, .	-	148	2.0	32.4	.0270	.0114	.0384	8.42	1.9000	.0150	-	-	47°
21, .	-	41	-	-	-	-	-	-	-	-	-	-	-
22, .	450	273	-	-	-	-	-	-	-	-	-	52°	47°
23, .	-	104	-	-	-	-	-	-	-	-	-	-	48°
24, .	450	290	-	-	-	-	-	8.00	2.6000	-	-	50°	49°
25, .	-	126	-	-	-	-	-	-	-	-	-	-	50°
26, .	450	377	-	-	-	-	-	-	-	-	18h.51m.	53°	51°
27, .	-	269	1.0	33.0	.0288	.0100	.0388	4.77	2.8000	.0250	-	-	50°
28, .	-	27	-	-	-	-	-	-	-	-	-	-	-
29, .	450	213	-	-	-	-	-	-	-	-	-	54°	52°
30, .	-	164	-	-	-	-	-	-	-	-	-	-	52°

Effluent clear and colorless and generally free from sediment.

April 3, 5, 15, 24 and 29. — Sewage applied disappeared during the night. April 17. — A thin coating of sediment on surface is cracking and curling up.

Total effluent to end of month, 57,693 gallons.

Filter Tank No. 2 — Continued.

May, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	450	230	1.2	31.0	.0012	.0094	.0106	4.62	2.6000	.0050	-	51°	52°
2, .	-	175	-	-	-	-	-	-	-	-	-	-	54°
3, .	450	203	-	-	-	-	-	-	-	-	-	52°	52°
4, .	-	215	1.4	31.8	.0066	.0118	.0184	4.34	2.8000	.0024	-	-	52°
5, .	-	48	-	-	-	-	-	-	-	-	-	-	-
6, .	450	184	-	-	-	-	-	-	-	-	-	54°	55°
7, .	-	173	-	-	-	-	-	-	-	-	-	-	53°
8, .	450	144	1.4	29.9	.0008	.0088	.0096	4.72	2.4000	.0000	29 h. 7 m.	56°	56°
9, .	-	202	-	-	-	-	-	-	-	-	-	-	54°
10, .	450	114	-	-	-	-	-	-	-	-	-	62°	59°
11, .	-	247	0.8	26.9	.0002	.0102	.0104	4.02	2.4000	.0001	-	-	55°
12, .	-	93	-	-	-	-	-	-	-	-	-	-	-
13, .	450	112	-	-	-	-	-	-	-	-	-	63°	58°
14, .	-	189	-	-	-	-	-	-	-	-	-	-	56°
15, .	300	167	1.5	29.7	.0012	.0092	.0104	4.66	2.0000	.0002	47 h. 57 m.	64°	57°
16, .	-	139	-	-	-	-	-	-	-	-	-	-	57°
17, .	300	129	-	-	-	-	-	-	-	-	51 h. 36 m.	65°	65°
18, .	-	139	0.8	30.2	.0010	.0088	.0098	5.02	2.4000	.0001	-	-	60°
19, .	-	75	-	-	-	-	-	-	-	-	-	-	-
20, .	300	75	-	-	-	-	-	-	-	-	93 h. 24 m.	65°	61°
21, .	-	152	-	-	-	-	-	-	-	-	-	-	60°
22, .	-	167	1.2	31.7	.0016	.0094	.0110	5.22	1.9000	.0000	-	-	60°
23, .	-	122	-	-	-	-	-	-	-	-	-	-	60°
24, .	-	63	-	-	-	-	-	-	-	-	-	-	61°
25, .	-	30	-	-	.0026	.0102	.0128	5.30	2.0000	.0004	-	-	63
26, .	-	20	-	-	-	-	-	-	-	-	-	-	-
27, .	300	101	-	-	-	-	-	-	-	-	-	59°	58°
28, .	-	171	-	-	-	-	-	-	-	-	-	-	61°
29, .	300	139	0.4	33.1	.0016	.0104	.0120	5.34	1.8000	.0004	-	60°	61°
30, .	-	124	-	-	-	-	-	-	-	-	-	-	-
31, .	300	102	-	-	-	-	-	-	-	-	-	61°	62°

Effluent colorless and generally clear and free from sediment.

May 1. — Outlet pipe sponged out. May 2. — Boiling water run through outlet pipe for 20 minutes. May 10 and 17. — Outlet pipe sponged out and hot water run through. May 1 and 29. — Sewage applied did not disappear till night. May 15 and 22. — Much water on surface. May 22. — A few spots of grass on surface.

Total effluent to end of month, 61,937 gallons.

Filter Tank No. 2—Continued.

June, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	154	1.8	29.9	.0016	.0120	.0136	5.25	1.8000	.0006	-	-	60°
2, .	-	110	-	-	-	-	-	-	-	-	-	-	-
3, .	300	128	-	-	-	-	-	-	-	-	-	64°	61°
4, .	-	142	-	-	-	-	-	-	-	-	-	-	60°
5, .	-	122	3.3	25.8	.0014	.0104	.0118	5.05	1.6000	.0001	-	-	61°
6, .	-	53	-	-	-	-	-	-	-	-	-	-	62°
7, .	300	118	-	-	-	-	-	-	-	-	-	65°	63°
8, .	-	124	1.8	26.8	.0016	.0128	.0144	4.68	1.2000	.0001	-	-	61°
9, .	-	46	-	-	-	-	-	-	-	-	-	-	-
10, .	300	116	-	-	-	-	-	-	-	-	22h.21m.	67°	66°
11, .	-	150	-	-	-	-	-	-	-	-	-	-	62°
12, .	300	123	-	-	-	-	-	-	-	-	-	-	63°
13, .	-	134	-	-	-	-	-	-	-	-	-	-	63°
14, .	300	122	-	-	-	-	-	-	-	-	-	68°	66°
15, .	-	148	1.3	27.2	.0006	.0102	.0108	3.85	1.8000	.0000	-	-	65°
16, .	-	34	-	-	-	-	-	-	-	-	-	-	-
17, .	300	166	-	-	-	-	-	-	-	-	-	71°	66°
18, .	-	85	-	-	-	-	-	-	-	-	-	-	64°
19, .	300	168	1.4	30.3	.0022	.0088	.0110	4.38	2.4000	.0003	-	69°	65°
20, .	-	81	-	-	-	-	-	-	-	-	-	-	66°
21, .	300	159	-	-	-	-	-	-	-	-	-	71°	68°
22, .	-	86	-	-	.0014	.0092	.0106	4.60	1.7000	.0000	-	-	67°
23, .	-	29	-	-	-	-	-	-	-	-	-	-	-
24, .	300	130	-	-	-	-	-	-	-	-	5 h. 9 m.	70°	66°
25, .	-	79	-	-	-	-	-	-	-	-	-	-	67°
26, .	300	162	1.4	25.8	.0040	.0100	.0140	4.60	1.3000	.0002	-	69°	67°
27, .	-	90	-	-	-	-	-	-	-	-	-	-	67°
28, .	300	189	-	-	-	-	-	-	-	-	-	71°	69°
29, .	-	78	2.2	25.0	.0028	.0100	.0128	4.67	1.3000	.0000	-	-	-
30, .	-	59	-	-	-	-	-	-	-	-	-	-	-

Effluent clear and colorless and generally free from sediment.

June 5.—Surface covered with water. June 7 and 21.—Sewage applied did not disappear till night. June 29.—Outlet closed from 10.10 to 11.40 A.M., and again at 1.47 P.M. Considerable leakage while closed.

Total effluent to end of month, 65,322 gallons.

Filter Tank No. 2 — Continued.

July, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	300	128	-	-	-	-	-	-	-	-	73°	69°
2, ...	-	91	-	-	-	-	-	-	-	-	-	68°
3, ...	300	227	3.2	24.7	.0042	.0102	.0144	4.92	1.5000	.0001	73°	68°
4, ...	-	86	-	-	-	-	-	-	-	-	-	-
5, ...	300	157	-	-	-	-	-	-	-	-	73°	69°
6, ...	-	76	3.2	23.4	.0010	.0100	.0110	5.72	1.2000	.0000	-	68°
7, ...	-	28	-	-	-	-	-	-	-	-	-	-
8, ...	300	127	-	-	-	-	-	-	-	-	74°	70°
9, ...	-	64	-	-	-	-	-	-	-	-	-	68°
10, ...	300	183	2.4	25.5	.0034	.0100	.0134	5.91	1.1000	.0000	72°	68°
11, ...	-	81	-	-	-	-	-	-	-	-	-	68°
12, ...	300	179	-	-	-	-	-	-	-	-	72°	69°
13, ...	-	93	2.2	25.2	.0010	.0098	.0108	6.47	1.2000	.0000	-	70°
14, ...	-	24	-	-	-	-	-	-	-	-	-	-
15, ...	300	210	-	-	-	-	-	-	-	-	73°	65°
16, ...	-	101	-	-	-	-	-	-	-	-	-	66°
17, ...	300	206	2.7	24.6	.0030	.0092	.0122	6.50	1.0000	.0002	72°	66°
18, ...	-	91	-	-	-	-	-	-	-	-	-	67°
19, ...	300	161	1.8	25.4	.0020	.0098	.0118	6.14	1.1000	.0000	72°	68°
20, ...	-	378	-	-	-	-	-	-	-	-	-	66°
21, ...	-	61	-	-	-	-	-	-	-	-	-	-
22, ...	300	130	-	-	-	-	-	-	-	-	72°	68°
23, ...	-	118	-	-	-	-	-	-	-	-	-	67°
24, ...	300	199	1.1	23.0	.0012	.0090	.0102	6.42	.7000	.0001	72°	68°
25, ...	-	83	-	-	-	-	-	-	-	-	-	68°
26, ...	300	138	-	-	-	-	-	-	-	-	70°	70°
27, ...	-	183	2.0	23.6	.0018	.0102	.0120	6.14	.7000	.0000	-	70°
28, ...	-	81	-	-	-	-	-	-	-	-	-	-
29, ...	300	136	-	-	-	-	-	-	-	-	69°	72°
30, ...	-	141	-	-	-	-	-	-	-	-	-	69°
31, ...	300	222	2.6	21.5	.0004	.0064	.0068	5.42	.5000	.0000	71°	69°

Effluent colorless, generally clear and with very slight or no sediment.

July 1. — Outlet opened at 10.40 A.M. July 5, 8.45 P.M., to July 6, 11.53 A.M. — Outlet closed. July 1, 8 and 15. — Sewage applied did not disappear till night.

Total effluent to end of month, 69,505 gallons.

Filter Tank No. 2 — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature Sewage.	Temperature Effluent.
1, ...	-	215	-	-	-	-	-	-	-	-	-	68°
2, ...	300	186	-	-	-	-	-	-	-	-	72°	69°
3, ...	-	154	1.3	20.2	.0016	.0084	.0100	4.59	.2700	.0002	-	69°
4, ...	-	39	-	-	-	-	-	-	-	-	-	-
5, ...	300	152	-	-	-	-	-	-	-	-	72°	68°
6, ...	-	102	-	-	-	-	-	-	-	-	-	70°
7, ...	300	149	-	-	-	-	-	-	-	-	71°	69°
8, ...	-	93	-	-	-	-	-	-	-	-	-	69°
9, ...	300	139	-	-	-	-	-	-	-	-	71°	70°
10, ...	-	101	.8	18.2	.0002	.0068	.0070	4.30	.6000	.0000	-	69°
11, ...	-	25	-	-	-	-	-	-	-	-	-	-
12, ...	300	108	-	-	-	-	-	-	-	-	70°	68°
13, ...	-	80	-	-	-	-	-	-	-	-	-	68°
14, ...	300	321	-	-	-	-	-	-	-	-	68°	68°
15, ...	-	142	-	-	-	-	-	-	-	-	-	66°
16, ...	300	168	-	-	-	-	-	-	-	-	68°	68°
17, ...	-	91	-	-	.0002	.0072	.0074	4.34	.5500	.0000	-	69°
18, ...	-	22	-	-	-	-	-	-	-	-	-	-
19, ...	300	130	-	-	-	-	-	-	-	-	69°	68°
20, ...	-	86	-	-	-	-	-	-	-	-	-	66°
21, ...	300	159	-	-	-	-	-	-	-	-	69°	66°
22, ...	-	85	-	-	-	-	-	-	-	-	-	68°
23, ...	300	156	-	-	-	-	-	-	-	-	70°	68°
24, ...	-	84	-	-	.0016	.0086	.0102	4.42	.6000	.0000	-	68°
25, ...	-	39	-	-	-	-	-	-	-	-	-	-
26, ...	300	130	-	-	-	-	-	-	-	-	70°	67°
27, ...	-	87	-	-	-	-	-	-	-	-	-	66°
28, ...	300	177	-	-	-	-	-	-	-	-	71°	66°
29, ...	-	77	-	-	-	-	-	-	-	-	-	66°
30, ...	300	155	-	-	-	-	-	-	-	-	71°	68°
31, ...	-	83	.4	21.4	.0004	.0062	.0066	4.74	.5000	.0000	-	67°

Effluent clear and colorless, and generally free from sediment.
August 19 and 21. — Sewage applied disappeared during the night.
Total effluent to end of month, 73,240 gallons.

Filter Tank No. 2 — Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	24	-	-	-	-	-	-	-	-	-	-	-
2, .	300	139	-	-	-	-	-	-	-	-	-	71°	68°
3, .	-	79	-	-	-	-	-	-	-	-	-	-	68°
4, .	300	187	-	-	-	-	-	-	-	-	8 h. 8 m.	70°	68°
5, .	-	79	-	-	-	-	-	-	-	-	-	-	68°
6, .	300	183	-	-	-	-	-	-	-	-	-	71°	68°
7, .	-	75	-	-	.0002	.0074	.0076	5.60	.4500	.0000	-	-	66°
8, .	-	0	-	-	-	-	-	-	-	-	-	-	-
9, .	300	179	-	-	-	-	-	-	-	-	-	71°	67°
10, .	-	79	-	-	.0002	.0058	.0060	6.00	.5200	.0000	-	-	66°
11, .	300	195	-	-	-	-	-	-	-	-	-	70°	66°
12, .	-	77	-	-	-	-	-	-	-	-	-	-	65°
13, .	300	200	-	-	-	-	-	-	-	-	4 h. 10 m.	68°	66°
14, .	-	138	1.8	26.4	.0008	.0072	.0080	7.80	.6500	.0000	-	-	66°
15, .	-	50	-	-	-	-	-	-	-	-	-	-	-
16, .	500	349	-	-	-	-	-	-	-	-	-	69°	68°
17, .	-	113	-	-	-	-	-	-	-	-	-	-	68°
18, .	500	416	-	-	-	-	-	-	-	-	-	69°	65°
19, .	-	225	-	-	-	-	-	-	-	-	-	-	65°
20, .	500	392	-	-	-	-	-	-	-	-	-	67°	65°
21, .	-	128	-	-	.0004	.0082	.0086	11.59	1.3000	.0000	-	-	66°
22, .	-	38	-	-	-	-	-	-	-	-	-	-	-
23, .	500	315	-	-	-	-	-	-	-	-	-	61°	65°
24, .	-	97	-	-	-	-	-	-	-	-	-	-	65°
25, .	500	332	-	-	-	-	-	-	-	-	-	60°	64°
26, .	-	131	-	-	.0048	.0104	.0152	7.87	1.4000	.0001	-	-	65°
27, .	500	352	-	-	-	-	-	-	-	-	-	60°	62°
28, .	-	130	-	-	-	-	-	-	-	-	-	-	61°
29, .	-	30	-	-	-	-	-	-	-	-	-	-	-
30, .	500	291	-	-	-	-	-	-	-	-	-	59°	62°

Effluent clear and colorless and generally free from sediment.

September 8, 7.37 A.M., to 9, 11.36 A.M. — Outlet closed. September 10. — Between 12.10 and 12.35 P.M. underdrains washed out with 30 gallons of effluent from Tank No. 8. September 18. — Sewage applied disappeared during the second night after; September 23, on the first night.

Total effluent to end of month, 78,263 gallons.

Filter Tank No. 2 — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1,	-	155	-	-	-	-	-	-	-	-	-	-	62°
2,	500	338	-	-	-	-	-	-	-	-	-	60°	61°
3,	-	141	-	-	.0018	.0098	.0116	4.77	1.2000	.0000	-	-	61°
4,	500	331	-	-	-	-	-	-	-	-	-	59°	61°
5,	-	139	-	-	-	-	-	-	-	-	-	-	59°
6,	-	39	-	-	-	-	-	-	-	-	-	-	-
7,	500	395	-	-	-	-	-	-	-	-	-	56°	60°
8,	-	141	-	-	-	-	-	-	-	-	-	-	59°
9,	500	345	-	-	-	-	-	-	-	-	-	54°	59°
10,	-	126	-	-	.0002	.0088	.0090	5.12	1.4400	.0000	-	-	58°
11,	500	320	-	-	-	-	-	-	-	-	-	51°	58°
12,	-	152	-	-	-	-	-	-	-	-	-	-	58°
13,	-	119	-	-	-	-	-	-	-	-	-	-	-
14,	500	299	-	-	-	-	-	-	-	-	-	50°	55°
15,	-	184	-	-	-	-	-	-	-	-	-	-	56°
16,	500	223	-	-	-	-	-	-	-	-	24 h. 55 m.	49°	58°
17,	-	210	-	-	.0004	.0082	.0086	5.53	1.3000	.0001	-	-	56°
18,	500	188	-	-	-	-	-	-	-	-	-	50°	56°
19,	-	253	-	-	-	-	-	-	-	-	-	-	55°
20,	-	71	-	-	-	-	-	-	-	-	-	-	-
21,	500	142	-	-	-	-	-	-	-	-	-	51°	54°
22,	-	239	-	-	-	-	-	-	-	-	-	-	54°
23,	500	189	-	-	-	-	-	-	-	-	-	49°	51°
24,	-	192	-	-	.0066	.0088	.0154	5.37	1.3400	.0004	-	-	52°
25,	-	175	-	-	-	-	-	-	-	-	24 h.	48°	53°
26,	-	182	-	-	-	-	-	-	-	-	24 h.	-	53°
27,	-	143	-	-	-	-	-	-	-	-	24 h.	-	-
28,	-	136	-	-	-	-	-	-	-	-	24 h.	-	53°
29,	-	110	-	-	-	-	-	-	-	-	24 h.	-	52°
30,	500	94	-	-	-	-	-	-	-	-	-	48°	52°
31,	-	93	-	-	.0128	.0094	.0222	5.12	1.6000	.0018	-	-	52°

Effluent colorless, free from sediment and generally clear.

October 7 and 11.—Sewage applied disappeared during the night. October 11.—A trap put on outlet pipe. September 23 and 25.—Some sewage on surface when regular application was made. September 26.—Grass cut from one-half of surface.

Total effluent to end of month, 84,127 gallons.

Series of Chemical Analyses, with the Number of Bacteria, Effluent from Tank No. 2.

Date.	Hour of Collection.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow Cubic Centimeters per Minute.
1889.											
March 26, . .	9.46	.8	19.3	.0004	.0050	.0054	3.43	.7000	.0002	–	–
26, . .	4.34	1.0	18.8	.0000	.0050	.0050	3.55	.7500	.0003	–	–
27, . .	9.45	.9	20.1	.0006	.0068	.0074	3.50	.8000	.0000	–	–
27, . .	3.41	1.2	17.2	.0004	.0060	.0064	3.45	.9000	.0002	–	–

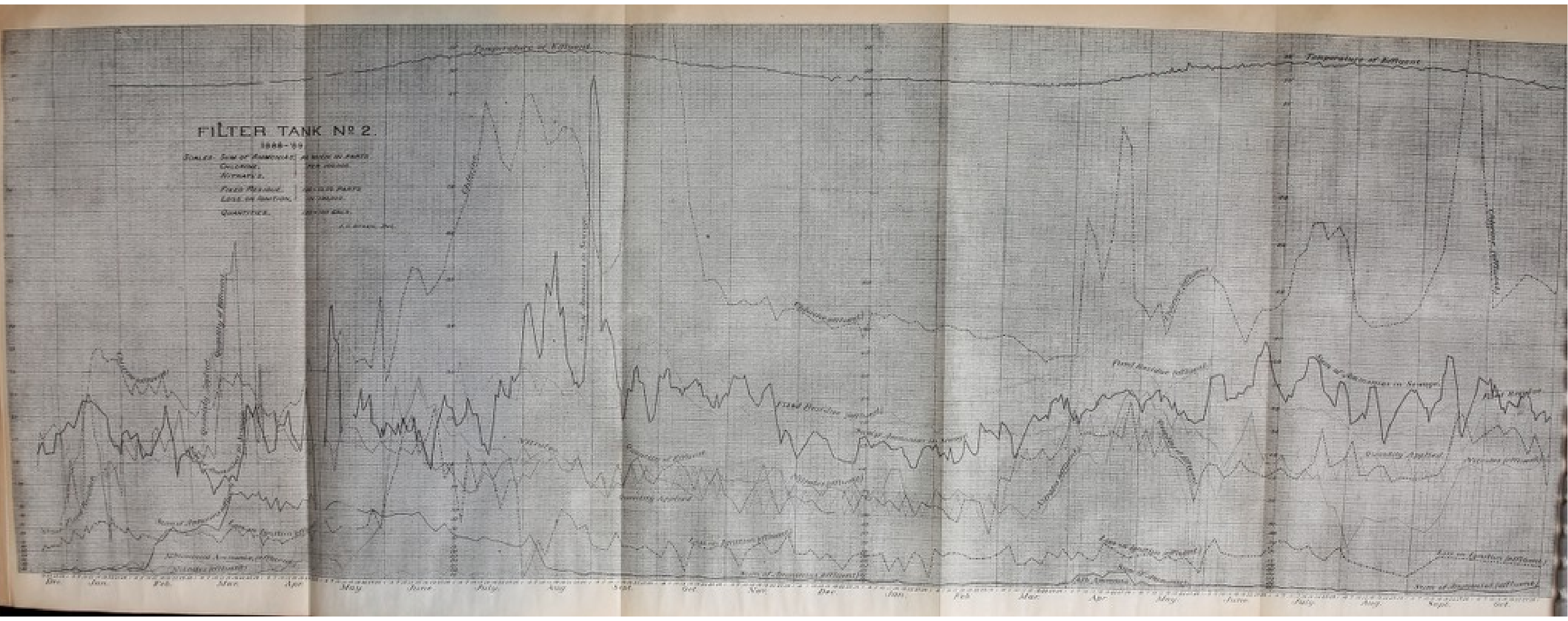
March 26. — No sewage applied. March 27. — 450 gallons applied from 11.54 to 12.21.

Date.	Hour of Collection.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow Cubic Centimeters per Minute.
Sept. 4, . .	8.0	–	–	.0006	.0060	.0066	4.81	.5000	.0000	–	96
4, . .	10.0	–	–	.0004	.0062	.0066	4.84	.4700	.0000	14	140
4, . .	12.0	–	–	.0002	.0054	.0056	4.86	.5000	.0000	–	192
4, . .	2.0	–	–	.0002	.0056	.0058	4.91	.5000	.0001	5	700
4, . .	4.0	–	–	.0000	.0064	.0064	4.93	.5000	.0000	5	980
4, . .	5.0	–	–	.0000	.0060	.0060	4.99	.5200	.0000	–	980
4, . .	7.0	–	–	.0002	.0070	.0072	5.02	.5000	.0000	6	840
4, . .	9.0	–	–	.0002	.0060	.0062	5.03	.5000	.0000	7	700
5, . .	5.0	–	–	.0004	.0062	.0066	5.13	.5000	.0001	14	325
5, . .	8.0	–	–	.0002	.0056	.0058	5.13	.5200	.0000	2	290
5, . .	12.0	–	–	.0004	.0062	.0066	5.14	.5000	.0000	5	228
5, . .	5.0	–	–	.0006	.0058	.0064	5.23	.5500*	.0001	109	174
6, . .	8.0	–	–	.0008	.0070	.0078	5.31	.5500	.0001	275	92
6, . .	12.0	–	–	.0006	.0084	.0090	5.43	.5500	.0000	9	188
6, . .	5.0	–	–	.0004	.0068	.0072	5.64	.5000	.0001	25	1,080

September 4. — 300 gallons sewage applied from 8.02 to 8.18 A.M. September 5. — None applied. September 6. — 300 gallons applied from 8.05 to 8.23 A.M.

Date.	Hour of Collection.	Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.	Rate of Flow Cubic Centimeters per Minute.
Sept. 9, . .	10.45	–	–	.0270	.0086	.0356	5.18	.6500	.0008	12	900
9, . .	10.59	–	–	.0008	.0072	.0080	5.23	.4000	.0000	21	1,500
9, . .	11.18	–	–	.0004	.0070	.0074	5.64	.3700	.0000	15	1,500
9, . .	11.36	–	–	.0012	.0074	.0086	5.62	.4200	.0000	9	400
9, . .	2.20	–	–	.0016	.0068	.0084	5.77	.4500	.0000	51	130
9, . .	7.7	–	–	.0058	.0078	.0136	6.00	.4500	.0000	16	1,040
9, . .	9.0	–	–	.0012	.0080	.0092	6.00	.4500	.0000	22	810

Samples to 11.36 from water backed up in underdrains; thereafter from regular effluent. First sample from water standing in pipe; contained iron rust. Microscopical examination of first sample showed nothing; of second, 1 anguillula, 7 spores. 300 gallons of sewage applied from 11.37 to 11.58 A.M.



FILTER TANK Nº 2.
Temperature of Effluent
Fixed Residue Effluent
Quantity Applied
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.

Table of the Number of Bacteria counted in a Cubic Centimeter of Effluent from Tank No. 2.

	Number of Bacteria.		Number of Bacteria.		Number of Bacteria.		Number of Bacteria.
1888.		**1888**—Con.		**1888**—Con.		**1889**—Con.	
Jan. 3,	6,618	March 22,	1,980	Sept. 15,	997	March 12,	62
5,	10,723	24,	1,507	20,	11	26,	12
7,	451	27,	8,422	25,	76	April 2,	5
10,	29,391	29,	1,850	29,	9	9,	10
12,	7,068	April 3,	1,488	Oct. 2,	76	16,	9
14,	23,047	19,	1,095	6,	20	24,	3
17,	11,491	25,	1,178	11,	26	30,	7
19,	9,840	28,	607	16,	10	May 7,	67
21,	4,906	May 8,	889	20,	10	14,	35
24,	20,880	10,	107	25,	33	21,	96
26,	8,010	12,	51	30,	97	28,	8
28,	3,160	19,	226	Nov. 3,	22	June 4,	8
31,	47	22,	14	8,	9	11,	117
Feb. 2,	10	26,	26	13,	5	18,	27
4,	351	29,	28	19,	16	26,	1
7,	108	31,	10	23,	8	July 2,	47
9,	334	June, 5,	14	28,	4	9,	3
11,	51	9,	27	Dec. 5,	4	16,	0
14.	377	14,	574	10,	2	23,	208
16,	261	21,	53	14,	6	30,	25
18,	642	26,	89	21,	5	Aug. 6,	3
21,	238	July, 3,	35	26,	7	12,	3
23,	3,930	7,	183	**1889.**		19,	5
25,	479	13,	404	Jan. 2,	4	24,	14
28,	1,875	17,	40	8,	9	Sept. 2,	2
March 1,	7,710	21,	576	15,	20	10,	10
3,	1,000	26,	96	22,	19	14,	15
6,	1,770	Aug. 2,	26	29,	8	24,	4
8,	1,248	7,	301	Feb. 6,	45	Oct. 2,	2
10,	787	11,	195	19,	3	10,	21
17,	1,568	16,	107	27,	21	16,	4
20,	2,730	Sept. 11,	745	March 5,	8	25,	2

The sands composing the filters which have given the foregoing results may be classed together as clean, sharp sands. Each of them contained less than one per cent. of organic matter. They were principally grains of quartz or of silicates insoluble in two hours' exposure in strong acid, — No. 1 containing 98.28 per cent , and No. 2, 97.74 per cent., of this character. The soluble portion yielded less than one per cent. of alumina and of oxide of iron and manganese. Their difference was principally in the size of the grains; those of No. 1 averaging about 0.06 inch in diameter and those of No. 2 averaging about 0.006 inch in diameter.

With the coarser of these sands we have found that, upon an acre, 60,000 gallons of sewage may be filtered daily for an indefinite period, and more for short periods; giving an effluent colorless and generally clear, containing only from one to three per cent. as much organic matter as the sewage, and containing generally but one-thousandth of the number of bacteria in the sewage, but liable to have a less purification and a larger number of bacteria (some of which come directly down from the surface) in an hour after applying sewage.

With the finer sand we have found that, upon an acre, 25,000 gallons of sewage may be filtered daily for an indefinite period; giving a bright, clear and colorless effluent, containing but one half of one per cent. as much organic matter as the sewage, and containing generally less than one ten-thousandth as many bacteria as the sewage, with the probability that few if any of these come down from the surface.

The effluent from this filter was used for some months as the exclusive drink of a dog, and many people have drank of it without unpleasant effects. A bottle of it has been kept fifteen months in a warm, light place, continuing bright and clear, with no sediment, no microscopic growth, and no bacteria to be found in it at the end of the time.

We have now to learn what results may be obtained from a still finer sand.

FILTER TANK No. 4.

Physical Characteristics.

There is in some of the valleys of the State a still finer sand known as river silt, which may be the most convenient material to use for a filtration area. This varies in fineness and in its constituents in different localities. In the Merrimack valley at Lawrence, the silt that has been left by high freshets on the banks of the river is much finer than the sand of Tank No. 2, averaging about 0.004 inch in diameter. This material obtained from the field at the station, was filled into Tank No. 4 to the depth of five feet above the usual layers of gravel and coarse sand which surround the underdrains and cover the bottom of the tank.

This is a very fine sand. There are but few particles that would not be called as fine as dust. The color is light brown.

A physical analysis gives the following results: —

	Approximate Diameter of Grains, in Inches.	Percentage of Whole Quantity.
Between sieve No. 40 and No. 55, ...	0.012 to 0.020	2
Between sieve No. 55 and No. 70, ...	0.010 to 0.012	1
Between sieve No. 70 and No. 100, ...	0.008 to 0.010	3
Between sieve No. 100 and No. 140, ...	0.005 to 0.008	13
	0.003 to 0.005	48
	0.001 to 0.003	30
	0.000 to 0.001	3

Besides the fine grains of quartz there are many small flat scales of mica. The particles that are insoluble in strong acid upon exposure for two hours amount to 94.13 per cent. The soluble portion contained the equivalent of 1.33 per cent., of the whole, of alumina and 2.22 per cent. of oxide of iron and manganese and about 0.18 of one per cent. of lime. The loss on heating the sand to redness amounted to 1.16 per cent. The part of this which is organic matter probably serves to fill up the interstices between the grains more than the small percentage by weight would indicate.

Besides being finer this sand differs from the preceding in containing abundant flakes of mica, a larger amount of organic matter and more alumina and oxide of iron and of manganese in form to be readily disolved by acid Some, and perhaps all, of these differing conditions would cause water and air as well as substances in suspension to pass through this sand with greater difficulty than the degree of fineness of the grains would indicate. We have now to learn the effect of these qualities upon the process of purification by nitrification within the sand.

Before sewage was applied trenches were cut in the top of this tank and filled with coarse sand, as described in the nineteenth annual report of the Board.

Quantity of Liquid ordinarily held by the Sand.

Sewage was first applied Dec. 19, 1887. The first indication that any of the sewage had reached the bottom was an increase of chlorine in the effluent, from 0.29 parts per 100,000 on December 27 to 0.63 parts on December 29, when 2,228 gallons of effluent had passed out after sewage was first applied. The further increase in the chlorine to 2.01 parts on January 1, when 2,820 gallons had passed through, indicates that nearly two-thirds of the effluent was then from sewage. From experiments made with samples of this material, the specific gravity of the solid substance was found to be 2.58, and its void space to be 42 per cent. of its volume. By boring into this tank when in use and taking out samples at different depths, it was found to be saturated in the lower foot, and about five-sixths saturated in the next two feet; the fourth foot from the bottom was about three-quarters saturated, and the upper foot, varied at different times and heights from one-third to full saturation. From data thus obtained it has been determined that the tank generally contained between 2,400 and 2,500 gallons of liquid, and that, after covering the surface with sewage, 2,400 gallons of liquid would flow out before this sewage reached the bottom. On this account the effluent has been compared with the sewage that was applied just previous to the last 2,400 gallons which has come through.

The time taken by particles of liquid to pass through the filter, has varied with the number of gallons applied daily, from ten days to forty-seven days.

While the above method of comparison may be taken as correct, it is evident, from the decided change in the chlorine, — from 0.29 parts when 1,466 gallons had passed out, after the application of sewage, to 0.63 parts, when 2,228 gallons had passed, — that some of the forward particles of the sewage passed by some of the water and pushed before them more than 1,466 gallons but less than 2,228 gallons of the previously contained water.

Sewage Applied at Very Low Temperatures and Frost Accumulates in the Sand.

Up to Feb. 12, 1888, the sewage was applied as it came in the pipe resting upon the river bed, at temperatures from 35° to 40° Fah., or about eight degrees lower than its temperature in the sewer. The temperature of the air, during these two months, averaged lower than for nearly thirty years. The mean morning temperature was 8°, and on sixteen days it was below zero, reaching 14° below and averaging 5° below.

During this cold time, frost in the sand and snow and ice on the surface interfered with the entrance of sewage at so low a temperature, when the morning temperature of the air was near zero. From December 19 to January 11, when the morning temperature averaged 15°, there was 96 per cent. as much effluent as of applied sewage: one inch of ice formed upon the surface, and frost was found to be six inches deep. In the next thirteen days, — seven of which were from 1° to 14° below zero, in the morning, — the ice increased in thickness to five inches and the frost in the sand to twelve inches, and there was but 72 per cent. as much effluent as of applied sewage.

For the next twenty days, or to February 12, sewage was applied to the sand through four or five holes cut through the ice and frost. On February 7, the ice was nine inches thick, and the frost twenty-four inches thick; and the sewage, poured into the holes at 38°, was not warm enough to prevent the holes growing smaller. During these twenty days there was 74 per cent. as much effluent as of applied sewage.

This river silt approaches clay in the hardness and depth to which it freezes; and it became evident that sewage, applied at a temperature seven degrees lower than that in the sewer, in the quantity here applied, — which was at the rate of 30,000 gallons per acre daily, — would not continue to enter this material satisfactorily, through a long-continued cold season. The sewage was then heated to 45° — the same temperature as in the sewer — and was put upon the tank at 44° for five days; but this lost a part of its heat by the mass of ice on the surface. On February 17 all of the ice upon the surface was removed, and a trench two inches deep, like that in Tank No. 2, was cut into the sand; and thereafter, sewage was applied at a higher temperature, which, until March 10, averaged 56°. The quantity applied was at the rate of 30,000 gallons per acre daily, and the quantity of effluent was 90 per cent. of this. The temperature of the effluent, during this time, was 36°; and that of the air, in the morning, averaged 17°.

To remove the frost more rapidly, the quantity and temperature were both increased, from March 10 to 22, — the quantity applied averaging 93,400 gallons per acre per day, and the temperature averaging 62°; while the effluent was 90 per cent. in quantity, and had temperatures of 35° and 36°.

The lowering of the temperature, as it passed through the filter, was evidently due to melting of frost within the sand. The material at this time allowed one inch in depth of sewage applied to the surface to disappear in one and a half hours.

During the month of April the temperature of the applied sewage was from 41° to 46°; and the effluent gradually increased from 37° to 42°.

BEGINNING OF NITRIFICATION.

When effluent from sewage first reached the outlet the contained nitrogen as nitrates and nitrites — which had previously been 0.035 parts per 100,000 — increased to 0.050 parts, near which it continued through the first half of January, then decreased and averaged 0.015 parts through February and March and till April 10, when, the temperature of the effluent being 38°, it increased to 0.050 parts, near which it continued through the month while the temperature increased to 42°. Upon closing the outlet, and ceasing to apply sewage for five days, and then drawing off that which had accumulated in the underdrains, it was found to contain 0.220 parts of nitrates and 0.0110 parts of nitrites: but these decreased to 0.050 and 0.0008 parts respectively upon continuing the usual application and flow for a week, — the temperature of the effluent then being 47°; but on May 19, with the temperature of the effluent at 49°, the nitrates increased to 0.200 parts, and thereafter rose rapidly to 2.200 parts on June 2, when the temperature was 55°.

The results of chemical analyses of samples of the effluent from this tank, in parts per 100,000; and other observations taken from day to day during twenty-two months since sewage has been applied, are given in tables at the end of this section.

There may also be found a diagram of daily results of analyses of the effluent and of the sum of ammonias found in the sewage applied to this tank, by which the general action of the filter may be readily traced, by the eye, through the changes of season and changes of quantity, and mode of application.

For convenient reference the monthly averages of daily results of analyses of effluent and of the sewage from which it came, together with the quantity applied and the number of bacteria found in a cubic centimeter of the effluent, are given in the following table.

Monthly Averages of Daily Results with Tank No. 4.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888.												
Dec. 22, '87–Jan. 13, '88.	Sewage, .	–	24.26	23.28	1.3448	.5436	1.8884	3.15	.007	–	–	–
January, . .	Effluent, .	218	2.14	10.74	.0060	.0095	.0155	3.34	.035	–	36°	4,983
	Per cent.,	–	9	46	.4of1	1.7	.8of1	–	–	–	–	–
Jan. 14–Feb. 11,	Sewage, .	–	35.25	19.28	.9221	.6743	1.5964	2.06	.007	–	–	–
February, . .	Effluent, .	121	1.34	10.49	.0262	.0117	.0379	2.76	.016	–	36°	403
	Per cent.,	–	4	54	3	1.7	2.4	–	–	–	–	–
Feb. 12–Mar. 21,	Sewage, .	–	16.64	16.62	.7362	.3893	1.1255	2.45	.007	–	–	–
March, . .	Effluent, .	248	2.12	9.19	.2636	.0264	.2900	2.45	.014	.0004	36°	3,494
	Per cent.,	–	13	50	36	7	26	–	–	–	–	–
Mar. 22–Apr. 12,	Sewage, .	–	41.66	49.49	1.1057	.7214	1.8271	2.88	.008	–	–	–
April, . .	Effluent, .	157	2.32	8.72	.4078	.0345	.4423	2.26	.033	.0006	39°	568
	Per cent.,	–	6	18	37	5	24	–	–	–	–	–
Apr. 13–May 12,	Sewage, .	–	36.73	43.67	1.0484	1.1803	2.2287	3.44	.007	–	–	–
May, . . .	Effluent, .	158	4.79	12.00	.4788	.0335	.5123	3.17	.588	.0042	49°	41
	Per cent.,	–	13	27	46	3	23	–	–	–	–	–
May 13–June 6,	Sewage, .	–	29.50	35.10	1.2843	.6436	1.9279	4.28	.009	.0005	–	–
June, . . .	Effluent, .	101	7.88	15.74	.6456	.0387	.6843	4.76	.674	.0029	61°	21
	Per cent.,	–	27	45	50	6	35	–	–	–	–	–
June 7–June 20,	Sewage, .	–	17.83	23.20	1.2130	.3190	1.5320	4.44	.006	.0005	–	–
July, . . .	Effluent, .	51	7.33	19.98	.3825	.0531	.4356	6.07	.258	.0046	67°	46
	Per cent.,	–	41	86	32	17	28	–	–	–	–	–
June 21–Aug. 7,	Sewage, .	–	23.88	29.66	2.1160	.5800	2.6960	6.42	.008	.0002	–	–
August, . .	Effluent, .	100	9.59	21.77	.4411	.0713	.5124	6.72	.328	.0057	69°	24
	Per cent.,	–	40	73	21	12	19	–	–	–	–	–
Aug. 8–Sept. 7,	Sewage, .	–	77.97	85.14	2.8156	1.9874	4.8030	8.58	–	.0000	–	–
September, .	Effluent, .	96	5.89	27.50	.3967	.0552	.4519	8.32	.137	.0025	66°	14
	Per cent.,	–	8	32	14	3	9	–	–	–	–	–
Sept. 8–Oct. 5,	Sewage, .	–	26.11	44.73	1.8979	.6735	2.5714	7.82	–	.0000	–	–
October, . .	Effluent, .	96	3.78	22.14	.2833	.0346	.3179	6.41	.132	.0014	58°	19
	Per cent.,	–	14	49	15	5	12	–	–	–	–	–
Oct. 6–Oct. 29,	Sewage, .	–	18.30	28.84	2.2890	.4360	2.7250	5.00	–	.0000	–	–
November, .	Effluent, .	76	4.04	19.21	.2733	.0324	.3057	5.28	.143	.0013	52°	18
	Per cent.,	–	22	67	12	7	11	–	–	–	–	–
Oct. 30–Nov. 23,	Sewage, .	–	18.36	28.96	1.9950	.4450	2.4400	4.93	.010	.0000	–	–
December, .	Effluent, .	56	1.47	16.69	.1174	.0164	.1338	3.96	.272	.0009	43°	7
	Per cent.,	–	8	58	6	4	5	–	–	–	–	–

Monthly Averages of Daily Results with Tank No. 4 — Concluded.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature.	Number of Bacteria per Cubic Centimeter.
1889.												
Nov. 24, '88–Dec. 21, '88,	Sewage,	–	14.19	31.46	1.1330	.2870	1.4200	4.40	.011	.0000	–	–
January,	Effluent,	60	0.91	15.91	.0561	.0112	.0673	3.75	.249	.0009	41°	11
	Per cent.,	–	6	51	5	4	5	–	–	–	–	–
Dec. 22, '88–Jan. 17, '89,	Sewage,	–	13.62	26.22	1.2160	.3390	1.5550	4.52	.020	.0004	–	–
February,	Effluent,	56	1.27	14.36	.0295	.0094	.0389	3.79	.250	.0006	40°	13
	Per cent.,	–	9	55	2.4	3	2.5	–	–	–	–	–
Jan. 18–Feb. 22,	Sewage,	–	9.06	19.85	1.0269	.2475	1.2744	3.70	.027	.0086	–	–
March,	Effluent,	67	1.67	14.71	.0088	.0092	.0180	2.38	.278	.0003	39°	4
	Per cent.,	–	18	74	.9 of 1	4	1.4	–	–	–	–	–
Feb. 23–Mar. 28,	Sewage,	–	13.43	23.70	1.5429	.3908	1.9437	4.48	.012	.0122	–	–
April,	Effluent,	74	1.60	18.22	.0041	.0108	.0149	3.43	.617	.0003	44°	5
	Per cent.,	–	12	77	.3 of 1	2.7	.8 of 1	–	–	–	–	–
Mar. 29–Apr. 27,	Sewage,	–	12.86	25.69	1.9362	.4369	2.3731	5.35	.007	.0010	–	–
May,	Effluent,	67	2.04	21.52	.0010	.0108	.0118	4.01	.880	.0001	56°	35
	Per cent.,	–	16	84	.05 of 1	2.5	.5 of 1	–	–	–	–	–
Apr. 28, May 22,	Sewage,	–	15.33	24.20	1.9645	.4246	2.3891	4.53	.002	.0000	–	–
June,	Effluent,	60	2.24	22.56	.0022	.0147	.0169	4.34	.812	.0001	64°	25
	Per cent.,	–	15	93	.1 of 1	3.5	.7 of 1	–	–	–	–	–
May 23–July 4,	Sewage,	–	23.05	29.59	2.3150	.5537	2.8687	4.98	.000	.0000	–	–
July,	Effluent,	87	3.86	20.88	.0100	.0181	.0281	5.08	.388	.0003	68°	91
	Per cent.,	–	17	71	.4 of 1	3.3	1	–	–	–	–	–
July 5–29,	Sewage,	–	22.69	30.85	2.4400	.6227	3.0627	5.56	.000	.0000	–	–
August,	Effluent,	67	2.10	20.50	.0009	.0174	.0183	4.47	.425	.0000	69°	27
	Per cent.,	–	9	66	.04 of 1	2.8	.6 of 1	–	–	–	–	–
July 30–Sept. 13,	Sewage,	–	26.80	36.81	1.8247	.6779	2.5026	6.19	.000	.0002	–	–
September,	Effluent,	127	3.09	20.40	.0087	.0155	.0242	5.32	.487	.0005	67°	94
	Per cent.,	–	11	55	.5 of 1	2.3	1	–	–	–	–	–
Sept. 14–Oct. 14,	Sewage,	–	26.98	34.75	1.8800	.7833	2.6633	4.73	.001	.0002	–	–
October,	Effluent,	135	–	–	.0017	.0112	.0129	4.80	.777	.0002	58°	91
	Per cent.,	–	–	–	.1 of 1	1.4	.5 of 1	–	–	–	–	–

For two months after sewage reached the outlet a very large part of its impurity was retained by the sand. The albuminoid ammonia of the effluent increased slowly from that obtained when filtering water, and averaged each month only one and seven-tenths per cent. of that of the sewage. The free ammonia increased somewhat more rapidly, averaging the first month four-tenths of one per cent., and the second month three per cent., of that of the sewage.

These small percentages occurred during the winter months, when sewage was entering the tank at low temperature, and much of the time through a few holes cut in the frost. The quantity of sewage filtered in this time was 10,000 gallons, or the equivalent of 2,000,000 gallons on an acre.

In the third month (March), when the effluent was at the rate of

50,000 gallons per acre per day, and there was no nitrification, the albuminoid ammonia, increased from 0.0184 parts to 0.0330 parts, and averaged 7 per cent. of that of the sewage, while the free ammonia increased from 0.0628 parts to 0.4500 parts, and averaged 36 per cent. of that of the sewage.

In April, although the nitrates increased from 0.018 parts in the first week to 0.050 parts in the latter part of the month and the ammonias decreased a little at the first increase in nitrates, yet the ammonias increased and became a little higher the last of the month than at the first. The albuminoid ammonia averaged 0.0345 parts, or 5 per cent. of that of the sewage; and the free ammonia, 0.4078 parts, or 37 per cent. of that of the sewage. The quantity filtered was at the rate of a little more than 31,000 gallons per acre per day.

The same quantity was continued through May: and while the nitrates increased from 0.220 parts to 1.000 parts, the albuminoid ammonia was the same at the end as at the beginning of the month, and averaged for the month 0.0335 parts, — which was but 3 per cent. of that of the sewage; and the free ammonia increased from 0.3500 to 0.5500, averaging 0.4788 parts or 46 per cent. of that of the sewage.

At this time it required about fifteen days for sewage applied to the surface of the tank to reach the outlet.

Organisms were observed by the naked eye, in the samples of effluent from this filter, from April to August, but unfortunately were not named or counted.

Early in June it was found that the 150 gallons of sewage applied daily did not all disappear before the next application, and after June 16 the quantity applied was but 100 gallons; but before the end of the month this quantity, with the ordinary rainfall, was more than would pass through the filter. It accumulated upon the surface until July 11, after which no sewage was applied for two weeks, in which time it entirely disappeared and the surface became dry.

Soon after the sewage remained continuously upon the surface, the nitrates decreased rapidly from 2.2000 parts on June 2 to 0.2000 parts on June 30, and to 0.1560 parts on July 7. The albuminoid ammonia increased from 0.0270 parts to 0.0530 parts; averaging during the month of June 0.0387 parts, or six per cent. of that of the sewage; and the free ammonia averaged for June 0.6456 parts. From July 12 to 24, when no sewage was applied and the amount draining out was but 26 gallons per day, the nitrates were higher, averaging 0.3410 parts. The albuminoid ammonia changed but little, averaging 0.0450 parts; and the free ammonia decreased noticeably, averaging 0.2866 parts.

Upon resuming on July 25 the usual supply of sewage, — the thin, tough layer of sediment having curled up when exposed to the sun, — the 100 gallons disappeared from the surface in less than an hour, and continued to do so for a week or ten days; after which the time increased to several hours, and on rainy days some liquid remained upon the surface continually.

The nitrates, which averaged 0.2576 parts in July, continued increasing through the most of August, averaging 0.3278 parts; but in September they decreased rapidly till the 17th, when they were but 0.0450 parts.

On account of the imperfect purification, as shown by the decrease in nitrates, a change was made in the application of sewage. Previous to September 15, 100 gallons of sewage were applied daily. After this date 200 gallons were applied on Monday, Wednesday and Friday of each week until the first of November, after which for seven months the quantity was 150 gallons applied on the same days of the week.

The average results of analyses of effluent for July, including the thirteen days when no sewage was applied, were as follows: Nitrites, 0.0046 parts; nitrates, 0.258; albuminoid ammonia, 0.0550 parts, or 17 per cent. of that of the sewage; free ammonia, 0.3825 parts, or 32 per cent. of that of the sewage.

In August the nitrates increased from the second to the fourth week, and later in the month the ammonias decreased. The average results for the month were: Nitrites, 0.0057 parts; nitrates, 0.328 parts; albuminoid ammonia, 0.0713 parts, the highest for the year although but 12 per cent. of that of the sewage; free ammonia, 0.4411 parts, or 21 per cent. of that of the sewage.

The fall of rain in September and October was unusually large, amounting to 13.66 inches; and, although about one-quarter of this was siphoned off from the top of the tank, liquid remained upon the surface more than half the time. The nitrates remained low; although after the change in application from 100 gallons daily to 200 gallons three times a week, the nitrates increased from 0.0450 parts on September 19 to 0.1900 parts on October 31. The monthly averages of nitrates remained nearly constant for the three months September, October and November, being 0.1370 parts, 0.1320 parts and 0.1430 parts, respectively. The nitrites were much lower than formerly and continued to decrease, being 0.0025, 0.0014 and 0.0013 parts.

The ammonias were also growing less, — albuminoid ammonia averaging, for each of these months, 0.0552, 0.0346 and 0.0324 parts, respectively; and free ammonia, 0.3967, 0,2833 and 0.2733 parts. The sum of ammonias was, in the last month, 11 per cent. of those of the sewage. The quantity of effluent was 19,200 gallons per acre per day for September and October and 15,200 gallons per acre per day for November.

Filtration by the river silt of Tank No. 4 from the beginning of nitrification in May to the latter part of November, 1888, with quantities varying from 30,000 gallons to 15,000 gallons per acre per day, has been unsatisfactory, the sum of ammonias averaging from 35 per cent. to 9 per cent. of those of the sewage; and, if experience with this material had then ceased, it would have been judged a very poor material to use for purifying sewage.

The extreme fineness of this sand, and flaky character of some of its particles and the alumina and oxide of iron it contains evidently put it at a disadvantage when compared with sand of No. 2 when filtering the above quantities of sewage.

The purification for the latter six months, as shown by the degree of nitrification and by the amount of ammonia remaining in the effluent, has been but one-quarter of that of Tank No. 2; and in the last three months a much smaller fraction.

The fall rains, which had been excessive, together with the amount of sewage applied, kept the surface of the tank covered much of the time; and when not covered the upper layers, being of so fine material, were continually so nearly saturated that little air could enter the sand to supply oxygen for nitrification; and in the last three months only five per cent. of the nitrogen of the sewage applied appeared in the effluent as nitrates.

Two changes were then made in the management of the filter. The quantity of sewage was reduced, and for seven months continued at about 12,000 gallons per acre per day, by applying 150 gallons three times a week; and rain and snow were excluded from the tank by a canvas covering from Nov. 22, 1888, to March 13, 1889.

An effect of the change was soon apparent in the increase of the nitrates and the decrease of the ammonias.

The relation of the nitrogen of the effluent in nitrates to the nitrogen of the sewage, throughout the eighteen months after nitrification commenced, is given for each month in the following table.

Percentage of Nitrogen applied to Tank No 4 in the Sewage that appears in the Effluent as Nitrates.

Date.	Nitrogen applied in Sewage.	Nitrates in Effluent corrected for Quantity.	Per Cent. of Nitrogen applied.	Average Daily Quantity. Gals.	Temperature.	
					Sewage.	Effluent.
1888.						
May,	2.8024	.551	20	158	45°	49°
June,	2.1181	.651	31	101	55°	61°
July,	1.5243	.218	14	51	66°	67°
August,	2.6945	.307	11	100	70°	69°
September,	5.5681	.128	2	96	70°	66°
October,	2.6608	.155	6	96	61°	58°
November,	2.5920	.163	6	76	50°	52°
December,	2.3757	.286	12	56	47°	43°
1889.						
January,	1.4107	.280	20	60	45°	41°
February,	1.5735	.237	15	56	44°	40°
March,	1.2836	.242	19	67	45°	39°
April,	1.9303	.655	34	74	39°	44°
May,	2.3122	.944	41	67	46°	56°
June,	2.3092	.886	38	60	60°	64°
July,	2.8064	.389	14	87	67°	68°
August,	3.0220	.534	18	67	72°	69°
September,	2.6082	.457	18	127	70°	67°
October,	2.8274	.833	29	135	59°	58°

Marked Improvement in Result by Filtering a Less Quantity.

After the reduction in quantity of sewage and exclusion of rain and snow, the nitrogen as nitrates in the effluent increased from 6 per cent. of the nitrogen in the sewage to 12 per cent. in December, 20 per cent. in January, 15 per cent. in February and 19 per cent. in March; averaging for these four cold months 16.5 per cent., and being about four-tenths as complete as in Tank No. 2. In the next three months, during the growing season of spring and early summer, the nitrates were higher, averaging 38 per cent. of the nitrogen of the sewage.

The sum of the ammonias, which in November was 0.3057 parts, or 11 per cent. of that in the sewage, decreased month by month as follows: December, 0.1338 parts; January, 0.0673 parts; February, 0.0389 parts; and in March, 0.0180 parts, or 1.4 per cent. of that in the sewage. The free ammonia decreased from 0.1174 in December to 0.0088 in March; and the albuminoid ammonia from 0.0164 in December to 0.0092 in March.

On March 13, 1889, the canvas covering was removed, and through the next three months the tank was exposed to rain; and the external conditions of the tank were similar to those of the same months in 1888, except that then 150 gallons of sewage were applied every day, and in 1889 the same amount was applied every other day, making the quantity of effluent in the latter period 13,400 gallons per acre per day.

In the first year nitrification was only beginning in April, while in the second year it had been continuous through the winter. The comparison of the effluent in June, 1888, when the tank had filtered 29,000 gallons of sewage, with June, 1889, after it had filtered 56,000 gallons, presents points of interest. In the first year, sewage had been applied in too large quantities; and the amount then received, which averaged 20,000 gallons per acre per day, kept the surface covered a large part of the time, while in the second year the quantity averaged 12,000 gallons per acre per day and disappeared promptly after application.

	Free Ammonia.	Albuminoid Ammonia.	Sum of Ammonias.	Nitrogen as Nitrates.
June, 1888, —				
Effluent,	0.6456	0.0387	0.6843	0.674
Per cent. of amount in Sewage,	50	6	35	-
June, 1889, —				
Effluent,	0.0022	0.0147	0.0169	0.812
Per cent. of amount in Sewage,	0.1 of 1	3.5	0.7 of 1	-

April and May of the second year gave quite as good results as June.

We find here that this fine filtering material, which gave so poor results the first year, could, by adapting the quantity to its capacities, be made to give an effluent as pure chemically as many public drinking waters. Having obtained this satisfactory result, a plan was devised to determine if still better results with larger quantities of sewage might not be obtained.

By Applying Sewage in Trenches Filled with Coarse Sand Excellent Results are Obtained with Larger Quantities.

On June 24, 1889, a trench was excavated in Tank No. 4 one foot and a half from the outside of the tank. It was cut 2 feet wide and 1 ft. 2 in. deep, and filled to within three inches of the surface of the tank with coarse sand like that of Tank No. 1. Sewage was to be applied only to the coarse sand, thus leaving dry about two-thirds of the area of the surface of the tank. The area of the two sides and bottom of the trench, where liquid filling the coarse sand came in contact with the fine river silt, equalled two-thirds of the area of the top of the tank.

Liquid, coming in contact with the fine river silt through the coarse sand, has the advantage that it does not have a motion over the silt in such a way that it is likely to take up the finest of the silt and deposit it in the interstices where it enters, thus clogging up the surface, as liquid moving over the surface of a field of silt would do. From the bottom of the coarse sand to the bottom of the filter, the liquid passes through a depth of 3 feet and 10 inches of fine silt.

From June 24, 1889, to August 29, the same amount of sewage — 150 gallons three times a week — was applied to the coarse sand.

The nitrification was not as complete, and the ammonias were somewhat higher, through the first month after the change; but in the second month the ammonias were very satisfactory.

The monthly averages of the analyses were as follows: —

	Free Ammonia.	Albuminoid Ammonia.	Sum of Ammonias.	Nitrogen as Nitrates.
July, —				
Effluent,	0.0100	0.0181	0.0281	0.388
Per cent. of amount in Sewage,	0.4 of 1	3.3	1.	-
August, —				
Effluent,	0.0009	0.0174	0.0183	0.425
Per cent. of amount in Sewage,	0.04 of 1	2.8	0.6 of 1	-

On the last days of August the quantity applied was doubled, and continued through September and October at 300 gallons three times a week. The effluent in October was at the rate of 27,000 gallons per acre per day. The change caused the free ammonia of the effluent to increase a little for three weeks; after which both ammonias steadily decreased. The monthly averages of analyses are as follows: —

	Free Ammonia.	Albuminoid Ammonia.	Sum of Ammonias.	Nitrogen as Nitrates.
September, —				
Effluent,	0.0087	0.0155	0.0242	0.487
Per cent. of amount in Sewage,	0.5 of 1	2.3	1.	–
October, —				
Effluent,	0.0017	0.0112	0.0129	0.777
Per cent. of amount in Sewage,	0.09 of 1	1.4	0.5 of 1	–

The nitrates increased through October, and the final analysis of the month showed the effluent to be among the best from all of the filters. It was as follows: Free ammonia, 0.0008; albuminoid ammonia, 0.0092; nitrates, 0.9500.

Still later observations through November and December show a continuance of as good results; so that this filter, which a year ago gave very imperfect and unsatisfactory results when filtering 20,000 gallons per acre per day, was found capable of filtering with entire satisfaction 12,000 gallons per acre per day, and has now by the modification indicated, been made capable of filtering 27,000 gallons per acre per day, and giving an effluent whose organic impurities, as shown by the ammonias, are less than those of the majority of the public drinking-water supplies of the State. The effluent has of late been generally free from color, turbidity, sediment and odor.

Amount of Nitrogen Applied Compared with That in the Effluent.

An attempt to determine the amount of stored nitrogen in the sand of No. 4, at different dates, failed to give satisfactory results; because the original sand contained small pieces of roots and organic matter so unevenly distributed that a small sample taken at any depth was not representative of the tank at that depth. The general results of examinations made on Dec. 19, 1888, and on May 24, 1889, indicated that in the upper three inches in depth there was much less nitrogenous matter in May than in the previous December. Below this depth there was but little less in May.

A computation of the amount of nitrogen applied in the sewage and the amount which came off in the effluent, as described for Tank No. 1, shows that in the first ten months up to Nov. 1, 1888, the amount found in the effluent of Tank No. 4 was 20 per cent. of the amount applied. In the last twelve months, from Nov. 1, 1888, to Nov. 1, 1889, the amount found in the effluent was 25 per cent. of the amount applied.

Only a little more than half as much of the nitrogen applied appears to have come off in the effluent of this tank as came off in the effluent of Tank No. 2, and yet this tank does not act like one storing up nitrogen. It may be that more escapes into the air.

Microscopic Organisms in Effluent of Tank No. 4.

The microscopic organisms found in the effluent of Tank No. 4 have been almost entirely limited to three forms found chiefly in the three months September, October and November, 1888; in which time Leptothrix averaged 2,450 in 5 gallons (most of which were found in September); Arcella averaged 17 (these appeared from July through October); and Monas averaged 3,000. All these were found when the effluent contained large amounts of ammonia; and it is believed that they did not come through the sand but grew in the bottom of the tank on the gravel and in the underdrains. No observations were, however, taken that prove they did not come through the sand. In the past year few examinations have been made of the effluent, because those that were made indicated no organisms.

Bacteria in Effluent of Tank No. 4.

The number of bacteria found in the effluent of Tank No. 4 in the ten days in December, 1887, when the first sewage was pushing city water before it, was 15 per cubic centimeter. On Jan. 3, 1888, when 3,830 gallons had passed out, after sewage was applied, the number increased to 95, and two days later the number was 8,509, per cubic centimeter. In the next two weeks, the number averaged

7,648, — the highest number counted (24,673) being on January 19. Immediately after this the number rapidly decreased, and on January 28 was only 8. The average number for February was 403; for March, 3,494; and for April, 568.

After nitrification began, the number was much reduced; and for eighteen months the average number counted in a cubic centimeter was 32.

In the six months previous to putting in the trench of open sand, the average number counted was 15. In the four months after the application of sewage was limited to the trench of coarse sand, the average number has been 76, — which is the same number counted in water from the city service pipe in the same months.

In October, 1889, counts were made on several different days, when the rate of flow varied from 84 cubic centimeters to 1,200 cubic centimeters per minute, to see if there was an increase in number with the rate of flow; but no relation between the number and the rate of flow could be recognized: the number varied from 2 to 48, and averaged 10.

The small average number for eighteen months of 32 per cubic centimeter, when the average number applied to the surface of the tank in the sewage was 700,000 per cubic centimeter, or one bacterium surviving the passage out of 22,000 applied, indicates very unfavorable conditions for the life of bacteria during the passage of from three weeks to six weeks through the sand. It may be that a small number of a very few species survive, but it is most probable that none survive, and that the small numbers found in the effluent grow in the underdrains. We have not yet sufficient data to determine with certainty whether or not any of the bacteria of the sewage are found in the effluent; but it is hoped that during the coming year this may be determined by a careful study of the species.

The number of bacteria observed in the effluent of Tank No. 4, from the first application of sewage to October 31, 1889, may be found in the following table.

Number of Bacteria per Cubic Centimeter found in the Effluent of Tank No. 4.

	Number of Bacteria.		Number of Bacteria		Number of Bacteria.		Number of Bacteria.
1888.		**1888.**—Con.		**1888.**—Con.		**1889.**—Con.	
Jan. 3, .	95	March 24, .	5,088	Sept. 15, .	50	March 12, .	6
5, .	8,509	27, .	3,973	20, .	5	19, .	8
7, .	1,707	29, .	1,940	25, .	7	26, .	0
10, .	12,244	31, .	2,800	29, .	4	April 2, .	9
12, .	1,635	April 3, .	1,324	Oct. 2, .	22	9, .	3
14, .	2,271	19, .	311	6, .	16	16, .	5
17, .	3,360	25, .	145	11, .	6	24, .	3
19, .	24,673	28, .	491	16, .	38	30, .	7
21, .	7,206	May 8, .	70	20, .	4	May 7, .	5
24, .	2,308	10, .	64	25, .	4	14, .	9
26, .	587	12, .	36	30, .	45	21, .	121
28, .	8	19, .	43	Nov. 3, .	84	28, .	3
31, .	175?	22, .	30	8, .	12	June 4, .	80
Feb. 2, .	76	26, .	35	13, .	1	11, .	13
4, .	4	29, .	3	19, .	3	18, .	0
7, .	44	31, .	48	23, .	1	26, .	8
9, .	887	June 5, .	5	28, .	9	July 2, .	0
11, .	61	9, .	31	Dec. 5, .	1	9, .	4
14, .	98	14, .	46	10, .	7	16, .	2
16, .	4	21, .	5	14, .	5	23, .	264
18, .	26	26, .	16	21, .	11	30, .	187
21, .	861	July 3, .	8	26, .	12	Aug. 6, .	4
23, .	851	7, .	83	**1889.**		12, .	30
25, .	731	13, .	147	Jan. 2, .	5	19, .	56
28, .	1,195	17, .	4	8, .	9	24, .	19
March 1, .	9,314	21, .	32	15, .	22	Sept. 2, .	11
3, .	216	26, .	4	22, .	12	10, .	30
6, .	3,038	Aug. 2, .	6	29, .	7	14, .	273
8, .	553	7, .	32	Feb. 6, .	42	24, .	60
10, .	783	11, .	44	12, .	3	Oct. 2, .	5
17, .	1,904	16, .	16	19, .	2	10, .	10
20, .	8,308	21, .	20	27, .	5	16, .	346
22, .	4,041	Sept. 11, .	3	March 5, .	1	25, .	2

The numbers of bacteria found in a gram of sand of Tank No. 4 at different depths, on two dates, are given in the following table:—

Distance below the Surface.	Number of Bacteria per Gram of Sand. December 19, 1888.	May 24, 1889.	Distance below the Surface.	Number of Bacteria per Gram of Sand. December 19, 1888.	May 24, 1889.
0 to ¼ inch, . . .	25,800	702,000	24 inches, ...	17,900	–
6 inches, . . .	14,000	–	36 inches, ...	7,800	–
7 inches, . . .	–	34,200	40 inches, ...	–	21,800
10 inches, . . .	5,700	–	48 inches, ...	10,200	–
11 inches, . . .	–	18,000	60 inches, ...	18,100	17,900
21 inches, . . .	–	8,200	61 inches, ...	300	–

To make conclusions from such data, observations should be extended to the return of similar seasons of the year. Here we see that the numbers increased much near the surface from the cold month of December to the warm month of May, but they increased very little below the upper foot.

In December, 1888, the bacteria found at 48 inches and 60 inches below the surface were observed to be nearly all of one kind, and the same kind as found in the lower part of Tank No. 1.

The average number found in the effluent during this month was 7, and these were observed to be not of the same species as those in the sand. This looks as if at this time nearly all of the species in the sewage died near the surface of the tank; that one species, finding the circumstances suitable, made its home in the sand and remained there, and that the very small number in the effluent grew in the underdrains and outlet pipe.

In May, 1889, the bacteria in the sand were observed to be of several different kinds, but no relation was recognized between them and those of the effluent. On Feb. 4, 1889, effluent collected from this tank that had been accumulating in the measuring basin for two days, and had a temperature of 35° Fah., was examined to see if bacteria increased upon the effluent standing exposed to the air. The number found was but 3, while the number in the effluent examined next previously was 7; indicating that no increase was taking place under these circumstances.

On Dec. 17, 1888, when this tank had begun to improve but was still giving a poor result, a sample of the effluent from No. 4 in a bottle, was put in a warm, sunny place, and kept there for ten months. The stopper was removed a few times. The liquid for many weeks appeared somewhat opalescent, but finally became clear with a dark sediment. At the end of the ten months, Oct. 28, 1889, it was examined. No bacteria were alive in it. The sediment was found to be black oxide of manganese.

TABLES

OF

ANALYSES OF EFFLUENT AND OBSERVATIONS

UPON

Filter Tank No. 4.

December, 1887.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
19, ...	136	107	.80	3.05	.0046	.0075	.0121	.25	.0400	Present.	-	-
20, ...	136	135	.85	2.20	.0048	.0076	.0124	.20	.0300	Present.	35°	-
21, ...	136	166	.90	3.30	.0032	.0086	.0118	.22	.0180	Present.	-	-
22, ...	136	135	.85	3.30	.0028	.0062	.0090	.24	.0380	Present.	-	-
23, ...	136	118	.85	3.25	.0030	.0072	.0102	.23	.0350	Present.	36°	-
24, ...	272	223	-	-	-	-	-	-	-	-	-	-
25, ...	272	249	-	-	-	-	-	-	-	-	-	-
26, ...	272	221	-	-	-	-	-	-	-	-	-	-
27, ...	272	245	.40	3.75	.0050	.0080	.0130	.29	.0350	Presept.	35°	-
28, ...	272	453	-	-	-	-	-	-	-	-	36°	-
29, ...	272	266	1.85	3.80	.0072	.0060	.0132	.63	.0580	None.	35°	-
30, ...	272	207	-	-	-	-	-	-	-	-	34°	-
31, ...	368	253	-	-	-	-	-	-	-	-	34°	-

December 19. — First sewage applied; 2 inches of snow on surface. December 20. — 1 inch. December 21, 23, 24 and 25. — 2 inches of snow and ice. December 26. — 1½ inches. December 27. — 1½ inches of ice. December 28. — 1⅜ inches. December 30. — 1-16 inch. December 31. — ¼ inch.

Total effluent to end of month, 2,778 gallons.

Filter Tank No. 4 — Continued.

January, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	183	417	2.90	5.40	.0088	.0068	.0156	2.01	.0500	Present	34°	–
2, ...	445	511	–	–	–	–	–	–	–	–	35°	–
3, ...	408	368	2.35	6.85	.0086	.0076	.0162	2.26	.0300	Present.	38°	–
4, ...	408	364	–	–	–	–	–	–	–	–	38°	–
5, ...	408	339	2.05	8.25	.0092	.0106	.0198	2.98	.0300	None.	36°	–
6, ...	408	364	–	–	–	–	–	–	–	–	34°	–
7, ...	408	385	–	–	–	–	–	–	–	–	35°	–
8, ...	408	377	2.00	7.90	.0060	.0102	.0162	2.07	.0500	Present.	35°	–
9, ...	408	342	–	–	–	–	–	–	–	–	35°	–
10, ...	408	368	1.95	9.20	.0074	.0086	.0160	2.76	.0600	Present.	37°	–
11, ...	408	262	–	–	–	–	–	–	–	–	37°	–
12, ...	235	151	2.00	9.75	.0058	.0088	.0146	3.17	.0400	Present.	38°	–
13, ...	310	222	1.65	9.95	.0020	.0088	.0108	3.14	.0500	.0005	40°	–
14, ...	355	301	–	–	–	–	–	–	–	–	40°	–
15, ...	300	323	1.90	10.85	.0058	.0088	.0146	3.73	.0650	.0007	40°	–
16, ...	300	246	2.80	11.30	.0058	.0086	.0144	3.84	.0500	.0008	40°	–
17, ...	220	186	2.45	11.60	.0032	.0104	.0136	3.89	.0350	Present	39°	–
18, ...	192	127	–	–	–	–	–	–	–	–	39°	–
19, ...	120	103	–	–	–	–	–	–	–	–	40°	–
20, ...	85	40	2.30	12.20	.0038	.0086	.0124	3.93	.0250	.0001	38°	–
21, ...	30	20	–	–	–	–	–	–	–	–	39°	–
22, ...	10	7	2.50	12.90	.0024	.0114	.0138	3.84	.0100	Present.	38°	–
23, ...	150	54	2.20	13.10	.0036	.0116	.0152	3.96	.0350	Present.	39°	–
24, ...	150	99	2.30	12.50	.0038	.0092	.0130	–	–	–	38°	–
25, ...	150	123	2.30	12.00	.0048	.0092	.0140	3.85	.0250	None.	38°	–
26, ...	150	114	–	–	–	–	–	–	–	–	37°	–
27, ...	150	122	2.00	12.60	.0070	.0092	.0162	3.86	.0200	Present.	40°	–
28, ...	150	107	–	–	–	–	–	–	–	–	40°	–
29, ...	150	98	1.70	12.55	.0078	.0106	.0184	3.74	.0180	.0001	40°	–
30, ...	150	108	1.70	12.70	.0080	.0106	.0186	3.62	.0200	.0005	40°	–
31, ...	150	113	1.70	12.40	.0110	.0100	.0210	3.54	.0150	None.	40°	36°

January 1.— ¾ inch of ice and 1 inch of snow on surface; January 6, ⅜ inch of ice; January 11, 1 inch; January 12, 2 inches; January 14, 3 inches; January 16 and 17, 2½ inches; January 25, 5 inches of ice and 17 inches of frost. January 23 to 28.— Sewage applied in from two to four holes cut through frost.

Total effluent to end of month, 9,539 gallons.

Filter Tank No. 4 — Continued.

February, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, . . .	150	108	1.40	12.50	.0112	.0116	.0228	3.34	.0180	.0001	40°	36°
2, . . .	150	109	–	–	–	–	–	–	–	–	37°	36°
3, . . .	150	99	1.80	11.40	.0134	.0112	.0246	3.12	.0150	.0001	43°	37°
4, . . .	150	96	–	–	–	–	–	–	–	–	37°	37°
5, . . .	63	118	1.50	11.60	.0130	.0078	.0208	3.00	.0180	None.	38°	36°
6, . . .	160	100	1.30	11.60	.0128	.0076	.0204	2.95	.0120	.0001	38°	36°
7, . . .	150	121	1.20	11.40	.0120	.0102	.0222	3.06	.0060	None.	39°	36°
8, . . .	150	104	1.50	11.10	.0104	.0080	.0184	2.98	.0180	Present.	37°	36°
9, . . .	130	111	–	–	–	–	–	–	–	–	36°	36°
10, . . .	150	124	1.10	10.60	.0154	.0094	.0248	2.80	.0250	None.	38°	–
11, . . .	150	95	–	–	–	–	–	–	–	–	38°	36°
12, . . .	150	94	1.50	10.40	.0194	.0094	.0288	2.72	.0250	None.	44°	–
13, . . .	150	117	1.30	10.20	.0234	.0114	.0348	2.70	.0250	None.	44°	–
14, . . .	120	111	1.00	10.20	.0266	.0108	.0374	2.52	.0150	Present.	44°	37°
15, . . .	150	91	1.30	9.80	.0314	.0116	.0430	2.52	.0150	Present.	44°	36°
16, . . .	150	84	–	–	–	–	–	–	–	–	44°	36°
17, . . .	100	60	1.30	10.10	.0372	.0136	.0508	2.62	.0150	None.	63°	36°
18, . . .	150	67	–	–	–	–	–	–	–	–	66°	–
19, . . .	150	110	–	–	–	–	–	–	–	–	54°	–
20, . . .	198	114	1.30	9.60	.0340	.0130	.0470	2.58	.0200	None.	44°	37°
21, . . .	150	103	1.60	9.50	.0348	.0132	.0480	2.57	.0150	Present.	45°	37°
22, . . .	150	127	1.20	9.80	.0348	.0132	.0480	2.52	.0150	Present.	54°	37°
23, . . .	150	206	–	–	–	–	–	–	–	–	55°	36°
24, . . .	150	213	1.20	9.80	.0340	.0152	.0492	2.68	.0100	None.	56°	–
25, . . .	150	199	–	–	–	–	–	–	–	–	56°	36°
26, . . .	150	229	–	–	–	–	–	–	–	–	62°	36°
27, . . .	150	157	1.40	9.60	.0544	.0176	.0720	2.46	.0080	Present.	44°	36°
28, . . .	150	116	1.30	9.70	.0540	.0152	.0692	2.52	.0150	Present.	57°	35°
29, . . .	150	128	–	–	–	–	–	–	–	–	63°	36°

* February 3. — 8 inches of water in holes through frost when sewage was applied; February 4, 12 inches; February 5, 16 inches; February 9, 10 inches. February 6. — Five holes in surface through 24 inches of frost and 9 inches of ice. February 7. — One new hole cut through 24 inches of frost. February 15. — Water removed from holes. February 17. — Trench cut 18 inches from edge of tank through ice and 2 inches of sand. February 18. — Ice all removed from surface. February 19. — 2 inches of ice and water removed. February 20. — 2½ inches. February 24. — Boiling water applied to thaw frost.

Total effluent to end of month, 13,050 gallons.

Filter Tank No. 4 — Continued.

March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	150	127	-	-	-	-	-	-	-	-	-	60°	36°
2, .	150	122	1.50	9.30	.0628	.0184	.0812	2.36	.0180	.0002	-	58°	-
3, .	150	159	-	-	-	-	-	-	-	-	-	58°	36°
4, .	150	129	-	-	-	-	-	-	-	-	-	57°	36°
5, .	150	133	2.10	8.60	.0736	.0178	.0914	2.20	.0100	.0002	-	54°	36°
6, .	150	119	-	-	-	-	-	-	-	-	-	61°	36°
7, .	150	120	2.10	8.30	.1200	.0186	.1386	2.22	.0180	.0003	-	55°	36°
8, .	150	134	-	-	-	-	-	-	-	-	-	48°	-
9, .	150	158	2.40	8.00	.1600	.0214	.1814	2.16	.0200	.0003	-	52°	36°
10, .	500	23	-	-	-	-	-	-	-	-	-	46°	-
11, .	300	166	-	-	-	-	-	-	-	-	-	65°	36°
12, .	150	151	1.50	9.40	.1520	.0220	.1740	2.22	.0200	.0003	-	75°	36°
13, .	150	160	-	-	-	-	-	-	-	-	-	71°	35°
14, .	500	150	-	-	-	-	-	-	-	-	-	55°	36°
15, .	500	393	-	-	-	-	-	-	-	-	24 h.	53°	35°
16, .	500	644	2.40	7.90	.2400	.0230	.2630	2.00	.0150	.0003	12 h.+	54°	35°
17, .	500	786	-	-	-	-	-	-	-	-	-	73°	35°
18, .	500	509	-	-	-	-	-	-	-	-	-	71°	36°
19, .	500	394	2.50	8.60	.3550	.0370	.3920	2.52	.0150	.0006	-	52°	35°
20, .	500	559	-	-	-	-	-	-	-	-	-	70°	36°
21, .	500	480	2.70	10.50	.4000	.0360	.4360	2.96	.0100	.0004	-	51°	36°
22, .	500	608	-	-	-	-	-	-	-	-	8 h.	66°	-
23, .	-	82	2.00	9.90	.3000	.0300	.3300	2.82	.0000	.0003	-	-	38°
24, .	150	126	-	-	-	-	-	-	-	-	2 h. 54 m	60°	36°
25, .	150	136	-	-	-	-	-	-	-	-	57 m.	50°	38°
26, .	150	160	2.10	10.60	.4000	.0260	.4260	2.80	.0100	.0006	1 h. 20 m.	54°	36°
27, .	150	267	-	-	-	-	-	-	-	-	1 h. 26 m.	52°	37°
28, .	150	220	2.30	9.10	.4750	.0360	.5110	2.76	.0080	.0004	1 h. 37 m.	52°	37°
29, .	150	180	-	-	-	-	-	-	-	-	1 h. 36 m.	51°	37°
30, .	150	141	1.80	10.10	.4250	.0300	.4550	2.36	.0180	.0004	1 h 8 m.	53°	37°
31, .	150	140	-	-	-	-	-	-	-	-	-	53°	37°

Effluent colorless and generally clear, or nearly so, and with very slight or no sediment.
March 14. — Snow and water all removed from surface. March 15. — Two inches of water removed.
Total effluent to end of month, 20,726 gallons.

Filter Tank No. 4 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	150	145	2.30	9.20	.4400	.0310	.4710	2.20	.0180	.0003	55 m.	41°	37°
2, .	150	304	2.50	8.50	.4000	.0370	.4370	1.86	.0100	.0003	–	41°	36°
3, .	150	161	2.00	9.10	.3800	.0430	.4230	1.94	.0200	.0004	1 h. 8 m.	44°	37°
4, .	150	148	1.70	8.80	.4000	.0500	.4500	2.00	.0200	.0004	1 h. 5 m.	42°	37°
5, .	150	192	–	–	–	–	–	–	–	–	1 h. 11 m.	44°	37°
6, .	150	227	2.60	8.00	.3950	.0380	.4330	2.25	.0180	.0004	–	46°	38°
7, .	150	–	–	–	–	–	–	–	–	–	–	45°	–
8, .	–	–	–	–	–	–	–	–	–	–	–	–	–
9, .	–	–	–	–	–	–	–	–	–	–	–	–	–
10, .	150	154	2.40	9.40	.3320	.0180	.3500	2.05	.0500	.0014	1 h. 11 m.	45°	38°
11, .	150	223	–	–	–	–	–	–	–	–	2 h. 38 m.	46°	38°
12, .	150	145	–	–	–	–	–	–	–	–	–	43°	38°
13, .	150	135	2.60	8.10	.4000	.0310	.4310	2.15	.0300	.0005	2 h. 8 m.	42°	38°
14, .	150	147	–	–	–	–	–	–	–	–	–	45°	38°
15, .	150	149	–	–	–	–	–	–	–	–		45°	39°
16, .	150	123	1.60	9.20	.3200	.0370	.3570	2.18	.0400	.0003	4 h. 43 m.	42°	40°
17, .	150	136	–	–	–	–	–	–	–	–	1 h. 43 m.	45°	40°
18, .	150	151	1.90	9.20	.3850	.0390	.4240	2.28	.0400	.0005	–	45°	40°
19, .	150	137	–	–	–	–	–	–	–	–	3 h. 54 m.	42°	40°
20, .	150	143	2.30	8.50	.4300	.0270	.4570	2.44	.0500	.0006	–	43°	40°
21, .	300	260	–	–	–	–	–	–	–	–	–	44°	40°
22, .	–	54	–	–	–	–	–	–	–	–	–	–	–
23, .	150	121	1.50	8.00	.4500	.0350	.4850	2.76	.0500	.0008	–	42°	41°
24, .	150	134	–	–	–	–	–	–	–	–	–	43°	41°
25, .	150	140	3.10	8.80	.5000	.0320	.5320	2.79	.0450	.0005	–	42°	42°
26, .	150	139	–	–	–	–	–	–	–	–	–	46°	42°
27, .	150	140	3.60	8.60	.4700	.0310	.5010	2.77	.0500	.0008	–	44°	42°
28, .	300	260	–	–	–	–	–	–	–	–		46°	42°
29, .	–	26	–	–	–	–	–	–	–	–	–	–	–
30, .	–	–	–	–	–	–	–	–	–	–	–	–	–

Effluent colorless, from very slightly to distinctly turbid, and with very little sediment. Organisms visible to naked eye in samples throughout the month.

April 7, 5.20 A.M., to 10, 8.11 A.M. — Outlet closed. River high. April 30, 5.12 A.M. — Outlet closed. River high.

Total effluent to end of month, 24,905 gallons.

Filter Tank No. 4 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	-	-	-	-	-	-	-	-	-	-	-	-
2, .	-	-	-	-	-	-	-	-	-	-	-	-	-
3, .	-	-	-	-	-	-	-	-	-	-	-	-	-
4, .	150	126	5.05	10.40	.3500	.0270	.3770	3.08	.2200	.0110	38 m.	45°	45°
5, .	300	274	-	-	-	-	-	-	-	-	-	45°	45°
6, .	-	41	-	-	-	-	-	-	-	-	-	-	-
7, .	150	104	3.80	11.70	.3800	.0440	.4240	3.30	.0850	.0020	2 h. 30 m.	50°	-
8, .	150	137	-	-	-	-	-	-	-	-	-	48°	46°
9, .	150	212	3.60	10.90	.4700	.0350	.5050	3.46	.0450	.0009	-	50°	47°
10, .	150	180	-	-	-	-	-	-	-	-	-	51°	47°
11, .	150	150	-	-	-	-	-	-	-	-	-	51°	47°
12, .	300	435	4.30	10.50	.5500	.0350	.5850	3.32	.0500	.0008	-	49°	47°
13, .	-	-	-	-	-	-	-	-	-	-	-	-	-
14, .	-	-	-	-	-	-	-	-	-	-	-	-	-
15, .	-	-	-	-	-	-	-	-	-	-	-	-	-
16, .	-	-	-	-	-	-	-	-	-	-	-	-	-
17, .	150	296	-	-	-	-	-	-	-	-	-	49°	49°
18, .	150	137	-	-	-	-	-	-	-	-	-	49°	49°
19, .	300	230	5.00	13.40	.5000	.0320	.5320	3.27	.2000	.0024	-	50°	49°
20, .	-	101	-	-	-	-	-	-	-	-	-	-	-
21, .	150	106	-	-	-	-	-	-	-	-	-	51°	51°
22, .	150	130	-	-	-	-	-	-	-	-	-	52°	49°
23, .	150	105	4.10	12.50	.5300	.0370	.5670	3.13	.3000	.0067	-	53°	51°
24, .	150	125	-	-	-	-	-	-	-	-	-	55°	51°
25, .	150	112	-	-	-	-	-	-	-	-	-	56°	51°
26, .	300	186	6.50	11.60	.5000	.0310	.5310	2.96	.4500	.0050	-	57°	52°
27, .	-	91	-	-	-	-	-	-	-	-	-	-	-
28, .	150	98	-	-	-	-	-	-	-	-	-	57°	52°
29, .	150	191	-	-	-	-	-	-	-	-	-	56°	54°
30, .	150	112	5.50	15.00	.5500	.0270	.5770	2.82	1.0000	.0048	-	57°	55°
31, .	150	115	-	-	-	-	-	-	-	-	-	57°	54°

Effluent colorless, from distinctly to very slightly turbid, and with little sediment. Organisms visible to naked eye in samples throughout the month.

May 4, 7.52 A.M. — Outlet opened. May 13, 4.41 A.M., to 17, 7.42 A.M. — Outlet closed. River high.

Total effluent to end of month, 28,699 gallons.

Filter Tank No. 4 — Continued.

June, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	150	120	-	-	-	-	-	-	-	-	24 h.	58°	54°
2, .	300	201	8.50	15.40	.6800	.0270	.7070	3.18	2.2000	.0045	24 h.	60°	55°
3, .	-	90	-	-	-	-	-	-	-	-	24 h.	-	-
4, .	150	81	-	-	-	-	-	-	-	-	24 h.	59°	56°
5, .	150	104	-	-	-	-	-	-	-	-	24 h.	61°	57°
6, .	150	106	10.60	15.20	.6500	.0370	.6870	4.04	1.0000	.0029	24 h.	61°	57°
7, .	150	110	-	-	-	-	-	-	-	-	24 h.	64°	58°
8, .	150	124	-	-	-	-	-	-	-	-	24 h.	64°	57°
9, .	300	225	7.80	13.80	.6500	.0480	.6980	4.23	.6500	.0030	24 h.	64°	59°
10, .	-	78	-	-	-	-	-	-	-	-	24 h.	-	-
11, .	150	111	-	-	-	-	-	-	-	-	24 h.	68°	59°
12, .	150	114	-	-	-	-	-	-	-	-	24 h.	65°	59°
13, .	150	87	7.70	15.60	.6000	.0320	.6320	4.80	.5000	.0024	24 h.	64°	61°
14, .	150	127	-	-	-	-	-	-	-	-	24 h.	65°	59°
15, .	150	150	-	-	-	-	-	-	-	-	24 h.	65°	60°
16, .	150	132	7.40	15.40	.8000	.0350	.8350	5.20	.4700	.0036	-	65°	61°
17, .	-	63	-	-	-	-	-	-	-	-	-	-	-
18, .	100	61	-	-	-	-	-	-	-	-	-	68°	64°
19, .	100	57	-	-	-	-	-	-	-	-	-	69°	63°
20, .	100	60	8.70	15.70	.6300	.0390	.6690	5.15	.4000	.0024	-	70°	63°
21, .	100	70	-	-	-	-	-	-	-	-	-	69°	62°
22, .	100	85	-	-	-	-	-	-	-	-	-	69°	64°
23, .	200	111	8.00	16.60	.6000	.0360	.6360	5.15	.3500	.0024	24 h.	72°	66°
24, .	-	60	-	-	-	-	-	-	-	-	24 h.	-	-
25, .	100	79	-	-	-	-	-	-	-	-	24 h.	71°	64°
26, .	100	115	-	-	-	-	-	-	-	-	-	69°	64°
27, .	100	83	6.20	16.40	.6000	.0450	.6450	5.40	.3000	.0027	24 h.	69°	64°
28, .	100	59	-	-	-	-	-	-	-	-	24 h.	68°	62°
29, .	100	90	-	-	-	-	-	-	-	-	24 h.	66°	64°
30, .	100	83	6.00	17.60	.6000	.0490	.6490	5.57	.2000	.0026	24 h.	66°	65°

Generally very nearly clear and free from sediment, and with color from 0 to 0.1. — Organisms visible to naked eye in samples throughout the month.

Total effluent to end of month, 31,740 gallons.

Filter Tank No. 4 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	40	-	-	-	-	-	-	-	-	24 h.	-	-
2, .	100	50	-	-	-	-	-	-	-	-	24 h.	65°	65°
3, .	100	61	-	-	-	-	-	-	-	-	24 h.	65°	66°
4, .	100	57	7.80	17.80	.5000	.0490	.5490	5.90	.1800	.0038	24 h.	-	68°
5, .	100	77	-	-	-	-	-	-	-	-	24 h.	68°	67°
6, .	100	53	-	-	-	-	-	-	-	-	24 h.	68°	66°
7, .	100	108	6.50	17.90	.5000	.0450	.5450	6.10	.1560	.0040	24 h.	69°	68°
8, .	-	36	-	-	-	-	-	-	-	-	24 h.	-	-
9, .	100	40	-	-	-	-	-	-	-	-	24 h.	69°	66°
10, .	100	47	-	-	-	-	-	-	-	-	24 h.	69°	67°
11, .	100	66	6.00	18.80	.4000	.0530	.4530	6.02	.1800	.0050	24 h.	69°	68°
12, .	-	68	-	-	-	-	-	-	-	-	24 h.	-	66°
13, .	-	24	-	-	-	-	-	-	-	-	24 h.	-	66°
14, .	-	24	8.60	19.70	.3500	.0470	.3970	6.09	.3000	.0040	24 h.	-	-
15, .	-	21	-	-	-	-	-	-	-	-	24 h.	-	-
16, .	-	18	-	-	-	-	-	-	-	-	24 h.	-	67°
17, .	-	16	-	-	-	-	-	-	-	-	24 h.	-	67°
18, .	-	20	8.50	20.30	.2300	.0340	.2640	6.05	.4000	.0025	24 h.	-	67°
19, .	-	22	-	-	-	-	-	-	-	-	24 h.	-	66°
20, .	-	49	-	-	-	-	-	-	-	-	-	-	68°
21, .	-	23	7.50	20.40	.2800	.0540	.3340	6.03	.3250	.0024	-	-	71°
22, .	-	50	-	-	-	-	-	-	-	-	-	-	-
23, .	-	31	-	-	-	-	-	-	-	-	-	-	70°
24, .	-	13	-	-	-	-	-	-	-	-	-	-	71°
25, .	100	55	7.10	22.30	.3300	.0750	.4050	6.17	.3200	.0090	-	73°	68°
26, .	100	73	-	-	-	-	-	-	-	-	36 m.	73°	68°
27, .	100	93	-	-	-	-	-	-	-	-	36 m.	72°	66°
28, .	200	153	6.60	22.60	.4700	.0680	.5380	6.20	.2000	.0060	-	71°	67°
29, .	-	29	-	-	-	-	-	-	-	-	-	-	-
30, .	100	75	-	-	-	-	-	-	-	-	50 m.	71°	68°
31, .	100	77	-	-	-	-	-	-	-	-	54 m.	72°	69°

Generally clear or nearly so and with very slight or no sediment and with color averaging 0.12.
July 11, 18, 21 and 25.—Organisms visible to naked eye in samples. July 20.—190 gallons of water siphoned from surface. July 28.—First 100 gallons applied disappeared in 1 hour 7 minutes.
Total effluent to end of month, 33,260 gallons.

Filter Tank No. 4 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	100	105	7.50	23.20	.4500	.0730	.5230	6.55	.2800	.0070	-	73°	69°
2, .	100	85	-	-	-	-	-	-	-	-	-	73°	69°
3, .	100	80	-	-	-	-	-	-	-	-	45 m.	73°	69°
4, .	200	173	8.80	22.00	.5000	.0700	.5700	6.43	.3000	.0080	-	75°	70°
5, .	-	29	-	-	-	-	-	-	-	-	-	-	-
6, .	100	159	-	-	-	-	-	-	-	-	-	74°	69°
7, .	100	127	-	-	-	-	-	-	-	-	-	72°	69°
8, .	100	94	8.40	22.30	.5000	.0890	.5890	6.88	.2300	.0080	-	72°	68°
9, .	100	93	-	-	-	-	-	-	-	-	-	73°	69°
10, .	100	80	-	-	-	-	-	-	-	-	-	72°	70°
11, .	200	160	8.60	23.10	.4200	.0760	.4960	7.38	.2700	.0060	-	73°	68°
12, .	-	45	-	-	-	-	-	-	-	-	-	-	-
13, .	100	166	-	-	-	-	-	-	-	-	24 h.	70°	68°
14, .	100	137	-	-	-	-	-	-	-	-	12 h. +	69°	68°
15, .	100	78	9.40	22.90	.4300	.0730	.5030	7.17	.3200	.0040	21 h. 47 m.	69°	69°
16, .	100	81	-	-	-	-	-	-	-	-	23 h. 55 m.	69°	70°
17, .	100	136	-	-	-	-	-	-	-	-	24 h.	70°	69°
18, .	200	144	11.00	20.30	.4500	.0580	.5080	6.90	.3500	.0060	32 h.	70°	69°
19, .	-	56	-	-	-	-	-	-	-	-	-	-	-
20, .	100	61	-	-	-	-	-	-	-	-	1 h. 49 m.	71°	70°
21, .	100	112	-	-	-	-	-	-	-	-	1 h. 21 m	71°	70°
22, .	100	203	12.00	21.20	.5200	.0790	.5990	6.80	.4000	.0040	12 h. +	71°	69°
23, .	100	97	-	-	-	-	-	-	-	-	6 h. 2 m.	70°	69°
24, .	100	78	-	-	-	-	-	-	-	-	3 h.	70°	71°
25, .	200	138	11.40	20.10	.3500	.0660	.4160	6.50	.5000	.0040	12 h. +	70°	71°
26, .	-	30	-	-	-	-	-	-	-	-	-	-	-
27, .	100	57	-	-	-	-	-	-	-	-	-	71°	69°
28, .	100	71	-	-	-	-	-	-	-	-	1 h. 35 m.	70°	68°
29, .	100	68	9.20	20.80	.3500	.0580	.4080	5.89	.3000	.0040	1 h. 48 m.	69°	69°
30, .	100	70	-	-	-	-	-	-	-	-	2 h. 14 m.	69°	69°
31, .	100	72	-	-	-	-	-	-	-	-	1 h. 38 m.	70°	70°

Effluent from slightly to distinctly turbid, generally with very little sediment and with an average color of 0.96 probably due to iron.

August 1, 18 and 22. — Organisms visible to naked eye in samples. After August 1 residue on evaporation obtained with sodium carbonate. August 14, 15 and 16. — Sewage applied, nearly all disappeared in from 6 to 7 hours. August 25. — First 100 gallons applied disappeared in 1 hour 57 minutes.

Total effluent to end of month, 36,346 gallons.

Filter Tank No. 4 — Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	200	178	6.10	23.50	.3700	.0580	.4280	5.69	.2600	.0040	12 h. +	71°	69°
2, .	-	40	-	-	-	-	-	-	-	-	-	-	-
3, .	100	56	-	-	-	-	-	-	-	-	1 h. 12 m.	70°	69°
4, .	100	73	-	-	-	-	-	-	-	-	-	71°	67°
5, .	100	56	5.80	21.20	.3500	.0720	.4220	5.15	.3000	.0025	4 h. 24 m.	70°	69°
6, .	100	59	-	-	-	-	-	-	-	-	-	68°	68°
7, .	100	65	-	-	-	-	-	-	-	-	6 h. 7 m	67°	66°
8, .	200	221	6.60	22.20	.3000	.0640	.3640	5.46	.2000	.0000	36 h. +	66°	69°
9, .	-	157	-	-	-	-	-	-	-	-	-	-	-
10, .	100	76	-	-	-	-	-	-	-	-	12 h. +	67°	69°
11, .	100	72	-	-	-	-	-	-	-	-	-	66°	69°
12, .	100	108	6.60	23.90	.3100	.0540	.3640	7.30	.1200	.0024	24 h.	66°	67°
13, .	100	83	-	-	-	-	-	-	-	-	24 h.	66°	68°
14, .	100	84	-	-	-	-	-	-	-	-	36 h. +	64°	68°
15, .	-	68	6.10	29.50	.4000	.0530	.4530	9.55	.0700	.0000	-	-	67°
16, .	-	30	-	-	-	-	-	-	-	-	-	-	-
17, .	200	72	-	-	-	-	-	-	-	-	36 h. +	65°	68°
18, .	-	171	-	-	-	-	-	-	-	-	-	-	66°
19, .	200	203	8.00	33.20	.5300	.0660	.5960	10.95	.0450	.0036	12 h. +	64°	66°
20, .	-	43	-	-	-	-	-	-	-	-	-	-	66°
21, .	200	203	-	-	-	-	-	-	-	-	-	63°	65°
22, .	-	106	5.60	32.20	.5300	.0550	.5850	10.80	.0700	.0044	-	-	66°
23, .	-	24	-	-	-	-	-	-	-	-	-	-	-
24, .	200	139	-	-	-	-	-	-	-	-	4 h. 4 m.	59°	64°
25, .	-	31	-	-	-	-	-	-	-	-	-	-	64°
26, .	200	241	5.00	32.60	.4500	.0510	.5010	9.80	.0500	.0040	-	58°	63°
27, .	-	49	-	-	-	-	-	-	-	-	-	-	65°
28, .	200	138	-	-	-	-	-	-	-	-	48 h. 41 m.	57°	63°
29, .	-	31	3.20	29.20	.3300	.0240	.3540	10.20	.1200	.0020	-	-	60°
30, .	-	11	-	-	-	-	-	-	-	-	-	-	-

Effluent decidedly turbid, generally with little sediment, and with an average color of 1.24, probably due to iron.

September 18. — 125 gallons of water siphoned from surface. September 22. — 80 gallons. September 26. — 85 gallons. Rain-water on surface from the morning of September 21 to 4.6 P.M. September 22.

Total effluent to end of month, 39,234 gallons.

Filter Tank No. 4 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	200	170	–	–	–	–	–	–	–	–	3 h.	53°	63°
2, .	–	98	–	–	–	–	–	–	–	–	–	–	62°
3, .	200	109	3.60	28.00	.3700	.0490	.4190	8.35	.1250	.0020	27 h.	53°	61°
4, .	–	84	–	–	–	–	–	–	–	–	–	–	61°
5, .	200	100	–	–	–	–	–	–	–	–	–	51°	61°
6, .	–	101	5.80	28.00	.4000	.0450	.4450	7.68	.0770	.0020	–	–	60°
7, .	–	106	–	–	–	–	–	–	–	–	–	–	–
8, .	200	204	–	–	–	–	–	–	–	–	21 h. 56 m.	53°	59°
9, .	–	66	–	–	–	–	–	–	–	–	–	–	57°
10, .	200	143	4.40	21.80	.3300	.0470	.3770	5.90	.1200	.0014	12 h. +	52°	59°
11, .	–	39	–	–	–	–	–	–	–	–	–	–	59°
12, .	200	162	–	–	–	–	–	–	–	–	12 h. +	51°	57°
13, .	–	65	2.80	22.60	.2400	.0410	.2810	6.78	.1100	.0006	–	–	57°
14, .	–	21	–	–	–	–	–	–	–	–	–	–	–
15, .	200	68	–	–	–	–	–	–	–	–	36 h. +	51°	57°
16, .	–	77	–	–	–	–	–	–	–	–	–	–	58°
17, .	200	77	3.20	21.20	.2300	.0290	.2590	6.34	.1300	.0014	36 h. +	50°	56°
18, .	–	109	–	–	–	–	–	–	–	–	–	–	55°
19, .	200	182	–	–	–	–	–	–	–	–	36 h. +	49°	56°
20, .	–	73	3.40	20.90	.3200	.0360	.3560	6.10	.1000	.0014	–	–	56°
21, .	–	15	–	–	–	–	–	–	–	–	–	–	–
22, .	200	125	–	–	–	–	–	–	–	–	12 h. +	51°	56°
23, .	–	41	–	–	–	–	–	–	–	–	–	–	56°
24, .	200	126	3.10	18.70	.1600	.0180	.1780	5.59	.1500	.0010	–	48°	54°
25, .	–	126	–	–	–	–	–	–	–	–	–	–	54°
26, .	200	105	–	–	–	–	–	–	–	–	–	47°	–
27, .	–	106	4.20	19.10	.2800	.0210	.3010	5.67	.1850	.0014	–	–	54°
28, .	–	69	–	–	–	–	–	–	–	–	–	–	–
29, .	200	54	–	–	–	–	–	–	–	–	24 h.	49°	55°
30, .	–	49	–	–	–	–	–	–	–	–	24 h.	–	54°
31, .	200	59	3.50	19.00	.2200	.0250	.2450	5.31	.1900	.0014	24 h.	48°	55°

Effluent generally decidedly turbid and with little sediment and with a color averaging 0.77, probably due to iron.

October 17. — Manganese in samples. October 18. — Sample taken through a glass tube showed that iron in samples does not come from outlet pipe. October 8. — 30 gallons siphoned from surface. October 18. — 85 gallons. Some water left each day. October 24. — Rain-water on surface.

Total effluent to end of month, 42,163 gallons.

Filter Tank No. 4 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1,	-	55	-	-	-	-	-	-	-	-	24 h.	-	57°
2,	-	51	-	-	-	-	-	-	-	-	24 h.	-	57°
3,	-	49	5.90	20.10	.2800	.0310	.3110	7.17	.1330	.0020	22h.30m.	-	57°
4,	-	23	-	-	-	-	-	-	-	-	-	-	-
5,	150	29	-	-	-	-	-	-	-	-	24 h.	49°	55°
6,	-	51	-	-	-	-	-	-	-	-	24 h.	-	55°
7,	150	34	2.70	20.40	.1800	.0280	.2080	7.11	.1280	.0014	24 h.	51°	54°
8,	-	39	-	-	-	-	-	-	-	-	24 h.	-	54°
9,	150	96	-	-	-	-	-	-	-	-	24 h.	51°	54°
10,	-	101	4.20	20.90	.3500	.0470	.3970	5.71	.1180	.0014	24 h.	-	54°
11,	-	63	-	-	-	-	-	-	-	-	24 h.	-	-
12,	150	104	-	-	-	-	-	-	-	-	24 h.	48°	53°
13,	-	73	-	-	-	-	-	-	-	-	24 h.	-	53°
14,	150	95	4.20	19.30	.2200	.0260	.2460	5.18	.1600	.0014	-	46°	54°
15,	-	88	-	-	-	-	-	-	-	-	-	-	53°
16,	150	143	-	-	-	-	-	-	-	-	25h.41m.	45°	53°
17,	-	69	5.20	18.60	.2800	.0320	.3120	4.85	.1250	.0020	-	-	52°
18,	-	13	-	-	-	-	-	-	-	-	-	-	-
19,	150	138	-	-	-	-	-	-	-	-	12 h.+	43°	51°
20,	-	43	-	-	-	-	-	-	-	-	-	-	51°
21,	150	106	3.50	18.40	.2900	.0350	.3250	4.68	.1300	.0014	-	43°	50°
22,	-	20	-	-	-	-	-	-	-	-	-	-	49°
23,	150	97	-	-	-	-	-	-	-	-	-	46°	49°
24,	-	29	2.50	17.70	.1300	.0290	.1590	4.35	.2000	.0010	-	-	49°
25,	-	11	-	-	-	-	-	-	-	-	-	-	-
26,	150	158	-	-	-	-	-	-	-	-	36 h.+	44°	49°
27,	-	164	-	-	-	-	-	-	-	-	-	-	48°
28,	150	177	4.90	19.10	.3500	.0300	.3800	4.25	.1400	.0000	3 h.30m.	45°	49°
29,	-	27	-	-	-	-	-	-	-	-	-	-	-
30,	150	128	3.30	18.40	.3800	.0340	.4140	4.22	.1500	.0010	3 h.	44°	48°

Effluent from slightly to distinctly turbid and with little sediment and with color averaging 1.10, probably due to iron.

November 12. — 1-16 inch of ice on surface; November 13, ¼ inch; November 22, ¼ inch in spots; November 23, a few spots; November 24, ¼ inch. November 12. — 110 gallons water siphoned from surface. Some left. November 16. — 40 gallons siphoned off. November 22. — Boards laid on loosely over tank. November 29, 9.19 A.M., to November 30, 8.13 A.M. — Outlet closed. River high.

Total effluent to end of month, 44,437 gallons.

Filter Tank No. 4 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	43	-	-	-	-	-	-	-	-	-	-	46°
2, .	-	17	-	-	-	-	-	-	-	-	-	-	-
3, .	150	93	-	-	-	-	-	-	-	-	1 h. 30 m.	45°	46°
4, .	-	38	-	-	-	-	-	-	-	-	-	-	45°
5, .	150	101	2.00	16.50	.2600	.0160	.2760	4.25	.1300	.0010	1 h. 43 m.	44°	45°
6, .	-	37	-	-	-	-	-	-	-	-	-	-	45°
7, .	150	94	-	-	-	-	-	-	-	-	2 h. 27 m.	45°	45°
8, .	-	37	2.20	18.40	.1700	.0210	.1910	4.10	.1900	.0008	-	-	45°
9, .	-	18	-	-	-	-	-	-	-	-	-	-	-
10, .	150	80	-	-	-	-	-	-	-	-	2 h. 30 m.	44°	-
11, .	-	48	-	-	-	-	-	-	-	-	-	-	43°
12, .	150	99	1.00	17.30	.0800	.0190	.0990	4.10	.1500	.0006	-	45°	43°
13, .	-	38	-	-	-	-	-	-	-	-	-	-	42°
14, .	150	63	-	-	-	-	-	-	-	-	-	44°	41°
15, .	-	34	1.70	16.40	.0720	.0150	.0870	4.00	.2950	.0004	-	-	43°
16, .	-	10	-	-	-	-	-	-	-	-	-	-	-
17, .	150	113	-	-	-	-	-	-	-	-	2 h. 42 m.	45°	43°
18, .	-	33	-	-	-	-	-	-	-	-	-	-	42°
19, .	-	-	-	-	-	-	-	-	-	-	-	-	-
20, .	-	-	-	-	-	-	-	-	-	-	-	-	-
21, .	150	98	-	-	-	-	-	-	-	-	4 h. 53 m.	46°	41°
22, .	-	27	.60	16.50	.0960	.0130	.1090	3.95	.3400	.0016	-	-	39°
23, .	-	7	-	-	-	-	-	-	-	-	-	-	-
24, .	150	64	-	-	-	-	-	-	-	-	-	42°	46°
25, .	-	46	-	-	-	-	-	-	-	-	-	-	-
26, .	150	105	1.30	16.50	.0360	.0100	.0460	3.85	.5000	.0010	-	46°	42°
27, .	-	44	-	-	-	-	-	-	-	-	-	-	44°
28, .	150	101	-	-	-	-	-	-	-	-	3 h. 33 m.	44°	42°
29, .	-	44	1.50	15.20	.1080	.0210	.1290	3.50	.3000	.0008	-	-	43°
30, .	-	16	-	-	-	-	-	-	-	-	-	-	-
31, .	150	84	-	-	-	-	-	-	-	-	5 h. 6 m.	44°	43°

Effluent generally very nearly clear and very nearly free from sediment, with color averaging less than 0.2.

December 5. — Boards over tank removed and canvas put on. December 7. — Ice in spots on surface; December 15, ¼ inch. December 19. — ⅝ inch of frost; December 21, 2 inches. December 21, 8.51 P.M., to December 21, 7.48 A.M. — Outlet closed. River high.

Total effluent to end of month, 46,069 gallons.

Filter Tank No. 4 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	50	-	-	-	-	-	-	-	-	-	-	43°
2, .	150	99	1.2	16.7	.1260	.0110	.1370	3.71	.2300	.0008	3 h. 52 m.	44°	41°
3, .	-	49	-	-	-	-	-	-	-	-	-	-	42°
4, .	150	93	-	-	-	-	-	-	-	-	-	44°	41°
5, .	-	50	2.1	14.7	.0800	.0170	.0970	3.50	.2200	.0010	-	-	41°
6, .	-	20	-	-	-	-	-	-	-	-	-	-	-
7, .	150	91	-	-	-	-	-	-	-	-	3 h. 19 m.	44°	41°
8, .	-	46	-	-	-	-	-	-	-	-	-	-	42°
9, .	150	100	1.7	16.2	.0470	.0130	.0600	3.70	.2800	.0012	2 h. 55 m.	45°	41°
10, .	-	50	-	-	-	-	-	-	-	-	-	-	42°
11, .	150	98	-	-	-	-	-	-	-	-	2 h. 26 m.	44°	41°
12, .	-	44	1.0	15.5	.0620	.0100	.0720	3.68	.2300	.0010	-	-	41°
13, .	-	11	-	-	-	-	-	-	-	-	-	-	-
14, .	150	74	-	-	-	-	-	-	-	-	3 h. 43 m.	44°	41°
15, .	-	38	-	-	-	-	-	-	-	-	-	-	42°
16, .	150	83	0.3	16.2	.0350	.0150	.0500	3.77	.2500	.0010	-	45°	40°
17, .	-	53	-	-	-	-	-	-	-	-	-	-	43°
18, .	150	97	-	-	-	-	-	-	-	-	2 h. 43 m.	46°	41°
19, .	-	47	0.4	16.6	.0520	.0120	.0640	3.87	.2600	.0010	-	-	40°
20, .	-	14	-	-	-	-	-	-	-	-	-	-	-
21, .	150	62	-	-	-	-	-	-	-	-	4 h. 2 m.	44°	40°
22, .	-	39	-	-	-	-	-	-	-	-	-	-	40°
23, .	150	90	1.2	15.0	.0230	.0100	.0330	3.82	.2400	.0008	-	45°	40°
24, .	-	45	-	-	-	-	-	-	-	-	-	-	41°
25, .	150	89	-	-	-	-	-	-	-	-	8 h. 18 m.	44°	40°
26, .	-	53	0.3	16.0	.0630	.0080	.0710	3.90	.2500	.0010	-	-	40°
27, .	-	18	-	-	-	-	-	-	-	-	-	-	-
28, .	150	80	-	-	-	-	-	-	-	-	-	45°	40°
29, .	-	44	-	-	-	-	-	-	-	-	-	-	41°
30, .	150	82	0.0	16.3	.0176	.0050	.0220	3.84	.2800	.0007	-	45°	39°
31, .	-	44	-	-	-	-	-	-	-	-	-	-	40°

Effluent generally very nearly clear and free from sediment and with color averaging less than 0.1.
January 22, 1 inch of frost in tank; January 26, 2 inches; January 29, None.
Total effluent to end of month, 47,927 gallons.

Filter Tank No. 4 — Continued.

February, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	150	93	-	-	-	-	-	-	-	-	-	46°	39°
2, .	-	52	1.1	14.4	.0490	.0090	.0580	3.78	.2800	.0010	-	-	40°
3, .	-	11	-	-	-	-	-	-	-	-	-	-	-
4, .	150	62	-	-	-	-	-	-	-	-	-	44°	40°
5, .	-	44	-	-	-	-	-	-	-	-	-	-	40°
6, .	150	107	1.1	15.4	.0120	.0100	.0220	3.85	.2700	.0008	-	46°	39°
7, .	-	44	-	-	-	-	-	-	-	-	-	-	39°
8, .	150	42	-	-	-	-	-	-	-	-	-	44°	39°
9, .	-	45	1.1	15.3	.0368	.0092	.0460	4.07	.2600	.0008	-	-	40°
10, .	-	13	-	-	-	-	-	-	-	-	-	-	-
11, .	150	39	-	-	-	-	-	-	-	-	-	45°	39°
12, .	-	34	-	-	-	-	-	-	-	-	-	-	40°
13, .	150	49	1.7	15.1	.0136	.0104	.0240	3.95	.3000	.0006	24 h.	45°	39°
14, .	-	59	-	-	-	-	-	-	-	-	24 h.	-	40°
15, .	150	91	-	-	-	-	-	-	-	-	-	46°	40°
16, .	-	73	1.2	13.7	.0784	.0086	.0870	3.63	.2200	.0004	-	-	40°
17, .	-	21	-	-	-	-	-	-	-	-	-	-	-
18, .	150	107	-	-	-	-	-	-	-	-	-	44°	39°
19, .	-	58	-	-	-	-	-	-	-	-	-	-	40°
20, .	150	91	1.4	13.1	.0140	.0100	.0240	3.70	.2000	.0004	12 h. +	46°	39°
21, .	-	51	-	-	-	-	-	-	-	-	-	-	40°
22, .	150	99	-	-	-	-	-	-	-	-	-	44°	40°
23, .	-	52	-	-	-	-	-	-	-	-	-	-	39°
24, .	-	7	-	-	-	-	-	-	-	-	-	-	-
25, .	150	51	-	-	-	-	-	-	-	-	-	44°	40°
26, .	-	48	-	-	-	-	-	-	-	-	-	-	39°
27, .	150	49	1.3	13.5	.0026	.0090	.0116	3.58	.2200	.0002	24 h.	46°	40°
28, .	-	72	-	-	-	-	-	-	-	-	-	-	39°

Effluent generally colorless, nearly clear and with very slight sediment.

February 2, 1 inch of frost in tank; February 5, 2 inches; February 7, 3½ inches; February 9, 1 inch; February 20, 3½ inches; February 25, 4½ inches. — Surface covered more or less with a coating of thin ice for about one-half of the days of the month.

Total effluent to end of month, 49,491 gallons.

Filter Tank No. 4 — Continued.

March, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	150	125	-	-	-	-	-	-	-	-	-	45°	39°
2, .	-	61	2.0	13.0	.0280	.0108	.0388	3.42	.2400	.0010	-	-	40°
3, .	-	18	-	-	-	-	-	-	-	-	-	-	-
4, .	150	110	-	-	-	-	-	-	-	-	-	35°	38°
5, .	-	54	-	-	-	-	-	-	-	-	-	-	40°
6, .	150	111	2.7	14.1	.0130	.0110	.0240	3.47	.2000	.0002	-	36°	38°
7, .	-	57	-	-	-	-	-	-	-	-	-	-	40°
8, .	150	94	-	-	-	-	-	-	-	-	-	35°	38°
9, .	-	56	1.0	13.9	.0170	.0040	.0210	3.40	.2000	.0003	-	-	39°
10, .	-	17	-	-	-	-	-	-	-	-	-	-	-
11, .	150	73	-	-	-	-	-	-	-	-	-	34°	39°
12, .	-	53	-	-	-	-	-	-	-	-	-	-	40°
13, .	150	95	1.6	14.3	.0048	.0102	.0150	3.50	.2400	.0001	-	37°	38°
14, .	-	62	-	-	-	-	-	-	-	-	-	-	40°
15, .	150	89	-	-	-	-	-	-	-	-	2 h. 8 m.	38°	38°
16, .	-	55	0.9	15.1	.0070	.0086	.0156	3.30	.2200	.0003	-	-	40°
17, .	-	42	-	-	-	-	-	-	-	-	-	-	-
18, .	150	120	-	-	-	-	-	-	-	-	2 h. 2 m.	38°	38°
19, .	-	66	-	-	-	-	-	-	-	-	-	-	40°
20, .	150	94	1.3	15.5	.0012	.0092	.0104	3.40	.2800	.0000	1 h. 22 m.	39°	38°
21, .	-	61	-	-	-	-	-	-	-	-	-	-	39°
22, .	150	82	-	-	-	-	-	-	-	-	1 h. 11 m.	37°	39°
23, .	-	60	1.8	15.4	.0038	.0098	.0136	3.44	.3000	.0002	-	-	41°
24, .	-	20	-	-	-	-	-	-	-	-	-	-	-
25, .	150	68	-	-	-	-	-	-	-	-	1 h. 2 m	43°	40°
26, .	-	49	-	-	-	-	-	-	-	-	-	-	41°
27, .	150	82	1.8	15.5	.0006	.0084	.0090	3.37	.3500	.0001	50 m.	42°	39°
28, .	-	58	-	-	-	-	-	-	-	-	-	-	41°
29, .	150	78	-	-	-	-	-	-	-	-	1 h.	41°	40°
30, .	-	57	1.9	15.6	.0036	.0112	.0148	3.10	.4700	.0002	-	-	41°
31, .	-	21	-	-	-	-	-	-	-	-	-	-	-

Effluent generally clear and with very slight sediment and with color less than 0.1.

March 1, 4, 6, 9 and 11. — A little ice on surface. March 4. — No frost in one-half of tank. Frost in other half from ½ inch to 3 inches below surface to a depth of from 4 inches to 7 inches. March 13. — Canvas cover removed from tank.

Total effluent to end of month, 51,579 gallons.

Filter Tank No. 4 — Continued.

April, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	150	149	-	-	-	-	-	-	-	-	1 h. 27 m.	41°	39°
2, .	-	121	-	-	-	-	-	-	-	-	-	-	40°
3, .	150	119	3.1	15.8	.0028	.0110	.0138	3.23	.6000	.0002	1 h. 36 m.	40°	40°
4, .	-	61	-	-	-	-	-	-	-	-	-	-	41°
5, .	150	97	-	-	-	-	-	-	-	-	1 h. 55 m.	41°	40°
6, .	-	63	0.6	17.4	.0042	.0098	.0140	3.24	.5500	.0003	-	-	41°
7, .	-	21	-	-	-	-	-	-	-	-	-	-	-
8, .	150	71	-	-	-	-	-	-	-	-	1 h. 27 m.	44°	41°
9, .	-	53	-	-	-	-	-	-	-	-	-	-	43°
10, .	150	79	1.7	17.3	.0014	.0104	.0118	3.17	.6000	.0002	1 h. 23 m.	46°	42°
11, .	-	55	-	-	-	-	-	-	-	-	-	-	45°
12, .	150	84	-	-	-	-	-	-	-	-	-	46°	43°
13, .	-	55	1.1	19.0	.0012	.0114	.0126	3.18	.5500	.0002	-	-	44°
14, .	-	18	-	-	-	-	-	-	-	-	-	-	-
15, .	150	65	-	-	-	-	-	-	-	-	1 h. 25 m.	47°	44°
16, .	-	45	-	-	-	-	-	-	-	-	-	-	44°
17, .	150	85	-	-	-	-	-	-	-	-	58 m.	47°	43°
18, .	-	77	-	-	-	-	-	-	-	-	-	-	45°
19, .	150	97	-	-	-	-	-	-	-	-	2 h. 30 m.	50°	46°
20, .	-	54	0.9	19.4	.0014	.0108	.0122	3.34	.5000	.0001	-	-	49°
21, .	-	22	-	-	-	-	-	-	-	-	-	-	-
22, .	150	59	-	-	-	-	-	-	-	-	48 m.	53°	46°
23, .	-	41	-	-	-	-	-	-	-	-	-	-	48°
24, .	150	77	-	-	-	-	-	-	-	-	1 h. 6 m.	51°	46°
25, .	-	44	-	-	-	-	-	-	-	-	-	-	50°
26, .	150	168	-	-	-	-	-	-	-	-	-	54°	48°
27, .	-	172	2.2	20.4	.0138	.0112	.0250	4.44	.9000	.0008	-	-	47°
28, .	-	49	-	-	-	-	-	-	-	-	-	-	-
29, .	150	79	-	-	-	-	-	-	-	-	-	55°	48°
30, .	-	50	-	-	-	-	-	-	-	-	-	-	51°

Effluent generally clear and with very slight sediment and with color 0 or less than 0.1.
Total effluent to end of month, 53,809 gallons.

Filter Tank No. 4 — Continued.

May, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	150	70	1.7	19.8	.0012	.0102	.0114	3.69	.8000	.0001	2 h.	52°	49°
2, .	–	43	–	–	–	–	–	–	–	–	–	–	52°
3, .	150	77	–	–	–	–	–	–	–	–	1 h. 17 m.	53°	49°
4, .	–	50	1.5	21.4	.0012	.0100	.0112	3.98	1.0000	.0002	–	–	51°
5, .	–	11	–	–	–	–	–	–	–	–	–	–	–
6, .	150	58	–	–	–	–	–	–	–	–	51 m.	55°	52°
7, .	–	39	–	–	–	–	–	–	–	–	–	–	53°
8, .	150	71	–	–	–	–	–	–	–	–	1 h. 13 m.	58°	52°
9, .	–	41	–	–	–	–	–	–	–	–	–	–	57°
10, .	150	74	–	–	–	–	–	–	–	–	43 m.	62°	58°
11, .	–	57	2.8	21.2	.0004	.0106	.0110	4.12	.6000	.0001	–	–	54°
12, .	–	14	–	–	–	–	–	–	–	–	–	–	–
13, .	150	61	–	–	–	–	–	–	–	–	35 m.	64°	54°
14, .	–	66	–	–	–	–	–	–	–	–	–	–	56°
15, .	150	108	–	–	–	–	–	–	–	–	3 h. 11 m.	65°	54°
16, .	–	49	–	–	–	–	–	–	–	–	–	–	57°
17, .	150	79	–	–	–	–	–	–	–	–	45 m.	66°	57°
18, .	–	36	0.6	22.6	.0020	.0118	.0138	4.17	1.0000	.0000	–	–	62°
19, .	–	10	–	–	–	–	–	–	–	–	–	–	–
20, .	150	163	–	–	–	–	–	–	–	–	–	68°	56°
21, .	–	209	–	–	–	–	–	–	–	–	–	–	56°
22, .	150	133	–	–	–	–	–	–	–	–	–	67°	57°
23, .	–	43	–	–	–	–	–	–	–	–	–	–	58°
24, .	150	75	–	–	–	–	–	–	–	–	53 m.	65°	58°
25, .	–	41	3.6	22.6	.0004	.0116	.0120	4.07	1.0000	.0000	–	–	60°
26, .	–	26	–	–	–	–	–	–	–	–	–	–	–
27, .	150	126	–	–	–	–	–	–	–	–	1 h. 9 m.	61°	57°
28, .	–	58	–	–	–	–	–	–	–	–	–	–	60°
29, .	150	86	–	–	–	–	–	–	–	–	53 m.	61°	59°
30, .	–	34	–	–	–	–	–	–	–	–	–	–	59°
31, .	150	84	–	–	–	–	–	–	–	–	1 h. 11 m.	62°	59°

Effluent colorless, generally clear, and with very little or no sediment.
May 22. — Thick grass in spots covering about one-half of surface.
Total effluent to end of month, 55,901 gallons.

Filter Tank No. 4 — Continued.

June, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	37	1.6	24.2	.0018	.0132	.0150	4.47	1.2000	.0000	-	-	62°
2, .	-	112	-	-	-	-	-	-	-	-	-	-	-
3, .	150	128	-	-	-	-	-	-	-	-	4h.51m.	65°	59°
4, .	-	83	-	-	-	-	-	-	-	-	-	-	50°
5, .	150	127	2.1	23.2	.0018	.0132	.0150	4.50	1.2000	.0001	-	66°	59°
6, .	-	45	-	-	-	-	-	-	-	-	-	-	61°
7, .	150	73	-	-	-	-	-	-	-	-	1 h. 5 m.	66°	60°
8, .	-	38	2.4	23.1	.0020	.0140	.0160	4.36	1.1000	.0001	-	-	61°
9, .	-	10	-	-	-	-	-	-	-	-	-	-	-
10, .	150	92	-	-	-	-	-	-	-	-	38 m.	67°	62°
11, .	-	41	-	-	-	-	-	-	-	-	-	-	66°
12, .	150	89	-	-	-	-	-	-	-	-	58 m.	69°	61°
13, .	-	31	-	-	-	-	-	-	-	-	-	-	66°
14, .	150	64	-	-	-	-	-	-	-	-	-	67°	71°
15, .	-	38	2.4	22.1	.0014	.0140	.0154	4.31	.8000	.0000	-	-	68°
16, .	-	6	-	-	-	-	-	-	-	-	-	-	-
17, .	150	75	-	-	-	-	-	-	-	-	33 m.	72°	63°
18, .	-	24	-	-	-	-	-	-	-	-	-	-	63°
19, .	150	82	2.2	22.4	.0018	.0154	.0172	4.34	.6000	.0001	40 m.	70°	62°
20, .	-	24	-	-	-	-	-	-	-	-	-	-	67°
21, .	150	75	-	-	-	-	-	-	-	-	36 m.	71°	64°
22, .	-	30	-	-	.0018	.0150	.0168	4.22	.6500	.0000	-	-	67°
23, .	-	5	-	-	-	-	-	-	-	-	-	-	-
24, .	150	77	-	-	-	-	-	-	-	-	12 m.	69°	67°
25, .	-	35	-	-	-	-	-	-	-	-	-	-	66°
26, .	150	108	2.4	21.3	.0012	.0154	.0166	4.22	.4500	.0000	10m.	69°	65°
27, .	-	36	-	-	-	-	-	-	-	-	-	-	68°
28, .	150	124	-	-	-	-	-	-	-	-	-	71°	65°
29, .	-	79	2.6	21.6	.0060	.0172	.0232	4.33	.5000	.0002	-	-	68°
30, .	-	13	-	-	-	-	-	-	-	-	-	-	-

Effluent generally colorless, and clear, or nearly so, and with very slight sediment.

June 24. — Weeds and grass removed from surface. Surface of outer ring of coarse sand removed and replaced by fresh sand. Surface left 3 inches below that of rest of tank. Sewage to be applied only to ring. Total effluent to end of month, 57,702 gallons.

Filter Tank No. 4 — Continued.

July, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1,	150	82	-	-	-	-	-	-	-	-	9 m.	-	73°
2,	-	38	-	-	-	-	-	-	-	-	-	-	68°
3,	150	148	-	-	-	-	-	-	-	-	11 m.	73°	66°
4,	-	39	-	-	-	-	-	-	-	-	-	-	-
5,	150	109	-	-	-	-	-	-	-	-	-	73°	67°
6,	-	30	3.7	20.0	.0010	.0168	.0178	4.37	.4500	.0000	-	-	69°
7,	-	9	-	-	-	-	-	-	-	-	-	-	-
8,	150	89	-	-	-	-	-	-	-	-	16 m.	74°	67°
9,	-	31	-	-	-	-	-	-	-	-	-	-	67°
10,	150	113	4.6	20.4	.0152	.0194	.0346	4.52	.3500	.0007	-	72°	67°
11,	-	33	-	-	-	-	-	-	-	-	-	-	66°
12,	150	106	-	-	-	-	-	-	-	-	-	72°	69°
13,	-	34	4.8	19.5	.0010	.0188	.0198	4.45	.4000	.0000	-	-	71°
14,	-	10	-	-	-	-	-	-	-	-	-	-	-
15,	150	161	-	-	-	-	-	-	-	-		73°	65°
16,	-	48	-	-	-	-	-	-	-	-	-	-	67°
17,	150	151	3.2	19.6	.0264	.0190	.0454	4.62	.3500	.0008	-	72°	66°
18,	-	43	-	-	-	-	-	-	-	-	-	-	68°
19,	150	110	3.2	21.6	.0270	.0204	.0474	5.87	.3500	.0008	10 m.	72°	67°
20,	-	299	-	-	-	-	-	-	-	-	-	-	66°
21,	-	42	-	-	-	-	-	-	-	-	-	-	-
22,	150	112	-	-	-	-	-	-	-	-	11 m.	72°	67°
23,	-	69	-	-	-	-	-	-	-	-		-	67°
24,	150	135	2.1	21.9	.0032	.0192	.0224	5.64	.4000	.0000	-	72°	69°
25,	-	36	-	-	-	-	-	-	-	-	-	-	69°
26,	150	93	-	-	-	-	-	-	-	-	-	70°	69°
27,	-	126	4.5	21.6	.0030	.0168	.0198	5.56	.4500	.0000	-	-	67°
28,	-	56	-	-	-	-	-	-	-	-	-	-	-
29,	150	105	-	-	-	-	-	-	-	-	-	69°	73°
30,	-	60	-	-	-	-	-	-	-	-	-	-	71°
31,	150	190	4.8	22.4	.0032	.0146	.0178	5.65	.3500	.0002	13 m.	71°	70°

Effluent clear or slightly milky, with very little or no sediment and with color from 0 to 0.2.
Total effluent to end of month, 60,409 gallons.

Filter Tank No. 4 — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1,	-	128	-	-	-	-	-	-	-	-	-	-	70°
2,	150	194	-	-	-	-	-	-	-	-	-	72°	70°
3,	-	48	-	-	-	-	-	-	-	-	-	-	71°
4,	-	17	-	-	-	-	-	-	-	-	-	-	-
5,	150	89	-	-	-	-	-	-	-	-	17 m.	70°	69°
6,	-	19	-	-	-	-	-	-	-	-	-	-	70°
7,	150	82	-	-	-	-	-	-	-	-	-	70°	69°
8,	-	24	-	-	-	-	-	-	-	-	-	-	70°
9,	150	96	-	-	-	-	-	-	-	-	-	70°	70°
10,	-	25	2.2	20.0	.0010	.0162	.0172	4.75	.5000	.0000	-	-	71°
11,	-	4	-	-	-	-	-	-	-	-	-	-	-
12,	150	76	-	-	-	-	-	-	-	-	16 m.	70°	68°
13,	-	26	-	-	-	-	-	-	-	-	-	-	69°
14,	150	242	-	-	-	-	-	-	-	-	-	69°	69°
15,	-	57	-	-	-	-	-	-	-	-	-	-	67°
16,	150	101	-	-	-	-	-	-	-	-	-	67°	69°
17,	-	29	-	-	.0006	.0182	.0188	4.52	.4500	.0000	-	-	67°
18,	-	9	-	-	-	-	-	-	-	-	-	-	-
19,	150	80	-	-	-	-	-	-	-	-	15 m.	68°	69°
20,	-	29	-	-	-	-	-	-	-	-	-	-	68°
21,	150	97	-	-	-	-	-	-	-	-	-	68°	67°
22,	-	22	-	-	-	-	-	-	-	-	-	-	71°
23,	150	84	-	-	-	-	-	-	-	-	-	70°	69°
24,	-	24	-	-	.0008	.0182	.0190	4.22	.3800	.0000	-	-	69°
25,	-	9	-	-	-	-	-	-	-	-	-	-	-
26,	150	76	-	-	-	-	-	-	-	-	-	69°	68°
27,	-	24	-	-	-	-	-	-	-	-	-	-	67°
28,	150	85	-	-	-	-	-	-	-	-	-	68°	68°
29,	-	27	-	-	-	-	-	-	-	-	-	-	69°
30,	300	208	-	-	-	-	-	-	-	-	-	69°	69°
31,	-	41	2.0	21.0	.0014	.0170	.0184	4.40	.3700	.0001	-	-	69°

Effluent clear and free from sediment, and generally colorless.
August 12. — Outlet closed from 5.5 A.M. to 1.57 P.M., on account of leak in measuring basin.
Total effluent to end of month, 62,481 gallons.

Filter Tank No. 4—Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	8	-	-	-	-	-	-	-	-	-	-	-
2, .	300	201	-	-	-	-	-	-	-	-	-	71°	68°
3, .	-	44	-	-	-	-	-	-	-	-	-	-	69°
4, .	300	211	-	-	-	-	-	-	-	-	-	71°	69°
5, .	-	55	-	-	-	-	-	-	-	-	-	-	69°
6, .	300	214	-	-	-	-	-	-	-	-	39 m.	72°	69°
7, .	-	55	-	-	.0106	.0170	.0276	4.43	.4000	.0003	-	-	69°
8, .	-	14	-	-	-	-	-	-	-	-	-	-	-
9, .	300	198	-	-	-	-	-	-	-	-	-	72°	68°
10, .	-	54	-	-	-	-	-	-	-	-	-	-	68°
11, .	300	223	-	-	-	-	-	-	-	-	-	68°	67°
12, .	-	48	-	-	-	-	-	-	-	-	-	-	68°
13, .	300	224	-	-	-	-	-	-	-	-	43 m.	66°	68°
14, .	-	114	3.0	20.4	.0090	.0192	.0282	5.10	.3500	.0006	-	-	68°
15, .	-	34	-	-	-	-	-	-	-	-	-	-	-
16, .	300	230	-	-	-	-	-	-	-	-	-	68°	68°
17, .	-	59	-	-	-	-	-	-	-	-	-	-	69°
18, .	300	269	-	-	-	-	-	-	-	-	-	68°	68°
19, .	-	176	-	-	-	-	-	-	-	-	-	-	66°
20, .	300	260	-	-	-	-	-	-	-	-	-	65°	68°
21, .	-	70	-	-	.0106	.0132	.0238	6.05	.6000	.0006	-	-	66°
22, .	-	17	-	-	-	-	-	-	-	-	-	-	-
23, .	300	192	-	-	-	-	-	-	-	-	46 m.	60°	66°
24, .	-	59	-	-	-	-	-	-	-	-	-	-	65°
25, .	300	206	-	-	-	-	-	-	-	-	-	68°	66°
26, .	-	67	-	-	.0048	.0124	.0172	5.69	.6000	.0004	-	-	66°
27, .	300	225	-	-	-	-	-	-	-	-	-	59°	65°
28, .	-	59	-	-	-	-	-	-	-	-	-	-	62°
29, .	-	18	-	-	-	-	-	-	-	-	-	-	-
30, .	300	200	-	-	-	-	-	-	-	-	-	58°	65°

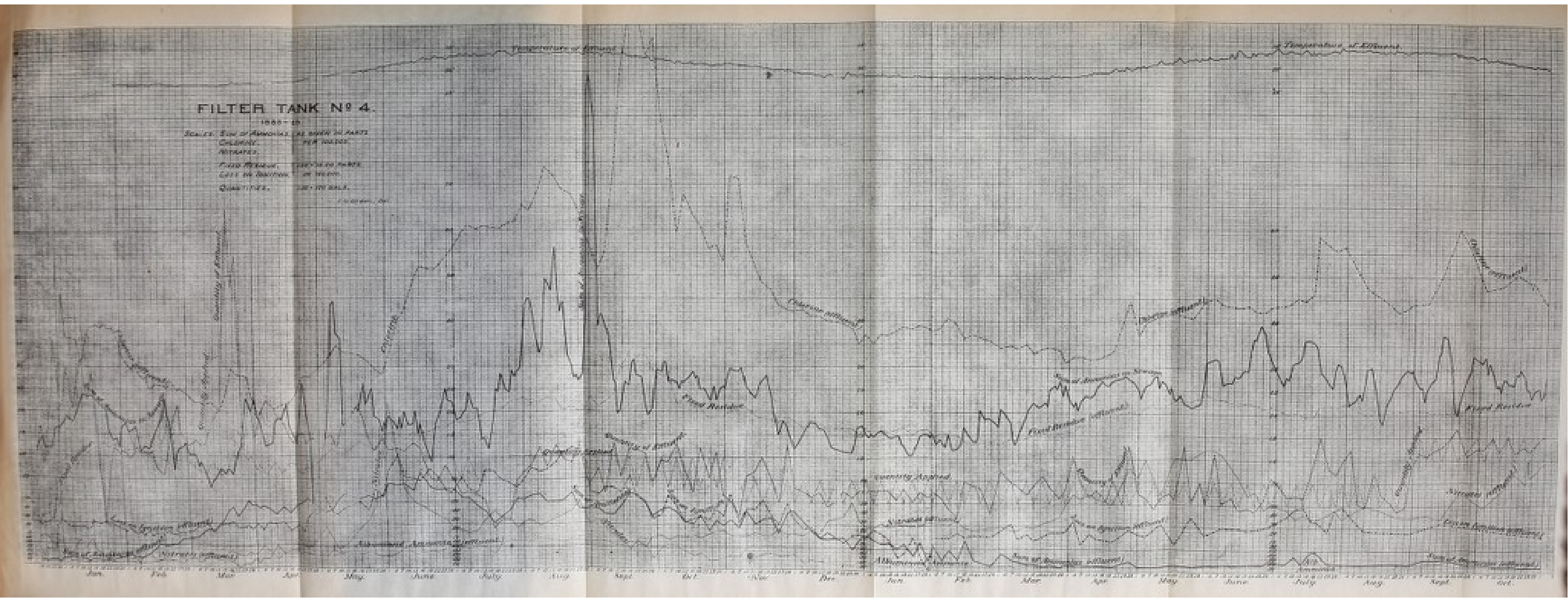
Effluent clear and colorless and free from sediment.
Total effluent to end of month, 66,285 gallons.

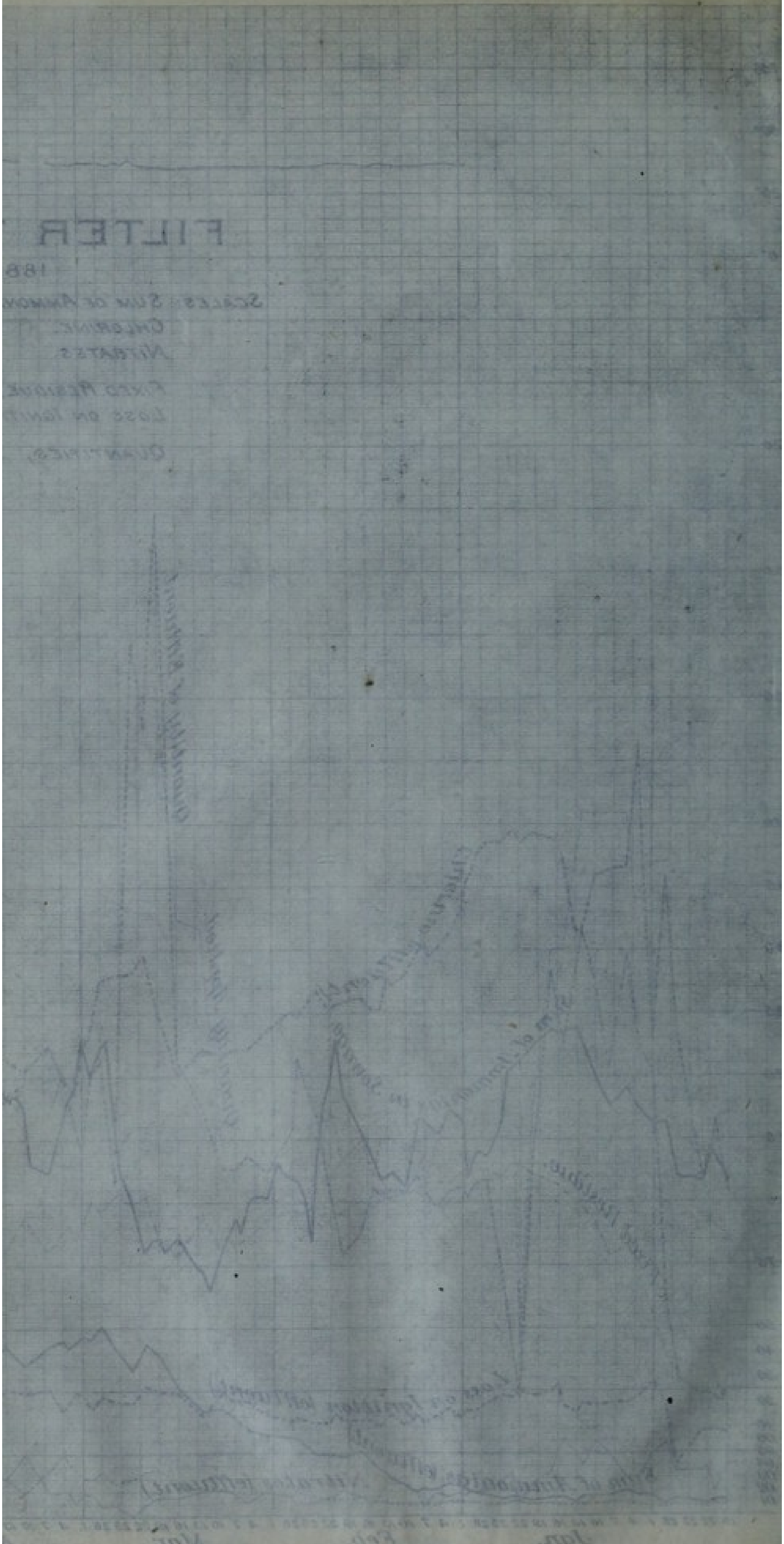
Filter Tank No. 4 — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	80	-	-	-	-	-	-	-	-	-	-	64°
2, .	300	224	-	-	-	-	-	-	-	-	-	59°	64°
3, .	-	71	-	-	.0042	.0150	.0192	4.72	.4800	.0002	-	-	60°
4, .	300	208	-	-	-	-	-	-	-	-	-	58°	62°
5, .	-	64	-	-	-	-	-	-	-	-	-	-	61°
6, .	-	24	-	-	-	-	-	-	-	-	-	-	-
7, .	300	307	-	-	-	-	-	-	-	-	-	55°	62°
8, .	-	81	-	-	-	-	-	-	-	-	-	-	60°
9, .	300	204	-	-	-	-	-	-	-	-	-	53°	61°
10, .	-	73	-	-	.0026	.0114	.0140	4.79	.6300	.0002	-	-	59°
11, .	300	208	-	-	-	-	-	-	-	-	-	50°	60°
12, .	-	82	-	-	-	-	-	-	-	-	-	-	59°
13, .	-	97	-	-	-	-	-	-	-	-	-	-	-
14, .	300	227	-	-	-	-	-	-	-	-	1 h.29 m.	49°	59°
15, .	-	73	-	-	-	-	-	-	-	-	-	-	58°
16, .	300	199	-	-	-	-	-	-	-	-	-	49°	57°
17, .	-	70	-	-	.0010	.0128	.0138	5.07	.8500	.0001	-	-	57°
18, .	300	198	-	-	-	-	-	-	-	-	-	49°	57°
19, .	-	81	-	-	-	-	-	-	-	-	-	-	56°
20, .	-	24	-	-	-	-	-	-	-	-	-	-	-
21, .	300	213	-	-	-	-	-	-	-	-	-	49°	56°
22, .	-	76	-	-	-	-	-	-	-	-	-	-	55°
23, .	300	206	-	-	.0006	.0094	.0100	4.90	.7300	.0001	-	48°	55°
23, .	-	-	-	-	.0020	.0098	.0118	4.75	1.0000	.0002	-	-	-
24, .	-	76	-	-	.0008	.0110	.0118	4.90	.8000	.0000	-	-	53°
25, .	300	200	-	-	-	-	-	-	-	-	-	47°	56°
26, .	-	73	-	-	-	-	-	-	-	-	-	-	55°
27, .	-	43	-	-	-	-	-	-	-	-	-	-	-
28, .	300	249	-	-	-	-	-	-	-	-	3 h.31 m.	48°	54°
29, .	-	131	-	-	-	-	-	-	-	-	-	-	54°
30, .	300	241	-	-	-	-	-	-	-	-	2 h.16 m.	47°	53°
31, .	-	78	-	-	.0008	.0092	.0100	4.44	.9500	.0006	-	-	53°

Effluent clear, with very slight or no sediment and generally colorless.
October 26. — Grass cut from one-half of surface.
Total effluent to end of month, 70,466 gallons.


FILTER TANK Nº 4.
Temperature of Effluent
Temperature of Effluent
Quantity of Effluent
Chlorine effluent
Fixed Residue
Fixed Residue
Quantity Applied
Jan.
Feb.
Mar.
Apr.
May.
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May.
June
July
Aug.
Sept.
Oct.



TRENCHES IN THE FIELD.

The trenches, in the field adjoining the filter tanks, are in the same kind of material as that in Tank No. 4; and, since they were filled with coarse sand, and the sewage was applied only to this sand, the filtration has been under the same general conditions as in Tank No. 4 since the sewage was applied to its trench only, — in June, 1889.

These trenches are described in the introductory chapter, and are shown upon the plan of the works. City water was applied to trenches 1 and 2, 5 and 6, and 7 and 8, in the winter of 1887–88, to see if, at the temperature at which it came in the pipes, — which was from three to five degrees above freezing, — it would keep the trenches from freezing when applied on alternate nights. The result varied with the amount of sand in the trench. Nos. 1 and 2 received about 1,600 gallons on each of seven nights in December, when it was found that, although the coarse sand was not frozen, the river silt around and below the coarse sand was frozen, and the application of water was discontinued; but, in trenches Nos. 5 and 6 and Nos. 7 and 8, it was continued through the extremely cold winter. On these trenches 2,400 gallons were applied every other night to each couple, from December, 1887, till May 24, 1888. It was applied continuously from 9 P. M. till 5 A. M., until the latter part of February; after which it was applied from 4 P. M. to 8 A. M.

During the extremely cold month of January the mean temperature of the water applied was 36°, and in February was 35°. This is nearly ten degrees colder than sewage would be, flowing out from a separate system of sewerage; and yet the trenches were open enough to receive and convey under the surface all that was put on. It is, however, to be noted that this amount of water followed, at times, the whole length of the trenches, which averaged 193 feet each. It generally disappeared before reaching the lower end; and, through the very cold weather, the length shortened up more and more, until the water entered the river silt through the sand entirely in the upper fifty or seventy-five feet in length of the trench.

This proved that 1,200 gallons of water, at the temperature of 35° or 36°, put upon a trench of the character of these, every other night through a January colder than we had had for twenty years, will be conveyed into and distributed through a field of river silt at about the rate of 80,000 gallons to an acre per day; from which we may conclude that sewage with its temperature eight or ten degrees higher would, under like circumstances, be capable of keeping open, in the winter months, a trench filled with coarse sand through a greater length from its source, and be distributed at the rate that would be desirable for filtration through fine river silt.

Sewage applied to the Trenches.

In the latter part of May, 1888, sewage was first applied to these four trenches, and has been continued till November, 1889. The quantity applied to each couple was 500 gallons a day, on week days, until Aug. 1, 1888; since which time the daily quantity applied to Nos. 5 and 6 has been 1,000 gallons, — 500 gallons in half an hour, about 9 A. M., and 500 gallons at about 4 P. M.; and the amount applied to Nos. 7 and 8 has been 1,500 gallons, applied about 9.30 A. M., 2 P. M. and 4.30 P. M., 500 gallons at a time. The stream is divided soon after it leaves the hose, one-half going into one trench and one-half into the other.

The length of each of these trenches is about 200 feet, and the distance along the surface which the sewage would flow depended on the amount of sediment upon the surface. The amount of sediment varied with the wetness of the season, with the completeness of nitrification, and with the time that had elapsed after the surface was cleaned. The trenches were enlarged in the lower fifty feet of their length, so that the amount applied at one time could accumulate there; but, if this had not all disappeared in the long interval between applications, it became necessary to clean the trenches, which was done by scraping off one-quarter inch in depth of sand and sediment from the surface of the sand filled into the trench. This surface was one foot wide, level across. These cleanings of the surface were made once a month in the fall of 1888, once in two months through the winter and early spring, and once in four and five months in the following warm weather. In the latter two periods a covering of boards was over the trenches.

After a cleaning, the time before an application of sewage of 500 gallons reached the lower end was from about one month to three months.

The underdrains, which cross under these trenches four feet below the surface, have not, except on rare occasions, conveyed any liquid to their outlets. The liquid from the trenches has passed by them down to the water table, several feet below, the distance depending upon the height of water in the Merrimack River adjoining the field.

Finding that no liquid from the sewage appeared at the outlet of the underdrains, two wells were dug, one, marked upon the plan of the Station Well No. 1, opposite the easterly underdrain, and one, marked Well No. 2, opposite the middle underdrain, between their outlets and the river. These wells were dug in the latter part of August, 1888; since which time samples have been taken, three or four times a month, and analyzed to determine the degree of purification of the sewage, and the character of the effluent going to the river.

Unfortunately, the river rises and falls so much that water is sometimes flowing from the river into the land, and at other times from the land towards the river. In the ordinary height of water of the river, water flows into the land, raising the water table, during the forenoon, when the river is rising from the pouring in of water from the factory wheels; and at night, after the factory wheels stop, the river falls a foot or more, and water flows from the land towards the river. To obtain the sample with the most direct flow from the sewage, water was pumped out of the well to the depth of a foot, late in the afternoon; soon after which the wheels stopped, and the river fell and kept down all night, and the sample was pumped from the well in the morning, before the river began to rise.

As sewage had been applied to the trenches for three months before the wells were dug, we have no analyses of samples of the ground water previous to the passage of sewage, nor have we any means of determining accurately how much soluble constituents of the ground affect the effluent; but, as the fixed residue of water from Well No. 2 is from two to four times the fixed residue from Well No. 1, and as the difference is found to consist largely of salts of lime, there is no doubt that the effluent reaching Well No. 2 passes through a deposit of lime, — very likely a mass of old mortar that has at some time been dumped there on the bank of the river, and covered by deposits of silt at times of freshets. Other refuse material may have been dumped there; but, if so, we have no means of determining its effect.

The uncertainty of material and of the character of ground water flowing out with the filtered sewage, and the uncertainty of the amount of river water flowing back and forth through the sand, render the results obtained here much less exact and reliable than those obtained from the river silt of Tank No. 4.

The uncertainty in regard to the amount of river and of ground water in the effluent analyzed is partially overcome by determining the amount of chlorine in the effluent. If the effluent were all from sewage, the chlorine would equal that of the sewage, which, in the last four months of 1888, averaged 6.58 parts; while, if the effluent were all from river water, it would be about 0.24 parts.

The results of analyses of the effluent obtained from each of the wells are given in tables at the end of this section, together with diagrams showing the sum of ammonias and the chlorine in each, and the relative height of the river and of the water in each well at the time of taking the sample. The diagrams also give the distance from the upper end of each trench to which the sewage flowed before disappearing.

Taking a general view, we see that in Well No. 1 the chlorine indicated, for nearly two months, that only three per cent. of the effluent was from sewage. This may be accounted for by the fact that in this time the river rose seven feet, and, while rising, its water was flowing into the sand, carrying some of the effluent from sewage away from the well; and, as the sample of effluent was pumped from a well containing a depth of five or six feet of water, it was mixed to some degree with this water.

After the river, in the latter part of January, 1889, fell three or four feet, the chlorine of the effluent became nearly the same as that of the sewage, indicating that nearly all of the effluent was then from sewage. In the following six months the chlorine of Well No. 1 followed nearly that of the sewage; from which we may regard the effluent as filtered sewage. There is, however, one condition that may affect erroneously the result. The well which for a year or more had been receiving effluent from sewage filtration, and had contained at times six feet in depth of water, probably received some organic material which settled to the bottom of the well and remained there; so that, when the river fell, and there remained but a few inches of water in the well, it may be that when this was pumped out some of this deposited organic matter entered the sample that made the whole amount greater than the organic matter in the present effluent from sewage filtration. If these conditions affect the results, as supposed, we are likely to get the true condition of the effluent by samples taken when the chlorine is like that of the sewage and the river is gradually falling through its lower stages or is stationary, but not at its lowest stage.

The monthly averages of analyses of samples taken from the wells are given in the following tables; which contain also the general character of the sewage applied to the trenches, and the percentage of the chlorine and ammonías of the latter in the wells. The results of chemical analysis are, in all cases, expressed in parts per 100,000.

Monthly Averages of Analyses of Sewage, and of Samples from Well No. 1.

Date.		Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as	
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.
1888.									
Aug. 8–Sept. 7,	Sewage,	77.97	85.14	2.8156	1.9874	4.8030	8.58	–	.0000
September,	Well No. 1,	3.82	18.12	.0308	.0210	.0518	.37	.422	.0072
	Per cent.,	–	–	1.1	1.1	1.1	4	–	–
Sept. 8–Oct. 5,	Sewage,	26.11	44.73	1.8979	.6735	2.5714	7.82	–	.0000
October,	Well No. 1,	2.54	15.56	.0065	.0172	.0237	.64	.302	.0146
	Per cent.,	–	–	.3of1	2.6	.9of1	8	–	–
Oct. 6–29,	Sewage,	18.30	28.84	2.2890	.4360	2.7250	5.00	–	.0000
November,	Well No. 1,	1.05	13.97	.0061	.0116	.0177	2.71	.184	.0016
	Per cent.,	–	–	.3of1	2.7	.6of1	54	–	–
Oct. 30–Nov. 23,	Sewage,	18.36	28.96	1.9950	.4450	2.4400	4.93	.010	.0000
December,	Well No. 1,	2.27	27.13	.0137	.0177	.0314	2.16	.297	.0011
	Per cent.,	–	–	.7of1	4	1.3	44	–	–
1889.									
Nov. 24–Dec. 21,	Sewage,	14.19	31.46	1.1330	.2870	1.4200	4.40	.011	.0000
January,	Well No. 1,	1.40	9.04	.0011	.0101	.0112	1.19	.142	.0005
	Per cent.,	–	–	.1of1	3.5	.8of1	27	–	–
Dec. 22–Jan. 17,	Sewage,	13.62	26.22	1.2160	.3390	1.5550	4.52	.020	.0004
February,	Well No. 1,	1.12	13.95	.0132	.0107	.0239	3.52	.085	.0005
	Per cent.,	–	–	1.1	3.2	1.5	78	–	–
Jan. 18–Feb. 22,	Sewage,	9.06	19.85	1.0269	.2475	1.2744	3.70	.027	.0086
March,	Well No. 1,	.80	17.15	.0210	.0095	.0305	3.78	.150	.0005
	Per cent.,	–	–	2.0	3.8	2.4	102	–	–
Feb. 23–Mar. 28,	Sewage,	13.43	23.70	1.5429	.3908	1.9437	4.48	.012	.0122
April,	Well No. 1,	1.53	16.83	.0130	.0118	.0248	3.33	.410	.0014
	Per cent.,	–	–	.8of1	3.0	1.3	74	–	–
Mar. 29–Apr. 27,	Sewage,	12.86	25.69	1.9362	.4369	2.3731	5.35	.007	.0010
May,	Well No. 1,	1.90	16.80	.0440	.0240	.0680	3.95	.600	.0014
	Per cent.,	–	–	2.3	5	2.9	74	–	–
Apr. 28–May 22,	Sewage,	15.33	24.20	1.9645	.4246	2.3891	4.53	.002	.0000
June,	Well No. 1,	1.10	19.10	.0600	.0210	.0810	4.36	.700	.0020
	Per cent.,	–	–	3.1	5	3.4	96	–	–
May 23–July 4,	Sewage,	23.05	29.59	2.3150	.5537	2.8687	4.98	.000	.0000
July,	Well No. 1,	3.50	23.80	0.460	.0120	.0580	5.29	1.200	.0024
	Per cent.,	–	–	2.0	2.2	2.0	106	–	–
July 5–July 29,	Sewage,	22.69	30.85	2.4400	.6227	3.0627	5.56	.000	.0000
August,	Well No. 1,	2.50	25.30	.3387	.0456	.3843	6.44	.287	.0510
	Per cent.,	–	–	14	7	13	116	–	–
Sept. 14–Oct. 14,	Sewage,	26.98	34.75	1.8800	.7833	2.6633	4.73	.001	.0002
October,	Well No. 1,	–	–	.0060	.0180	.0240	5.29	.190	.0030
	Per cent.,	–	–	.3of1	2.3	.9of1	112	–	–

Monthly Averages of Analyses of Sewage, and of Samples from Well No. 2.

Date.		Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as	
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.
1888.									
June 21–Aug. 7,	Sewage,	23.88	29.66	2.1160	.5800	2.6960	6.42	.008	.0002
August,	Well No. 2,	4.57	20.67	.0829	.0499	.1328	1.80	.018	.0002
	Per cent.,	–	–	3.9	9	5	28	–	–
Aug. 8–Sept. 7,	Sewage,	77.97	85.14	2.8156	1.9874	4.8030	8.58	–	.0000
September,	Well No. 2,	4.97	35.50	.0555	.0305	.0860	.99	.027	.0001
	Per cent.,	–	–	2.0	1.5	1.8	12	–	–
Sept. 8–Oct. 5,	Sewage,	26.11	44.73	1.8979	.6735	2.5714	7.82	–	.0000
October,	Well No. 2,	3.33	35.57	.0093	.0202	.0295	3.43	.125	.0033
	Per cent.,	–	–	.5of1	3	1.1	44	–	–
Oct. 6–29,	Sewage,	18.30	28.84	2.2890	.4360	2.7250	5.00	–	.0000
November,	Well No. 2,	1.82	53.03	.0443	.0248	.0691	5.49	.060	.0076
	Per cent.,	–	–	1.9	6	2.5	110	–	–
Oct. 30–Nov. 23,	Sewage,	18.36	28.96	1.9950	.4450	2.4400	4.93	.010	.0000
December,	Well No. 2,	2.27	46.67	.0473	.0337	.0810	4.25	.023	.0000
	Per cent.,	–	–	2.4	8	3.3	86	–	–
1889.									
Nov. 24–Dec. 21,	Sewage,	14.19	31.46	1.1330	.2870	1.4200	4.40	.011	.0000
January,	Well No. 2,	1.22	30.96	.0162	.0163	.0325	2.80	.027	.0002
	Per cent.,	–	–	1.4	6	2.3	64	–	–
Dec. 22–Jan. 17,	Sewage,	13.62	26.22	1.2160	.3390	1.5550	4.52	.020	.0004
February,	Well No. 2,	1.67	49.25	.0575	.0275	.0850	4.54	.024	.0001
	Per cent.,	–	–	4.7	8	5	100	–	–
Jan. 18–Feb. 22,	Sewage,	9.06	19.85	1.0269	.2475	1.2744	3.70	.027	.0086
March,	Well No. 2,	3.30	39.20	.0350	.0105	.0455	3.23	.070	.0009
	Per cent.,	–	–	3.4	4	3.6	87	–	–
Feb. 23–Mar. 28,	Sewage,	13.43	23.70	1.5429	.3908	1.9437	4.48	.012	.0122
April,	Well No. 2,	1.30	38.50	.0247	.0173	.0420	3.53	.353	.0037
	Per cent.,	–	–	1.6	4	2.2	79	–	–
Mar. 29–Apr. 27,	Sewage,	12.86	25.69	1.9362	.4369	2.3731	5.35	.007	.0010
May,	Well No. 2,	2.50	41.20	.0320	.0310	.0630	3.90	.020	.0000
	Per cent.,	–	–	1.7	7	2.7	73	–	–
Apr. 28–May 22,	Sewage,	15.33	24.20	1.9645	.4246	2.3891	4.53	.002	.0000
June,	Well No. 2,	3.60	42.30	.0560	.0330	.0890	3.85	.020	.0000
	Per cent.,	–	–	2.9	8	3.7	85	–	–
May 23–July 4,	Sewage,	23.05	29.59	2.3150	.5537	2.8687	4.98	.000	.0000
July,	Well No. 2,	4.40	38.20	.0720	.0240	.0960	3.67	.000	.0006
	Per cent.,	–	–	3.1	4	3.3	74	–	–
July 5–29,	Sewage,	22.69	30.85	2.4400	.6227	3.0627	5.56	.000	.0000
August,	Well No. 2,	3.80	58.20	.0273	.0235	.0508	4.95	.007	.0000
	Per cent.,	–	–	1.1	3.8	1.7	89	–	–
Sept. 14–Oct. 14,	Sewage,	26.98	34.75	1.8800	.7833	2.6633	4.73	.001	.0002
October,	Well No. 2.	–	–	.0258	.0284	.0542	5.12	.010	.0000
	Per cent.,	–	–	1.4	3.6	2.0	108	–	–

Turning to the results from Well No. 1, we find the chlorine indicates that in the first two months sewage effluent formed only about three per cent. of the sample, and that it did not attain to 75 per cent. of the sample until February, since which time, through the seven months, it has averaged 95 per cent.

We may then throw out all the results before March 1, 1889, as containing too much ground water from other sources to indicate the degree of purification of sewage by filtration; and, upon examining the conditions attending the exceptionally high ammonias of August, we find they were obtained when the water in the well was but a few inches deep and was probably contaminated by deposit therein. There was but one observation in October, 1889; hence this may be discarded in taking the average of months. We have remaining five months, March to July, in which the chlorine indicates the samples to be about 90 per cent. from sewage, and the chemical condition is quite constant, giving the following average result of analyses:—

	Parts per 100,000.
Free ammonia, ...	0.0368, or 2 per cent. of that in the sewage.
Albuminoid ammonia, . .	0.0157, or 3.8 per cent. of that in the sewage.
Sum of ammonias, . . .	0.0525, or 2.4 per cent. of that in the sewage.
Chlorine, ...	4.14, or 90 per cent. of that in the sewage.
Nitrates, ...	0.6120.
Nitrites, ...	0.0015.

During these five months the nitrates increased from 0.150 parts to 1.200 parts, averaging 0.612 parts; and the ammonias indicated that 97.6 per cent. of the nitrogenous organic matter was removed from the sewage.

The chlorine of samples from Well No. 2 is equal to that of the sewage in November, 1888; and in the following months the chlorine approaches that of the sewage, except in January, 1889, which, if omitted, leaves the average chlorine for the year, from November, 1888, to October, 1889, 89 per cent. of that of the sewage.

The monthly averages of free ammonia vary from 0.0247 parts to 0.0720 parts, and from 1.1 per cent. to 4.7 per cent. of that of the sewage. The albuminoid ammonia varies from 0.0150 parts to 0.0337 parts, and from 3.6 per cent. to 8 per cent. of that of the sewage.

The nitrates vary from 0.000 to 0.353, and average 0 0587 parts. With these low nitrates the fixed residue has averaged 45.17 parts, which is 71 per cent. more than the fixed residue of the sewage,—showing that this effluent, in flowing through the sand, has come in contact with mineral matter which it has dissolved. By chemical analysis this mineral matter is found to be mostly lime.

The average of the monthly averages of analyses of effluent taken from Well No. 2, from November, 1888, to October, 1889, omitting January, is as follows: —

	Parts per 100,000.
Free ammonia, ...	0.0422, or 2.2 per cent. of that in the sewage.
Albuminoid ammonia, . .	0.0254, or 5.4 per cent. of that in the sewage.
Sum of ammonias, . . .	0.0676, or 2.9 per cent. of that in the sewage.
Chlorine, ...	4.25, or 89 per cent. of that in the sewage.
Nitrates, ...	0.0587.
Nitrites, ...	0.0013.

This average of the analyses shows that, for ten months in the second year of filtration, there was 97 per cent. less organic matter, as shown by the ammonias, in the effluent than in the sewage.

The effluent from the sewage applied to the trenches in the field, found in the wells, though containing but three per cent. of the impurity of the sewage, is not so well purified by nitrification as the effluent from a trench in similar material in Tank No, 4, where less than one per cent. of the impurity remains. This may be due to the fact that the material in the field is not underdrained. It is very fine sand, resting in water, which keeps a greater portion of the depth, down to which water would stand in the well, more completely saturated than in Tank No. 4, which is completely underdrained; and thus renders this material in the field more nearly in the condition of No. 4 in the first year, when it was kept too wet to nitrify satisfactorily.

Distribution of the Sewage through the Ground.

The quantity of land, through which filters the sewage applied to the trenches, varies with the condition of the surface of the trenches, and this depends upon the frequency of cleaning them.

After the wells were dug and samples were obtained, the surfaces of the trenches were for a time cleaned once a month, by removing one-quarter inch in depth of sand and sediment; but from the first of November to the middle of April, 1889, they were cleaned but once in two months. After this nothing was removed from the surface of No. 7 and No. 8 until the second week in August, and from No. 5 and No. 6 until a month later, — periods of about four months and five months respectively.

After Nov. 20, 1888, and nearly all of the time since the effluent from either of the wells showed by its chlorine that it was principally from sewage, the four trenches have been covered with boards. The boards were put on in the winter to keep snow out of the trenches, and they were kept on through one summer to show the effect of keeping the surface of trenches away from the direct action of sun and wind.

Immediately after the trenches have been cleaned by the removal of one-quarter inch of sand and sediment from the surface, there are a few days in which the 250 gallons applied in half an hour to No. 7 or No. 8 disappear before running more than fifty feet along the trench; in which case the rate of application is about 130,000 gallons to the acre per day. From this condition, and in about ten days, the area is increased and the rate reduced to about 60,000 gallons to an acre per day; and up to this time, after the cleaning, it would appear that most of the effluent would pass near Well No. 1, and only a small part of it near to Well No. 2. As the upper part of the trenches became more clogged by deposit on the surface, the sewage would extend along a greater length, until it reached the lower end, when the sewage from No. 7 or 8 would be distributed at the rate of about 33,000 gallons per acre, and that from No. 5 or 6 at the rate of about 22,000 gallons per acre; and in the whole field the distribution would be at about the rate of 28,000 gallons per acre per day.

As the trenches became more clogged, more sewage accumulated in the lower ends nearer Well No. 2; and perhaps for a short time, before cleaning the trenches, the distribution from the lower part of the trenches amounted to a rate of 100,000 gallons an acre per day. The lower ends and the upper ends of the trenches, which have at times to filter so large an amount, have their periods of rest, before or after the cleaning of the trenches, by which the actual amount of purification required of any section in a year is nearly equalized.

This method of applying sewage to a filtering field of very fine sand by means of narrow trenches filled with coarse sand, though tried here under very unfavorable circumstances, has given satisfactory results, and bids fair to be a means of utilizing areas for filtration with good results, that otherwise would be useless.

The advantages of this method of application are the following: if sewage were applied over the whole surface of such a field, the very fine particles of sand would be taken up by the sewage as it moved along, and be deposited in the interstices, to such an extent as to soon choke up the surface; and in winter the layers of such material near the surface, being continually nearly saturated, would freeze so readily as to allow but little sewage to pass into them.

By making the trenches say one foot wide and two feet deep and five feet apart, and filling them nearly full with coarse sand, this sand will readily receive the sewage and take it below the surface. The area of the surface of fine material on the sides and bottom of the trench is equal to the whole area of the surface of fine material in the field; but the sewage comes to the area in the sides and bottom of the trench freed from its own sediment by straining through the coarse sand; and comes to the fine material without motion over its surface by which its finest particles can be taken up and deposited in its interstices. The underground surface of fine material thus remains permanently open to receive sewage, and the surface of the coarse sand that occasionally will require to be renewed is limited to one-fifth of the area of the whole field. The sewage also is required to keep but one-fifth of the surface of the field free from frost; and the small area to which the sewage is applied can, when necessary, be effectually protected from snow by boards, covering about one-third of the area of the field.

This may be the best method of arranging filtering areas in this climate. With it many areas on sloping land can be utilized without the expense of levelling the surface. The field here used has a slope of about one foot in ten; the trenches are carried in such a direction that they slope from one in fifty to one in a hundred.

Fields covered with soil having a coarse sand or gravel beneath can thus be provided with trenches cut through the poorer filtering material near the surface, and often made very efficient filtering areas, with little expense for levelling and none for underdrains.

Chemical Analyses of Water from Well No. 1.

Date.	Quantity applied. Gallons.	Color.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Height of Water in Well.
1888.											
Sept. 4,	2,500	–	5.50	12.30	.0720	.0190	.0910	0.80	.0300	.0000	5.18
11,	2,500	.30	3.30	10.00	.0200	.0190	.0390	.25	.0150	.0000	5.73
18,	2,500	.00	2.60	12.70	.0410	.0090	.0500	.23	.0150	.0000	5.30
25,	2,500	.00	4.40	28.00	.0050	.0270	.0320	.39	1.0000	.0040	10.97
28,	2,500	.00	3.30	27.60	.0160	.0310	.0470	.20	1.0500	.0320	12.92
Oct. 2,	2,500	.00	3.10	21.00	.0090	.0240	.0330	.41	.7000	.0325	9.66
5,	2,500	.00	2.30	19.60	.0110	.0180	.0290	.33	.4200	.0300	10.46
9,	2,500	.05	2.80	15.20	.0080	.0270	.0350	.32	.2100	.0150	12.62
12,	2,500	.00	3.40	15.10	.0052	.0144	.0196	.29	.1900	.0120	10.69
16,	2,500	.05	2.00	13.70	.0052	.0116	.0168	.37	.2050	.0060	10.02
23,	2,500	.00	1.20	12.90	.0046	.0132	.0178	1.08	.1900	.0040	9.80
30,	2,000	.20	3.00	11.40	.0024	.0122	.0146	1.71	.2000	.0025	11.34
Nov. 6,	2,500	.00	1.10	14.50	.0056	.0126	.0182	2.45	.3000	.0030	9.57
13,	2,500	.05	0.80	14.70	.0056	.0112	.0168	2.51	.1680	.0016	11.82
20,	2,500	.00	.80	13.00	.0040	.0108	.0148	2.54	.1100	.0014	10.80
27,	2,500	.00	1.50	13.70	.0092	.0118	.0210	3.33	.1600	.0006	9.92
Dec. 4,	2,500	.00	4.80	54.40	.0186	.0302	.0488	1.58	.4400	.0008	12.25
11,	2,500	.00	1.50	12.40	.0128	.0112	.0240	1.90	.3000	.0020	9.89
18,	2,500	.00	0.50	14.60	.0096	.0118	.0214	3.00	.1500	.0004	10.81
1889.											
Jan. 1,	2,500	.15	1.10	6.20	.0004	.0108	.0112	.44	.1000	.0000	10.86
8,	2,500	.00	1.70	9.80	.0012	.0096	.0108	1.19	.1700	.0006	10.68
15,	2,500	.05	1.70	10.00	.0008	.0116	.0124	1.17	.1350	.0006	11.19
22,	2,500	.00	1.70	9.70	.0012	.0080	.0092	1.58	.1070	.0005	10.23
29,	2,500	.00	0.80	9.50	.0020	.0106	.0126	1.55	.2000	.0008	9.65
Feb. 5,	2,500	.05	1.30	11.00	.0030	.0070	.0100	1.80	.1600	.0006	8.57
12,	2,500	.10	1.20	14.20	.0146	.0138	.0284	4.00	.0350	.0004	8.30
19,	2,500	.10	0.80	15.00	.0170	.0106	.0276	4.02	.0450	.0006	8.06
26,	2,500	–	1.20	15.60	.0182	.0114	.0296	4.27	.1000	.0004	7.44
Mar. 5,	2,500	.00	0.50	17.10	.0250	.0070	.0320	4.08	.1800	.0006	7.30
19,	2,500	.10	1.10	17.20	.0170	.0120	.0290	3.48	.1200	.0004	9.72
April 2,	2,500	.05	0.50	15.90	.0106	.0096	.0202	3.38	.3600	.0010	9.72
9,	2,500	.00	0.90	16.60	.0050	.0082	.0134	3.25	.3200	.0012	10.09
23,	2,500	.00	3.20	18.00	.0234	.0176	.0410	3.36	.5500	.0020	9.89
May 28,	2,500	.00	1.90	16.80	.0440	.0240	.0680	3.95	.6000	.0014	7.89
June 11,	2,500	.00	1.10	19.10	.0600	.0210	.0810	4.36	.7000	.0020	8.14
July 23,	2,500	.00	3.50	23.80	.0460	.0120	.0580	5.29	1.2000	.0024	7.95
Aug. 13,	2,500	.00	2.50	25.30	.1600	.0310	.1910	6.15	.7000	.0150	6.81
20,	2,500	.00	–	–	.3900	.0340	.4240	6.40	.0800	.1300	6.74
27,	2,500	.00	–	–	.4660	.0720	.5380	6.77	.0800	.0080	6.02
Oct. 30,	2,500	–	–	–	.0060	.0180	.0240	5.29	.1900	.0030	7.80

To Oct. 9, 1888, water generally distinctly turbid and with more or less sediment. Oct. 10 to Feb. 1, 1889, slightly turbid and with slight sediment; February 1 to April 9, decidedly turbid and with considerable sediment; thereafter slightly turbid, and after June but a slight sediment.

One foot of water generally pumped from well in the afternoon previous to day on which sample was collected.

July 16, 1889, there was no water in the well.

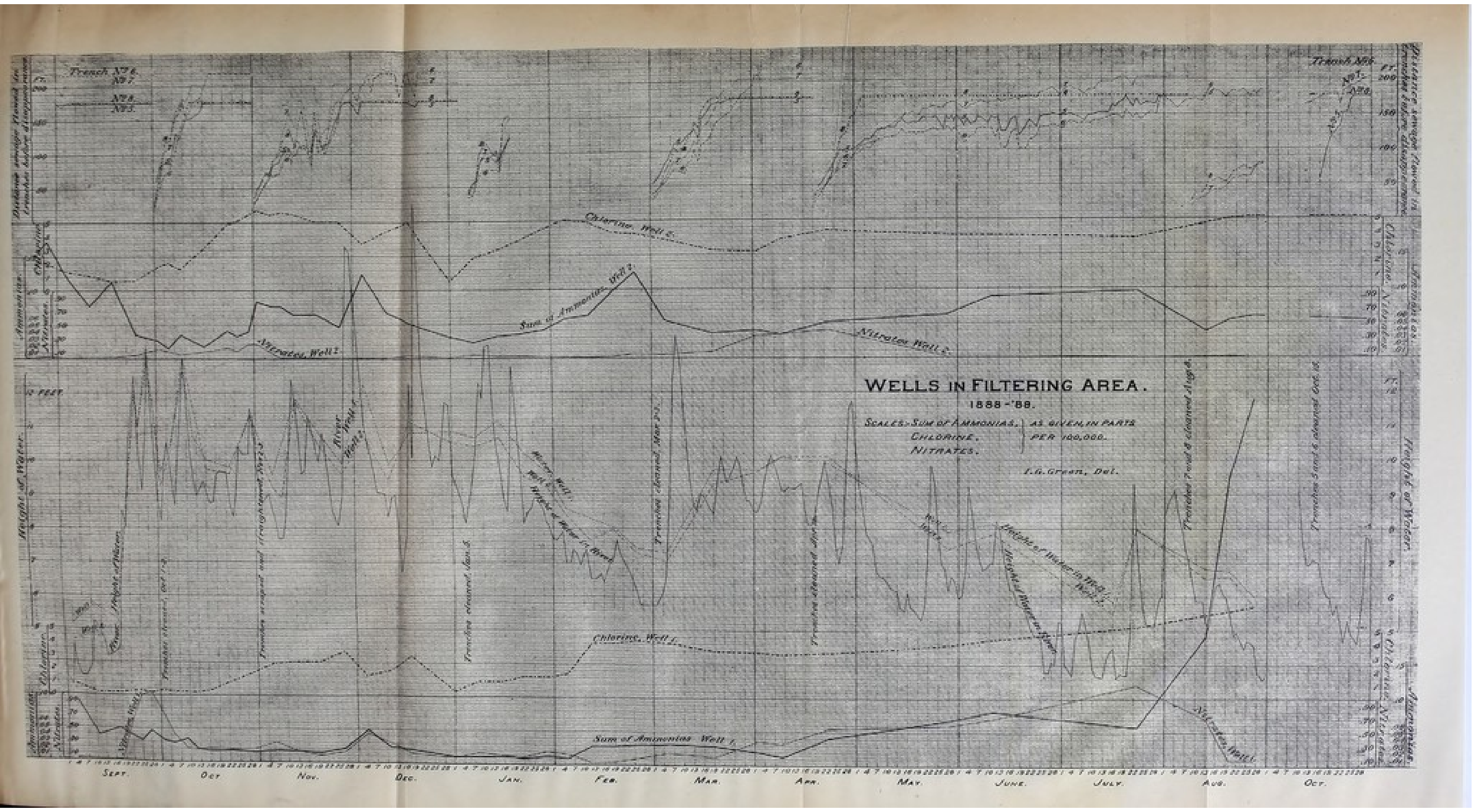
Chemical Analyses of Water from Well No. 2.

Date	Quantity applied. Gallons.	Color.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Height of Water in Well.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	
1888.											
Aug. 14,	2,500	.10	2.00	4.90	.0512	.0372	.0884	0.83	.0150	.0002	-
21,	2,500	.00	5.00	27.40	.0816	.0566	.1382	2.57	.0100	.0001	-
28,	2,500	.20	6.70	29.70	.1160	.0560	.1720	2.00	.0300	.0004	-
Sept. 4,	2,500	-	3.40	29.30	.0960	.0230	.1190	1.40	.0200	.0002	4.68
11,	2,500	.30	6.40	33.60	.0400	.0370	.0770	1.10	.0200	.0000	4.88
18,	2,500	.30	5.80	37.40	.0840	.0290	.1130	0.71	.0200	.0000	5.15
25,	2,500	.00	4.30	41.70	.0020	.0330	.0350	.74	.0500	.0000	10.98
Oct. 2,	2,500	.40	2.20	24.10	.0040	.0220	.0260	1.78	.1420	.0006	9.24
5,	2,500	-	2.40	28.20	.0012	.0142	.0154	2.02	.1000	.0024	10.24
9,	2,500	.20	4.30	23.20	.0020	.0330	.0350	1.60	.0550	.0050	13.03
16,	2,500	.10	3.20	42.10	.0004	.0166	.0170	3.10	.1000	.0030	9.75
23,	2,500	.05	1.70	51.10	.0216	.0196	.0412	4.90	.1540	.0040	9.61
26,	2,500	.10	5.60	30.00	.0134	.0196	.0330	5.05	.1120	.0045	10.43
30,	2,500	.10	3.90	50.30	.0224	.0164	.0388	5.59	.2100	.0035	11.36
Nov. 2,	2,500	.10	2.50	48.60	.0590	.0248	.0838	5.93	.2100	.0325	10.15
6,	2,500	.00	1.00	52.90	.0540	.0230	.0770	5.58	.0900	.0130	9.20
9,	2,500	.05	2.30	54.50	.0540	.0230	.0770	5.73	.0130	.0000	8.92
13,	2,500	.05	1.60	56.20	.0430	.0220	.0650	5.64	.0140	.0000	11.75
20,	2,500	.10	2.00	53.30	.0370	.0280	.0650	5.00	.0140	.0000	10.46
27,	2,500	.10	1.50	52.70	.0190	.0280	.0470	5.04	.0200	.0000	9.59
Dec. 4,	2,500	-	4.00	43.20	.0700	.0540	.1240	3.40	.0130	.0000	10.75
11,	2,500	.10	1.30	42.80	.0360	.0310	.0670	4.31	.0150	.0000	9.44
18,	2,500	.10	1.50	54.00	.0360	.0160	.0520	5.04	.0400	.0000	11.15
1889.											
Jan. 1,	2,500	.25	1.00	8.50	.0130	.0180	.0310	.62	.0160	.0002	10.54
8,	2,500	.30	1.30	27.60	.0114	.0120	.0234	2.37	.0500	.0002	10.41
15,	2,500	.20	1.50	31.90	.0148	.0172	.0320	2.90	.0230	.0000	10.67
22,	2,500	.10	0.90	42.80	.0174	.0180	.0354	3.69	.0240	.0006	9.53
29,	2,500	.05	1.40	44.00	.0242	.0166	.0408	4.42	.0200	.0000	9.22
Feb. 5,	2,500	.10	1.60	50.00	.0430	.0140	.0570	5.08	.0120	.0000	8.20
12,	2,500	.50	1.30	50.30	.0450	.0170	.0620	4.90	.0050	.0000	7.66
19,	2,500	.10	1.20	49.50	.0720	.0240	.0960	4.15	.0200	.0002	7.97
26,	2,500	.25	2.60	47.20	.0700	.0550	.1250	4.05	.0600	.0000	7.31
Mar. 5,	2,500	.10	5.40	43.30	.0470	.0080	.0550	3.64	.0500	.0006	7.01
19,	2,500	.20	1.20	35.10	.0230	.0130	.0360	2.83	.0900	.0012	9.31
April 2,	2,500	.05	0.90	39.60	.0230	.0170	.0400	2.73	.3200	.0024	9.69
9,	2,500	.05	1.20	35.80	.0210	.0130	.0340	3.62	.3400	.0036	10.11
23,	2,500	.15	1.80	40.10	.0300	.0220	.0520	4.25	.4000	.0050	10.11
May 28,	2,500	-	2.50	41.20	.0320	.0310	.0630	3.90	.0200	.0000	7.41
June 11,	2,500	.90	3.60	42.30	.0560	.0330	.0890	3.85	.0200	.0000	7.85
July 23,	2,500	.80	4.40	38.20	.0720	.0240	.0960	3.67	.0000	.0006	7.09
Aug. 13,	2,500	-	3.80	58.20	.0170	.0208	.0378	4.67	.0100	.0000	6.53
20,	2,500	-	-	-	.0310	.0234	.0544	5.00	.0100	.0000	6.59
27,	2,500	-	-	-	.0340	.0264	.0604	5.17	.0000	.0000	5.73
Oct. 20,	2,500	-	-	-	.0258	.0284	.0542	5.12	.0100	.0000	8.06

Water generally distinctly turbid, except from Nov. 9 to 27, 1888, and during January, 1890, when it was only slightly so. It generally contained considerable sediment throughout the whole time.

One foot of water generally pumped from well in the afternoon previous to day on which sample was collected.

July 16, 1889, there was very little water in well.


WELLS IN FILTERING AREA.
1888-'89.
SCALES: SUM OF AMMONIAS, CHLORINE, NITRATES. AS GIVEN, IN PARTS PER 100,000.
I. G. Green, Del.
Chlorine, Well 2.
Sum of Ammonias, Well 2.
Nitrates, Well 2.
Chlorine, Well 1.
Sum of Ammonias, Well 1.
Nitrates, Well 1.
Height of Water.
Trench No. 6.
Trench No. 5.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY.
JUNE.
JULY.
AUG.
OCT.

The sands with which we have experimented and have obtained varying but satisfactory purification through nitrification, already reported, have varied in size of grains from coarse mortar-sand to the finest sand we are likely to find in our valleys.

When these experiments were undertaken, it was commonly thought by experimenters that soil was an essential part of a good filter. We have found that sands, from the coarsest to the finest, without soil, when treated by a method adapted to the capacity of each, have given very satisfactory results.

In order to determine the advantages and disadvantages of soil in a filter, we will first learn what can be accomplished with a large filter made entirely of garden soil.

FILTER TANK No. 5.

Physical Characteristics.

This tank in the field, about seventeen feet in diameter and six feet deep, had the usual underdrains, and the bottom covered with coarse gravel, and this with finer gravel and coarse sand, making a depth of about seven inches; above which was a depth of five feet of fine garden soil.

A physical analysis gives the following results: —

	Approximate Diameter of Grains, in Inches.	Percentage of the Whole.
Coarser than sieve No. 2,	–	1
Between sieve No. 2 and No. 4,	–	4
Between sieve No. 4 and No. 10,	–	4
Between sieve No. 10 and No. 20,	–	6
Between sieve No. 20 and No. 40,	0.020 to 0.040	7
Between sieve No. 40 and No. 55,	0.012 to 0.020	9
Between sieve No. 55 and No. 70,	0.010 to 0.012	5
Between sieve No. 70 and No. 100,	0.008 to 0.010	8
Between sieve No. 100 and No. 140,	0.005 to 0.008	10
	0.003 to 0.005	22
	0.001 to 0.003	20
	0.0 to 0.001	4

This soil contained much more organic matter than the sands that have been used. The loss on heating to redness was 5.77 per cent., which is about five times that in No. 4. The grains of quartz or other material insoluble in strong acid, in two hours, amounted to 88.88 per cent. Of the parts dissolved, alumina formed 2.67 per cent. of the whole, or twice that in No. 4, and oxides of iron and manganese formed 2.06 per cent. There was 0.06 of one per cent. of lime. The specific gravity of the solid particles is 2.52. When packed dry, the specific gravity of the mass is 1.28, and the air space 49 per cent.; but, packed as it was in the tank by being thrown scattering into water, its water space was found to be about 44 per cent. of its volume.

It is to be noticed that this garden soil, though not as fine as the sand of No. 4, is a remarkably fine soil. Fifty-six per cent. of it would go through a sieve having 100 meshes to an inch; and one-quarter of its particles are less than 0.003 inch in diameter.

Besides this fineness, the particles of organic matter soften by water and fill up the interstices between the coarser particles, and make it less pervious to water than would be the same sized grains of clean sand. The increased amount of alumina may have a similar effect.

This tank of garden soil first received sewage Dec. 27, 1887; since which time the rate of flow, in gallons per acre per day, has been for each month as follows: —

January, 1888,	19,200	December, 1888,	4,000
February, 1888,	14,200	January, 1889,	4,200
March, 1888,	26,800	February, 1889,	3,800
April, 1888,	30,100	March, 1889,	5,200
May, 1888,	29,000	April, 1889,	6,400
June, 1888,	19,600	May, 1889,	8,000
July, 1888,	15,600	June, 1889,	7,400
August, 1888,	10,600	July, 1889,	7,200
September, 1888,	9,600	August, 1889,	8,400
October, 1888,	8,800	September, 1889,	7,400
November, 1888,	6,800	October, 1889,	7,000

Frost interfered with the entrance into the tank of the applied sewage during January, February and March, 1888, very much as in tanks numbered 4 and 7; but, as the effect upon the effluent is not apparent, a summary of changes only will be given.

On January 12 two rings were cut out, as in No. 2, and filled with coarse sand. Frost was then 9 inches deep. This increased to 24 inches on February 3, and was 22 inches deep on February 13. Five holes were cut through the frost, to admit sewage, on January 24; and new holes were cut January 26, February 3, 13, 24, and March 3, and 5. On February 17 the ice was all cut and removed from the surface, and a trench two inches deep cut into the sand of the outer ring. Before applying sewage in the morning, the ice and sewage remaining over from the previous day were often taken from the surface and thrown away, during February and March.

The temperature of the sewage when applied was like that recorded for No. 1 and No. 2. The temperature of the effluent was 37° to 39° in February, 36° to 38° in March, and 38° to 43° in April. In May it reached 54°, in June 66°, in July 69°, and in August 70°. In September it was at first 70°, and fell to 61°. It continued falling in October to 54°, and in November to 47°.

From Nov. 22, 1888, to March 12, 1889, a canvas covering was over the tank, to exclude snow. Sewage was applied once in two or three days at a temperature of 45° Fah. The winter was much milder than the previous winter, and frost was but a few inches deep in the tank, — eight inches being the greatest depth found, and this over but a small section. The effluent was at all times above 39° Fah. Generally, between December and March, it was between 40° and 43°.

The quantity of about 30,000 gallons per acre, applied daily, disappeared from the surface during April, 1888, within six hours after its application; but in the latter part of May it did not always disappear in twenty-four hours. As the surface remained covered, the quantity applied was, after the middle of June, reduced to 20,000 gallons per acre per day; but this also accumulated, and, during the week previous to July 18, no sewage was applied. Some remained upon the surface five days, and, a few hours after it disappeared from the surface, the flow from the outlet ceased.

From examinations, made later in the season, of the quantity of water held by this fine material, it is probable that, at this time, when the flow from the outlet had ceased, the whole filter was completely saturated with liquid, entirely excluding air; except, it may be, within two or three inches from the top, where there was probably less than one-quarter as much air as water.

The surface appearing very much choked by a fine deposit from sewage, one-half inch in depth of the top of the filtering material was removed on July 18; after which the same quantity of 20,000 gallons per acre per day was applied for two weeks, or until August 2; but, this accumulating on the surface, none was applied for five days, and then the quantity was reduced to 10,000 gallons per acre per day. This disappeared in a few hours, except when it rained, when the surplus was siphoned off the top.

During this month, when 10,000 gallons per acre per day were being applied, and the movement of water within the filter was so slow that any particle of water applied to the surface would require seventy days to go through the filter, the impurities of the effluent reached, and finally exceeded, those of the applied sewage.

The removal of the half inch in depth of soil from the tank in July was the only change made in the surface during the first year, after the frost was out in the spring. The surface has generally been uncovered a part of the time between applications of sewage, except in June and July, 1888.

From June 26 to July 28, a cap was on the outlet pipe, with a short, bent glass tube, forming a trap, which allowed liquid to flow out continually, but prevented air entering the underdrains. At other times air has been free to enter.

The application of 50 gallons a day, which was at the rate of 10,000 gallons per acre per day, was continued till Oct. 10, 1888. In the latter part of this period there was but little time when the surface had no water upon it, and the application was changed to 100 gallons three times a week; but, this accumulating on the surface, none was applied in the first four days of November; and from this time till April 17, 1889, 50 gallons were applied three times a week, and the surface was uncovered a large part of the time.

On April 17, 1889, the soil at the surface of the tank was spaded over to the depth of about nine inches; and after this, until November, 1889, 100 gallons were applied on three days in the week, and water was on the surface less than half of the time.

A table of chemical analyses of the sewage applied to this tank may be found with the tables of Tank No. 1. The chemical analyses of the effluent are given in a table at the end of this section.

Before sewage was applied to this filter, Dec. 26, 1887, the chlorine of the effluent, which came from the application of water with chlorine at about 0.20 parts per 100,000, was from 0 32 to 0.66 parts. After sewage was applied, the chlorine of the effluent exceeded 0.66 parts, on January 15; and afterward continually increased, until, on February 9, it became about equal to that of the sewage first applied.

This indicates that some liquid from the sewage reached the bottom of the tank January 15, when 1,962 gallons of sewage had been applied, but came down in small areas, and was much diluted with water coming through the soil in other areas; and that the water that was previously in the tank was not all pressed out until February 9, when 4,262 gallons of effluent had passed out after the first application of sewage.

From other experiments made with this material, it appears to have a water space of about 44 per cent. of its volume; and to be, in these experiments, so nearly saturated as to be continually within one or two per cent. of complete saturation below the upper five inches of its depth; and above this to contain a varying amount of water, which may average about three-quarters of complete saturation. The quantity of water ordinarily contained in the material of this tank is, from these results, estimated to be about 3,500 gallons; and in the following statements the effluent is compared with the sewage which was applied long enough before to have pushed out 3,500 gallons. The time required for any particle of sewage to pass through the filter has been from three weeks to five months, depending upon the amount of sewage applied daily.

Nearly all of the Ammonia Applied was Stored for Two Months, and a Part of it for Eleven Months; after which more Came Off than was Applied.

While the chlorine of the effluent indicates that some liquid from the sewage reached the outlet by January 15, and that all of the effluent was from sewage on February 9, still, the ammonias of the effluent were no higher than when water had been passing through the filter, until March 8; that is, up to the latter date, the soil held back the ammonias, — both the free, and the albuminoid ammonia, — so that they did not reach the bottom. That part of the ammonia which did not escape into the air must have been stored in the soil through two months, or while more than 6,000 gallons of sewage entered the tank.

From March 6, when the free ammonia consisted of 0.0720 parts, and the albuminoid ammonia of 0.0590 parts, per 100,000, both increased together, — slowly at first, and then more rapidly, — until, in August, 1888, both exceeded those of the sewage. The free and albuminoid ammonia of the effluent averaged for the month of August, 1.8200 parts and 0.4113 parts respectively, while these of the sewage then coming through averaged 1.5408 parts and 0.3415 parts respectively. The effluent then contained 19 per cent. more ammonia than the sewage from which it came. It was then evidently taking with it some of the ammonia which had previously been stored in the filter.

In the following month both ammonias of the effluent increased, and both were greater than those of the sewage, — the free being 19 per cent., and the albuminoid 7 per cent., greater.

In October the free ammonia of the effluent averaged 3.1678 parts, being 12 per cent. greater than that of the sewage; but the albuminoid ammonia decreased from 0.4276 parts, for the previous month, to 0.3356 parts for this month, while that of the sewage increased to 1.5783 parts.

During the next seven months the quantity of effluent averaged but 5,500 gallons per acre per day. The sum of the ammonias of the effluent decreased, nearly with the decrease of those of the sewage, from 3.4650 parts in November to 2.2350 parts in May, and averaged eleven per cent. in excess of those of the sewage.

One Step in Purification taken for a Time.

The albuminoid ammonia decreased from 0.3000 parts in November, 1888, to 0.2150 parts in May, 1889, averaging 0.2430 parts, — which was only 48 per cent. of that of the sewage, — while the free ammonia averaged 32 per cent. more than that of the sewage; indicating that, during this period, in the long time of four months or more which it took any particle of sewage to pass from the top to the bottom of this filter, about one-half of the albuminoid ammonia of the entering sewage was converted to free ammonia.

It appears that during those months enough oxygen entered the upper part of the tank or was provided by the oxide of iron within the tank, to combine with enough carbon to liberate one-half of the combined nitrogen, but not enough oxygen to combine with this and form nitric acid or nitrates. Thus one step in purification was during that time taken by a part of the nitrogenous organic matter by which it became inorganic.

The averages of the chemical analyses of the effluent from Tank No. 5, for each of the months since sewage was applied, and of the sewage which produced the effluent, are given, in parts per 100,000, in the following table.

The table also contains the daily number of gallons of effluent, which, multiplied by 200, will give the number of gallons which, at the same rate, would have been filtered upon an acre. It also contains the number of bacteria counted in a cubic centimeter of the effluent, as observed once or twice a week for the two years.

The percentages which the residue on evaporation and the ammonias of the effluent are of those of the sewage, are also given for each month; and the temperature of the effluent is given.

Monthly Averages of Daily Results with Tank No. 5.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature.	Number of Bacteria per Cubic Centimeter.
1888.												
Dec. 26, '87–Jan. 16, '88, . .	Effluent,	104	3.21	7.28	0.0665	0.0614	0.1279	0.50	.012	–	–	43
Dec. 27, '87, .	Sewage,	–	12.60	19.60	0.8800	0.3900	1.2700	2.98	.007	–	–	–
Jan. 17-31, .	Effluent,	90	3.90	8.53	0.0630	0.0498	0.1128	1.44	.014	–	38°	60
		–	31	44	7	13	9					
Dec. 28–Jan. 16,	Sewage,	–	27.36	25.11	1.5200	0.6333	2.1533	3.17	.006	–	–	–
February, . .	Effluent,	71	6.47	10.97	0.0609	0.0532	0.1141	2.82	.011	–	37°	34
		–	24	44	4	8	5					
Jan. 17–Mar. 8, .	Sewage,	–	25.68	17.28	0.8763	0.5259	1.4022	2.39	.007	–	–	–
March, . .	Effluent,	134	8.44	13.26	0.0925	0.0786	0.1711	2.79	.009	.0003	37°	154
		–	33	77	11	15	12					
Mar. 9–Apr. 3, .	Sewage,	–	29.46	36.22	0.7963	0.5369	1.3332	2.31	.009	–	–	–
April, . .	Effluent,	150½	8.41	15.01	0.1383	0.1233	0.2616	2.33	.010	.0006	40°	244
		–	29	41	17	23	20					
Apr. 4–Apr. 29,	Sewage,	–	28.98	36.52	0.9265	0.6592	1.5857	3.40	.006	–	–	–
May, . . .	Effluent,	145	12.45	22.28	0.1973	0.1435	0.3408	3.71	.021	.0005	49°	81
			43	61	21	22	21					
Apr. 30–May 26,	Sewage,	–	46.71	50.86	1.3350	1.4464	2.7814	3.92	.009	.0000	–	–
June, . . .	Effluent,	98	21.02	39.19	0.4678	0.2266	0.6944	4.32	.012	.0002	60°	56
			45	77	35	16	25					
May 27–June 16,	Sewage,	–	18.26	24.50	1.3233	0.3827	1.7060	4.50	.007	.0007	–	–
July, . . .	Effluent,	78	35.70	62.86	1.0829	0.3323	1.4152	5.43	.011	.0000	67°	32
			196	257	82	87	83					
June 17–July 5,	Sewage,	–	15.38	25.90	1.5408	0.3415	1.8823	5.02	.008	.0003	–	–
August, . .	Effluent,	53	39.89	55.58	1.8200	0.4113	2.2313	6.11	.020	.0000	69°	7,026
			259	215	118	120	119					
July 6–July 26,	Sewage,	–	16.00	27.16	2.0350	0.3980	2.4330	7.43	.011	.0000	–	–
September, .	Effluent,	48	27.13	55.83	2.4289	0.4276	2.8565	7.32	.021	.0000	66°	1,883
			170	206	119	107	117					
July 27–Aug. 16,	Sewage,	–	77.55	71.87	2.8234	1.5783	4.4017	6.34	.009	.0000	–	–
October, . .	Effluent,	44	22.42	55.40	3.1678	0.3356	3.5034	9.72	.024	.0000	58°	50
			29	77	112	21	80					
Aug. 17-Sept. 8,	Sewage,	–	67.45	79.19	2.7718	2.0106	4.7824	10.47	–	.0000	–	–
November, .	Effluent,	34	19.29	53.71	3.1650	0.3000	3.4650	9.75	.030	.0000	52°	36
			29	68	114	15	72					
Sept. 9–Sept. 19,	Sewage,	–	22.37	39.54	1.9543	0.5071	2.4614	9.53	–	.0000	–	–
December, .	Effluent,	20	12.34	42.54	2.8400	0.2557	3.0957	7.54	.022	.0000	43°	161
			55	108	145	50	126					
1889.												
Sept. 20–Oct. 2,	Sewage,	–	28.62	47.39	1.8533	0.7456	2.5989	6.79	–	.0000	–	–
January, . .	Effluent,	21	12.80	42.09	1.5867	0.2222	2.8089	6.37	–	.0000	42°	16
			45	89	140	30	108					
Oct. 3–Oct. 13, .	Sewage,	–	17.17	33.06	2.2271	0.4657	2.6928	8.71	–	.0000	–	–
February, . .	Effluent,	19	12.83	38.40	2.4914	0.2614	2.7528	4.93	–	.0000	40°	25
			75	116	112	56	102					
Oct. 14–Nov. 2.	Sewage,	–	17.75	28.70	2.3313	0.4112	2.7425	4.78	–	.0000	–	–
March, . .	Effluent,	26	12.56	38.24	2.2800	0.2320	2.5120	4.27	.010	.0000	41°	24
			71	133	98	56	92					

Monthly Averages of Daily Results with Tank No. 5 — Concluded.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature.	Number of Bacteria per Cubic Centimeter.
Nov. 3–Dec. 1, .	Sewage,	–	17.12	30.93	1.7308	0.4159	2.1467	4.75	.010	.0000	–	–
April, . .	Effluent,	32	11.70	35.50	2.4400	0.2150	2.6550	3.83	.015	.0000	46°	9
			68	115	141	52	124					
Dec. 2–Feb. 1, .	Sewage,	–	12.84	26.23	1.1521	0.2917	1.4438	4.30	.021	.0024	–	–
May, . . .	Effluent,	40	14.00	35.80	2.0200	0.2150	2.2350	3.47	.005	.0000	56°	75
			109	136	175	74	155					
Feb. 2–Mar. 23,	Sewage,	–	11.02	20.48	1.2457	.3211	1.5668	3.54	.016	.0120	–	–
June, . . .	Effluent,	37	15.87	35.60	3.2000	.3550	3.5550	3.92	.000	.0000	64°	8
			144	174	257	111	227					
Mar. 24–Apr. 29,	Sewage,	–	13.27	26.48	1.9680	.4527	2.4207	6.06	.008	.0011	–	–
July, . . .	Effluent,	36	15.90	41.30	4.8100	.3850	5.1950	4.55	.000	.0000	68°	10
			120	156	244	85	215					
Apr. 30–June 1,	Sewage,	–	16.75	24.42	2.0109	.4600	2.4709	4.53	.000	.0000	–	–
August, . .	Effluent,	42	19.60	43.90	3.6500	.3967	4.0467	4.66	.000	.0000	68°	11
			117	180	182	86	164					
June 2–July 1, .	Sewage,	–	25.91	27.20	2.5720	.5890	3.1610	5.14	.000	.0000	–	–
September, .	Effluent,	37	18.00	45.60	4.6150	.4700	5.0850	2.30	.000	.0000	66°	9
			69	168	179	80	161					
July 2–31, . .	Sewage,	–	23.94	33.28	2.2769	.6077	2.8846	5.50	.000	.0000	–	–
October, . .	Effluent,	35	–	–	4.1133	.4033	4.5166	3.02	.000	.0000	56°	4
					181	66	157					

Stored Nitrogen drawn out of the Filter.

In June, 1889, the effluent was from sewage that had been applied to the surface in February and March; but the ammonias of the effluent were two and a quarter times those of the sewage, and were higher than those of the sewage had been at any time since the preceding September, in which time 9,000 gallons of effluent had passed out, or the liquid in the tank had been renewed nearly three times. It must follow that the large excess of ammonia then coming out was from nitrogenous matter stored in the tank during the first year. In this month, as well as in August and September, 1888, the albuminoid ammonia was greater than that of the applied sewage; and these are the only months in the two years when this has been the case. It was 11 per cent. greater in this month, and constituted 0.3550 parts per 100,000, while that in the sewage formed 0.3211 parts. The free ammonia in this month formed 3.2000 parts, and was 257 per cent. of that of the sewage.

In July the ammonias were still higher, averaging 5.1950 parts, or 215 per cent. of those of the sewage. The free ammonia averaged 4.8100 parts, or 244 per cent. of that of the sewage; and the albuminoid ammonia averaged 0.3850 parts, or 85 per cent. of that of the sewage.

In the three following months, August, September and October, 1889, the effluent was of quite constant quality. The ammonias were 61 per cent. higher than those of the sewage. The free ammonia averaged 4.1261 parts, which was 80 per cent. higher than that of the sewage; and the albuminoid ammonia averaged 0.4233 parts, or 77 per cent. of that of the sewage.

During the last fifteen months, since the ammonias of the effluent became equal to those of the sewage, 14 per cent. more nitrogen has come from the tank in effluent than has been applied to it in sewage. In this time the free ammonia of the effluent has averaged 154 per cent. of that of the sewage, and the albuminoid ammonia has averaged 67 per cent. of that of the sewage.

In the last six months more stored nitrogenous matter is being removed than formerly. The effluent, though containing more nitrogenous matter than the sewage, does not contain more nitrogenous organic matter. Its organic nitrogen indicated by the albuminoid ammonia, is but one-sixth of the total nitrogen, while in the sewage the organic nitrogen is one-third of the total nitrogen. It has a strong odor and great turbidity. The turbidity is not like the turbidity of sewage, but is due in great part to iron dissolved from the soil, which, upon exposure to the air, oxidizes, forming iron-rust; but when this has settled there still remains an opalescence that is characteristic of sewage.

Garden soil, as fine as this, is useless as a filter for purifying sewage.

On account of the large amount of oxide of iron and manganese dissolved out of this soil, the determinations of the loss on ignition are regarded as giving no definite indication of the organic matter in the effluent.

The nitrates have been low throughout the twenty-two months,— probably not higher than those of the applied sewage; the figures obtained range from 0.000 to 0.040 parts, but, on account of the large amount of organic matter and of oxide of iron and manganese, these results are uncertain. There appears to have been a very slight nitrification in the fall of 1888, but none in the summer and fall of 1889.

Biological Examination of Effluent from Tank No. 5.

During the greater part of the time no microscopic organisms have been found in the effluent of Tank No. 5. On five occasions

Leptothrix, in numbers averaging 40 in a gallon, has been found. On three occasions, Ciliate Infusoria to the number of 31, Paramecium to the number of 13, and Amœba to the number of 4, have been found.

On July 29, 1889, in order to determine if these organisms were living in the underdrains, a hole was bored into the side of the tank, and a glass tube pushed up one of the underdrains, and the water and detached sediment were drawn into it. The material withdrawn was brown, dirty sediment, flocculent and somewhat gelatinous. There appeared under the microscope, besides dirt and iron-rust, tangled masses of mould hyphæ and many bacteria, some living and actively moving; Infusoria abundant, especially living Vorticellæ and other Ciliata, and Monads; large clusters of Leptothrix or Cladothrix in parallel bundles, and Zoöglœa abundant. There were no Algæ or diatoms.

The general appearance indicated that these lived and grew there, and could not recently, nor in their present form, have come through the sand.

On August 13 a sample obtained in a similar way contained a few monads and several moulds.

Bacteria in Effluent of Tank No. 5.

After sewage was applied to the surface, and before any of it reached the outlet, the number of bacteria in the effluent averaged 33. With the first increase of chlorine, indicating that the most advanced particles of the sewage had reached the bottom, the number increased to 95;* and five days later, on January 19, the number reached 118, which was the highest until the middle of March. This slight increase in the number of bacteria from 33 to 118, when sewage first mingled with the water coming out of the tank, — so unlike the result in tanks Nos. 1, 2, 4, 6 and 7, when sewage first came through, in each of which from 24,000 to 387,000 were counted, — indicates the comparatively unfavorable condition for bacteria to survive the passage through this tank, under circumstances which in the other tanks allowed the greatest number to pass through. The highest number, 118, found in the effluent of Tank No. 5, was on the twenty-fourth day after sewage was first applied, when 2,724 gallons had flowed out, and when the chlorine

* See table following table of chemical analyses; also, the preceding table of monthly averages.

indicated that twenty-two per cent. of the effluent was from sewage. The number decreased in one week to 26, and averaged 34 in the month of February and 154 in the month of March. The temperature of the effluent was then 37° Fah. In April the temperature was a little warmer, rising from 38° to 43°, and the number of bacteria averaged 244. In May, with temperature from 45° to 53°, the number was 81. In June the number was 35, until a trap was put upon the outlet, which caused some of the effluent to be held back in the pipe, when the number on the next day was 118; but in eighteen days it gradually fell to 10, on July 17. Again, having held effluent in the pipe thirty-six hours, the number rose to 128; but two days later it was 14. The average number for June, 1888, was 56, and for July, 32. Up to this time sewage has been from 23 to 50 days in passing through the tank. The average number found in the effluent for two years — excepting in August and September, 1888 — was 54; and it is most probable that these did not come down through the sand, but grew in the underdrains. Through August the number increased from 10 to 28,620; and through September decreased quite regularly to 190, and continued decreasing till October 16, when it was 27.

No cause is seen for this great rise and fall, unless it be in the increase in temperature in the underdrains from 69° to 71°, and the subsequent fall to 58°. The very high numbers were all when the effluent was from 66° to 71°, the highest temperature for the season; and it may be that some species of bacteria find this temperature particularly favorable for their growth.

There was no corresponding rise when the same temperature was reached in the second year.

The largest number counted was on August 21. The effluent of that day must have been about 52 days in passing through, and been applied about the last day of June. Nothing was observed at the surface of the tank at that time to which an increase in bacteria in the effluent can be attributed. In the third week after that time no sewage was applied, and that upon the surface disappeared; and at the end of this week one-half inch in depth of the surface of the filter was removed. As soon as the sewage disappeared from the surface, the effluent stopped; hence the material did not, at this time, become so drained that the sewage of the next application could flow down more rapidly than usual, and thus carry down bacteria in an unusual manner. While this change may, in some way not apparent, have caused the number of bacteria to increase, the most probable cause is thought to be a rapid increase of growth in the underdrains, which continued while the conditions were favorable.

In October, 1888, the average number was 50; in November, 36; and in December, 161.

In the second year — January to October, 1889 — the monthly averages varied from 4 to 75, and averaged 19.

On July 27, 1889, three counts of samples taken at different hours in the day gave the following numbers: 0, 5 and 67. On July 29, four counts gave 13, 3, 0 and 0.

To determine if these irregular numbers were due to growths in the underdrains, a sample of the water and sediment drawn from the underdrain, as described above, was examined, and found to contain 3,700 bacteria in a cubic centimeter.

On Aug. 10, 1889, a sample from the underdrains, taken 8 feet from the outlet, contained 2,000 bacteria per c. c., when the effluent contained only 5 per c. c. On August 13 the number found from one to three feet from the outlet was 5,200 per c. c.

From these results it appears that the small, irregular numbers found probably come from growth in the underdrains, and not from bacteria coming down through the filter.

On August 16, immediately after a count gave 2 bacteria in the effluent, twelve gallons of water which contained 3 bacteria per c. c. were forced into the underdrain. Upon coming out with a rapid velocity the water contained 69 bacteria per c. c. A second twelve gallons brought out 49 bacteria per c. c.; and a third twelve gallons gave an average of 33 per c. c.

These experiments also show that bacteria were growing in the underdrains, and came out when disturbed.

Although we have not proved that none have come through the filter in the past year, this is probably the case; and the average number, 19, found in the effluent, have probably grown in the underdrains, instead of being the remnant of half a million applied daily to the surface.

The unfavorable circumstances which cause their extermination to be nearly if not quite complete, are, in this tank, independent of nitrification, for no nitrification occurs; and there is abundant food supply, as indicated by excessive ammonias; but the amount of oxygen entering the soil must be exceedingly small, and they are probably as completely deprived of this small amount of oxygen by the process in which the albuminoid ammonia becomes free ammonia as if there were additional oxygen supplied, and this were used in the next step of converting free ammonia into nitrates.

The fact that the effluent from this tank continually contains a considerable amount of protoxide of iron is sufficient evidence that there can be no free oxygen in the lower part of the tank.

The being deprived of oxygen for the long time — three months or more — of the passage is probably the fatal condition.

Conclusions in Regard to Filter No. 5.

This garden soil proves to be entirely unadapted to the purification of sewage, even when applied in small quantities. During the last six months the quantity filtered has been only 7,500 gallons per acre, per day, or less than two and a half times the ordinary rainfall. There has been no nitrification, and the albuminoid ammonia of the effluent has been 82 per cent. of that of the sewage.

It is evident that its continuance of almost entire saturation, even when the intervals between applications are long, prevents sufficient air entering to oxidize but a small percentage of the carbon and none of the nitrogen. Hence its effluent contains nearly as much nitrogenous organic matter as the sewage.

The same qualities that enable the soil to hold water to give sap to the roots of plants prevent the transmission of the needed amount of air to accomplish the purification of sewage in quantities much greater than the ordinary rainfall. The qualities which we have noted in which this differs from No. 4, where nitrification does take place, are not increased fineness, for it is coarser, but an increased amount of organic matter and more alumina and oxide of iron and manganese in form to be readily dissolved by acid.

The long time of the passage and the inability of any free oxygen to pass with the sewage through the soil, appear to cause the death of the bacteria that are applied with the sewage, so that none of them are found in the effluent; and it is most probable that no larger organisms get through.

These results have been obtained in applying sewage to an unusual depth of soil, having unusual fineness. We shall next learn, from Tank No. 6, what may be done in purifying sewage with mixed sand containing some gravel and having no soil, and afterward compare the results with those obtained with similar material in Tank No. 7, having above it a layer of yellow loam and of brown soil, as they are often found in our valleys.

TABLES

OF

CHEMICAL ANALYSES OF THE EFFLUENT,

AND

DAILY OBSERVATIONS

Upon Filter Tank No. 5.

[The chemical results are expressed in parts per 100,000.]

December, 1887.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
26, ...	136	41	-	-	-	-	-	-	-	-	-	-
27, ...	136	112	2.60	7.35	.0708	.0594	.1302	.34	.0080	None.	-	-
28, ...	136	151	-	-	-	-	-	-	-	-	36°	-
29, ...	136	180	3.20	7.15	.0610	.0684	.1294	.36	.0080	None.	35°	-
30, ...	136	101	-	-	-	-	-	-	-	-	34°	-
31, ...	144	75	-	-	-	-	-	-	-	-	34°	-

December 26.—First sewage applied. December 26 and 27.—Two and one-half inches of ice on surface of tank. December 28, 2 inches; December 29, 2½ inches; December 30, 2¾ inches; December, 31, 3 inches.

Total effluent to end of month, 660 gallons.

Filter Tank No. 5 — Continued.

January, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	70	95	3.45	6.40	.0800	.0646	.1446	.36	.0080	None.	34°	-
2, ...	172	86	-	-	-	-	-	-	-	-	35°	-
3, ...	122	86	2.85	7.15	.0792	.0706	.1498	.49	.0090	None.	38°	-
4, ...	82	89	-	-	-	-	-	-	-	-	38°	-
5, ...	110	73	2.60	7.05	.0690	.0690	.1380	.42	.0100	None.	36°	-
6, ...	100	68	-	-	-	-	-	-	-	-	34°	-
7, ...	75	90	-	-	-	-	-	-	-	-	35°	-
8, ...	108	62	3.40	6.75	.0650	.0670	.1320	.63	.0100	None.	35°	-
9, ...	63	60	-	-	-	-	-	-	-	-	35°	-
10, ...	95	54	3.20	7.30	.0630	.0560	.1190	.62	.0180	None.	37°	-
11, ...	-	29	-	-	-	-	-	-	-	-	-	-
12, ...	300	89	3.35	7.15	.0560	.0400	.0960	.53	.0180	Present.	38°	-
13, ...	300	168	3.40	8.60	.0570	.0560	.1130	.54	.0150	.0002	40°	-
14, ...	212	188	-	-	-	-	-	-	-	-	40°	-
15, ...	192	192	4.00	7.90	.0640	.0630	.1270	.72	.0180	None.	40°	-
16, ...	200	192	-	-	-	-	-	-	-	-	40°	-
17, ...	192	192	3.40	8.40	.0580	.0590	.1170	.90	.0100	None.	39°	-
18, ...	238	172	4.10	7.75	.0600	.0550	.1150	1.01	.0150	None.	39°	-
19, ...	180	168	4.05	8.15	.0630	.0370	.1000	1.09	.0100	None.	40°	-
20, ...	190	156	-	-	-	-	-	-	-	-	38°	-
21, ...	158	136	-	-	-	-	-	-	-	-	39°	-
22, ...	148	82	-	-	-	-	-	-	-	-	38°	-
23, ...	105	73	3.45	9.30	.0700	.0488	.1188	1.83	.0150	Present.	39°	-
24, ...	150	49	-	-	-	-	-	-	-	-	38°	-
25, ...	120	61	-	-	-	-	-	-	-	-	38°	-
26, ...	130	53	4.20	8.30	.0590	.0520	.1110	1.77	.0150	Present.	37°	-
27, ...	112	48	-	-	-	-	-	-	-	-	39°	-
28, ...	150	42	-	-	-	-	-	-	-	-	40°	-
29, ...	130	43	-	-	-	-	-	-	-	-	40°	-
30, ...	80	40	4.20	9.25	.0680	.0470	.1150	2.04	.0200	.0006	39°	-
31, ...	120	37	-	-	-	-	-	-	-	-	39°	38°

January 1. — Four inches of ice and snow on surface. January 2. — Two and one-half inches of ice. January 3 and 4. — Three inches of ice and water. January 5. — Two and three-quarters inches of ice. January 6 to 8. — Three inches. January 9 and 12. — Four inches. January 14. — Three-quarters inch. January 17. — One and one-half inches. January 2. — Water all removed from surface. January 12. — Two circular trenches dug in surface and filled with coarse sand; 9 inches of frost present. January 24 to 28. — Sewage applied in from 5 to 7 holes dug through frost. January 26. — Fourteen inches of water in holes when sewage was applied.

Total effluent to end of month, 3,633 gallons.

Filter Tank No. 5 — Continued.

February, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	110	39	-	-	-	-	-	-	-	-	40°	-
2, ...	100	45	4.65	9.45	.0640	.0530	.1170	2.40	.0050	.0003	37°	37°
3, ...	160	69	-	-	-	-	-	-	-	-	43°	-
4, ...	150	92	-	-	-	-	-	-	-	-	39°	37°
5, ...	108	85	-	-	-	-	-	-	-	-	39°	-
6, ...	115	88	6.10	10.20	.0630	.0530	.1160	2.65	.0200	Present.	39°	37°
7, ...	120	90	-	-	-	-	-	-	-	-	43°	37°
8, ...	110	84	-	-	-	-	-	-	-	-	37°	-
9, ...	100	76	6.05	10.35	.0520	.0360	.0880	3.16	.0100	Present.	-	37°
10, ...	125	83	-	-	-	-	-	-	-	-	43°	-
11, ...	125	81	-	-	-	-	-	-	-	-	40°	36°
12, ...	120	74	-	-	-	-	-	-	-	-	45°	-
13, ...	150	83	5.80	10.70	.0590	.0510	.1100	3.12	.0100	Present.	44°	-
14, ...	80	88	-	-	-	-	-	-	-	-	44°	38°
15, ...	150	76	-	-	-	-	-	-	-	-	44°	37°
16, ...	150	81	7.30	10.30	.0590	.0520	.1110	2.85	.0080	Present.	44°	37°
17, ...	100	64	-	-	-	-	-	-	-	-	68°	-
18, ...	150	62	-	-	-	-	-	-	-	-	66°	-
19, ...	150	63	7.30	11.10	.0650	.0570	.1220	2.88	.0100	Present.	54°	-
20, ...	150	60	-	-	-	-	-	-	-	-	44°	38°
21, ...	150	52	6.30	11.30	.0540	.0500	.1040	2.84	.0200	Present	45°	39°
22, ...	150	50	-	-	-	-	-	-	-	-	51°	38°
23, ...	150	57	7.40	11.90	.0580	.0460	.1040	3.02	.0100	Present.	57°	39°
24, ...	150	56	-	-	-	-	-	-	-	-	55°	-
25, ...	150	80	-	-	-	-	-	-	-	-	57°	37°
26, ...	150	62	6.80	11.80	.0670	.0720	.1390	2.88	.0100	Present	62°	39°
27, ...	150	69	-	-	-	-	-	-	-	-	44°	37°
28, ...	150	67	7.00	12.60	.0680	.0620	.1300	2.42	.0100	None.	57°	-
29, ...	150	69	-	-	-	-	-	-	-	-	63°	37°

February 1. — Twenty-two inches of frost and 7 inches of snow and ice on surface. February 3. — Twenty-four inches of frost and 7 inches of ice. February 13. — Twenty-two inches of frost. February 1 to 11. — Generally from 15 inches to 18 inches of water in holes through frost when sewage was applied. February 3. — Two new holes dug. February 13. — One. February 14. — Water all removed from holes. February 17. — Trench cut through ice. Coarse sand, put in trench last month, removed. February 18. — Ice all removed from surface. February 19. — Two inches of ice and water removed. February 20. — Three and one-half inches. February 26. — Water all removed. February 27. — One inch of water. February 28. — One and one-fourth inches of ice. February 29. — One and three-eighths inches. February 24. — Boiling water applied, to thaw frost.

Total effluent to end of month, 5,678 gallons.

Filter Tank No. 5 — Continued.

March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	150	73	–	–	–	–	–	–	–	–	–	62°	37°
2, .	150	76	–	–	–	–	–	–	–	–	–	64°	–
3, .	150	84	–	–	–	–	–	–	–	–	–	66°	37°
4, .	150	67	7.00	13.90	.0720	.0680	.1400	2.44	.0100	.0002	–	60°	37°
5, .	150	79	–	–	–	–	–	–	–	–	–	61°	37°
6, .	150	85	8.30	13.10	.0720	.0590	.1310	2.80	.0100	.0004	–	61°	37°
7, .	200	85	–	–	–	–	–	–	–	–	–	59°	36°
8, .	150	100	9.50	14.30	.0920	.0960	.1880	2.80	.0080	.0001	–	48°	–
9, .	150	101	–	–	–	–	–	–	–	–	24 h.	55°	37°
10, .	150	120	–	–	–	–	–	–	–	–	–	49°	38°
11, .	150	123	8.10	12.90	.1120	.0800	.1920	3.04	.0070	.0001	–	50°	38°
12, .	150	132	–	–	–	–	–	–	–	–	–	58°	37°
13, .	150	128	8.50	12.90	.0920	.0690	.1610	2.60	.0080	.0004	–	52°	–
14, .	150	129	–	–	–	–	–	–	–	–	–	53°	37°
15, .	150	137	–	–	–	–	–	–	–	–	24 h.	52°	–
16, .	150	147	–	–	–	–	–	–	–	–	24 h.	53°	36°
17, .	150	163	–	–	–	–	–	–	–	–	–	55°	36°
18, .	150	139	8.80	12.90	.0960	.0770	.1730	2.80	.0150	.0002	–	51°	36°
19, .	150	159	–	–	–	–	–	–	–	–	–	48°	36°
20, .	150	153	8.90	12.60	.1000	.0830	.1830	3.00	.0100	.0002	–	54°	36°
21, .	150	171	–	–	–	–	–	–	–	–	24 h.	55°	37°
22, .	150	177	–	–	–	–	–	–	–	–	–	54°	37°
23, .	150	173	–	–	–	–	–	–	–	–	–	–	36°
24, .	150	161	–	–	–	–	–	–	–	–	–	51°	37°
25, .	150	147	8.40	13.50	.1040	.0970	.2010	2.82	.0050	.0002	–	50°	37°
26, .	150	156	–	–	–	–	–	–	–	–	24 h.	54°	37°
27, .	150	188	–	–	–	–	–	–	–	–	–	52°	37°
28, .	150	181	–	–	–	–	–	–	–	–	–	52°	37°
29, .	150	178	–	–	–	–	–	–	–	–	–	51°	38°
30, .	150	171	–	–	–	–	–	–	–	–	–	53°	38°
31, .	150	169	–	–	–	–	–	–	–	–	–	53°	38°

Effluent decidedly turbid, with much brown, flocculent sediment, and with color averaging 1.17.

March 1 — One inch of ice removed from surface. March 2. — One-half inch. March 3. — One and one-half inches of water. March 4. — One and three eighths inches of ice. March 5. — Three-fourths inch. March 6. — One-half inch. March 7. — One and one-quarter inches. March 14. — Snow and water all removed. March 18. — One-half inch of ice removed. March 23. — One-quarter inch ice removed. March 28. — Water all removed. March 3. — Two new holes dug through frost. March 5. — One. March 8. — Leak in measuring basin mended.

Total effluent to end of month, 9,830 gallons.

Filter Tank No. 5 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	150	161	-	-	-	-	-	-	-	-	-	41°	38°
2, .	150	187	-	-	-	-	-	-	-	-	-	41°	38°
3, .	150	191	6.90	15.00	.1320	.0940	.2260	2.56	.0150	.0003	-	43°	38°
4, .	150	182	-	-	-	-	-	-	-	-	-	40°	38°
5, .	150	178	-	-	-	-	-	-	-	-	-	43°	38°
6, .	150	194	-	-	-	-	-	-	-	-	-	46°	39°
7, .	-	-	-	-	-	-	-	-	-	-	-	-	-
8, .	-	-	-	-	-	-	-	-	-	-	-	-	-
9, .	-	-	-	-	-	-	-	-	-	-	-	-	-
10, .	150	156	8.60	12.90	.1040	.1110	.2150	2.21	.0150	.0005	4 h. 2 m.	40°	39°
11, .	150	183	-	-	-	-	-	-	-	-	-	42°	39°
12, .	150	160	-	-	-	-	-	-	-	-	-	47°	40°
13, .	150	146	-	-	-	-	-	-	-	-	-	46°	39°
14, .	150	150	-	-	-	-	-	-	-	-	-	43°	39°
15, .	150	142	8.10	13.60	.1320	.1180	.2500	2.20	.0100	.0002	-	45°	40°
16, .	150	128	-	-	-	-	-	-	-	-	5 h. 10 m.	41°	40°
17, .	150	130	7.10	15.00	.1480	.1280	.2760	2.20	.0100	.0008	-	44°	41°
18, .	150	146	-	-	-	-	-	-	-	-	-	45°	40°
19, .	150	131	-	-	-	-	-	-	-	-	4 h. 54 m.	42°	41°
20, .	150	132	-	-	-	-	-	-	-	-	4 h. 48 m.	43°	41°
21, .	300	193	9.80	14.60	.1520	.1340	.2860	2.28	.0050	.0010	-	43°	41°
22, .	-	126	-	-	-	-	-	-	-	-	-	-	-
23, .	150	125	-	-	-	-	-	-	-	-	-	43°	41°
24, .	150	134	8.00	17.80	.1400	.1250	.2650	2.40	.0080	.0010	-	44°	41°
25, .	150	128	-	-	-	-	-	-	-	-	-	42°	42°
26, .	150	126	-	-	-	-	-	-	-	-	-	45°	42°
27, .	150	121	-	-	-	-	-	-	-	-	-	43°	43°
28, .	300	188	10.40	16.20	.1600	.1530	.3130	2.46	.0080	.0006	-	46°	43°
29, .	-	75	-	-	-	-	-	-	-	-	-	-	-
30, .	-	-	-	-	-	-	-	-	-	-	-	-	-

Effluent very decidedly turbid, and generally with much brown, flocculent sediment, and with color averaging 2.06.

April 7. — 5.20 A.M. to April 10, 8.11 A.M., outlet closed. River high. April 10. — Organisms visible to naked eye in sample. April 29. — Outlet closed at 8.42 P.M. River high.

Total effluent to end of month, 13,788 gallons.

Filter Tank No. 5 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	–	–	–	–	–	–	–	–	–	–	–	–
2, ...	–	–	–	–	–	–	–	–	–	–	–	–
3, ...	–	–	–	–	–	–	–	–	–	–	–	–
4, ...	150	138	–	–	–	–	–	–	–	–	45°	45°
5, ...	300	182	10.40	16.40	.1600	.1300	.2900	2.66	.0200	.0005	45°	45°
6, ...	–	93	–	–	–	–	–	–	–	–	–	–
7, ...	150	98	–	–	–	–	–	–	–	–	50°	–
8, ...	150	112	11.10	17.50	.1600	.1300	.2900	3.10	.0300	.0004	48°	47°
9, ...	150	178	–	–	–	–	–	–	–	–	50°	46°
10, ...	150	163	–	–	–	–	–	–	–	–	51°	47°
11, ...	150	159	13.00	20.90	.2000	.1260	.3260	3.90	.0200	.0007	51°	47°
12, ...	300	246	–	–	–	–	–	–	–	–	50°	47°
13, ...	–	–	–	–	–	–	–	–	–	–	–	–
14, ...	–	–	–	–	–	–	–	–	–	–	–	–
15, ...	–	–	–	–	–	–	–	–	–	–	–	–
16, ...	–	–	–	–	–	–	–	–	–	–	–	–
17, ...	150	195	–	–	–	–	–	–	–	–	49°	49°
18, ...	150	181	10.00	23.50	.2160	.1680	.3840	4.34	.0180	.0007	50°	49°
19, ...	300	179	–	–	–	–	–	–	–	–	50°	49°
20, ...	–	140	–	–	–	–	–	–	–	–	–	–
21, ...	150	131	–	–	–	–	–	–	–	–	52°	51°
22, ...	150	123	15.20	27.40	.2320	.1530	.3850	4.06	.0150	.0002	–	50°
23, ...	150	121	–	–	–	–	–	–	–	–	53°	50°
24, ...	150	125	–	–	–	–	–	–	–	–	54°	51°
25, ...	150	122	15.60	28.00	.2160	.1540	.3700	4.22	.0200	.0003	56°	51°
26, ...	300	180	–	–	–	–	–	–	–	–	57°	51°
27, ...	–	100	–	–	–	–	–	–	–	–	–	–
28, ...	150	124	–	–	–	–	–	–	–	–	56°	51°
29, ...	150	143	–	–	–	–	–	–	–	–	56°	53°
30, ...	150	126	–	–	–	–	–	–	–	–	57°	54°
31, ...	150	117	–	–	–	–	–	–	–	–	57°	53°

Effluent very decidedly turbid, and with very much brown, flocculent sediment, and with color averaging 2.78.

May 4 and 17. — Very offensive odor to effluent when outlet was opened. May 4. — Outlet opened at 7.55 A.M. May 5. — First 150 gallons of sewage applied disappeared in 3 hours, 12 minutes. May 13. — 4.38 A.M. to May 17., 7.43 A.M., outlet closed. River high. May 17. — Water siphoned from surface.

Total effluent to end of month, 17,264 gallons.

Filter Tank No. 5 — Continued.

June, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	150	108	-	-	-	-	-	-	-	-	24 h.	58°	53°
2, .	300	137	14.90	30.70	.3400	.2830	.6230	3.42	.0200	.0001	24 h.	59°	54°
3, .	-	94	-	-	-	-	-	-	-	-	24 h.	-	-
4, .	150	98	-	-	-	-	-	-	-	-	24 h.	59°	55°
5, .	150	106	-	-	-	-	-	-	-	-	24 h.	61°	56°
6, .	150	100	15.80	33.70	.3500	.2110	.5610	3.60	.0050	.0004	24 h.	61°	57°
7, .	150	97	-	-	-	-	-	-	-	-	24 h.	64°	57°
8, .	150	99	-	-	-	-	-	-	-	-	24 h.	64°	57°
9, .	300	126	17.10	33.00	.4000	.1800	.5800	4.44	.0150	.0002	24 h.	66°	58°
10, .	-	80	-	-	-	-	-	-	-	-	24 h.	-	-
11, .	150	91	-	-	-	-	-	-	-	-	24 h.	68°	59°
12, .	150	93	-	-	-	-	-	-	-	-	24 h.	65°	59°
13, .	150	91	18.50	36.30	.4000	.1580	.5580	4.27	.0150	.0003	24 h.	-	59°
14, .	150	115	-	-	-	-	-	-	-	-	24 h.	66°	58°
15, .	150	123	-	-	-	-	-	-	-	-	24 h.	65°	59°
16, .	150	127	18.60	38.20	.5200	.1690	.6890	4.30	.0070	.0005	-	67°	61°
17, .	-	75	-	-	-	-	-	-	-	-	-	-	-
18, .	100	98	-	-	-	-	-	-	-	-	-	68°	63°
19, .	100	103	-	-	-	-	-	-	-	-	-	69°	62°
20, .	100	106	22.30	40.60	.4800	.2420	.7220	4.50	.0100	.0000	-	71°	62°
21, .	100	100	-	-	-	-	-	-	-	-	-	70°	61°
22, .	100	96	-	-	-	-	-	-	-	-	-	70°	63°
23, .	200	101	24.90	41.90	.6600	.2760	.9360	4.50	.0150	.0003	24 h.	73°	66°
24, .	-	70	-	-	-	-	-	-	-	-	24 h.	-	-
25, .	100	79	-	-	-	-	-	-	-	-	24 h.	71°	63°
26, .	100	39	-	-	-	-	-	-	-	-	-	72°	63°
27, .	100	5	27.90	47.30	.4000	.2220	.6220	4.98	.0130	.0004	-	71°	-
28, .	100	-	-	-	-	-	-	-	-	-	-	68°	-
29, .	100	147	-	-	-	-	-	-	-	-	24 h.	66°	63°
30, .	100	128	29.20	51.00	.6600	.2980	.9580	4.87	.0100	.0000	24 h.	67°	65°

Effluent generally very decidedly turbid, and with much brown, flocculent sediment.

June 16 and 23. — Iron in samples. June 26 — 5.10 P.M. to June 29, 9.37 A.M., outlet closed. June 27. — Trap put in outlet pipe. Total effluent to end of month, 20,105 gallons.

Filter Tank No. 5 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1,	–	88	–	–	–	–	–	–	–	–	24 h.	–	–
2,	100	84	–	–	–	–	–	–	–	–	24 h.	66°	65°
3,	100	85	–	–	–	–	–	–	–	–	24 h.	67°	65°
4,	100	81	30.40	55.00	.8000	.2900	1.0900	5.16	.0130	.0000	–	69°	66°
5,	100	73	–	–	–	–	–	–	–	–	–	70°	66°
6,	100	70	–	–	–	–	–	–	–	–	24 h.	70°	66°
7,	100	73	32.50	56.30	.8600	.3280	1.1880	4.93	.0100	.0000	24 h.	71°	68°
8,	–	61	–	–	–	–	–	–	–	–	24 h.	–	–
9,	100	68	–	–	–	–	–	–	–	–	24 h.	69°	66°
10,	100	67	–	–	–	–	–	–	–	–	24 h.	72°	67°
11,	100	74	34.60	59.80	1.0600	.3380	1.3980	5.14	.0100	.0000	24 h.	72°	68°
12,	–	71	–	–	–	–	–	–	–	–	24 h.	–	66°
13,	–	64	–	–	–	–	–	–	–	–	24 h.	–	66°
14,	–	60	33.00	66.70	.9600	.3120	1.2720	5.26	.0070	.0000	24 h.	–	67°
15,	–	46	–	–	–	–	–	–	–	–	24 h.	–	–
16,	–	29	–	–	–	–	–	–	–	–	24 h.	–	67°
17,	–	9	–	–	–	–	–	–	–	–	–	–	68°
18,	–	–	–	–	–	–	–	–	–	–	–	–	–
19,	100	–	–	–	–	–	–	–	–	–	–	71°	–
20,	100	99	–	–	–	–	–	–	–	–	24 h.	70°	68°
21,	200	117	40.80	67.60	1.1400	.3140	1.4540	6.12	.0120	.0000	24 h.	71°	68°
22,	–	100	–	–	–	–	–	–	–	–	24 h.	–	–
23,	100	100	–	–	–	–	–	–	–	–	24 h.	72°	69°
24,	100	95	–	–	–	–	–	–	–	–	24 h.	72°	69°
25,	100	95	39.40	69.20	1.2600	.3280	1.5880	5.71	.0120	.0000	24 h.	73°	68°
26,	100	92	–	–	–	–	–	–	–	–	–	73°	65°
27,	100	83	–	–	–	–	–	–	–	–	–	72°	67°
28,	200	118	39.20	65.40	1.5000	.4160	1.9160	5.70	.0100	.0000	24 h.	71°	66°
29,	–	79	–	–	–	–	–	–	–	–	24 h.	–	–
30,	100	83	–	–	–	–	–	–	–	–	24 h.	71°	68°
31,	100	84	–	–	–	–	–	–	–	–	24 h.	72°	69°

Effluent generally very decidedly turbid, and with much brown, flocculent sediment.

July 11. — One-fourth of surface covered with grass and weeds. July 17. — Flow from tank ceased during the night. Some effluent lost. July 18. — Grass cut, and one-half inch of material removed from surface. July 19. — 11.25 A.M., to July 20, 1.41 P.M., outlet closed. Leak in measuring basin. July 28. — Trap removed from outlet pipe.

Total effluent to end of month, 22,353 gallons.

Filter Tank No. 5 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1,	100	72	42.80	66.00	1.6600	.4360	2.0960	5.80	.0130	.0000	24 h.	72°	69°
2,	100	77	-	-	-	-	-	-	-	-	24 h.	73°	69°
3,	-	79	-	-	-	-	-	-	-	-	24 h.	-	69°
4,	-	74	44.00	60.00	1.9000	.4000	2.3000	5.72	.0100	.0000	24 h.	-	70°
5,	-	52	-	-	-	-	-	-	-	-	24 h.	-	-
6,	-	48	-	-	-	-	-	-	-	-	24 h.	-	69°
7,	-	64	-	-	-	-	-	-	-	-	24 h.	-	69°
8,	50	52	42.80	61.80	1.4800	.4700	1.9500	6.10	.0140	.0000	-	72°	69°
9,	50	48	-	-	-	-	-	-	-	-	-	73°	71°
10,	50	44	-	-	-	-	-	-	-	-	-	72°	71°
11,	100	56	39.20	57.80	1.7200	.3500	2.0700	5.92	.0200	.0000	-	73°	68°
12,	-	46	-	-	-	-	-	-	-	-	-	-	-
13,	50	60	-	-	-	-	-	-	-	-	-	70°	68°
14,	50	60	-	-	-	-	-	-	-	-	20 h. 34 m.	69°	69°
15,	50	62	38.20	55.80	1.6300	.3400	2.0200	6.00	.0200	.0000	5 h. 31 m.	69°	69°
16,	50	52	-	-	-	-	-	-	-	-	3 h. 39 m.	69°	71°
17,	50	56	-	-	-	-	-	-	-	-	24 h.	70°	69°
18,	100	66	39.40	49.20	1.8000	.3900	2.1900	6.50	.0400	.0000	32 h. +	70°	69°
19,	-	52	-	-	-	-	-	-	-	-	-	-	-
20,	50	48	-	-	-	-	-	-	-	-	1 h. 35 m.	71°	71°
21,	50	48	-	-	-	-	-	-	-	-	57 m.	71°	70°
22,	50	55	39.00	50.80	2.1000	.4920	2.5920	6.25	.0250	.0000	12 h. +	71°	69°
23,	50	58	-	-	-	-	-	-	-	-	12 h. +	70°	68°
24,	50	50	-	-	-	-	-	-	-	-	4 h. 40 m.	70°	70°
25,	100	53	37.60	49.80	2.0000	.4680	2.4680	6.48	.0150	.0000	12 h. +	70°	71°
26,	-	41	-	-	-	-	-	-	-	-	-	-	-
27,	50	39	-	-	-	-	-	-	-	-	-	71°	70°
28,	50	31	-	-	-	-	-	-	-	-	40 m.	70°	67°
29,	50	34	36.00	49.00	2.0400	.3560	2.3960	6.20	.0250	.0000	41 m.	69°	69°
30,	50	32	-	-	-	-	-	-	-	-	40 m.	69°	69°
31,	50	30	-	-	-	-	-	-	-	-	38 m.	70°	70°

Effluent generally of a deep red color, decidedly turbid, and with considerable brown, flocculent sediment. After August 1, residue on evaporation obtained with sodium carbonate. August 14.—Sixty gallons siphoned from surface. August 22.—Eighty-five gallons. Some water left. August 25.—First 50 gallons applied disappeared in 2 hours 3 minutes.

Total effluent to end of month, 23,992 gallons.

Filter Tank No. 5 — Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	100	53	27.20	58.40	2.2200	.3380	2.5580	7.00	.0150	.0000	12 h.+	71°	69°
2, .	–	45	–	–	–	–	–	–	–	–	–	–	–
3, .	50	35	–	–	–	–	–	–	–	–	40 m.	70°	70°
4, .	50	40	–	–	–	–	–	–	–	–	33 m.	71°	67°
5, .	50	37	26.80	52.80	2.1200	.4000	2.5200	7.20	.0200	.0000	43 m.	70°	69°
6, .	50	32	–	–	–	–	–	–	–	–	39 m.	68°	68°
7, .	50	32	–	–	–	–	–	–	–	–	42 m.	67°	66°
8, .	100	56	30.40	56.40	2.2000	.4000	2.6000	7.04	.0200	.0000	–	66°	68°
9, .	–	62	–	–	–	–	–	–	–	–	–	–	–
10, .	50	57	–	–	–	–	–	–	–	–	12 h.+	67°	69°
11, .	50	59	–	–	–	–	–	–	–	–	–	66°	68°
12, .	50	55	29.00	50.80	2.2000	.4400	2.6400	7.43	.0300	.0000	12 h.+	66°	67°
13, .	50	49	–	–	–	–	–	–	–	–	12 h.+	66°	68°
14, .	50	42	–	–	–	–	–	–	–	–	–	64°	68°
15, .	100	48	28.00	57.60	2.6000	.2800	2.8800	7.65	.0200	.0000	12 h.+	64°	67°
16, .	–	43	–	–	–	–	–	–	–	–	–	–	–
17, .	50	47	–	–	–	–	–	–	–	–	–	65°	68°
18, .	50	54	–	–	–	–	–	–	–	–	12 h.+	65°	66°
19, .	50	51	28.00	55.80	2.4000	.4500	2.8500	7.95	.0200	.0000	12 h.+	64°	65°
20, .	50	53	–	–	–	–	–	–	–	–	24 h.	64°	66°
21, .	50	57	–	–	–	–	–	–	–	–	–	63°	65°
22, .	100	56	27.60	54.00	2.8000	.7700	3.5700	8.20	.0250	.0000	–	62°	66°
23, .	–	48	–	–	–	–	–	–	–	–	–	–	–
24, .	50	50	–	–	–	–	–	–	–	–	12 h.+	58°	64°
25, .	50	49	–	–	–	–	–	–	–	–	–	58°	65°
26, .	50	51	26.20	54.20	2.5200	.3700	2.8900	6.92	.0200	.0000	–	58°	63°
27, .	50	44	–	–	–	–	–	–	–	–	–	58°	65°
28, .	50	44	–	–	–	–	–	–	–	–	–	57°	63°
29, .	100	46	21.00	58.00	2.8000	.4000	3.2000	6.49	.0200	.0000	12 h.+	55°	61°
30, .	–	42	–	–	–	–	–	–	–	–	–	–	–

Effluent of a deep red color, distinctly turbid, and generally with little sediment.

Much iron in samples throughout the month. September 10. — One hundred and ten gallons of water siphoned from surface. September 12. — Ninety-five gallons. September 18 and 22. — One hundred and ninety gallons. September 26. — Two hundred and ninety gallons. September 15. — First 50 gallons of sewage applied disappeared in 2 hours 54 minutes.

Total effluent to end of month, 25,429 gallons.

Filter Tank No. 5 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	50	40	-	-	-	-	-	-	-	-	-	53°	61°
2, .	50	53	-	-	-	-	-	-	-	-	24 h.	53°	62°
3, .	50	50	22.40	54.40	2.8000	.3900	3.1900	6.90	.0300	.0000	-	51°	61°
4, .	50	49	-	-	-	-	-	-	-	-	-	50°	62°
5, .	50	48	-	-	-	-	-	-	-	-	24 h.	50°	61°
6, .	100	52	26.80	50.80	2.4400	.4300	2.8700	7.38	.0200	.0000	-	52°	61°
7, .	-	48	-	-	-	-	-	-	-	-	-	-	-
8, .	50	47	-	-	-	-	-	-	-	-	24 h.	52°	59°
9, .	50	45	-	-	-	-	-	-	-	-	24 h.	52°	57°
10, .	50	43	23.40	55.20	3.1100	.3300	3.4400	8.00	.0200	.0000	-	49°	59°
11, .	-	44	-	-	-	-	-	-	-	-	12 h.+	-	59°
12, .	100	44	-	-	-	-	-	-	-	-	-	47°	57°
13, .	-	49	21.80	55.20	3.2000	.3600	3.5600	8.33	.0250	.0000	-	-	58°
14, .	-	40	-	-	-	-	-	-	-	-	-	-	-
15, .	100	41	-	-	-	-	-	-	-	-	24 h.	47°	58°
16, .	-	47	-	-	-	-	-	-	-	-	24 h.	-	58°
17, .	100	44	20.00	56.60	3.0800	.3600	3.4400	9.74	.0200	.0000	24 h.	48°	56°
18, .	-	45	-	-	-	-	-	-	-	-	24 h.	-	55°
19, .	100	41	-	-	-	-	-	-	-	-	24 h.	46°	56°
20, .	-	43	20.80	58.80	3.2000	.3500	3.5500	10.75	.0250	.0000	24 h.	-	-
21, .	-	38	-	-	-	-	-	-	-	-	24 h.	-	-
22, .	100	40	-	-	-	-	-	-	-	-	-	45°	57°
23, .	-	42	-	-	-	-	-	-	-	-	-	-	55°
24, .	100	44	21.60	56.00	3.4000	.3400	3.7400	11.87	.0250	.0000	-	45°	55°
25, .	-	44	-	-	-	-	-	-	-	-	-	-	54°
26, .	100	39	-	-	-	-	-	-	-	-	-	45°	-
27, .	-	45	21.60	56.80	3.8000	.2500	4.0500	11.77	-	.0000	-	-	54°
28, .	-	43	-	-	-	-	-	-	-	-	-	-	-
29, .	100	42	-	-	-	-	-	-	-	-	24 h.	46°	55°
30, .	-	39	-	-	-	-	-	-	-	-	24 h.	-	55°
31, .	100	45	23.40	54.80	3.4800	.2100	3.6900	12.78	.0300	.0000	24 h.	45°	55°

Effluent of a deep red color, distinctly turbid, and with little sediment.

October 3 and 10. — Much iron in samples. October 17. — Manganese in sample. October 4. — One hundred gallons of water siphoned from surface. October 8. — One hundred and seventy gallons. October 18. — One hundred and five gallons. October 25. — One hundred and forty-five gallons. October 15, 24 and 29. — Water on surface before application of sewage.

Total effluent to end of month, 26,803 gallons.

Filter Tank No. 5 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	38	-	-	-	-	-	-	-	-	24 h.	-	57°
2, .	-	48	-	-	-	-	-	-	-	-	24 h.	-	57°
3, .	-	38	26.40	54.40	3.0800	.3500	3.4300	11.46	.0300	.0000	24 h.	-	56°
4, .	-	27	-	-	-	-	-	-	-	-	-	-	-
5, .	50	37	-	-	-	-	-	-	-	-	7 h.18 m.	49°	55°
6, .	-	30	-	-	-	-	-	-	-	-	-	-	55°
7, .	50	26	18.20	56.20	3.6000	.2200	3.8200	10.78	-	.0000	3 h.	51°	55°
8, .	-	25	-	-	-	-	-	-	-	-	-	-	54°
9, .	50	39	-	-	-	-	-	-	-	-	-	51°	55°
10, .	-	49	17.60	56.40	3.0400	.3000	3.3400	10.89	-	.0000	-	-	54°
11, .	-	39	-	-	-	-	-	-	-	-	-	-	-
12, .	50	41	-	-	-	-	-	-	-	-	47 h.18 m.	48°	53°
13, .	-	41	-	-	-	-	-	-	-	-	-	-	53°
14, .	50	42	18.00	57.00	3.2000	.2500	3.4500	10.40	.0300	.0000	22 h.47 m	46°	54°
15, .	-	48	-	-	-	-	-	-	-	-	-	-	53°
16, .	50	41	-	-	-	-	-	-	-	-	-	45°	53°
17, .	-	41	18.00	52.40	3.2800	.2900	3.5700	10.95	-	.0000	-	-	52°
18, .	-	30	-	-	-	-	-	-	-	-	-	-	-
19, .	50	40	-	-	-	-	-	-	-	-	-	43°	51°
20, .	-	39	-	-	-	-	-	-	-	-	-	-	51°
21, .	50	31	17.00	59.60	3.2000	.3300	3.5300	8.80	-	.0000	-	43°	50°
22, .	-	23	-	-	-	-	-	-	-	-	-	-	49°
23, .	50	21	-	-	-	-	-	-	-	-	-	46°	48°
24, .	-	20	20.00	51.40	3.2800	.3900	3.6700	8.30	-	.0000	-	-	49°
25, .	-	18	-	-	-	-	-	-	-	-	-	-	-
26, .	50	21	-	-	-	-	-	-	-	-	12 h.+	44°	49°
27, .	-	26	-	-	-	-	-	-	-	-	-	-	48°
28, .	50	22	-	-	-	-	-	8.17	-	.0000	-	45°	50°
29, .	-	-	-	-	-	-	-	-	-	-	-	-	-
30, .	50	51	19.10	42.30	2.6400	.2700	2.9100	7.98	-	.0000	-	45°	47°

Effluent of a deep red color, distinctly turbid, and generally with little sediment.

November 12. — One-sixteenth inch of ice on surface. November 13. — One-quarter inch. November 20. — Little. November 21. — Two inches of frost. November 22. — One-eighth inch of ice in spots. November 23, 24 and 26. — A few spots. November 16. — Fifty gallons of water siphoned from surface. November 22. — Canvas cover put over tank. November 29. — 2.55 A.M. to November 30, 10.22 A.M., outlet closed. River high.

Total effluent to end of month, 27,795 gallons.

Filter Tank No. 5 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	33	-	-	-	-	-	-	-	-	-	-	45°
2, .	-	24	-	-	-	-	-	-	-	-	-	-	-
3, .	50	23	-	-	-	-	-	-	-	-	1 h. 30 m.	45°	46°
4, .	-	26	-	-	-	-	-	-	-	-	-	-	45°
5, .	50	26	15.60	42.00	3.0000	.2100	3.2100	7.40	.0300	.0000	3 h. 11 m.	44°	45°
6, .	-	22	-	-	-	-	-	-	-	-	-	-	45°
7, .	50	25	-	-	-	-	-	-	-	-	2 h. 13 m.	45°	45°
8, .	-	24	16.40	42.40	3.4000	.3200	3.7200	7.23	.0250	.0000	-	-	45°
9, .	-	18	-	-	-	-	-	-	-	-	-	-	-
10, .	50	20	-	-	-	-	-	-	-	-	1 h. 23 m.	44°	45°
11, .	-	27	-	-	-	-	-	-	-	-	-	-	43°
12, .	50	22	12.20	45.00	2.9200	.2900	3.2100	6.87	.0250	.0000	1 h. 17 m.	45°	43°
13, .	-	19	-	-	-	-	-	-	-	-	-	-	41°
14, .	50	13	-	-	-	-	-	-	-	-	57 m.	44°	38°
15, .	-	12	10.40	45.40	2.2800	.2900	2.5700	9.30	.0300	.0000	-	-	43°
16, .	-	10	-	-	-	-	-	-	-	-	-	-	-
17, .	50	16	-	-	-	-	-	-	-	-	2 h. 47 m.	45°	45°
18, .	-	12	-	-	-	-	-	-	-	-	-	-	42°
19, .	-	-	-	-	-	-	-	-	-	-	-	-	-
20, .	-	-	-	-	-	-	-	-	-	-	-	-	-
21, .	50	39	-	-	-	-	-	-	-	-	4 h. 32 m.	46°	40°
22, .	-	13	8.80	40.20	3.0400	.2200	3.2600	7.80	.0150	.0000	-	-	38°
23, .	-	5	-	-	-	-	-	-	-	-	-	-	-
24, .	50	10	-	-	-	-	-	-	-	-	-	42°	45°
25, .	-	15	-	-	-	-	-	-	-	-	-	-	-
26, .	50	15	10.60	41.20	2.6400	.1700	2.8100	7.91	.0120	.0000	-	46°	41°
27, .	-	25	-	-	-	-	-	-	-	-	-	-	44°
28, .	50	20	-	-	-	-	-	-	-	-	3 h. 50 m.	44°	43°
29, .	-	19	12.40	41.60	2.6000	.2900	2.8900	6.30	.0200	.0000	-	-	43°
30, .	-	15	-	-	-	-	-	-	-	-	-	-	-
31, .	50	22	-	-	-	-	-	-	-	-	4 h. 53 m.	44°	43°

Effluent of a deep red color, distinctly turbid, and with much sediment.

December 10. — Leak in measuring basin repaired. December 14. — A few spots of ice on surface. December 19. — Five-eighths inch of frost in tank. December 21. — Two inches. December 18. — 8.52 P.M. to December 21, 7.49 P.M., outlet closed. River high.

Total effluent to end of month, 28,365 gallons.

Filter Tank No. 5 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	24	-	-	-	-	-	-	-	-	-	-	43°
2, .	50	22	12.0	44.4	2.5600	.2000	2.7600	6.50	-	.0000	3h. 50m.	44°	41°
3, .	-	21	-	-	-	-	-	-	-	-	-	-	41°
4, .	50	22	-	-	-	-	-	-	-	-	-	44°	42°
5, .	-	29	11.4	47.0	3.2000	.2900	3.4900	7.49	.0120	.0000	-	-	41°
6, .	-	22	-	-	-	-	-	-	-	-	-	-	-
7, .	50	23	-	-	-	-	-	-	-	-	2h. 54m.	44°	41°
8, .	-	25	-	-	-	-	-	-	-	-	-	-	42°
9, .	50	25	13.6	42.8	2.6000	.2200	2.8200	8.10	-	.0000	-	45°	41°
10, .	-	25	-	-	-	-	-	-	-	-	-	-	42°
11, .	50	24	-		-	-	-	-	-	-	2h. 53m.	44°	42°
12, .	-	25	9.2	46.6	2.6400	.2500	2.8900	7.70	-	.0000	-	-	41°
13, .	-	15	-	-	-	-	-	-	-	-	-	-	-
14, .	50	16	-	-	-	-	-	-	-	-	2h. 10m.	44°	42°
15, .	-	18	-	-	-	-	-	-	-	-	-	-	42°
16, .	50	19	15.0	40.4	2.7200	.2100	2.9300	6.10	-	.0000	-	45°	42°
17, .	-	22	-	-	-	-	-	-	-	-	-	-	43°
18, .	50	24	-	-	-	-	-	-	-	-	3h. 33m.	46°	43°
19, .	-	20	10.6	42.0	2.4800	.2600	2.7400	5.25	.0150	.0000	-	-	41°
20, .	-	17	-	-	-	-	-	-	-	-	-	-	-
21, .	50	19	-	-	-	-	-	-	-	-	3h. 44m.	44°	41°
22, .	-	15	-	-	-	-	-	-	-	-	-	-	40°
23, .	50	16	13.2	37.2	2.3200	.2300	2.5500	5.43	-	.0000	5h. 14m.	45°	41°
24, .	-	20	-	-	-	-	-	-	-	-	-	-	42°
25, .	50	20	-	-	-	-	-	-	-	-	7h. 47m.	44°	42°
26, .	-	22	16.4	40.8	2.3600	.2400	2.6000	5.27	-	.0000	-	-	41°
27, .	-	20	-	-	-	-	-	-	-	-	-	-	-
28, .	50	19	-	-	-	-	-	-	-	-	-	45°	42°
29, .	-	19	-	-	-	-	-	-	-	-	-	-	-
30, .	50	18	13.8	37.6	2.4000	.1000	2.5000	5.53	.0120	.0000	3h. 46m.	45°	40°
31, .	-	22	-	-	-	-	-	-	-	-	-	-	41°

Effluent of a deep red color, distinctly turbid, and with considerable brown, flocculent sediment.

January 22. — One inch of frost in tank. January 26. — One and one-half inches. January 29. — None. January 30. — Thin ice in spots on surface.

Total effluent to end of month, 29,014 gallons.

Filter Tank No. 5 — Continued.

February, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	50	17	-	-	-	-	-	-	-	-	-	46°	41°
2, .	-	24	13.2	40.0	2.5600	.3100	2.8700	5.11	-	.0000	-	-	40°
3, .	-	12	-	-	-	-	-	-	-	-	-	-	-
4, .	50	12	-	-	-	-	-	-	-	-	-	44°	41°
5, .	-	18	-	-	-	-	-	-	-	-	-	-	40°
6, .	50	22	14.6	35.8	2.0800	.2300	2.3100	5.50	-	.0000	-	46°	42°
7, .	-	13	-	-	-	-	-	-	-	-	-	-	40°
8, .	50	18	-	-	-	-	-	-	-	-	-	4[illegible]°	39°
9, .	-	20	12.8	40.8	2.6000	.2700	2.8700	4.50	.0150	.0000	-	-	41°
10, .	-	11	-	-	-	-	-	-	-	-	-	-	-
11, .	50	12	-	-	-	-	-	-	-	-	-	45°	39°
12, .	-	18	-	-	-	-	-	-	-	-	-	-	40°
13, .	50	16	12.4	38.8	2.6000	.2300	2.8300	5.08	-	.0000	-	45°	40°
14, .	-	19	-	-	-	-	-	-	-	-	-	-	40°
15, .	50	18	-	-	-	-	-	-		-	24 h.	46°	42°
16, .	-	26	13.0	38.8	2.4300	.2900	2.7700	5.00	0070	.0000	24 h.	-	41°
17, .	-	18	-	-	-	-	-	-	-	-	24 h.	-	-
18, .	50	30	-	-	-	-	-	-	-	-	-	44°	39°
19, .	-	22	-	-	-	-	-	-	-	-	-	-	40°
20, .	50	24	11.2	37.4	2.3200	.2400	2.5600	4.80	.0100	.0000	12 h. +	46°	40°
21, .	-	27	-	-	-	-	-	-	-	-	-	-	40°
22, .	50	24	-	-	-	-	-	-	-	-	-	44°	41°
23, .	-	25	-	-	-	-	-	-	-	-	-	-	39°
24, .	-	16	-	-	-	-	-	-	-	-	-	-	-
25, .	50	12	-	-	-	-	-	-	-	-	-	4[illegible]°	40°
26, .	-	14	-	-	-	-	-	-	-	-	-	-	40°
27, .	50	16	12.6	37.2	2.8000	.2600	3.0600	4.55	.0120	.0000	24 h.	46°	41°
28, .	-	20	-	-	-	-	-	-	-	-	24 h.	-	42°

Effluent of a deep red color, distinctly turbid, and with considerable brown, flocculent sediment. More or less ice on surface of tank about one-half the days of the month.

February 2. — One and one-half inches of frost in tank. February 5. — Two and one-half inches. February 7. — Three inches. February 9 and 14. — Four inches. February 20 and 25. — Five and one-half inches.

Total effluent to end of month, 29,538 gallons.

Filter Tank No. 5 — Continued.

March, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1,	50	20	-	-	-	-	-	-	-	-	-	45°	42°
2,	-	29	13.8	35.8	2.3200	.3100	2.6300	4.20	.0100	.0000	-	-	[illegible]
3,	-	15	-	-	-	-	-	-	-	-	-	-	-
4,	50	26	-	-	-	-	-	-	-	-	-	-	42°
5,	-	28	-	-	-	-	-	-	-	-	-	-	40°
6,	50	25	16.4	38.2	2.0300	.2100	2.2900	4.34	.0100	.0000	-	36°	40°
7,	-	29	-	-	-	-	-	-	-	-	-	-	41°
8,	50	23	-	-	-	-	-	-	-	-	-	35°	40°
9,	-	31	-	-	-	-	-	-	-	-	-	-	39°
10,	-	17	-	-	-	-	-	-	-	-	-	-	-
11,	50	18	-	-	-	-	-	-	-	-	-	34°	41°
12,	-	23	-	-	-	-	-	-	-	-	-	-	41°
13,	50	24	10.8	38.2	2.3200	.2500	2.5700	4.25	.0100	.0000	-	37°	41°
14,	-	22	-	-	-	-	-	-	-	-	-	-	41°
15,	50	30	-	-	-	-	-	-	-	-	-	38°	40°
16,	-	30	9.2	33.0	2.2400	.1700	2.4100	4.35	.0100	.0000	-	-	41°
17,	-	28	-	-	-	-	-	-	-	-	-	-	-
18,	50	34	-	-	-	-	-	-	-	-	-	38°	40°
19,	-	38	-	-	-	-	-	-	-	-	-	-	40°
20,	50	35	12.6	40.0	2.4400	.2200	2.6600	4.20	.0100	.0000	12 h.+	39°	39°
21,	-	33	-	-	-	-	-	-	-	-	-	-	40°
22,	50	34	-	-	-	-	-	-	-	-	7 h. 21 m.	37°	42°
23,	-	30	-	-	-	-	-	-	-	-	-	-	42°
24,	-	32	-	-	-	-	-	-	-	-	-	-	-
25,	50	27	-	-	-	-	-	-	-	-	1 h. 48 m.	43°	41°
26,	-	22	-	-	-	-	-	-	-	-	-	-	42°
27,	50	22	-	-	-	-	-	-	-	-	1 h. 36 m.	42°	42°
28,	-	27	-	-	-	-	-	-	-	-	-	-	41°
29,	50	23	-	-	-	-	-	-	-	-	-	-	42°
30,	-	26	-	-	-	-	-	-	-	-	-	-	42°
31,	-	18	-	-	-	-	-	-	-	-	-	-	-

Effluent of a deep red color, distinctly turbid, and with considerable brown, flocculent sediment.

March 1. — Considerable ice on surface. March 4 and 9, little. March 4. — No frost in one-half of tank. Frost in other half between ½ inch to 3 inches down, and 4 inches to 8 inches down. Surface levelled. March 13. — Canvas cover removed from tank.

Total effluent to end of month, 30,357 gallons.

Filter Tank No. 5 — Continued.

April, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	50	31	-	-	-	-	-	-	-	-	-	41°	40°
2, .	-	48	-	-	-	-	-	-	-	-	-	-	41°
3, .	50	44	9.2	37.2	2.4800	.2000	2.6800	4.04	.0150	.0000	24 h.	40°	40°
4, .	-	41	-	-	-	-	-	-	-	-	24 h.	-	41°
5, .	50	40	-	-	-	-	-	-	-	-	12 h.+	41°	42°
6, .	-	39	-	-	-	-	-	-	-	-	-	-	42°
7, .	-	30	-	-	-	-	-	-	-	-	-	-	-
8, .	50	33	-	-	-	-	-	-	-	-	1 h. 38 m.	44°	43°
9, .	-	24	-	-	-	-	-	-	-	-	-	-	44°
10, .	50	19	-	-	-	-	-	-	-	-	1 h. 10 m.	46°	44°
11, .	-	19	-	-	-	-	-	-	-	-	-	-	47°
12, .	50	20	-	-	-	-	-	-	-	-	-	46°	48°
13, .	-	14	-	-	-	-	-	-	-	-	-	-	47°
14, .	-	13	-	-	-	-	-	-	-	-	-	-	-
15, .	50	9	-	-	-	-	-	-	-	-	45 m.	47°	49°
16, .	-	12	-	-	-	-	-	-	-	-	-	-	47°
17, .	50	11	-	-	-	-	-	-	-	-	43 m.	47°	47°
18, .	-	26	-	-	-	-	-	-	-	-	-	-	45°
19, .	100	32	-	-	-	-	-	-	-	-	18 m.	50°	50°
20, .	-	33	14.2	33.8	2.4000	.2300	2.6300	3.62	.0150	.0000	-	-	49°
21, .	-	25	-	-	-	-	-	-	-	-	-	-	-
22, .	200	22	-	-	-	-	-	-	-	-	-	53°	48°
23, .	-	38	-	-	-	-	-	-	-	-	-	-	47°
24, .	200	41	-	-	-	-	-	-	-	-	2 h. 36 m.	51°	48°
25, .	-	40	-	-	-	-	-	-	-	-	-	-	49°
26, .	200	48	-	-	-	-	-	-	-	-	-	54°	49°
27, .	-	56	-	-	-	-	-	-	-	-	-	-	48°
28, .	-	47	-	-	-	-	-	-	-	-	-	-	-
29, .	-	47	-	-	-	-	-	-	-	-	24 h.	-	49°
30, .	-	47	-	-	-	-	-	-	-	-	24 h.	-	50°

Effluent of a deep red color, distinctly turbid, and with considerable brown, flocculent sediment.

April 3. — Rain water on surface. April 17. — Material of surface, except in sand rings, dug up and turned over to a depth of 9 inches. April 29. — Surface covered with water.

Total effluent to end of month, 31,306 gallons.

Filter Tank No. 5 — Continued.

May, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1,	-	45	-	-	-	-	-	-	-	-	12 h.+	-	49°
2,	-	48	-	-	-	-	-	-	-	-	-	-	50°
3,	100	45	-	-	-	-	-	-	-	-	6 h. 3 m.	53°	50°
4,	-	43	16.0	36.8	2.2000	.2100	2.4100	3.61	.0100	.0000	-	-	50°
5,	-	35	-	-	-	-	-	-	-	-	-	-	-
6,	100	38	-	-	-	-	-	-	-	-	45 m.	55°	52°
7,	-	33	-	-	-	-	-	-	-	-	-	-	53°
8,	100	38	-	-	-	-	-	-	-	-	-	58°	55°
9,	-	35	-	-	-	-	-	-	-	-	-	-	57°
10,	100	34	-	-	-	-	-	-	-	-	-	62°	57°
11,	-	38	-	-	-	-	-	-	-	-	-	-	54°
12,	-	28	-	-	-	-	-	-	-	-	-	-	-
13,	100	23	-	-	-	-	-	-	-	-	1 h. 9 m.	64°	56°
14,	-	38	-	-	-	-	-	-	-	-	-	-	55°
15,	100	39	-	-	-	-	-	-	-	-	3 h. 6 m.	65°	56°
16,	-	38	-	-	-	-	-	-	-	-	-	-	56°
17,	100	37	-	-	-	-	-	-	-	-	-	66°	58°
18,	-	40	12.0	34.8	1.8400	.2200	2.0600	3.33	.0000	.0000	-	-	61°
19,	-	27	-	-	-	-	-	-	-	-	-	-	-
20,	100	34	-	-	-	-	-	-	-	-	99 h. 26 m.	68°	59°
21,	-	54	-	-	-	-	-	-	-	-	-	-	58°
22,	-	46	-	-	-	-	-	-	-	-	-	-	58°
23,	-	48	-	-	-	-	-	-	-	-	-	-	57°
24,	-	47	-	-	-	-	-	-	-	-	-	-	57°
25,	-	45	-	-	-	-	-	-	-	-	-	-	59°
26,	-	34	-	-	-	-	-	-	-	-	-	-	-
27,	100	45	-	-	-	-	-	-	-	-	-	61°	56
28,	-	42	-	-	-	-	-	-	-	-	-	-	59°
29,	100	40	-	-	-	-	-	-	-	-	12 h.+	61°	59°
30,	-	41	-	-	-	-	-	-	-	-	-	-	58°
31,	100	43	-	-	-	-	-	-	-	-	-	62°	60°

Effluent of a deep red color, distinctly turbid, and with considerable flocculent sediment.
May 22. — A very little grass on surface.
Total effluent to end of month, 32,532 gallons.

Filter Tank No. 5 — Continued.

June, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	47	18.0	35.2	2.5200	.2900	2.8100	3.37	.0000	.0000	-	-	61°
2, .	-	41	-	-	-	-	-	-	-	-	-	-	-
3, .	100	49	-	-	-	-	-	-	-	-	24 h.	65°	60°
4, .	-	43	-	-	-	-	-	-	-	-	24 h.	-	60°
5, .	-	50	-	-	-	-	-	-	-	-	24 h.	-	60°
6, .	-	42	-	-	-	-	-	-	-	-	24 h.	-	61°
7, .	100	47	-	-	-	-	-	-	-	-	-	66°	61°
8, .	-	53	-	-	-	-	-	-	-	-	-	-	60°
9, .	-	37	-	-	-	-	-	-	-	-	-	-	-
10, .	100	46	-	-	-	-	-	-	-	-	46h.44m.	67°	64°
11, .	-	42	-	-	-	-	-	-	-	-	-	-	64°
12, .	100	42	-	-	-	-	-	-	-	-	-	69°	62°
13, .	-	48	-	-	-	-	-	-	-	-	-	-	64°
14, .	100	40	-	-	-	-	-	-	-	-	-	67°	66°
15, .	-	49	14.8	35.2	3.3200	.3300	3.6500	3.77	.0000	.0000	-	-	67°
16, .	-	35	-	-	-	-	-	-	-	-	-	-	-
17, .	100	38	-	-	-	-	-	-	-	-	-	72°	65°
18, .	-	32	-	-	-	-	-	-	-	-	-	-	63°
19, .	100	39	-	-	-	-	-	-	-	-	12 h.+	70°	62°
20, .	-	31	-	-	-	-	-	-	-	-	-	-	66°
21, .	100	31	-	-	-	-	-	-	-	-	6 h. 38 m.	71°	67°
22, .	-	33	-	-	3.4000	.3900	3.7900	4.32	.0000	.0000	-	-	67°
23, .	-	17	-	-	-	-	-	-	-	-	-	-	-
24, .	100	14	-	-	-	-	-	-	-	-	3 h. 27 m.	70°	67°
25, .	-	25	-	-	-	-	-	-	-	-	-	-	66°
25, .	100	22	-	-	-	-	-	-	-	-	5 h. 5 m.	70°	68°
27, .	-	26	-	-	-	-	-	-	-	-	-	-	68°
28, .	100	27	-	-	-	-	-	-	-	-	-	72°	70°
29, .	-	42	14.8	36.4	3.5600	.4100	3.9700	4.24	.0000	.0000	-	-	69°
30, .	-	25	-	-	-	-	-	-	-	-	-	-	-

Effluent of a deep red color, distinctly turbid, and with considerable sediment.
June 3. — Water on surface when sewage applied.
Total effluent to end of month, 33,645 gallons.

Filter Tank No. 5 — Continued.

July, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	100	27	–	–	–	–	–	–	–	–	5 h. 51 m.	74°	73°
2, .	–	25	–	–	–	–	–	–	–	–	–	–	68°
3, .	100	36	–	–	–	–	–	–	–	–	–	74°	69°
4, .	–	39	–	–	–	–	–	–	–	–	–	–	–
5, .	100	34	–	–	–	–	–	–	–	–	–	74°	68°
6, .	–	36	16.0	38.4	4.2000	.3200	4.5200	4.44	.0000	.0000	–	–	69°
7, .	–	23	–	–	–	–	–	–	–	–	–	–	–
8, .	100	19	–	–	–	–	–	–	–	–	–	72°	70°
9, .	–	29	–	–	–	–	–	–	–	–	–	–	67°
10, .	100	22	–	–	–	–	–	–	–	–	–	73°	67°
11, .	–	29	–	–	–	–	–	–	–	–	–	–	66°
12, .	100	30	–	–	–	–	–	–	–	–	–	72°	69°
13, .	–	37	17.2	40.0	3.9200	.4400	4.3600	4.48	.0000	.0000	–	–	70°
14, .	–	17	–	–	–	–	–	–	–	–	–	–	–
15, .	100	18	–	–	–	–	–	–	–	–	–	73°	64°
16, .	–	40	–	–	–	–	–	–	–	–	–	–	67°
17, .	100	38	–	–	–	–	–	–	–	–	–	71°	66°
18, .	–	39	–	–	–	–	–	–	–	–	–	–	67°
19, .	100	38	–	–	–	–	–	–	–	–	–	72°	67°
20, .	–	44	–	.	–	–	–	–	–	–	–	–	66°
21, .	–	42	–	–	–	–	–	–	–	–	–	–	–
22, .	100	49	–	–	–	–	–	–	–	–	–	73°	67°
23, .	–	42	–	–	–	–	–	–	–	–	–	–	66°
24, .	100	42	15.6	43.2	5.2400	.4300	5.6700	4.67	.0000	.0000	–	71°	68°
25, .	–	45	–	–	–	–	–	–	–	–	–	–	69°
26, .	100	45	–	–	–	–	–	–	–	–	–	71°	68°
27, .	–	51	14.8	43.6	5.8800	.3500	6.2300	4.63	.0000	.0000	–	–	66°
28, .	–	40	–	–	–	–	–	–	–	–	–	–	–
29, .	100	41	–	–	–	–	–	–	–	–	–	71°	71°
30, .	–	44	–	–	–	–	–	–	–	–	–	–	69°
31, .	100	44	–	–	–	–	–	–	–	–	–	72°	70°

Effluent of an orange or yellow color, distinctly turbid, and with considerable sediment.

July 29. — A two-inch hole bored ¾ inch from bottom of tank, from which to collect samples for bacterial analysis.

Total effluent to end of month, 34,750 gallons.

Filter Tank No. 5 — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	47	-	-	-	-	-	-	-	-	-	-	69°
2, .	100	47	-	-	-	-	-	-	-	-	-	72°	70°
3, .	-	43	-	-	-	-	-	-	-	-	-	-	69°
4, .	-	47	-	-	-	-	-	-	-	-	-	-	-
5, .	100	42	-	-	-	-	-	-	-	-	-	70°	67°
6, .	-	41	-	-	-	-	-	-	-	-	-	-	68°
7, .	100	47	-	-	-	-	-	-	-	-	-	70°	68°
8, .	-	41	-	-	-	-	-	-	-	-	-	-	68°
9, .	100	48	-	-	-	-	-	-	-	-	-	70°	69°
10, .	-	45	18.8	43.0	3.2500	.3300	3.5800	4.62	.0000	.0000	-	-	70°
11, .	-	36	-	-	-	-	-	-	-	-	-	-	-
12, .	100	41	-	-	-	-	-	-	-	-	-	70°	67°
13, .	-	40	-	-	-	-	-	-	-	-	-	-	68°
14, .	100	45	-	-	-	-	-	-	-	-	24 h.	69°	67°
15, .	-	37	-	-	-	-	-	-	-	-	24 h.	-	66°
16, .	100	44	20.4	44.8	4.0000	.3300	4.3300	4.66	.0000	.0000	24 h.	67°	68°
17, .	-	47	-	-	-	-	-	-	-	-	24 h.	-	67°
18, .	-	38	-	-	-	-	-	-	-	-	24 h.	-	-
19, .	100	42	-	-	-	-	-	-	-	-	24 h.	68°	68°
20, .	-	40	-	-	-	-	-	-	-	-	24 h.	-	67°
21, .	100	41	-	-	-	-	-	-	-	-	24 h.	68°	66°
22, .	-	41	-	-	-	-	-	-	-	-	24 h.	-	69°
23, .	100	42	-	-	-	-	-	-	-	-	24 h.	70°	68°
24, .	-	41	-	-	3.7000	.5300	4.2300	4.70	.0000	.0000	-	-	68°
25, .	-	34	-	-	-	-	-	-	-	-	-	-	-
26, .	100	45	-	-	-	-	-	-	-	-	-	69°	69°
27, .	-	39	-	-	-	-	-	-	-	-	-	-	66°
28, .	100	39	-	-	-	-	-	-	-	-	24 h.	68°	67°
29, .	-	37	-	-	-	-	-	-	-	-	24 h.	-	66°
30, .	100	42	-	-	-	-	-	-	-	-	-	69°	68°
31, .	-	39	-	-	-	-	-	-	-	-	-	-	67°

Effluent of deep amber or red color, from clear to very turbid, and with slight sediment.

August 10. — Iron in sample. August 16. — Underdrains washed out three times with effluent of Tank No. 8, between 11.30 A.M. and 11.40.

Total effluent to end of month, 36,048 gallons.

Filter Tank No. 5 — Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	35	-	-	-	-	-	-	-	-	-	-	-
2, .	100	38	-	-	-	-	-	-	-	-	-	71°	67°
3, .	-	34	-	-	-	-	-	-	-	-	-	-	68°
4, .	100	34	-	-	-	-	-	-	-	-	-	71°	69°
5, .	-	41	-	-	-	-	-	-	-	-	-	-	68°
6, .	100	31	-	-	-	-	-	-	-	-	-	72°	70°
7, .	-	37	-	-	-	-	-	-	-	-	-	-	66°
8, .	-	30	-	-	-	-	-	-	-	-	-	-	-
9, .	100	33	-	-	-	-	-	-	-	-	-	72°	67°
10, .	-	33	-	-	-	-	-	-	-	-	-	-	66°
11, .	100	35	-	-	-	-	-	-	-	-	-	68°	65°
12, .	-	32	18.0	45.6	4.7300	.5000	5.2300	2.70	.0000	.0000	-	-	65°
13, .	100	33	-	-	-	-	-	-	-	-	3 h. 33 m.	66°	65°
14, .	-	47	-	-	-	-	-	-	-	-	-	-	67°
15, .	-	33	-	-	-	-	-	-	-	-	-	-	-
16, .	100	39	-	-	-	-	-	-	-	-	-	68°	65°
17, .	-	40	-	-	-	-	-	-	-	-	-	-	68°
18, .	100	39	-	-	-	-	-	-	-	-	-	68°	66°
19, .	-	37	-	-	-	-	-	-	-	-	-	-	64°
20, .	100	44	-	-	-	-	-	-	-	-	24 h.	65°	64°
21, .	-	41	-	-	-	-	-	-	-	-	24 h.	-	65°
22, .	-	33	-	-	-	-	-	-	-	-	24 h.	-	-
23, .	100	39	-	-	-	-	-	-	-	-	24 h.	60°	64°
24, .	-	39	-	-	-	-	-	-	-	-	24 h.	-	64°
25, .	100	38	-	-	-	-	-	-	-	-	24 h.	68°	64°
26, .	-	40	-	-	4.5000	.4400	4.9400	1.89	.0000	.0000	24 h.	-	64°
27, .	100	39	-	-	-	-	-	-	-	-	-	59°	63°
28, .	-	40	-	-	-	-	-	-	-	-	-	-	62°
29, .	-	33	-	-	-	-	-	-	-	-	-	-	-
30, .	100	39	-	-	-	-	-	-	-	-	24 h.	58°	63°

Effluent of red color, and very turbid.
September 20. — Surface covered with water in the morning.
Total effluent to end of month, 37,154 gallons.

Filter Tank No. 5 — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	39	-	-	-	-	-	-	-	-	24 h.	-	6[illegible]°
2, .	100	38	-	-	-	-	-	-	-	-	24 h.	59°	62°
3, .	-	37	-	-	-	-	-	-	-	-	24 h.	-	61°
4, .	100	38	-	-	-	-	-	-	-	-	24 h.	58°	62°
5, .	-	40	-	-	-	-	-	-	-	-	24 h.	-	59°
6, .	-	38	-	-	-	-	-	-	-	-	24 h.	-	-
7, .	100	33	-	-	-	-	-	-	-	-	24 h.	55°	60°
8, .	-	38	-	-	-	-	-	-	-	-	24 h.	-	59°
9, .	100	38	-	-	-	-	-	-	-	-	24 h.	53°	59°
10, .	-	37	-	-	4.0000	.3500	4.3500	2.34	.0000	.0000	24 h.	-	57°
11, .	100	38	-	-	-	-	-	-	-	-	24 h.	50°	58°
12, .	-	39	-	-	-	-	-	-	-	-	24 h.	-	58°
13, .	-	36	-	-	-	-	-	-	-	-	24 h.	-	-
14, .	100	38	-	-	-	-	-	-	-	-	24 h.	49°	56°
15, .	-	33	-	-	-	-	-	-	-	-	24 h.	-	57°
16, .	100	40	-	-	-	-	-	-	-	-	24 h.	49°	56°
17, .	-	37	-	-	-	-	-	-	-	-	24 h.	-	56°
18, .	100	34	-	-	-	-	-	-	-	-	24 h.	49°	57°
19, .	-	42	-	-	-	-	-	-	-	-	24 h.	-	56°
20, .	-	34	-	-	-	-	-	-	-	-	24 h.	-	-
21, .	-	34	-	-	-	-	-	-	-	-	-	-	54°
22, .	-	23	-	-	-	-	-	-	-	-	-	-	54°
23, .	100	26	-	-	-	-	-	-	-	-	12 m.	48°	52°
24, .	-	25	-	-	3.6700	.3000	3.9700	3.05	.0000	.0000	-	-	52°
25, .	100	28	-	-	-	-	-	-	-	-	-	47°	53°
26, .	-	29	-	-	-	-	-	-	-	-	-	-	53°
27, .	-	28	-	-	-	-	-	-	-	-	-	-	-
28, .	100	31	-	-	-	-	-	-	-	-	-	48°	54°
29, .	-	35	-	-	-	-	-	-	-	-	-	-	52°
30, .	100	42	-	-	-	-	-	-	-	-	12 m.	47°	52°
31, .	-	43	-	-	4.6700	.5600	5.2300	3.67	.0000	.0000	-	-	52°

Effluent of red color, and very turbid.

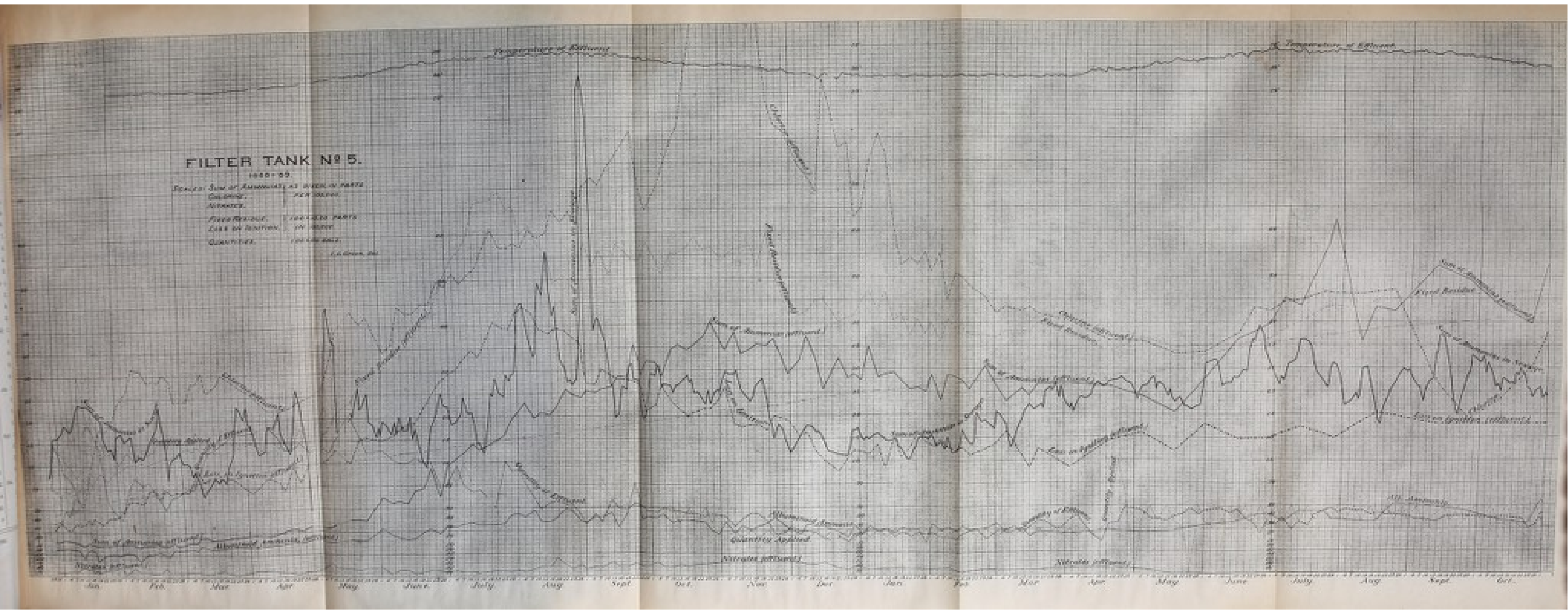
October 21. — Water and sewage on surface nearly all siphoned off. October 21 and 22. — A trench one and one-half feet wide and two and one-half feet deep, with sides sloped four inches, was dug one and one-half feet from rim of tank, and filled to within three inches of top with sand like that in Tank No. 1. October 23. — Sewage applied, distributed evenly over ring of sand. October 24. — Grass cut from one half of surface.

Total effluent to end of month, 38,245 gallons.

Number of Bacteria found in a Cubic Centimeter of Effluent from Tank No 5.

Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.
1888.		**1888**—Con.		**1888**—Con.		**1889**—Con.	
Jan. 3, .	29	March 27, .	95	Sept. 11, .	2,627	March 5, .	5
5, .	42	29, .	411	15, .	3,947	12, .	18
7, .	39	31, .	178	20, .	2,036	19, .	72
10, .	38	April 3, .	104	25, .	614	26, .	2
12, .	43	19, .	192	29, .	190	April 2, .	7
14, .	95	25, .	209	Oct. 2, .	48	9, .	7
17, .	104	28, .	473	6, .	86	16, .	10
19, .	118	May 8, .	231	11, .	31	24, .	11
21, .	68	10, .	158	16, .	27	30, .	12
24, .	40	12, .	105	19, .	19	May 7, .	8
26, .	26	19, .	21	20, .	24	14, .	10
28, .	32	22, .	35	25, .	131	21, .	276
31, .	32	26, .	53	30, .	31	28, .	4
Feb. 2, .	20	29, .	35	Nov. 3, .	125	June 4, .	2
4, .	32	31, .	11	8, .	49	11, .	8
7, .	46	June 9, .	36	13, .	9	18, .	6
9, .	36	21, .	33	19, .	9	26, .	17
11, .	33	26, .	36	23, .	11	July 2, .	38
14, .	29	29, .	118	28, .	12	9, .	3
16, .	36	July 3, .	88	Dec. 5, .	14	16, .	0
18, .	49	5, .	81	10, .	109	23, .	1
21, .	25	7, .	41	14, .	642	30, .	6
23, .	49	10, .	31	21, .	8	Aug. 6, .	16
25, .	26	13, .	17	26, .	31	12, .	16
28, .	29	17, .	10	**1889.**		19, .	6
March 1, .	54	21, .	14	Jan. 2, .	38	24, .	5
3, .	40	24, .	7	8, .	2	Sept. 2, .	6
6, .	43	26, .	16	15, .	19	10, .	9
10, .	79	28, .	10	22, .	15	16, .	14
15, .	583	Aug. 2, .	10	29, .	6	24, .	6
17, .	99	7, .	473	Feb. 6, .	82	Oct. 2, .	3
20, .	145	11, .	1,202	12, .	4	10, .	3
22, .	54	16, .	4,824	19, .	15	16, .	6
24, .	63	21, .	28,620	27, .	0	25, .	4

Trap on outlet pipe from June 27 to July 28, 1888.



FILTER TANK No 5.
Temperature of Effluent
Quantity Applied
Nitrates (effluent)
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct.

FILTER TANK No. 6.

Above the seven inches of gravel and sand around and above the underdrains, this tank was filled to the depth of 3 feet 8 inches with a mixture of fine gravel and coarse and fine sand, making about four feet of filtering material above the underdrains.

Upon passing samples of this material through sieves, and measuring with a microscope, the following results were obtained: —

	Approximate Diameter of Grains, in Inches.	Percentage of Whole Quantity.
Coarser than sieve No. 2,	–	17
Between sieve No. 2 and No. 4,	–	10
Between sieve No. 4 and No. 10,	–	16
Between sieve No. 10 and No. 20,	–	25
Between sieve No. 20 and No. 40,	0.020 to 0.040	19
Between sieve No. 40 and No. 55,	0.012 to 0.020	5
Between sieve No. 55 and No. 70,	0.010 to 0.012	1
Between sieve No. 70 and No. 100,	0.008 to 0.010	2
Between sieve No. 100 and No. 140,	0.005 to 0.008	1
	0.003 to 0.005	1.8
	0.001 to 0.003	2.0
	0.000 to 0.001	.2

This material is upon the whole coarser than the sand of Tank No. 1; but it is more mixed, and has a larger amount of very fine material, so that water will not pass through it as readily. Upon applying 750 gallons of water to this tank within an hour, there was a maximum rate of outflow of 350 gallons in an hour, which is at the rate of 1,680,000 gallons to an acre in a day.

The sand and gravel were clean, like the sand of No. 1 and No. 2. The specific gravity of the particles was 2.63; and, owing to its having such a variety of sizes, its open space, when packed dry, was only 32 per cent. of its volume. The loss on heating to redness was 0.87 of one per cent., showing a very small amount of organic matter. About one-sixth of this was in the four per cent. of very fine material. Quartz particles, and other material insoluble in strong acid, formed 98.17 per cent.; and, of the soluble parts, alumina formed 0.55 of one per cent. of the whole, and oxide of iron and of manganese formed 0.67 of one per cent.

Application of Sewage.

The filter was used about two months for the filtration of water.

Sewage was first applied Jan. 12, 1888. Some particles of this, shown by the increase in chlorine of the effluent from 0.25 to 0.37 parts, had reached the outlet on the next day, when 238 gallons had passed out.

Two days later, after 677 gallons had flowed out, the chlorine of the effluent had increased to two-thirds of that of the sewage, showing that the effluent was then about three-fifths from sewage and two-fifths from the water previously in the sand. During the next week the chlorine of the effluent gradually approached and reached the amount of that in the sewage, showing that then the water previously in the sand had been entirely replaced by sewage.

The daily quantity of sewage applied was 300 gallons, till January 23; after which it was 150 gallons, with three short intermissions, till June 18.

Until February 1 about eight-tenths of the applied sewage reached the outlet; the remainder was in one foot in depth of ice on the surface, and in eight inches in depth of frost in the sand. At this time sewage was entering the tank through the frost by one hole, two or three feet in diameter, which it had kept thawed. It was applied at temperatures between 35° and 40°.

To spread the sewage over more area of the tank, two or three holes were cut through the ice and frost in the first half of February; and on February 18 all of the ice was removed, and a trench, 18 inches wide and two inches deep, was cut into the sand at 18 inches from the outside of the tank, into which sewage was applied. Again, on March 14, all the snow was removed from the tank; after which there was little frost to interfere with the general distribution of sewage through the tank.

From January 23 to March 14 frost interfered much with the even distribution of sewage through the tank; and this may be one cause why, within this time, the organic impurities of the effluent were so much greater than at any time since.

Upon the first coming through of the sewage, and while it was mingling with water previously in the sand, the nitrogen of the effluent as nitrates increased from 0.020 parts per 100,000 to 0.110 parts, but after two days decreased rapidly; and as soon as the original water had left the tank, and the effluent was entirely from sewage, the nitrogen as nitrates became as low as that of the sewage, and continued so for two months. In February it averaged 0.004 parts, and in March 0.009 parts; while the temperature of the effluent was from 35° to 38°. On April 1, with the temperature of the effluent at 39°, it increased to 0.015 parts, and continued higher through the month, averaging 0.041 parts, and reaching 0.060 parts at the end, when the temperature of the effluent was 44°.

The chemical analyses and daily observations upon Tank No. 6 are arranged in tables at the end of this section.

For immediate reference a table of the monthly averages of the chemical analyses of the effluent and of the sewage from which the effluent came, and the percentage which the former is of the latter, is here presented.

This table includes also the average daily quantity of effluent in gallons, which, if multiplied by 200, will give the rate per acre. It also gives the temperature of the effluent, and the average number of bacteria found in a cubic centimeter of the effluent.

The effluent is compared with sewage from which it came, estimating 700 gallons to be held in the sand after it is drained, and that this amount is to be pushed out before liquid from the new sewage reaches the bottom.

Monthly Averages of Daily Results with Tank No. 6.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888.												
Jan. 1-14, . .	Effluent, .	529	.51	1.89	.0001	.0031	.0032	.26	.017	–	–	59
Jan. 12-24, .	Sewage, .	–	59.40	28.55	1.2357	.9057	2.1414	2.66	.006	–	35°	–
Jan. 15-31, .	Effluent, .	191	2.25	9.59	.2073	.0169	.2242	2.66	.043	–	35°	26,255
	Per cent.,	–	4	34	17	1.9	10	–	–	–	–	–
Jan. 25-Feb. 24,	Sewage, .	–	19.97	14.01	.9983	.4683	1.4666	2.46	.008	–	42°	–
February, . .	Effluent, .	168	1.66	9.10	.2934	.0374	.3308	2.37	.004	–	35°	6,107
	Per cent.,	–	8	65	29	8	23	–	–	–	–	–
Feb. 25-Mar. 22,	Sewage, .	–	14.50	17.88	.5435	.3685	.9120	2.18	.007	.0032	52°	–
March, . .	Effluent, .	171	2.00	8.41	.2460	.0133	.2593	2.25	.009	.0005	36°	2,618
	Per cent.,	–	14	47	45	3.6	28	–	–	–	–	–
Mar. 23-Apr. 22,	Sewage, .	–	38.75	46.90	1.0938	.7410	1.8348	3.14	.007	–	46°	–
April, . .	Effluent, .	152	2.69	9.74	.2116	.0131	.2247	2.73	.041	.0006	41°	280
	Per cent.,	–	7	21	19	1.8	12	–	–	–	–	–

Monthly Averages of Daily Results with Tank No. 6 — Concluded.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888 — Con.												
Apr. 23–May 19,	Sewage, .	–	36.59	43.00	1.0500	1.2919	2.3419	3.37	.007	.0029	47°	–
May, . . .	Effluent, .	173	10.98	13.62	.1057	.0106	.1163	2.92	1.245	.0056	52°	19
	Per cent.,	–	30	32	10	.8of1	5	–	–	–	–	–
May 20–June 26,	Sewage, .	–	22.91	28.50	1.3515	.4677	1.8192	4.34	.008	.0005	62°	–
June, . . .	Effluent, .	223	12.48	17.50	.0035	.0089	.0124	5.02	1.539	.0035	64°	133
	Per cent.,	–	55	61	.3of1	1.9	.7of1	–	–	–	–	–
June 27–July 24,	Sewage, .	–	15.04	26.60	1.7120	.3730	2.0850	5.96	.009	.0002	69°	–
July, . . .	Effluent, .	287	6.31	26.73	.0032	.0128	.0160	7.91	.996	.0017	70°	164
	Per cent.,	–	42	100	.2of1	3.4	.8of1	–	–	–	–	–
July 25–Aug. 22,	Sewage, .	–	55.21	54.68	2.7524	1.1090	3.8614	6.62	.011	.0000	72°	–
August, . .	Effluent, .	211	3.66	22.73	.0130	.0122	.0252	5.26	.725	.0110	71°	243
	Per cent.,	–	6	42	.5of1	1.1	.7of1	–	–	–	–	–
Aug. 23–Sept. 25,	Sewage, .	–	53.33	70.55	2.4600	1.6025	4.0625	10.28	–	.0000	67°	–
September, .	Effluent, .	175	2.07	35.57	.0010	.0094	.0104	10.46	1.123	.0006	66°	161
	Per cent.,	–	4	50	.04of1	.6of1	.3of1	–	–	–	–	–
Sept. 26–Oct. 26,	Sewage, .	–	18.04	32.79	2.0900	.4965	2.5865	6.57	–	.0000	52°	–
October, . .	Effluent, .	168	1.44	22.23	.0003	.0062	.0065	4.83	.936	.0000	55°	217
	Per cent.,	–	8	68	.01of1	1.3	.3of1	–	–	–	–	–
Oct. 27–Nov. 24,	Sewage, .	–	14.84	33.56	2.0509	.3991	2.4500	10.97	.010	.0000	48°	–
November, .	Effluent, .	140	1.43	21.13	.0008	.0073	.0081	4.35	1.011	.0003	50°	193
	Per cent.,	–	10	63	.04of1	1.8	.3of1	–	–	–	–	–
Nov. 25–Dec. 22,	Sewage, .	–	13.57	30.74	1.2600	.3283	1.5883	7.70	.041	.0000	45°	–
December, .	Effluent, .	121	1.34	21.71	.0005	.0074	.0079	5.69	.790	.0001	41°	18
	Per cent.,	–	10	71	.04of1	2.3	.5of1	–	–	–	–	–
1889.												
Dec. 23, '88–Jan. 26, '89, . .	Sewage, .	–	11.10	22.98	1.1560	.3320	1.4880	4.70	.009	.0008	44°	–
January, . .	Effluent, .	133	.69	21.59	.0006	.0072	.0078	5.68	.499	.0000	39°	1,690
	Per cent.,	–	6	94	.05of1	2.2	.5of1	–	–	–	–	–
Jan. 27–Feb. 23,	Sewage, .	–	11.55	19.97	1.3200	.4600	1.7800	4.42	.010	.0024	45°	–
February, . .	Effluent, .	129	1.16	16.24	.0021	.0072	.0093	3.24	.501	.0000	38°	302
	Per cent.,	–	10	81	.2of1	1.6	.5of1	–	–	–	–	–
Feb. 24–Mar. 26,	Sewage, .	–	12.88	33.80	1.7111	.4389	2.1500	3.86	.011	.0011	39°	–
March, . .	Effluent, .	130	1.17	20.27	.0050	.0079	.0129	3.81	.922	.0005	39°	120
	Per cent.,	–	9	60	.3of1	1.8	.6of1	–	–	–	–	–
Mar. 27–Apr. 26,	Sewage, .	–	13.60	25.64	2.2533	.4967	2.7500	4.98	.009	.0001	46°	–
April, . .	Effluent, .	137	1.23	26.21	.0008	.0083	.0091	3.68	2.100	.0001	46°	9
	Per cent.,	–	9	102	.04of1	1.7	.3of1	–	–	–	–	–
Apr. 27–May 25,	Sewage, .	–	16.73	25.64	2.0989	.4367	2.5356	5.35	.001	.0000	60°	–
May, . . .	Effluent, .	134	1.34	29.44	.0008	.0075	.0083	4.78	2.129	.0000	59°	3
	Per cent.,	–	8	115	.04of1	1.7	.3of1	–	–	–	–	–
May 26–June 27,	Sewage, .	–	24.62	26.98	2.5589	.5733	3.1322	5.56	–	–	67°	–
June, . . .	Effluent, .	168	1.64	25.56	.0068	.0109	.0177	4.65	1.863	.0005	66°	72
	Per cent.,	–	7	95	.3of1	1.9	.6of1	–	–	–	–	–
June 28–July 27,	Sewage, .	–	25.29	37.64	2.5067	.7044	3.2111	7.05	.000	.0000	72°	–
July, . . .	Effluent, .	219	2.17	22.17	.0032	.0105	.0137	4.89	1.111	.0003	70°	867
	Per cent.,	–	9	59	.1of1	1.5	.4of1	–	–	–	–	–
July 28–Aug. 29,	Sewage, .	–	21.40	42.13	1.9611	.6700	2.6311	4.71	.000	.0000	70°	–
August, . .	Effluent, .	215	1.63	26.67	.0049	.0107	.0156	5.96	1.600	.0000	68°	733
	Per cent.,	–	8	63	.2of1	1.6	.6of1	–	–	–	–	–
Aug. 30–Sept. 26,	Sewage, .	–	43.14	64.63	1.9487	1.1413	3.0900	4.18	.000	.0000	67°	–
September, .	Effluent, .	195	2.60	26.60	.0029	.0103	.0132	4.72	1.500	.0004	66°	1,031
	Per cent.,	–	6	41	.1of1	.9of1	.4of1	–	–	–	–	–
Sept. 27–Oct. 29,	Sewage, .	–	29.91	31.67	1.9893	.8436	2.8329	4.98	.000	.0001	52°	–
October, . .	Effluent, .	228	–	–	.0036	.0100	.0136	4.27	1.880	.0003	55°	261
	Per cent.,	–	–	–	.2of1	1.2	.5of1	–	–	–	–	–

The ammonias of the effluent, which had been 0.0032 parts per 100,000 when water was filtering, rose to 0.2860 parts at the end of eleven days, when all of the original water had been pushed out of the tank; and in the month of February, while frost interfered the most with the even distribution of sewage through the tank, they rose on one day to 0.5400 parts, of which albuminoid ammonia was 0.0900 parts. These are the highest ammonias that have been found in the effluent from this tank. For the month of February the sum of ammonias averaged 0.3308 parts, which is 23 per cent. of the ammonias of the sewage. The albuminoid ammonia averaged 0.0374 parts.

During March no nitrification occurred; the albuminoid ammonia was much less, averaging 0.0133 parts, or less than 4 per cent. of that of the sewage; and the sum of the ammonias averaged 0.2593 parts, or 28 per cent. of that of the sewage, which was, this month, unusually dilute, owing to the large amount of rain and melting snow.

The continual decrease of albuminoid ammonia in the effluent from the middle of February to the first of April, until it became less than four per cent. of that of the sewage, shows that with intermittent filtration in this filter purification reached a good degree of completeness, by the destruction of nearly all of the nitrogenous organic matter, before nitrification began.

During April the ammonias of the effluent continued nearly constant, averaging 0.2247 parts; but, the applied sewage being stronger, the percentage is reduced to 12. The free ammonia averaged 0.2116 parts, or 19 per cent. of that of the sewage; and the albuminoid ammonia 0.0131, or 1.8 per cent. of that in the sewage.

Partial Purification by Nitrification.

Nitrification began and progressed very slowly during the month of April.

In the three following months, while nitrification was very active, the albuminoid ammonia changed but little; but the free ammonia decreased very rapidly, until it became less than one-tenth of one per cent. of that of the sewage.

The rapid increase in nitrification began with May. On the fifth, after a few days suspension of operations, because the freshet brought the river water above the outlet of the tank, the nitrates had reached 0.200 parts. They rose very rapidly to 3.000 parts on the twenty-fifth of the month; were 2.500 parts on June 2, and 3.200 parts on June 6; after which they fell to 0.550 parts on July 1, but rose again, averaging 0.996 parts for the month of July.

The quantity of sewage applied was, on June 18, increased from 150 to 300 gallons per day, and continued at this amount daily, until August 13, when it was reduced to 150 gallons.

Nitrification Checked by Sewage remaining upon the Surface, but again Increased when the Quantity was Reduced.

The continued daily application of 300 gallons, which was at the rate of 60,000 gallons per acre, was more than this material could then bear while the surface remained undisturbed. A leathery scurf, about one-eighth of an inch thick, continually damp, formed upon the surface of the sand, and prevented the sewage disappearing as promptly as formerly; instead of disappearing in one hour, four or five hours were required by the first of August; and this time rapidly increased, until, in the middle of August, the surface was continually covered from day to day. As a consequence, the nitrates, which on August 4 were 1.300 parts, decreased to 0.075 parts on August 18.

On August 13 the daily quantity was reduced to 150 gallons; and in about ten days the leathery scurf separated into small patches and curled up in the sun, and the applied sewage disappeared in less than half an hour.

The nitrates again increased to 2.000 parts on August 29, and, with the same quantity continued, averaged 1.123 parts for the month of September.

Nitrification and Purification vary with the Condition of the Surface.

With the increase in nitrates, which, in May, averaged 1.245 parts, the free ammonia decreased rapidly, and averaged 0.1057 parts, or ten per cent. of that of the sewage; and the albuminoid ammonia also decreased, averaging 0.0106 parts, or eight-tenths of one per cent. of that of the sewage.

With the continued higher nitrates in June, which averaged 1.539 parts, the free ammonia continued decreasing while 150 gallons per day were applied, till it became but 0.0004 parts; and the albuminoid ammonia changed but little, becoming, at the lowest, 0.0060 parts. Then the ammonias were less than in the ordinary drinking water supplies of the State. After June 18 the quantity applied was doubled, being at the rate of 60,000 gallons per acre per day; and the ammonias increased somewhat, making the average for the month 0.0035 parts of free ammonia, or three-tenths of one per cent. of that of the sewage; and 0.0089 parts per 100,000 of albuminoid ammonia, or 1.9 per cent. of that of the sewage.

During the first three weeks of July, while the 300 gallons applied daily, disappeared in from one to three hours, the nitrates increased, and were, on July 21, 1.370 parts, the free ammonia was but 0.0018 parts, and the albuminoid ammonia 0.0102 parts; but, as the time that the sewage remained on the surface increased, the ammonias increased; and when the sewage and the rainfall kept the surface covered for several days, the free ammonia, on August 11, had increased to 0.0332 parts, and the albuminoid ammonia to 0.0150 parts.

After the quantity applied had been reduced, and the scurf upon the surface had dried and curled up, so that air could enter the sand, the nitrates increased and the ammonias again decreased; the free ammonia being, on August 29, 0.0016 parts, and the albuminoid ammonia 0.0102 parts.

In September the free ammonia decreased to 0.0004 parts, averaging 0.0010 parts; and the albuminoid ammonia decreased to 0.0052 parts, averaging 0.0094 parts; and the sum of the ammonias averaged for the month but one-quarter of one per cent. of those of the sewage.

The nitrogen in the effluent, as nitrites, was low during the spring of 1888, averaging 0.0006 parts. This increased during May, and, on June 1, amounted to 0.0133 parts; after which the quantity fell to 0 0002 parts, in the latter part of June. It was higher again in July, averaging 0.0017 parts; and in August, when the surface of the tank was covered with sewage much of the time, the nitrites increased and were very irregular, averaging for the month 0.0110 parts. After the sewage again disappeared rapidly from the surface, the nitrites decreased, and in the latter half of September, and through October, were not present in the effluent.

During October the quantity of sewage applied was continued as before, — 150 gallons daily, — except that on Saturdays 300 gallons were applied, and none was applied on Sundays; but in the latter part of the month, there being much rain, the sewage remained on the surface several hours; and, on the first of November, a change was made in the application. From this time on, for seven months, 300 gallons were applied every other day, except that, when the time for application came on Sunday, there was an intermission of two days. During these seven months the average daily application of sewage was at the rate of 25,714 gallons per acre per day.

Snow Excluded from the Tank.

Another change is to be noted; from Nov. 22, 1888, to March 12, 1889, this tank was covered with canvas stretched over a frame, to exclude snow. At all other times the surface of the tank has been exposed to snow and rain and wind and sunshine.

In October the nitrates were somewhat higher in the latter part of the month, and averaged 0.936 parts. In November they were quite constant, averaging 1.011 parts. The applied sewage had temperatures varying from 52° to 44° Fah.; and the effluent varied from 54° to 43°.

In December the temperatures were a little lower, being, when applied, 46° to 40°, and at the outlet 43° to 38°. The nitrates were also lower, averaging 0.790 parts.

In January and February, 1889, the applied sewage was from 44° to 46°. In the former month the effluent was from 37° to 41°, averaging 39°; and in the latter month the effluent was from 36° to 39°, averaging 38.

The nitrates of the effluent, for these months, were 0.499 parts and 0.501 parts respectively.

It is of importance to notice, that, although the temperature of the effluent was, for the whole month of February, below that at which, the year before, nitrification first began, yet, being in operation the second winter, it continued quite actively through temperatures two or three degrees lower.

Degree of Completeness of Nitrification.

The true measure of the relative completeness of nitrification at different times is not the amount of nitrogen that appears in the effluent as nitrates, but is the percentage which this amount is of the total nitrogen applied in the sewage. These percentages for each month after nitrification became active are given in the following table: —

Percentage of the Total Nitrogen applied in the Sewage that appears in the Effluent as Nitrates.

Date.	Nitrogen in Sewage applied.	Nitrates in Effluent corrected for Quantity.	Per Cent.	Quantity of Effluent. Gallons.	Temperature.	
					Sewage.	Effluent.
1888.						
May,	2.9867	1.380	46	173	47°	52°
June,	1.8837	1.549	82	223	62°	64°
July,	2.0247	.978	48	287	69°	70°
August,	4.0868	.751	18	211	72°	71°
September,	4.6453	1.265	27	175	67°	66°
October,	2.5281	1.013	40	168	52°	55°
November,	2.3362	1.139	49	140	48°	50°
December,	1.6126	.773	48	121	45°	41°
1889.						
January,	1.5022	.457	30	133	44°	39°
February,	1.8492	.495	27	129	45°	38°
March,	2.1350	.926	43	130	39°	39°
April,	2.6714	2.212	83	137	46°	46°
May,	2.4383	2.265	93	134	60°	59°
June,	3.0385	1.801	59	168	67°	66°
July,	3.2107	1.159	36	219	72°	70°
August,	2.7069	1.522	56	215	70°	68°
September,	3.4697	1.465	42	195	67°	66°
October,	3.0148	1.894	63	228	52°	55°

Nitrification continues Active through the Winter.

By this table we see that during the four cold months, December to March, the nitrates averaged 0.6627 parts, which is lower than in the previous four months, when they averaged 1.0420 parts; but the nitrogen applied in the four cold months, which averaged 1.7747, was, to a greater degree, less than the nitrogen applied in the previous four months, when it averaged 3.3991 parts; so that the nitrogen in the form of nitrates in the effluent, in the four cold months, formed a higher percentage, 37 per cent., of the nitrogen applied in the sewage; and nitrification was therefore more complete than in the previous four months, when the nitrogen of the nitrates formed 31 per cent. of the applied nitrogen.

The winter of 1888–89 was warmer than usual, particularly in January, which was about 8° warmer than the average; but in February the average daily minimum temperature was 12°, which is a little lower than in the average year; and the lowest temperature of the month was 7° below zero.

There was, during this month of February, from one inch to five inches in depth of frost in the upper layers of the filter; but the sewage disappeared quite freely over all parts of the surface, and, with the temperature of the effluent as low as 37° for half of the month, nitrification continued actively.

In March the sewage was applied for two weeks at temperatures from 35° to 38°; and the corresponding effluent was from 36° to 39°; and during this time the nitrates increased from 0.600 parts to 1.000 parts. As the temperature of the effluent rose to 42°, at the end of the month the nitrates increased to 1.500 parts. They averaged for the month 0.922 parts, and formed 43 per cent. of the total nitrogen applied in the sewage. There was no succession of extremely cold days this winter, like that of January of the previous winter; and we have not yet had opportunity to carry the filtration through such a winter since nitrification began. But, by applying the sewage through March at a temperature from 6° to 10° lower than it is likely to come from a sewer of the separate system of sewerage, the liquid within the sand has been kept for four months at as low a temperature as it is likely to hold in any winter in this climate, in a filtering area whose surface is protected from snow; from which we conclude, that purification by nitrification will continue efficiently through the coldest winters of this State, in a filtering area of material like that of Tank No. 6, if the surface is protected from snow.

During April, 1889, the temperature of the effluent gradually increased to 53°, and the nitrates increased to 3.000 parts.

In May the temperature rose to 63°; but the nitrates decreased to 1.700 parts, averaging 2.129 parts.

The free ammonia of the effluent continued very low through October, November, December, 1888, and January, 1889, being but a fraction of one-tenth of one per cent. of that of the sewage, and averaging 0.0005 parts. In February it averaged 0.0021 parts, or two-tenths of one per cent. of that of the sewage. In March it averaged 0.0050 parts, or three-tenths of one per cent. of that of the sewage. In April and May it averaged 0.0008 parts, or four hundredths of one per cent. of that of the sewage.

The albuminoid ammonia was nearly constant from October, 1888, through May, 1889, the monthly averages being from 0.0062 parts to 0.0083 parts, and the mean 0.0074 parts, or one and eight-tenths per cent. of that of the sewage.

RESULTING PURIFICATION WHEN FILTERING 27,400 GALLONS PER ACRE DAILY.

The constant condition of the effluent from Oct. 1, 1888, to June 1, 1889, shows what may be expected from a filter of this material, four feet in depth, when filtering this quantity of sewage.

Mean result for eight months : —

Daily quantity of effluent, 27,400 gallons per acre.

	Parts per 100,000.
Loss on ignition, . .	1.22.
Fixed residue, . .	22.35.
Free ammonia, . .	0.0014 or 0.08 of 1 per cent. of that in the sewage.
Albuminoid ammonia,	0.0074 or 1.8 per cent. of that in the sewage.
Sum of ammonias, .	0.0088 or 0.4 of 1 per cent of that in the sewage.
Chlorine, . . .	4.51
Nitrogen as nitrates, .	1.1111 or 54 per cent. of the total nitrogen of the sewage.
Nitrogen as nitrites, .	0.0001.

Bacteria per cubic centimeter, 319, or 1 in 2,000 of those in the sewage.

The surface of the filter was not worked over, nor was it in any way disturbed during this time; and it had less sediment upon it at the end of the eight months than at the beginning; and no reason appeared why the same quantity of sewage could not be applied, in the same way, for an indefinite number of years, without cleansing or renewal of material, with a like result.

The effluent had less organic impurity than ordinary public supplies of drinking water, and an amount of inorganic matter not excessive nor known to be objectionable, being made up in large part of saltpetre and common salt; and had a less number of bacteria than many drinking waters.

From the chemical examinations there would appear no valid reason why this effluent may not be turned into a drinking-water stream; but we do not know enough of the possibilities of the preservation of disease germs to say whether they may form a part of the one in 20,000 that survive the passage. Further experiments should be made to determine whether any of the known disease-producing bacteria can survive such a passage through sand, and, if so, whether they can increase in numbers in the resulting effluent mingled with a potable water.

Resulting Purification when Filtering 42,600 Gallons per Acre Daily.

The quantity of 300 gallons of sewage applied three times a week was continued until June 18, 1889, when it was increased to 500 gallons applied three times a week, which has been continued since; making the average effluent for the last four months, July to October, 1889, 42,600 gallons per acre per day.

With this increased quantity there was a small decrease of the nitrates for a month, while the filter was becoming adapted to its new work; but after that time the nitrification was as complete as in the other efficient filters. In the month after the change the nitrogen of the nitrates formed 36 per cent. of the nitrogen applied, and in the three following months it formed 56, 42 and 63 per cent.

In these four months the ammonias have been nearly constant, amounting to one-half of one per cent. of those of the sewage. The free ammonia has averaged 0.0036 parts, which is 0.15 of one per cent. of that of the sewage. The albuminoid ammonia has averaged 0.0104 parts, which is 1.2 per cent. of that of the sewage; and the nitrogen of the nitrates has averaged 49 per cent. of the total nitrogen applied, which is the same as the average percentage in the eighteen months since nitrification became active.

There is no apparent accumulation of sediment upon the surface, and no reason is suggested by the action of the filter why this quantity of sewage may not be purified, as well as at present, for an indefinite period. A larger quantity will be tried.

Amount of Nitrogen applied compared with That which came off and That which remained in the Filter.

We have already found that in filters No. 1 and No. 2, when purifying efficiently, only about fifty per cent. of the nitrogen that is applied in the sewage has been found in the effluent; and that after the first year there was no increase in the amount of nitrogen stored in the sand. Now we find that about the same percentage is coming away with the effluent from this filter.

The quantity of nitrogen stored in the sand at different depths, expressed in parts per 100,000 of the weight of the dry sand, has been determined for several dates, as described under Tank No. 1, and placed in the following table.

Nitrogen Stored in the Sand of Tank No. 6.

[Parts per 100,000 of weight.]

Distance below Surface. (Inches.)	December, 1888.	June, 1889.	November, 1889.	Distance below Surface. (Inches.)	December, 1888.	June, 1889.	November, 1889.
0 to ¼,	36.60?	55.55	84.21	12,	3.45	3.85	4.10
1,	25.50	32.70	34.20	18,	3.40	2.35	2.50
2,	16.10	21.80	24.70	24,	3.40	1.75	2.10
4,	8.45	12.90	16.85	36,	3.40	1.60	2.10
8,	4.50	6.35	8.50	44,	3.40	1.60	2.10

Above a depth of thirteen inches below the surface the quantity of nitrogen has continually increased. Below this depth it has decreased since the first year. This decrease was rapid during the spring months of very high nitrification; after which there was some accumulation until November, when there was two-thirds as much as in the previous December. This will probably be reduced again by high nitrification of the following spring. In the upper thirteen inches in depth of the tank the increase in quantity is a little greater than the decrease in the lower part.

The changes that have occurred in the whole tank from time to time are given in the following table.

Summary of the Total Nitrogen applied to Tank No. 6, the Amount which came away in the Effluent, and the Amount stored in the Sand, together with a Balance unaccounted for.

	From Jan. 1, 1888, to Dec. 1, 1888. Pounds.	Per Cent. of Nitrogen applied.	From Dec. 1, 1888, to June 1, '89. Pounds.	Per Cent. of Nitrogen applied.	From June 1, 1889, to Nov. 1, 1889. Pounds.	Per Cent. of Nitrogen applied.	From Jan. 1, 1888, to Nov. 1, 1889. Pounds.	Per Cent. of Nitrogen applied.
Amount of nitrogen applied,	11.68	–	3.98	–	8.13	–	23.79	–
Amount came off in effluent,	4.15	36	2.34	59	4.19	51	10.68	45
Difference,	7.53	–	1.64	–	3.94	–	13.11	–
Amount stored in tank,	3.53	30	–.43	–11	1.28	16	4.38	18
Amount not accounted for,	4.00	34	2.07	52	2.66	33	8.73	37

In the first year, 36 per cent. of the nitrogen applied came away in the effluent; in the second year, 54 per cent.; and in the whole time, 45 per cent. During the six months including the spring nitrification, 59 per cent. came away. The amount stored in the sand the first year was 30 per cent. of the amount applied; in the second year, 7 per cent.; and in the whole time, 18 per cent. During the six months that include the spring nitrification, the amount stored was diminished by a quantity equal to 11 per cent. of the amount applied, or equal to 12 per cent. of the amount stored at the beginning of this period. It is remarkable that, during this period, when only 59 per cent. of the nitrogen applied came away in the effluent, the amount stored was decreased by 11 per cent. of the amount applied. In the same period, when 72 per cent. came away in the effluent, from Tank No. 1, there was a decrease of 3 per cent. in the amount stored; and from Tank No. 2, 67 per cent. came away in the effluent, and 12 per cent. was stored. From these results it would appear that, when 48 per cent., 69 per cent. and 79 per cent., or from one-half to three-quarters — averaging about two-thirds — of the applied nitrogen, is found in the effluent, during seasons of high nitrification, we may conclude that no nitrogen is being stored in the sand.

We may conclude, further, that, if the nitrogen of the nitrates of the effluent amounts to about two-thirds of the nitrogen of the applied sewage, the nitrification is complete; and, if more than this is found in the effluent, it is probably from stored nitrogen being removed from the sand.

The part of the nitrogen applied to Tank No. 6 that has not been found in the effluent nor stored in the tank, in the first year was 34 per cent.; in the second year it was 39 per cent.; and in the whole time 37 per cent.

In the three tanks for which this has been determined, the part that has in some way escaped us has been, in No. 1, 30 per cent.; in No. 2, 31 per cent.; and in No. 6, 37 per cent.; or an average of 33 per cent. of the amount of nitrogen applied. We have yet to learn where this quantity, so nearly constant in the different tanks, is to be found. It may have escaped into the air; but we do not know in what form. Experiments are in progress to seek it.

The effluent from Tank No. 6 has been from the first, colorless, and remarkably bright and clear. In February and March, 1889, the chemist observed at times very slight sediment and scum; and a bottle filled December, 1888, after standing a year, shows a light-brown sediment; but all recent samples are without sediment, turbidity, color or odor. It appears like a good spring water.

Bacteria in Effluent from Tank No. 6.

The number of bacteria found in the effluent from Tank No. 6, by counts from 4 to 12 times a month, is given in a table at the end of this section.

When city water was applied during the two weeks previous to the application of sewage, the number in the effluent averaged 59 per cubic centimeter. The city water during this time contained 98 per cubic centimeter.

Upon applying sewage containing about one million bacteria per cubic centimeter, the number in the effluent increased, while the sewage was pushing the water in the tank before it, to 64,839 per cubic centimeter; but the conditions for their continued existence appear to be less favorable, probably from want of oxygen, after the sand was filled with liquid from the sewage; and after January 21, their number rapidly decreased to 1,724 per cubic centimeter in ten days. During February there was much variation in the number, — from 74 to 23,236, averaging 6,107 per cubic centimeter. In March, the variation was from 186 to 10,257, averaging 2,618 per cubic centimeter, — or one-sixth of one per cent. of the number applied in the sewage.

The continued passage of sewage through the filter, and perhaps its more even distribution throughout the whole area, causing any particle to be a longer time in passing through, appear to be unfavorable to the life of bacteria; and, with the end of March, we find in the effluent but one per cent. of the number found when the greatest, on January 21. But, with the increase in temperature and the begining of nitrification in April, the number decreased still more; and with the nitrates for the month averaging 0.041 parts per 100,000, the bacteria averaged but 280 per cubic centimeter. More striking still is the result of the month of May, when the nitrates increased to an average of 1.245 parts; the number of bacteria averaged but 19 per cubic centimeter; and, when the nitrates were the highest, the number of bacteria counted was but 3 per cubic centimeter.

These facts, substantially repeated as they are in nearly all of these filters, strongly suggest that, while bacteria are necessary in the process of nitrification, the process of nitrification is one of death to bacteria. The average number of bacteria found each month in the effluent from this tank is given in the preceding table of monthly averages of daily results with Tank No. 6. This table includes all of the observations upon bacteria in the effluent until December, 1888, and nearly all of these were taken in the forenoon. From this time on through the second year, series of samples taken at different hours in the same day were examined from time to time, with results which show that, with an open sand like this, receiving large quantities of sewage at intervals, the number of bacteria varies much from hour to hour; and that a single sample taken before the sewage of the day has affected the flow is likely to give much too small a number for the average of the day; and a sample taken while the sewage of the day is causing the greatest flow of effluent would give much too high a number.

Examples of occasions when the number of bacteria increased in a very marked manner, when the rate of flow was increased by the newly applied sewage, are presented in the following tables:—

Date.	Time.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.	Date.	Time.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.
1888.				**1888.**			
Dec. 28, . .	4.32 P.M.	–	13	Dec. 29, . .	11.15 A.M.	5,160	719
29, . .	9.45 A.M.	92	20	29, . .	11.30 A.M.	4,380	466
29, . .	10.15 A.M.	94	13	29, . .	11.45 A.M.	3,640	356
29, . .	10.30 A.M.	96	46	29, . .	12.45 P.M.	2,040	48

Three hundred gallons of sewage were applied between 9.56 and 10.15, and all had disappeared from the surface at 11.

On July 9, 1889, the following series was taken:—

Time.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.	Time.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.
5.00 A.M., ...	50	8	11.03 A.M., ...	2,400	936
6.00 A.M., ...	47	9	1.00 P.M., ...	1,200	550
7.00 A.M., ...	42	3	3.35 P.M., ...	720	350
7.35 A.M., ...	44	152	4.30 P.M., ...	580	203
8.05 A.M., ...	44	18	5.15 P.M., ...	580	95
9.05 A.M., ...	11,520	4,416	7.00 P.M., ...	425	113
9.23 A.M., ...	9,360	2,025	9.00 P.M., ...	355	88
10.03 A.M., ...	4,020	1,975			

Five hundred gallons of sewage were applied between 8.08 and 8.41 A.M., and all had disappeared from the surface at 8.48.

Much consideration has been given to the cause of this increase in number with the increase in flow; and these investigations have been complicated by quite conflicting results, obtained in April and May, 1889, of which the following are examples: —

Date.	Time.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.	Date.	Time.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.
April 16,	11.15 A.M.,	43	10	May 27,	8.10 A.M.,	100	7
16,*	11.35 to 11.54 A.M.,	–	–	28,*	10.24 to 10.38 A.M.,	–	–
16,	2.04 P.M.,	2,160	28	28,	2 P.M.,	1,820	5
16,	2.37 P.M.,	1,940	39	28,	5 P.M.,	820	1
16,	5.05 P.M.,	1,000	37	29,	8.18 A.M.,	198	79
17,	9.15 A.M.,	204	11	29,	2.15 P.M.,	144	1
17,	4.45 P.M.,	120	5	30,	8.05 A.M.,	80	60
May 25,	8.10 A.M.,	76	0	30,*	9.55 to 10.16 A.M.,	–	–
25,*	9.51 to 10.17 A.M.,	–	–	30,	2 P.M.,	1,520	8
25,	2.95 P.M.,	1,600	1	30,	5.05 P.M.,	780	37
25,	4.50 P.M.,	800	1				

* 300 gallons of sewage applied.

Here we find the increase with increased rate of flow very slight in April, and not at all in May, and the number in the effluent very small at all times.

The only remarkable differences in the condition of the filter, that have been found, are shown in the table of the percentages of the nitrogen applied that appear in the effluent as nitrates, where we find that the monthly averages of these percentages in December and July were 48 and 36 respectively, and in April and May they were 83 and 93. That is, with the very complete nitrification of April and May, the conditions for the short passage of only four feet through this filter are extremely unfavorable, if not entirely fatal, to the more than 1,000,000 bacteria per cubic centimeter applied in the sewage in those months; and the conditions for growing in the underdrains must also be very unfavorable at this time.

The amount of ammonia in the effluent was very small in these two months, only a little in excess of excellent spring waters; and it was about three-quarters as much as in December and July.

Later experiments upon other tanks have led to the conclusion that the large increase in numbers of bacteria with the increased flow is not due simply to increased velocity of movement through the sand, but is due to the following conditions: when sewage is applied in quantities of 300 or 500 gallons within an hour, and none is again applied for two days, we find that, with the sand completely underdrained, nearly all the water that can leave the sand has left it before the second application. The water is then leaving the sand in occasional drops, amounting to less than a gallon in an hour. At this time the quantity of water held in the sand is about 700 gallons. This is held in thin films on the particles of sand, and suspended between their nearest points; but the air space in the sand is as much as 1,500 gallons. When 500 gallons of sewage are run on to the surface in thirty-five minutes, none is to be seen eight minutes later. It has gone into the space previously occupied by air; and the most forward particles, carrying their bacteria, pass by much of the water held in the more minute interstices, and push on rapidly toward the bottom; and, within an hour, some of these particles, mingled with original water held in the tank, reach the bottom, bringing a small fraction of the number of bacteria with which they started. After this, the percentage of liquid directly from the sewage in the effluent increases; but the percentage of the number of bacteria, which each particle of sewage brings with it, decreases. Processes detrimental to the survival of bacteria and favorable to the purification of the sewage begin immediately.

In this stage of the flow, particles — which from the amount of chlorine are evidently from sewage — that were fifteen minutes longer on the passage than those which came in the effluent a short time before, have been noticeably more completely purified from organic matter and freed from bacteria than their predecessors, so rapid are the chemical processes going on in the sand. The first effluent, that contains the forward particles of the sewage last applied to the very open sands, generally has somewhat higher ammonias and lower nitrates than that coming through later, which has been longer on the passage.

In April and May we unfortunately have no counts of bacteria in the first two hours or more after sewage was applied. It is probable that, within the first hour, the number was greater than any observed; but the action of the process must be rapid and fatal, when, two to three hours after being applied, with 1,000,000 bacteria, some of the effluent, containing perhaps one-quarter of its volume of applied liquid, has but 28, or 1, or 5, or 8 bacteria.

It may be that none get through the sand at this time, and that this small number was detached from those growing in the under-drains by the increased rapidity of the current. There is, however, little doubt that they have been brought through the sand when the time of passage was the same; and the only different condition that we recognize was, less completeness of nitrification.

In the eighteen months after nitrification became active, — from May, 1888, to October, 1889, — the average number of bacteria found in the effluent, as counted in samples taken once or twice a week, generally in the forenoon, was 346, or about one in 2,000 of those applied. The two months when the numbers were the smallest were April and May, 1889, when the nitrates were the highest and the nitrification was most complete. Then the numbers averaged for April, 9, and for May, 3 bacteria per cubic centimeter.

There were, however, occasions in June and July, 1889, and in other months, when the numbers counted at other days and hours than those of the regular collections were very much higher than the above average would indicate. These are given in a table at the end of this section, and some of them will now be examined.

Increased Number of Bacteria probably due to Holes bored down through the Sand being Imperfectly Filled.

On July 2, 1889, a series of samples, examined chemically and bacteriologically, gave results so marked and exceptional as to require notice. They are given in the following table: —

Date.	Hour of Collection.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Number of Bacteria per Cubic Centimeter.	Rate of Flow, Cubic Centimeters per Minute.
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1889.											
July 2, . . .	10.00	–	–	–	–	–	–	–	–	76	–
2, . . .	12.10	2.7	26.1	.0028	.0102	.0130	5.75	1.5000	.0002	3,498	44
2, . . .	2.38	1.8	27.0	.0094	.0174	.0268	6.32	1.4000	.0010	69,700	5,520
2, . . .	2.50	2.4	27.0	.0116	.0178	.0294	6.32	1.1000	.0011	33,326	19,500
2, . . .	5.5	3.1	23.6	.0020	.0210	.0230	6.02	.9000	.0005	28,080	1,440
3, . . .	10.00	2.2	24.4	.0022	.0122	.0144	5.90	1.0000	.0005	10,234	168
3, . . .	3.00	1.8	24.2	.0014	.0110	.0124	5.92	1.0000	.0002	2,291	126

Five hundred gallons of sewage applied from 1.40 to 2.31 on July 2.

It will be seen that, soon after the sewage was applied, the bacteria increased to very unusual numbers, and the nitrates decreased from 1.5 to 1.4 parts; and twelve minutes later were 1.1 parts, followed, two and a quarter hours after, by 0.9 parts, and, on the next morning, were 1.0 parts. The free ammonia, which, before the application of sewage, was 0.0028 parts, rose with the increased flow to 0.0116 parts, and the next day fell to 0.0014 parts; while the albuminoid ammonia rose from 0.0102 parts to 0.0210 parts, and again fell to 0.0110 parts.

Such marked changes in the chemical composition of the effluent, as well as in the number of bacteria, have not been found in any other series of observations upon this tank. The series following in the same month show much less marked changes; and, the farther removed from this date, the less do they resemble these.

It is evident that some of the sewage applied went to the bottom of the tank more rapidly than usual, giving less time for the destruction of bacteria and the conversion of ammonia into nitrates.

The only conditions known that would tend to bring this about, at this time, are these: Two weeks before this date, — on June 18, — the quantity of sewage applied was increased from 300 to 500 gallons; and, on June 20, a hole was bored down through the sand to near the bottom of the tank, for the purpose of taking out samples of sand at different depths for chemical and bacteriological examination. The hole was two inches in diameter, and the sand removed that was not retained for examination was carefully replaced; but it may be that, when sewage was applied, this sand settled and formed a freer passage than in the rest of the area, by which some sewage reached the bottom in shorter time and with less purification and less destruction to bacteria than usual.

It is possible that the unusually high counts of bacteria made from June 7 to 17 may be due to such a condition following May 29, when a similar hole was bored through the tank; although, as in the case above given, we have no marked indication of it until nine days after it occurred. A hole eight inches deep was also dug to obtain samples on June 13.

Other irregularities in the number of bacteria may be due to a cause like that just mentioned. Besides the dates mentioned, sand has been taken out for examination as follows: Dec. 10, 1888, to the depth of 37 inches; December 27, to the depth of 7 inches; Feb. 11, 1889, to the depth of 11 inches.

Many millions of the Bacillus prodigiosus were put upon Tank No. 6 on May 23, 1889, and examinations made three times a day for the next week; but none were found in the effluent.

Bacteria in the Sand of Tank No. 6.

The number of bacteria in a gram of the sand of Tank No. 6, taken from different depths below the surface, has been determined on the following dates of 1889: —

Distance below the Surface.	Number of Bacteria per Gram of Sand.			
	Feb. 11.	May 29.	June 20.	Nov. 12.
0 to ¼ inch,	-	126,400	83,431	360,000
½ inch,	137,800	-	-	370,000
½ to ¾ inch,	-	289,100	-	-
1 inch,	-	-	58,491	411,000
1 to 1¼ inches,	-	263,800	-	-
1¼ to 1½ inches,	370,380	-	-	-
2 inches,	-	149,000	182,913	219,000
2½ inches,	128,800	-	-	-
3 inches,	-	33,900	-	202,500
4 inches,	86,100	-	69,906	-
5 inches,	-	93,100	-	169,700
6 inches,	53,538	-	-	-
7 inches,	-	-	26,762	-
8 inches,	-	20,300	-	64,000
11 inches,	20,215	-	-	-
12 inches,	-	56,800	-	45,600
13 inches,	-	-	8,750	-
14 inches,	-	-	-	21,500
17 inches,	-	4,500	-	-
20 inches,	-	-	25,666	-
24 inches,	-	6,700	-	-
25 inches,	-	-	-	11,690
30 inches,	-	-	15,727	-
36 inches,	-	10,900	-	16,900
39 inches,	-	31,100	-	-

The number decreases rapidly below the upper two inches in depth, and the same amount of sand in the lower two feet has but 6 per cent. as many as in the upper two inches.

Microscopic Examination of Sand and of Effluent.

Examining the sand with the microscope on Nov. 12, 1889, the grains at the surface were found to be much cleaner than those of No. 1 or No. 2. Ulothrix, Rotifera, Anguillula, and bacteria chiefly in Zoögloea, were found with the sand at the surface; but no microscopic organisms were found below the surface except clots of Zoögloea, which were very abundant, appearing on almost every grain of sand.

Microscopic examination of the effluent of Tank No. 6, in the summer and fall of 1888, indicated Leptothrix, in half of the samples examined, to the number of 36 in a gallon; Monas, on two occasions only, to the number of 6; and Rotifera, about one-third of the time, to the number of 4 in a gallon. A few other organisms were found on two or three occasions. In November and December, 1888, no organisms were found. On July 20 and 25, 1889, series of samples were examined; and the only organisms that averaged as many as one in 100 cubic centimeters of effluent were Chlorococcus, 7, and Crenothrix, 1.

If any of these microscopic organisms came through the sand, or if the spores of any of them came through, it is evident that the conditions are very unfavorable for them either to come through the sand or to live in the underdrains.

General View of Results with Filter No. 6.

To obtain a general view of the results with this filter of mixed sands and fine gravel four feet in depth, an examination should be made of the diagram of daily observations accompanying the tables.

There we shall find that the ammonias of the effluent increased for a month after sewage was applied; and for the three following months, with little or no nitrification, they amounted to about one-quarter of the ammonias of the sewage. But, even in this time, the albuminoid ammonia was high only in the month of February, when frost prevented sewage being distributed through the filter, and then averaged but 8 per cent. of that of the sewage.

Nitrification began with April, 1888, and increased very rapidly, and became complete in May. About a month behind the increase in nitrates the ammonias decreased, and became in June about 0.0100 parts per 100,000; and for the next seventeen months they were generally a little above or below this quantity, or not far from the amounts found in the ordinary drinking waters of the State. The occasions when the ammonias were higher were in July and August, 1888, in March, 1889, and in July, 1889.

The first of these began a month after the quantity of sewage had been increased from 30,000 to 60,000 gallons per acre per day, and the surface had become covered with a deposit of organic matter kept continually damp, excluding air and reducing the nitrates. Upon reducing the quantity applied to 30,000 gallons per acre per day, the scurf curled up in the sun, the nitrates increased, and the ammonias were soon reduced to 0.0070 per 100,000. On the second occasion — in March, 1889 — there was a slight rise after two months of low nitrates, probably favored by frost in the upper layers of the sand; but this was followed by an increase of nitrates and a decrease of ammonias, which averaged, for the month of March, 0.0129 parts, or only 0.6 of one per cent. of those in the sewage.

The third occasion began in the latter part of June, 1889, soon after the increase in quantity from 27,000 to 43,000 gallons of sewage upon an acre, when the nitrates also decreased for a time, but it was only while the tank was becoming adapted to the disposing of the increased quantity; and in the following month of July the sum of ammonias averaged 0.0137 parts, or only 0.4 of one per cent. of those of the sewage; after which, by continuing the large quantity, the nitrates continued to include increasing percentages of the nitrogen of the sewage, until in October, 1889, they included 63 per cent. of the nitrogen of the sewage, and probably no nitrogen was then being stored in the tank.

The total amount of nitrogen stored in the tank from the beginning has been but 18 per cent. of that applied; and the amount stored in the past year has been but seven per cent. of the amount applied in this year.

In the whole time since purification by nitrification began in June, 1888, there has been removed from the applied sewage 99½ per cent. of all the organic matter. This has been done when filtering 42,600 gallons per acre per day, in the last four months, as well as when filtering a less quantity.

This mixed sand, like the coarse sand of Tank No. 1, allows some bacteria to go through it. When nitrification is quite complete, the number is reduced to one in 50,000 of the number applied. When nitrification is less complete, the number increases sometimes to one-quarter of one per cent.; and for a short time after sewage is applied the number sometimes has reached three per cent. of the number applied.

We may then conclude that through four feet in depth of this mixed sand and gravel we may filter 42,000 gallons of sewage per acre daily, for an indefinite period, removing 99½ per cent. of the organic matter, as shown by the sum of the ammonias; and removing ordinarily a much larger fraction of the bacteria, but sometimes allowing as many as three per cent. to come through alive for a fraction of an hour soon after sewage has been applied after a long interval.

The filtered water will be bright, clear and colorless, with every appearance of good spring water.

We will now turn to learn what can be done with the same sand and gravel covered with a layer of loam and of garden soil.

TABLES

OF

ANALYSES OF EFFLUENT AND OBSERVATIONS

Upon Filter Tank No. 6.

[The chemical results are expressed in parts per 100,000.]

FILTER TANK No. 6.

January, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1,	272	257	-	-	-	-	-	-	-	-	-	-	-
2,	272	429	0.50	1.75	.0004	.0054	.0058	.24	.0100	Present.	-	-	-
3, .	272	242	-	-	-	-	-	-	-	-	-	-	-
4, .	272	224	0.50	1.75	.0000	.0028	.0028	.22	.0090	None.	-	-	-
5, .	272	239	-	-	-	-	-	-	-	-	-	-	-
6, .	1,000	938	0.50	1.80	.0000	.0028	.0028	.21	.0200	Present.	-	-	-
7, .	1,000	811	-	-	-	-	-	-	-	-	-	-	-
8, .	1,000	817	-	-	-	-	-	-	-	-	4 h. 10 m.	-	-
9, .	1,000	947	0.35	1.80	.0000	.0006	.0006	.23	.0120	Present.	6 h. 25 m.	-	-
10, .	1,000	975	0.50	1.85	.0000	.0028	.0028	.28	.0230	Present.	-	-	-
11, .	1,000	940	0.60	2.20	.0004	.0042	.0046	.25	.0250	Present.	-	-	-
12, .	300	197	-	-	-	-	-	-	-	-	-	34°	-
13, .	300	122	0.60	2.10	.0002	.0030	.0032	.37	.0200	.0005	-	36°	-
14, .	300	268	-	-	-	-	-	-	-	-	-	36°	-
15, .	300	301	2.50	5.80	.0074	.0188	.0262	1.94	.0850	.0013	-	38°	-
16, .	300	336	2.45	6.65	.0378	.0140	.0518	1.94	.1100	.0015	-	36°	-
17, .	300	233	2.35	8.15	.0772	.0188	.0960	2.31	.1100	.0150	-	34°	-
18, .	300	193	2.30	8.85	.0940	.0196	.1136	2.51	.0800	Present.	-	34°	-
19, .	300	217	-	-	-	-	-	-	-	-	-	35°	-
20, .	300	250	3.70	9.00	.1214	.0154	.1368	2.37	.0350	.0080	-	34°	-
21, .	300	249	-	-	-	-	-	-	-	-	-	35°	-
22, .	300	221	-	-	-	-	-	-	-	-	-	35°	-
23, .	265	206	2.30	11.10	.2700	.0160	.2860	3.03	.0100	Present.	-	35°	-
24, .	150	163	2.30	11.00	.2230	.0210	.2440	3.09	.0090	None.	-	34°	-
25, .	150	149	1.55	11.00	.3230	.0210	.3440	2.70	.0080	Present.	-	35°	-
26, .	150	141	-	-	-	-	-	-	-	-	-	34°	-
27, .	150	140	1.25	10.25	.3010	.0130	.3140	2.40	.0070	Present.	-	36°	-
28, .	150	137	-	-	-	-	-	-	-	-	-	36°	-
29, .	150	118	-	-	-	-	-	-	-	-	-	37°	-
30, .	150	98	2.10	11.80	.3980	.0130	.4110	3.52	.0080	.0001	-	36°	-
31, .	150	94	2.00	11.90	.4270	.0150	.4420	3.47	.0070	.0004	-	40°	35°

January 12.—First sewage applied. January 1.—One inch of snow on surface. January 6.—One-eighth inch of ice. January 12.—One-half inch. January 14.—One inch. January 16.—Two inches. January 17.—Two and one-quarter inches. January 18.—Two and one-half inches. January 6.—Ice removed from surface. January 9.—Second 500 gallons water applied disappeared in 1 hour 21 minutes.

Total effluent to end of month, 3,833 gallons.

Filter Tank No. 6 — Continued.

February, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	150	127	1.50	11.30	.3330	.0190	.3520	3.05	.0080	.0005	40°	34°
2, ...	150	129	-	-	-	-	-	-	-	-	36°	34°
3, ...	150	175	1.20	9.60	.2320	.0110	.2430	2.23	.0090	.0014	43°	35°
4, ...	150	168	-	-	-	-	-	-	-	-	-	35°
5, ...	150	280	-	-	-	-	-	-	-	-	-	-
6, ...	150	181	1.15	8.30	.2500	.0080	.2580	1.88	.0060	.0015	-	34°
7, ...	150	162	1.15	8.35	.2300	.0300	.2600	2.04	.0180	Present.	43°	35°
8, ...	150	162	1.55	8.80	.2500	.0200	.2700	2.14	.0000	Present.	40°	-
9, ...	150	143	-	-	-	-	-	-	-	-	39°	34°
10, ...	150	141	5.95	10.95	.3500	.0200	.3700	3.27	.0050	None.	43°	-
11, ...	150	123	-	-	-	-	-	-	-	-	40°	34°
12, ...	150	140	-	-	-	-	-	-	-	-	45°	-
13, ...	150	159	1.80	9.10	.1300	.0300	.1600	2.75	.0080	Present.	42°	-
14, ...	150	219	1.30	9.80	.2400	.0300	.2700	2.66	.0000	Present.	44°	35°
15, ...	150	206	1.20	9.90	.4500	.0900	.5400	2.17	.0000	Present.	44°	34°
16, ...	150	150	-	-	-	-	-	-	-	-	43°	35°
17, ...	100	96	1.40	10.60	.2400	.0500	.2900	2.90	.0000	None.	49°	35°
18, ...	150	187	-	-	-	-	-	-	-	-	51°	-
19, ...	150	187	1.60	9.30	.3400	.0700	.4100	2.42	.0000	Present.	48°	-
20, ...	150	245	1.40	9.60	.3400	.0500	.3900	2.43	.0000	Present.	44°	35°
21, ...	150	198	-	-	-	-	-	-	-	-	47°	35°
22, ...	150	147	1.20	7.90	.3500	.0700	.4200	1.92	.0050	None.	57°	35°
23, ...	150	144	-	-	-	-	-	-	-	-	50°	35°
24, ...	150	184	1.80	8.00	.3600	.0300	.3900	2.10	.0000	Present.	47°	-
25, ...	150	193	-	-	-	-	-	-	-	-	46°	35°
26, ...	150	250	1.10	8.20	.3400	.0300	.3700	2.05	.0020	Present.	48°	35°
27, ...	150	170	1.20	7.70	.2900	.0100	.3000	2.05	.0000	Present.	46°	35°
28, ...	150	118	-	-	-	-	-	-	-	-	48°	35°
29, ...	150	100	1.80	7.40	.2630	.0680	.3310	2.18	.0080	.0001	51°	35°

February 1.—Sewage entering tank through one opening in the frost. February 2.—One hole cut through eight inches of frost and twelve inches of ice. February 12.—Hole cut through twenty-seven inches of frost. February 18.—All the ice and a circle of gravel one and one-half feet wide and two inches deep, one and one-half feet from rim of tank, removed from surface.

Total effluent to end of month, 8,717 gallons.

Filter Tank No. 6 — Continued.

March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	150	174	-	-	-	-	-	-	-	-	-	58°	35°
2, .	150	143	-	-	-	-	-	-	-	-	-	54°	-
3, .	150	177	-	-	-	-	-	-	-	-	-	54°	35°
4, .	150	118	2.00	7.60	.3000	.0170	.3170	2.16	.0100	.0002	-	47°	35°
5, .	150	146	-	-	-	-	-	-	-	-	-	52°	35°
6, .	150	131	3.40	8.40	.2400	.0120	.2520	2.78	.0090	Present.	-	50°	36°
7, .	150	136	-	-	-	-	-	-	-	-	-	59°	35°
8, .	150	149	-	-	-	-	-	-	-	-	-	52°	-
9, .	150	166	-	-	-	-	-	-	-	-	-	53°	36°
10, .	150	175	-	-	-	-	-	-	-	-	-	57°	36°
11, .	150	160	2.10	8.90	.3360	.0180	.3540	2.04	.0100	.0010	20 m.	50°	36°
12, .	150	170	-	-	-	-	-	-	-	-	-	58°	36°
13, .	150	170	2.10	8.70	.2400	.0150	.2550	2.22	.0080	.0010	-	52°	-
14, .	150	186	-	-	-	-	-	-	-	-	-	55°	36°
15, .	150	178	-	-	-	-	-	-	-	-	-	52°	-
16, .	150	167	-	-	-	-	-	-	-	-	-	53°	35°
17, .	150	161	-	-	-	-	-	-	-	-	-	55°	36°
18, .	150	133	2.10	8.80	.2200	.0160	.2360	2.36	.0100	.0002	-	51°	36°
19, .	150	143	-	-	-	-	-	-	-	-	-	48°	36°
20, .	150	160	2.10	8.80	.2000	.0080	.2080	2.50	.0120	.0004	-	54°	-
21, .	150	271	-	-	-	-	-	-	-	-	-	55°	36°
22, .	150	239	-	-	-	-	-	-	-	-	27 m.	54°	37°
23, .	150	163	-	-	-	-	-	-	-	-	-	53°	38°
24, .	150	139	-	-	-	-	-	-	-	-	28 m.	51°	38°
25, .	150	140	1.50	8.30	.2200	.0120	.2320	2.12	.0090	.0001	26 m.	50°	39°
26, .	150	163	-	-	-	-	-	-	-	-	-	54°	37°
27, .	150	317	1.40	7.80	.2120	.0080	.2200	1.80	.0050	.0004	-	52°	37°
28, .	150	238	-	-	-	-	-	-	-	-	47 m.	52°	37°
29, .	150	177	-	-	-	-	-	-	-	-	26 m.	51°	37°
30, .	150	159	-	-	-	-	-	-	-	-	20 m.	53°	38°
31, .	150	147	-	-	-	-	-	-	-	-	-	53°	38°

Effluent colorless, generally clear, and with very slight sediment.
March 14. — Snow removed from surface of tank.
Total effluent to end of month, 14,013 gallons.

Filter Tank No. 6 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	150	151	2.00	8.00	.2320	.0110	.2430	1.66	.0150	.0005	26 m.	41°	39°
2, .	150	337	-	-	-	-	-	-	-	-	-	41°	39°
3, .	150	148	1.80	8.50	.2000	.0170	.2170	2.14	.0350	.0008	22 m.	43°	40°
4, .	150	148	2.10	7.70	.2200	.0130	.2330	2.16	.0280	.0007	16 m.	40°	40°
5, .	150	155	-	-	-	-	-	-	-	-	24 m.	43°	40°
6, .	150	258	-	-	-	-	-	-	-	-	25 m,	46°	40°
7, .	-	-	-	-	-	-	-	-	-	-	-	-	-
8, .	-	-	-	-	-	-	-	-	-	-	-	-	-
9, .	-	-	-	-	-	-	-	-	-	-	-	-	-
10, .	150	151	2.10	9.30	.1720	.0060	.1780	2.24	.0600	.0008	16 m.	40°	41°
11, .	150	217	-	-	-	-	-	-	-	-	22 m.	42°	41°
12, .	150	109	-	-	-	-	-	-	-	-	-	43°	41°
13, .	150	97	-	-	-	-	-	-	-	-	36 m.	46°	42°
14, .	150	91	-	-	-	-	-	-	-	-	-	43°	41°
15, .	150	98	2.30	8.90	.1840	.0130	.1970	2.32	.0300	.0004	18 m.	45°	42°
16, .	150	81	-	-	-	-	-	-	-	-	24 m.	41°	42°
17, .	150	123	1.80	10.40	.2280	.0150	.2430	2.52	.0300	.0004	22 m.	43°	42°
18, .	150	134	-	-	-	-	-	-	-	-	-	45°	42°
19, .	150	161	-	-	-	-	-	-	-	-	18 m.	42°	43°
20, .	150	144	-	-	-	-	-	-	-	-	-	43°	42°
21, .	300	314	3.10	10.20	.2080	.0120	.2200	3.11	.0500	.0004	-	43°	43°
22, .	-	56	-	-	-	-	-	-	-	-	-	-	-
23, .	150	101	-	-	-	-	-	-	-	-	-	43°	42°
24, .	150	134	5.30	13.30	.2400	.0180	.2580	4.74	.0600	.0006	-	49°	43°
25, .	150	142	-	-	-	-	-	-	-	-	-	42°	43°
26, .	150	147	-	-	-	-	-	-	-	-	-	45°	43°
27, .	150	144	-	-	-	-	-	-	-	-	-	43°	44°
28, .	300	282	3.70	11.40	.2200	.0130	.2330	3.66	.0600	.0007	-	46°	44°
29, .	-	39	-	-	-	-	-	-	-	-	-	-	-
30, .	-	-	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, nearly clear, and with very slight sediment. Organisms visible to naked eye in samples throughout the month.

April 7. — 5.20 A.M. to April 10, 8.12 A.M., outlet closed. River high. April 12. — First 75 gallons of sewage applied disappeared in 10 minutes. April 17. — Leak in measuring basin repaired. April 29. — 6.03 P.M., outlet closed. River high.

Total effluent to end of month, 17,975 gallons.

Filter Tank No. 6 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	-	-	-	-	-	-	-	-	-	-	-	-
2, ...	-	-	-	-	-	-	-	-	-	-	-	-
3, ...	-	-	-	-	-	-	-	-	-	-	-	-
4, ...	150	121	-	-	-	-	-	-	-	-	46°	47°
5, ...	300	290	6.50	11.50	.1320	.0080	.1400	3.02	.2000	.0011	45°	48°
6, ...	-	58	-	-	-	-	-	-	-	-	-	-
7, ...	150	111	-	-	-	-	-	-	-	-	50°	-
8, ...	150	135	5.50	13.50	.1720	.0210	.1930	3.24	.3200	.0022	48°	49°
9, ...	150	223	-	-	-	-	-	-	-	-	50°	50°
10, ...	150	179	-	-	-	-	-	-	-	-	51°	50°
11, ...	150	145	12.90	7.40	.1560	.0150	.1710	3.16	.4500	.0027	51°	51°
12, ...	300	413	-	-	-	-	-	-	-	-	50°	51°
13, ...	-	-	-	-	-	-	-	-	-	-	-	-
14, ...	-	-	-	-	-	-	-	-	-	-	-	
15, ...	-	-	-	-	-	-	-	-	-	-	-	-
16, ...	-	-	-	-	-	-	-	-	-	-	-	-
17, ...	150	369	-	-	-	-	-	-	-	-	49°	51°
18, ...	150	140	5.50	13.80	.0920	.0060	.0980	2.02	1.2000	.0042	50°	50°
19, ...	300	305	-	-	-	-	-	-	-	-	50°	51°
20, ...	-	57	-	-	-	-	-	-	-	-	-	-
21, ...	150	101	-	-	-	-	-	-	-	-	52°	52°
22, ...	150	147	17.90	17.10	.0470	.0068	.0538	2.90	2.3000	.0133	52°	51°
23, ...	150	138	-	-	-	-	-	-	-	-	53°	52°
24, ...	150	137	-	-	-	-	-	-	-	-	54°	53°
25, ...	150	131	17.60	18.40	.0350	.0068	.0418	3.18	3.0000	.0099	55°	54°
26, ...	300	271	-	-	-	-	-	-	-	-	57°	55°
27, ...	-	48	-	-	-	-	-	-	-	-	-	-
28, ...	150	101	-	-	-	-	-	-	-	-	56°	55°
29, ...	150	240	-	-	-	-	-	-	-	-	56°	56°
30, ...	150	166	-	-	-	-	-	-	-	-	57°	56°
31, ...	150	130	-	-	-	-	-	-	-	-	57°	57°

Effluent colorless, clear or nearly so, and with very slight sediment.

Organisms visible to naked eye in samples throughout the month.

May 4. — Outlet opened at 8.01 A.M. May 12. — 8.54 P.M. to May 17. — 7.44 A.M., outlet closed. River high.

Total effluent to end of month, 22,131 gallons.

Filter Tank No. 6 — Continued.

June, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	150	139	-	-	-	-	-	-	-	-	59°	57°
2, ...	300	274	18.30	18.00	.0120	.0070	.0190	4.66	2.5000	.0133	59°	59°
3, ...	-	46	-	-	-	-	-	-	-	-	-	-
4, ...	150	100	-	-	-	-	-	-	-	-	59°	59°
5, ...	150	145	-	-	-	-	-	-	-	-	61°	60°
6, ...	150	128	18.50	15.70	.0060	.0084	.0144	4.62	3.2000	.0100	62°	60°
7, ...	150	148	-	-	-	-	-	-	-	-	64°	61°
8, ...	150	136	-	-	-	-	-	-	-	-	65°	61°
9, ...	300	266	14.00	18.20	.0040	.0076	.0116	4.55	2.1000	.0030	65°	63°
10, ...	-	51	-	-	-	-	-	-	-	-	-	-
11, ...	150	102	-	-	-	-	-	-	-	-	68°	63°
12, ...	150	142	-	-	-	-	-	-	-	-	66°	63°
13, ...	150	135	18.40	17.10	.0010	.0060	.0070	4.92	1.7000	.0005	66°	63°
14, ...	150	196	-	-	-	-	-	-	-	-	66°	63°
15, ...	150	189	-	-	-	-	-	-	-	-	-	62°
16, ...	300	295	9.20	18.70	.0018	.0076	.0094	5.75	1.3200	.0006	66°	64°
17, ...	-	49	-	-	-	-	-	-	-	-	-	-
18, ...	300	240	-	-	-	-	-	-	-	-	68°	65°
19, ...	300	279	-	-	-	-	-	-	-	-	68°	65°
20, ...	200	285	10.20	17.00	.0004	.0108	.0112	5.05	.9000	.0030	71°	67°
21, ...	300	290	-	-	-	-	-	-	-	-	70°	67°
22, ...	300	293	-	-	-	-	-	-	-	-	70°	67°
23, ...	600	568	8.90	15.00	.0020	.0090	.0110	4.05	.7500	.0002	73°	68°
24, ...	-	57	-	-	-	-	-	-	-	-	-	-
25, ...	300	291	-	-	-	-	-	-	-	-	68°	69°
26, ...	300	337	-	-	-	-	-	-	-	-	71°	69°
27, ...	300	322	9.60	19.10	.0012	.0076	.0088	6.55	.8300	.0002	70°	69°
28, ...	300	272	-	-	-	-	-	-	-	-	68°	67°
29, ...	300	293	-	-	-	-	-	-	-	-	67°	68°
30, ...	650	625	5.20	18.70	.0028	.0158	.0186	5.00	.5500	.0007	67°	68°

Effluent colorless, generally clear, and with very slight sediment. Organisms visible to naked eye in samples throughout the month.

Total effluent to end of month, 28,824 gallons.

Filter Tank No. 6 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	53	-	-	-	-	-	-	-	-	-	-	-
2, .	300	260	-	-	-	-	-	-	-	-	-	65°	67°
3, .	300	283	-	-	-	-	-	-	-	-	-	66°	67°
4, .	300	279	10.40	27.00	.0002	.0118	.0120	11.52	.5700	.0014	-	66°	68°
5, .	300	278	-	-	-	-	-	-	-	-	-	68°	68°
6, .	300	287	-	-	-	-	-	-	-	-	-	70°	68°
7, .	600	540	5.20	25.40	.0028	.0108	.0136	7.58	.8300	.0040	-	71°	70°
8, .	-	51	-	-	-	-	-	-	-	-	-	-	-
9, .	300	234	-	-	-	-	-	-	-	-	-	69°	69°
10, .	300	280	-	-	-	-	-	-	-	-	-	70°	71°
11, .	300	317	6.30	26.10	.0012	.0094	.0106	7.87	1.0000	.0006	-	71°	71°
12, .	300	369	-	-	-	-	-	-	-	-	1 h.38 m.	-	69°
13, .	300	280	-	-	-	-	-	-	-	-	54 m.	70°	70°
14, .	600	594	5.70	23.50	.0030	.0094	.0124	5.41	1.1000	.0011	-	69°	71°
15, .	-	57	-	-	-	-	-	-	-	-	-	-	-
16, .	300	219	-	-	-	-	-	-	-	-	-	69°	70°
17, .	300	303	-	-	-	-	-	-	-	-	-	69°	71°
18, .	300	285	8.10	29.50	.0014	.0102	.0116	8.06	1.4000	.0003	-	70°	70°
19, .	300	394	-	-	-	-	-	-	-	-	-	70°	71°
20, .	300	341	-	-	-	-	-	-	-	-	-	70°	71°
21, .	600	528	5.40	26.60	.0018	.0102	.0120	6.16	1.3700	.0008	-	71°	71°
22, .	-	95	-	-	-	-	-	-	-	-	-	-	-
23, .	300	285	-	-	-	-	-	-	-	-	-	72°	71°
24, .	300	255	-	-	-	-	-	-	-	-	-	72°	71°
25, .	300	300	5.20	29.60	.0054	.0198	.0252	9.62	.9500	.0030	-	72°	69°
26, .	300	277	-	-	-	-	-	-	-	-	-	74°	72°
27, .	300	286	-	-	-	-	-	-	-	-	-	72°	71°
28, .	600	545	4.20	26.10	.0094	.0208	.0302	7.05	.7500	.0020	-	72°	71°
29, .	-	99	-	-	-	-	-	-	-	-	-	-	-
30, .	300	252	-	-	-	-	-	-	-	-	-	71°	70°
31, .	300	263	-	-	-	-	-	-	-	-	4 h.35 m.	72°	71°

Effluent colorless, generally clear, and with little or no sediment.
Total effluent to end of month, 57,713 gallons.

Filter Tank No. 6 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	300	256	3.20	31.30	.0332	.0138	.0470	8.14	1.1500	.0080	24 h.	72°	71°
2, .	300	262	-	-	-	-	-	-	-	-	-	73°	71°
3, .	300	235	-	-	-	-	-	-	-	-	-	73°	72°
4, .	600	536	2.70	26.50	.0056	.0106	.0162	5.68	1.3000	.0040	-	73°	72°
5, .	-	160	-	-	-	-	-	-	-	-	-	-	-
6, .	300	261	-	-	-	-	-	-	-	-	24 h.	73°	72°
7, .	300	297	-	-	-	-	-	-	-	-	24 h.	72°	72°
8, .	300	335	3.90	17.00	.0140	.0132	.0272	4.34	.6000	.0024	24 h.	72°	71°
9, .	300	257	-	-	-	-	-	-	-	-	-	72°	72°
10, .	300	295	-	-	-	-	-	-	-	-	-	72°	72°
11, .	600	354	1.50	20.60	.0332	.0150	.0482	4.20	.8000	.0300	-	73°	70°
12, .	-	210	-	-	-	-	-	-	-	-	-	-	-
13, .	150	146	-	-	-	-	-	-	-	-	-	70°	70°
14, .	150	240	-	-	-	-	-	-	-	-	24 h.	69°	70°
15, .	150	148	2.10	16.60	.0040	.0120	.0160	5.57	.0810	.0002	24 h.	69°	70°
16, .	150	164	-	-	-	-	-	-	-	-	24 h.	69°	71°
17, .	150	218	-	-	-	-	-	-	-	-	24 h.	70°	70°
18, .	300	225	5.00	15.60	.0048	.0120	.0168	4.62	.0750	.0006	36 h.+	70°	70°
19, .	-	110	-	-	-	-	-	-	-	-	-	-	-
20, .	150	150	-	-	-	-	-	-	-	-	1 h. 35 m.	71°	72°
21, .	150	161	-	-	-	-	-	-	-	-	46 m.	71°	71°
22, .	150	301	5.00	21.50	.0134	.0136	.0270	4.70	.3200	.0014	1 h. 2 m.	71°	70°
23, .	150	141	-	-	-	-	-	-	-	-	-	70°	70°
24, .	150	129	-	-	-	-	-	-	-	-	22 m.	70°	71°
25, .	300	269	4.00	25.90	.0068	.0096	.0164	4.01	.2000	.0040	49 m.	70°	71°
26, .	-	35	-	-	-	-	-	-	-	-	-	-	-
27, .	150	99	-	-	-	-	-	-	-	-	13 m.	71°	71°
28, .	150	125	-	-	-	-	-	-	-	-	16 m.	70°	69°
29, .	150	132	5.50	29.60	.0016	.0102	.0118	6.07	2.0000	.0480	19 m.	69°	70°
30, .	150	130	-	-	-	-	-	-	-	-	20 m.	69°	70°
31, .	150	136	-	-	-	-	-	-	-	-	20 m.	70°	70°

Effluent colorless, generally clear, and with very slight sediment.

After August 1, residue on evaporation obtained with sodium carbonate. August 6 and 14. — Rain water on surface in the morning.

Total effluent to end of month, 44,239 gallons.

Filter Tank No. 6 — Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1,	300	303	1.60	52.60	.0018	.0114	.0132	19.25	1.4000	.0040	-	71°	70°
2,	-	48	-	-	-	-	-	-	-	-	-	-	-
3,	150	89	-	-	-	-	-	-	-	-	17 m.	70°	71°
4,	150	129	-	-	-	-	-	-	-	-	22 m.	71°	69°
5,	150	121	5.70	46.40	.0008	.0114	.0122	17.40	1.3700	.0010	29 m.	70°	70°
6,	150	130	-	-	-	-	-	-	-	-	27 m.	68°	70°
7,	150	131	-	-	-	-	-	-	-	-	31 m.	67°	63°
8,	300	475	2.10	43.60	.0020	.0112	.0132	15.20	1.2800	.0002	12 h.+	66°	69°
9,	-	72	-	-	-	-	-	-	-	-	-	-	-
10,	150	104	-	-	-	-	-	-	-	-	1 h. 25 m.	67°	68°
11,	150	131	-	-	-	-	-	-	-	-	1 h. 39 m.	66°	68°
12,	150	227	3.00	35.50	.0016	.0116	.0132	11.65	1.1700	.0004	-	66°	67°
13,	150	138	-	-	-	-	-	-	-	-	2 h. 30 m.	66°	68°
14,	150	127	-	-	-	-	-	-	-	-	1 h. 39 m.	64°	68°
15,	300	255	2.00	32.30	.0006	.0100	.0106	6.22	1.2000	.0000	12 h.+	64°	67°
16,	-	58	-	-	-	-	-	-	-	-	-	-	-
17,	150	96	-	-	-	-	-	-	-	-	2 h. 30 m.	65°	68°
18,	150	342	-	-	-	-	-	-	-	-	12 h.+	65°	66°
19,	150	150	1.60	35.90	.0012	.0092	.0104	9.60	1.0200	.0000	4 h. 28 m.	64°	65°
20,	150	142	-	-	-	-	-	-	-	-	-	64°	66°
21,	150	319	-	-	-	-	-	-	-	-	-	63°	64°
22,	300	302	.50	29.90	.0004	.0074	.0078	7.48	1.0000	.0000	-	62°	65°
23,	-	65	-	-	-	-	-	-	-	-	-	-	-
24,	150	87	-	-	-	-	-	-	-	-	2 h. 45 m.	59°	63°
25,	150	138	-	-	-	-	-	-	-	-	-	58°	64°
26,	150	412	.90	22.40	.0004	.0068	.0072	4.20	.8600	.0000	-	58°	62°
27,	150	176	-	-	-	-	-	-	-	-	-	58°	63°
28,	150	138	-	-	-	-	-	-	-	-	2 h. 26 m.	57°	62°
29,	300	266	1.20	21.50	.0004	.0052	.0056	3.15	.8100	.0000	10 h.+	56°	60°
30,	-	65	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, generally clear, and free from sediment.

September 5. — Vinegar eels in sample. September 15. — First 150 gallons sewage applied disappeared in 1 hour 20 minutes. September 22. — A very little rain-water on surface in the morning.

Total effluent to end of month, 49,475 gallons.

Filter Tank No. 6 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	150	96	-	-	-	-	-	-	-	-	1 h.50 m.	53°	60°
2, .	150	262	-	-	-	-	-	-	-	-	4 h.14 m.	55°	60°
3, .	150	177	2.50	23.20	.0000	.0062	.0062	5.77	.8300	.0000	4 h.35 m.	53°	59°
4, .	150	137	-	-	-	-	-	-	-	-	4 h.	54°	59°
5, .	150	144	-	-	-	-	-	-	-	-	3 h.44 m.	51°	58°
6, .	300	308	2.30	23.40	.0002	.0056	.0058	5.57	.9000	.0000	-	52°	58°
7, .	-	222	-	-	-	-	-	-	-	-	-	-	-
8, .	150	147	-	-	-	-	-	-	-	-	-	53°	56°
9, .	150	145	-	-	-	-	-	-	-	-	-	52°	56°
10, .	150	139	.40	22.10	.0004	.0082	.0086	4.50	.8000	.0000	-	52°	57°
11, .	150	142	-	-	-	-	-	-	-	-	-	52°	57°
12, .	150	142	-	-	-	-	-	-	-	-	-	51°	54°
13, .	300	322	.30	22.20	.0004	.0066	.0070	4.36	.9700	.0000	-	51°	54°
14, .	-	63	-	-	-	-	-	-	-	-	-	-	-
15, .	150	106	-	-	-	-	-	-	-	-	-	51°	54°
16, .	150	126	-	-	-	-	-	-	-	-	12 h.+	49°	55°
17, .	150	200	1.20	22.10	.0002	.0052	.0054	4.50	.9400	.0000	-	50°	53°
18, .	150	185	-	-	-	-	-	-	-	-	12 h.+	52°	52°
19, .	150	146	-	-	-	-	-	-	-	-	-	49°	53°
20, .	300	310	1.30	22.70	.0004	.0086	.0090	4.62	1.2000	.0000	-	55°	53°
21, .	-	75	-	-	-	-	-	-	-	-	-	-	-
22, .	150	103	-	-	-	-	-	-	-	-	-	51°	53°
23, .	150	129	-	-	-	-	-	-	-	-	-	49°	52°
24, .	150	268	.40	22.70	.0006	.0048	.0054	4.41	.8300	.0000	-	48°	51°
25, .	150	151	-	-	-	-	-	-	-	-	7 h.11 m.	49°	51°
26, .	150	139	-	-	-	-	-	-	-	-	-	47°	-
27, .	300	289	2.80	19.50	.0002	.0062	.0064	4.25	.9800	.0000	12 h.+	50°	50°
28, .	-	104	-	-	-	-	-	-	-	-	-	-	-
29, .	150	134	-	-	-	-	-	-	-	-	-	49°	52°
30, .	150	141	-	-	-	-	-	-	-	-	-	50°	52°
31, .	150	144	1.80	22.20	.0000	.0044	.0044	5.48	.9700	.0000	12 h.+	48°	52°

Effluent colorless and generally clear, and free from sediment.
October 10. — Sewage applied nearly all disappeared in 7 hours 12 minutes.
Total effluent to end of month, 54,671 gallons.

Filter Tank No. 6 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	150	152	-	-	-	-	-	-	-	-	23 h.17 m.	-	53°
2, .	-	58	-	-	-	-	-	-	-	-	-	-	54°
3, .	300	253	1.00	22.80	.0008	.0126	.0134	4.78	1.0000	.0000	10 h.52 m.	50°	52°
4, .	-	50	-	-	-	-	-	-	-	-	-	-	-
5, .	-	30	-	-	-	-	-	-	-	-	-	-	53°
6, .	300	212	-	-	-	-	-	-	-	-	1 h.35 m.	50°	51°
7, .	-	53	1.00	23.80	.0000	.0052	.0052	4.72	1.0500	.0000	-	-	52°
8, .	300	231	-	-	-	-	-	-	-	-	1 h.24 m.	52°	53°
9, .	-	73	-	-	-	-	-	-	-	-	-	-	53°
10, .	300	398	1.20	22.70	.0000	.0074	.0074	4.54	1.1000	.0000	12 h.+	51°	52°
11, .	-	79	-	-	-	-	-	-	-	-	-	-	-
12, .	-	36	-	-	-	-	-	-	-	-	-	-	52°
13, .	300	208	-	-	-	-	-	-	-	-	-	47°	51°
14, .	-	54	1.90	22.50	.0004	.0062	.0066	4.15	1.1800	.0000	-	-	52°
15, .	300	314	-	-	-	-	-	-	-	-	-	46°	50°
16, .	-	81	-	-	-	-	-	-	-	-	-	-	50°
17, .	300	274	2.30	19.10	.0034	.0088	.0122	4.32	.8000	.0024	1 h.8 m.	44°	48°
18, .	-	47	-	-	-	-	-	-	-	-	-	-	-
19, .	-	29	-	-	-	-	-	-	-	-	-	-	50°
20, .	300	265	-	-	-	-	-	-	-	-	51 m.	43°	48°
21, .	-	60	1.50	21.70	.0002	.0042	.0044	4.54	1.0500	.0001	-	-	47°
22, .	300	195	-	-	-	-	-	-	-	-	-	44°	46°
23, .	-	63	-	-	-	-	-	-	-	-	-	-	46°
24, .	300	248	1.60	19.40	.0026	.0098	.0124	4.30	1.0500	.0002	-	45°	46°
25, .	-	50	-	-	-	-	-	-	-	-	-	-	-
26, .	-	27	-	-	-	-	-	-	-	-	-	-	46°
27, .	300	396	-	-	-	-	-	-	-	-	-	46°	43°
28, .	-	66	.50	19.70	.0002	.0052	.0054	3.87	.9500	.0000	-	-	46°
29, .	-	-	-	-	-	-	-	-	-	-	-	-	-
30, .	-	55	1.90	18.50	.0000	.0060	.0060	3.90	.9200	.0000	-	-	44°

Effluent clear and colorless and generally free from sediment.

November 22. — Canvas cover put over tank. November 26. — Considerable snow sifted in under the canvas. November 29, 2.50 A.M. to November 30, 1.40 P.M. — Outlet closed. River high.

Total effluent to end of month, 58,728 gallons.

Filter Tank No. 6 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	300	217	-	-	-	-	-	-	-	-	1 h.	44°	42°
2, .	-	47	-	-	-	-	-	-	-	-	-	-	-
3, .	-	26	-	-	-	-	-	-	-	-	-	-	43°
4, .	300	215	-	-	-	-	-	-	-	-	1 h. 7m.	44°	42°
5, .	-	56	2.30	17.20	.0002	.0044	.0046	3.45	1.0000	.0000	-	-	42°
6, .	300	249	-	-	-	-	-	-	-	-	45 m.	45°	42°
7, .	-	57	-	-	-	-	-	-	-	-	-	-	43°
8, .	300	254	1.00	24.70	.0004	.0078	.0082	6.69	.7500	.0000	-	44°	42°
9, .	-	44	-	-	-	-	-	-	-	-	-	-	-
10, .	-	29	-	-	-	-	-	-	-	-	-	-	42°
11, .	300	213	-	-	-	-	-	-	-	-	-	45°	41°
12, .	-	54	.80	24.50	.0000	.0042	.0042	7.54	.7800	.0000	-	-	41°
13, .	300	218	-	-	-	-	-	-	-	-	1h. 15m.	44°	40°
14, .	-	57	-	-	-	-	-	-	-	-	-	-	39°
15, .	300	187	2.30	24.10	.0008	.0110	.0118	6.01	.8500	.0000	1h. 58m.	-	41°
16, .	-	45	-	-	-	-	-	-	-	-	-	-	-
17, .	-	25	-	-	-	-	-	-	-	-	-	-	43°
18, .	300	215	1.10	21.10	.0000	.0076	.0076	5.66	.8200	.0000	1h.	45°	40°
19, .	-	-	-	-	-	-	-	-	-	-	-	-	-
20, .	-	-	-	-	-	-	-	-	-	-	-	-	-
21, .	-	169	-	-	-	-	-	-	-	-	-	-	39°
22, .	300	132	1.20	19.30	.0002	.0064	.0066	3.98	.7300	.0001	-	45°	38°
23, .	-	49	-	-	-	-	-	-	-	-	-	-	-
24, .	-	27	-	-	-	-	-	-	-	-	-	-	41°
25, .	300	241	-	-	-	-	-	-	-	-	-	46°	-
26, .	-	48	1.20	18.40	.0010	.0064	.0074	3.88	1.0500	.0000	-	-	41°
27, .	300	272	-	-	-	-	-	-	-	-	1h. 30m.	44°	39°
28, .	-	47	-	-	-	-	-	-	-	-	-	-	40°
29, .	300	258	.80	24.40	.0016	.0114	.0130	8.31	.3400	.0004	1h. 4m.	40°	39°
30, .	-	43	-	-	-	-	-	-	-	-	-	-	-
31, .	-	27	-	-	-	-	-	-	-	-	-	-	42°

Effluent colorless, generally clear and with very slight or no sediment.

December 18.—5.28 P.M. to December 21, 7.49 A.M., outlet closed. River high. December 19, ⅜ inch of frost in tank. December 21, 2 inches.

Total effluent to end of month, 62,249 gallons.

Filter Tank No. 6 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	300	225	-	-	-	-	-	-	-	-	52 m.	45°	39°
2, .	-	51	0.7	21.7	.0004	.0062	.0066	5.18	.5700	.0000	-	-	39°
3, .	300	243	-	-	-	-	-	-	-	-	-	44°	38°
4, .	-	50	-	-	-	-	-	-	-	-	-	-	40°
5, .	300	246	0.6	22.2	.0008	.0090	.0098	5.97	.5000	.0001	-	44°	38°
6, .	-	46	-	-	-	-	-	-	-	-	-	-	-
7, .	-	25	-	-	-	-	-	-	-	-	-	-	40°
8, .	300	222	-	-	-	-	-	-	-	-	-	44°	39°
9, .	-	73	0.9	21.8	.0008	.0066	.0074	5.74	.5500	.0000	-	-	40°
10, .	300	241	-	-	-	-	-	-	-	-	-	45°	38°
11, .	-	49	-	-	-	-	-	-	-	-	-	-	41°
12, .	300	248	1.2	21.5	.0012	.0106	.0118	4.81	.5000	.0000	46 m.	45°	39°
13, .	-	43	-	-	-	-	-	-	-	-	-	-	-
14, .	-	28	-	-	-	-	-	-	-	-	-	-	41°
15, .	300	201	-	-	-	-	-	-	-	-	1 h. 6 m.	45°	39°
16, .	-	59	0.7	19.0	.0000	.0066	.0066	4.69	.5200	.0000	-	-	40°
17, .	300	260	-	-	-	-	-	-	-	-	-	45°	39°
18, .	-	58	-	-	-	-	-	-	-	-	-	-	40°
19, .	300	252	0.6	24.6	.0012	.0086	.0098	7.53	.4000	.0000	1 h. 34 m.	44°	38°
20, .	-	44	-	-	-	-	-	-	-	-	-	-	-
21, .	-	23	-	-	-	-	-	-	-	-	-	-	40°
22, .	300	199	-	-	-	-	-	-	-	-	52 m.	46°	38°
23, .	-	52	0.7	22.7	.0002	.0052	.0054	6.17	.5000	.0001	-	-	39°
24, .	300	243	-	-	-	-	-	-	-	-	-	45°	38°
25, .	-	56	-	-	-	-	-	-	-	-	-	-	40°
26, .	300	255	0.6	20.5	.0008	.0084	.0092	5.90	.4500	.0000	48 m.	44°	38°
27, .	-	44	-	-	-	-	-	-	-	-	-	-	-
28, .	-	22	-	-	-	-	-	-	-	-	-	-	40°
29, .	300	235	-	-	-	-	-	-	-	-	-	46°	38°
30, .	-	53	0.2	20.3	.0002	.0036	.0038	5.17	.5000	.0000	-	-	38°
31, .	350	274	-	-	-	-	-	-	-	-	-	45°	37°

Effluent colorless, generally clear, and with very slight or no sediment.
January 22. — One inch of frost in tank. January 26 and 29. — No frost.
Total effluent to end of month, 66,369 gallons.

Filter Tank No. 6 — Continued.

February, 1889.

Date.	Quantity applied, Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	68	-	-	-	-	-	-	-	-	-	-	38°
2, .	300	253	0.7	17.4	.0010	.0074	.0084	3.45	.6500	.0001	1 h.	45°	37°
3, .	-	44	-	-	-	-	-	-	-	-	-	-	-
4, .	-	29	-	-	-	-	-	-	-	-	-	-	39°
5, .	300	205	-	-	-	-	-	-	-	-	-	45°	37°
6, .	-	62	0.9	16.4	.0002	.0064	.0066	3.16	.4700	.0000	-	-	39°
7, .	300	224	-	-	-	-	-	-	-	-	1 h. 40 m.	44°	37°
8, .	-	62	-	-	-	-	-	-	-	-	-	-	37°
9, .	300	239	1.4	14.4	.0026	.0086	.0112	2.40	.5500	.0001	3 h. 2 m.	45°	37°
10, .	-	47	-	-	-	-	-	-	-	-	-	-	-
11, .	-	28	-	-	-	-	-	-	-	-	-	-	38°
12, .	300	226	-	-	-	-	-	-	-	-	-	44°	37°
13, .	-	47	1.2	16.7	.0006	.0058	.0064	3.78	.5200	.0000	-	-	38°
14, .	300	250	-	-	-	-	-	-	-	-	2 h. 58 m.	45°	37°
15, .	-	47	-	-	-	-	-	-	-	-	-	-	39°
16, .	300	266	1.6	16.5	.0086	.0064	.0150	3.53	.3500	.0000	-	44°	37°
17, .	-	42	-	-	-	-	-	-	-	-	-	-	-
18, .	-	37	-	-	-	-	-	-	-	-	-	-	38°
19, .	300	264	-	-	-	-	-	-	-	-	2 h. 45 m.	44°	37°
20, .	-	43	1.0	16.2	.0014	.0068	.0082	3.20	.5000	.0000	-	-	38°
21, .	300	247	-	-	-	-	-	-	-	-	2 h. 56 m.	44°	37°
22, .	-	41	-	-	-	-	-	-	-	-	-	-	39°
23, .	300	266	-	-	-	-	-	-	-	-	1 h. 57 m.	44°	36°
24, .	-	33	-	-	-	-	-	-	-	-	-	-	-
25, .	-	19	-	-	-	-	-	-	-	-	-	-	38°
26, .	300	221	-	-	-	-	-	-	-	-	-	44°	36°
27, .	-	32	1.3	16.1	.0006	.0088	.0094	3.17	.4700	.0001	-	-	39°
28, .	300	267	-	-	-	-	-	-	-	-	5 h. 35 m.	45°	37°

Effluent colorless, generally clear, and with very slight or no sediment.

Frost in tank: February 2. — One inch. February 5. — None. February 7. — Three inches. February 9. — Three and one-half inches. February 14. — Three inches. February 20. — One and one-half inches. February 23. — Three inches. February 25. — Five inches. February 23. — A few spots of ice on surface.

Total effluent to end of month, 69,978 gallons.

Filter Tank No. 6 — Continued.

March, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	32	-	-	-	-	-	-	-	-	-	-	40°
2, .	300	264	1.6	18.2	.0206	.0146	.0352	4.56	.3500	.0014	-	37°	37°
3, .	-	30	-	-	-	-	-	-	-	-	-	-	-
4, .	-	20	-	-	-	-	-	-	-	-	-	-	42°
5, .	300	231	-	-	-	-	-	-	-	-	1 h. 1 m.	35°	37°
6, .	-	50	1.8	17.5	.0010	.0070	.0080	3.80	.6000	.0020	-	-	38°
7, .	300	275	-	-	-	-	-	-	-	-	1 h. 45 m.	36°	37°
8, .	-	58	-	-	-	-	-	-	-	-	-	-	38°
9, .	300	244	0.8	20.0	.0046	.0090	.0136	4.67	.6000	.0001	54 m.	34°	36°
10, .	-	47	-	-	-	-	-	-	-	-	-	-	-
11, .	-	23	-	-	-	-	-	-	-	-	-	-	39°
12, .	300	212	-	-	-	-	-	-	-	-	-	36°	36°
13, .	-	60	1.8	18.7	.0004	.0068	.0072	3.69	.7000	.0000	-	-	38°
14, .	400	357	-	-	-	-	-	-	-	-	51 m.	38°	36°
15, .	-	57	-	-	-	-	-	-	-	-	-	-	38°
16, .	300	248	1.3	20.1	.0108	.0084	.0192	3.83	.9500	.0002	55 m.	36°	36°
17, .	-	50	-	-	-	-	-	-	-	-	-	-	-
18, .	-	37	-	-	-	-	-	-	-	-	-	-	39°
19, .	300	265	-	-	-	-	-	-	-	-	27 m.	38°	37°
20, .	-	43	0.6	19.7	.0014	.0070	.0084	3.50	1.0000	.0000	-	-	38°
21, .	300	233	-	-	-	-	-	-	-	-	32 m.	39°	37°
22, .	-	46	-	-	-	-	-	-	-	-	-	-	41°
23, .	300	228	1.0	22.3	.0034	.0079	.0113	3.34	1.3000	.0001	44 m.	40°	39°
24, .	-	40	-	-	-	-	-	-	-	-	-	-	-
25, .	-	24	-	-	-	-	-	-	-	-	-	-	42°
26, .	300	210	-	-	-	-	-	-	-	-	30 m.	42°	40°
27, .	-	48	0.6	21.8	.0002	.0026	.0028	3.50	1.3000	.0001	-	-	42°
28, .	300	242	-	-	-	-	-	-	-	-	27 m.	43°	40°
29, .	-	52	-	-	-	-	-	-	-	-	-	-	42°
30, .	300	248	1.0	24.1	.0024	.0080	.0104	3.43	1.5000	.0004	30 m.	43°	40°
31, .	-	44	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, very nearly clear and with very slight sediment.

March 1. — One-half inch of frost in the half of tank where sewage runs on directly from hose and 7 inches in the other half. March 9. — No frost in one-half of tank and ½ inch in other. March 13. — Canvas cover removed from tank.

Total effluent to end of month, 73,996 gallons.

Filter Tank No. 6 — Continued.

April, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	34	-	-	-	-	-	-	-	-	-	-	42°
2, .	300	388	-	-	-	-	-	-	-	-	37 m.	39°	40°
3, .	-	54	0.8	23.2	.0008	.0080	.0088	3.43	1.8000	.0000	-	-	41°
4, .	300	245	-	-	-	-	-	-	-	-	47 m.	41°	39°
5, .	-	53	-	-	-	-	-	-	-	-	-	-	42°
6, .	300	246	0.9	22.1	.0012	.0072	.0084	2.76	1.4000	.0001	46 m.	42°	40°
7, .	-	44	-	-	-	-	-	-	-	-	-	-	-
8, .	-	28	-	-	-	-	-	-	-	-	-	-	44°
9, .	300	199	-	-	-	-	-	-	-	-	36 m.	44°	41°
10, .	-	51	1.0	20.9	.0010	.0064	.0074	3.14	1.5000	.0000	-	-	44°
11, .	300	228	-	-	-	-	-	-	-	-	45 m.	45°	43°
12, .	-	55	-	-	-	-	-	-	-	-	-	-	46°
13, .	300	234	0.6	26.3	.0012	.0090	.0102	3.79	1.9000	.0002	52 m.	47°	44°
14, .	-	46	-	-	-	-	-	-	-	-	-	-	-
15, .	-	22	-	-	-	-	-	-	-	-	-	-	49°
16, .	300	186	-	-	-	-	-	-	-	-	29 m.	46°	45°
17, .	-	53	1.8	26.7	.0002	.0070	.0072	4.02	2.1000	.0001	-	-	47°
18, .	300	291	-	-	-	-	-	-	-	-	40 m.	48°	46°
19, .	-	51	-	-	-	-	-	-	-	-	-	-	51°
20, .	300	256	1.3	30.9	.0006	.0096	.0102	4.68	3.0000	.0000	38 m.	52°	48°
21, .	-	42	-	-	-	-	-	-	-	-	-	-	-
22, .	-	27	-	-	-	-	-	-	-	-	-	-	51°
23, .	300	208	-	-	-	-	-	-	-	-	32 m.	51°	50°
24, .	-	49	-	-	-	-	-	-	-	-	-	-	51°
25, .	300	220	-	-	-	-	-	-	-	-	36 m.	52°	51°
26, .	-	101	-	-	-	-	-	-	-	-	-	-	52°
27, .	300	410	2.2	33.4	.0006	.0106	.0112	3.92	3.0000	.0000	52 m.	53°	52°
28, .	-	52	-	-	-	-	-	-	-	-	-	-	-
29, .	-	28	-	-	-	-	-	-	-	-	-	-	53°
30, .	300	207	-	-	-	-	-	-	-	-	28 m.	53°	52°

Effluent colorless, and generally clear and free from sediment.
Total effluent to end of month, 78,104 gallons.

Filter Tank No. 6 — Continued.

May, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	50	1.5	28.0	.0008	.0068	.0076	4.60	2.0000	.0001	-	-	53°
2, .	300	228	-	-	-	-	-	-	-	-	30 m.	52°	53°
3, .	-	47	-	-	-	-	-	-	-	-	-	-	53°
4, .	300	232	1.0	31.3	.0008	.0082	.0090	6.13	2.0000	.0000	38 m.	53°	53°
5, .	-	44	-	-	-	-	-	-	-	-	-	-	-
6, .	-	23	-	-	-	-	-	-	-	-	-	-	56°
7, .	300	197	-	-	-	-	-	-	-	-	-	56°	54°
8, .	-	43	1.8	29.8	.0004	.0054	.0058	5.52	2.2000	.0000	-	-	57°
9, .	300	231	-	-	-	-	-	-	-	-	31 m.	59°	56°
10, .	-	49	-	-	-	-	-	-	-	-	-	-	59°
11, .	300	239	1.2	32.2	.0002	.0058	.0060	4.94	2.4000	.0000	31 m.	63°	57°
12, .	-	47	-	-	-	-	-	-	-	-	-	-	-
13, .	-	21	-	-	-	-	-	-	-	-	-	-	61°
14, .	300	252	-	-	-	-	-	-	-	-	30 m.	64°	58°
15, .	-	65	-	-	-	-	-	-	-	-	-	-	60°
16, .	300	241	-	-	-	-	-	-	-	-	32 m.	64°	59°
17, .	-	48	-	-	-	-	-	-	-	-	-	-	62°
18, .	300	228	1.4	34.4	.0018	.0090	.0108	5.00	2.8000	.0000	32 m.	66°	61°
19, .	-	40	-	-	-	-	-	-	-	-	-	-	-
20, .	-	38	-	-	-	-	-	-	-	-	-	-	63°
21, .	300	530	-	-	-	-	-	-	-	-	-	67°	63°
22, .	-	48	-	-	-	-	-	-	-	-	-	-	63°
23, .	300	226	-	-	-	-	-	-	-	-	34 m.	66°	63°
24, .	-	44	-	-	-	-	-	-	-	-	-	-	62°
25, .	300	245	2.5	25.1	.0002	.0086	.0088	3.07	1.8000	.0001	34 m.	63°	63°
26, .	-	47	-	-	-	-	-	-	-	-	-	-	-
27, .	-	30	-	-	-	-	-	-	-	-	-	-	59°
28, .	300	295	-	-	-	-	-	-	-	-	28 m.	60°	62°
29, .	-	51	0.0	25.3	.0014	.0088	.0102	4.19	1.7000	.0000	-	-	62°
30, .	300	221	-	-	-	-	-	-	-	-	35 m.	61°	61°
31, .	-	50	-	-	-	-	-	-	-	-	-	-	62°

Effluent clear and colorless, and generally free from sediment.
May 22. — Grass on surface in a few spots.
Total effluent to end of month, 82,254 gallons.

Filter Tank No. 6 — Continued.

June, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	300	228	1.6	26.2	.0120	.0122	.0242	4.25	1.6000	.0006	36 m.	64°	61°
2, .	-	163	-	-	-	-	-	-	-	-	-	-	-
3, .	-	53	-	-	-	-	-	-	-	-	-	-	63°
4, .	300	294	-	-	-	-	-	-	-	-	35 m.	65°	60°
5, .	-	56	1.4	24.7	.0014	.0078	.0092	4.03	2.2000	.0001	-	-	63°
6, .	300	230	-	-	-	-	-	-	-	-	-	64°	63°
7, .	-	50	-	-	-	-	-	-	-	-	-	-	65°
8, .	300	236	1.3	25.5	.0008	.0090	.0098	3.99	1.9000	.0004	33 m.	66°	63°
9, .	-	49	-	-	-	-	-	-	-	-	-	-	-
10, .	-	25	-	-	-	-	-	-	-	-	-	-	68°
11, .	300	242	-	-	-	-	-	-	-	-	36 m.	68°	64°
12, .	-	43	-	-	-	-	-	-	-	-	-	-	65°
13, .	300	219	-	-	-	-	-	-	-	-	43 m.	68°	65°
14, .	-	50	-	-	-	-	-	-	-	-	-	-	68°
15, .	300	219	2.1	25.0	.0020	.0084	.0104	4.75	2.0000	.0001	41 m.	69°	67°
16, .	-	39	-	-	-	-	-	-	-	-	-	-	-
17, .	-	24	-	-	-	-	-	-	-	-	-	-	68°
18, .	500	394	-	-	-	-	-	-	-	-	59 m.	70°	67°
19, .	-	48	1.4	27.1	.0028	.0074	.0102	4.75	2.4000	.0002	-	-	66°
20, .	500	388	-	-	-	-	-	-	-	-	-	70°	67°
21, .	-	54	-	-	-	-	-	-	-	-	-	70°	-
22, .	500	421	-	-	.0038	.0158	.0196	5.02	1.7000	.0005	41 m.	72°	68°
23, .	-	45	-	-	-	-	-	-	-	-	-	-	-
24, .	-	22	-	-	-	-	-	-	-	-	-	-	69°
25, .	500	380	-	-	-	-	-	-	-	-	39 m.	-	69°
26, .	-	47	1.3	24.4	.0034	.0090	.0124	4.95	1.6000	.0003	-	-	69°
27, .	500	406	-	-	-	-	-	-	-	-	42 m.	71°	69°
28, .	-	53	-	-	-	-	-	-	-	-	-	-	71°
29, .	500	507	2.4	26.0	.0282	.0176	.0458	5.45	1.5000	.0018	46 m.	72°	70°
30, .	-	42	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless and generally clear, and with very slight sediment.
Total effluent to end of month, 87,281 gallons.

Filter Tank No. 6 — Continued.

July, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	22	-	-	-	-	-	-	-	-	-	-	74°
2, .	500	392	-	-	-	-	-	-	-	-	58 m.	74°	70°
3, .	-	79	2.2	24.4	.0022	.0122	.0144	5.90	1.0000	.0005	-	-	71°
4, .	500	451	-	-	-	-	-	-	-	-	-	74°	-
5, .	-	40	-	-	-	-	-	-	-	-	-	-	72°
6, .	500	416	2.0	26.0	.0074	.0222	.0296	6.05	1.4000	.0008	-	74°	71°
7, .	-	41	-	-	-	-	-	-	-	-	-	-	-
8, .	-	20	-	-	-	-	-	-	-	-	-	-	72°
9, .	500	384	-	-	-	-	-	-	-	-	40 m.	71°	70°
10, .	-	42	1.9	24.4	.0018	.0094	.0112	6.12	1.2000	.0000	-	-	67°
11, .	500	417	-	-	-	-	-	-	-	-	41 m.	73°	70°
12, .	-	51	-	-	-	-	-	-	-	-	-	-	71°
13, .	500	421	2.8	21.4	.0074	.0128	.0202	5.32	1.1000	.0004	-	72°	70°
14, .	-	33	-	-	-	-	-	-	-	-	-	-	-
15, .	-	19	-	-	-	-	-	-	-	-	-	-	67°
16, .	500	478	-	-	-	-	-	-	-	-	47 m.	71°	68°
17, .	-	37	2.0	23.4	.0018	.0020	.0038	4.42	1.2000	.0000	-	-	68°
18, .	500	468	-	-	-	-	-	-	-	-	45 m.	72°	68°
19, .	-	45	-	-	-	-	-	-	-	-	-	-	69°
20, .	500	746	2.2	20.2	.0014	.0120	.0134	3.94	1.1000	.0005	41 m.	70°	67°
21, .	-	31	-	-	-	-	-	-	-	-	-	-	-
22, .	-	14	-	-	-	-	-	-	-	-	-	-	72°
23, .	500	455	-	-	-	-	-	-	-	-	46 m.	73°	67°
24, .	-	58	1.5	16.8	.0012	.0080	.0092	3.69	.8000	.0004	-	-	71°
25, .	500	427	-	-	-	-	-	-	-	-	-	69°	70°
26, .	-	37	-	-	-	-	-	-	-	-	-	-	72°
27, .	500	550	1.9	22.7	.0048	.0104	.0152	4.52	1.2000	.0000	48 m.	71°	69°
28, .	-	59	-	-	-	-	-	-	-	-	-	-	-
29, .	-	16	-	-	-	-	-	-	-	-	-	-	74°
30, .	500	435	-	-	-	-	-	-	-	-	47 m.	72°	69°
31, .	-	95	3.0	20.2	.0006	.0058	.0064	4.03	1.0000	.0000	-	-	69°

Effluent colorless and generally clear, and free from sediment.
Total effluent to end of month, 94,060 gallons.

Filter Tank No. 6 — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	500	588	-	-	-	-	-	-	-	-	-	72°	69°
2, .	-	58	-	-	-	-	-	-	-	-	-	-	71°
3, .	500	452	1.8	19.0	.0034	.0108	.0142	3.52	1.1000	.0002	43 m.	71°	70°
4, .	-	39	-	-	-	-	-	-	-	-	-	-	-
5, .	-	14	-	-	-	-	-	-	-	-	-	-	69°
6, .	500	412	-	-	-	-	-	-	-	-	57 m.	70°	69°
7, .	-	46	-	-	-	-	-	-	-	-	-	-	70°
8, .	500	400	-	-	-	-	-	-	-	-	43 m.	70°	69°
9, .	-	38	-	-	-	-	-	-	-	-	-	-	70°
10, .	500	417	1.0	22.7	.0042	.0096	.0138	4.67	1.6000	.0002	46 m.	70°	69°
11, .	-	37	-	-	-	-	-	-	-	-	-	-	-
12, .	-	19	-	-	-	-	-	-	-	-	-	-	69°
13, .	500	376	-	-	-	-	-	-	-	-	-	70°	68°
14, .	-	170	-	-	-	-	-	-	-	-	-	-	68°
15, .	500	494	-	-	-	-	-	-	-	-	56 m.	68°	69°
16, .	-	48	-	-	-	-	-	-	-	-	-	-	69°
17, .	500	414	-	-	.0046	.0104	.0150	3.92	1.8000	.0000	-	68°	67°
18, .	-	35	-	-	-	-	-	-	-	-	-	-	-
19, .	-	22	-	-	-	-	-	-	-	-	-	-	69°
20, .	500	373	-	-	-	-	-	-	-	-	41 m.	68°	65°
21, .	-	45	-	-	-	-	-	-	-	-	-	-	66°
22, .	500	388	-	-	-	-	-	-	-	-	-	69°	67°
23, .	-	48	-	-	-	-	-	-	-	-	-	-	68°
24, .	500	400	-	-	.0056	.0108	.0164	5.24	1.9000	.0001	47 m.	69°	67°
25, .	-	35	-	-	-	-	-	-	-	-	-	-	-
26, .	-	17	-	-	-	-	-	-	-	-	-	-	67°
27, .	500	369	-	-	-	-	-	-	-	-	-	68°	66°
28, .	-	46	-	-	-	-	-	-	-	-	-	-	67°
29, .	500	412	-	-	-	-	-	-	-	-	-	69°	67°
30, .	-	38	-	-	-	-	-	-	-	-	-	-	68°
31, .	500	410	2.1	38.3	.0066	.0118	.0184	12.47	1.6000	.0002	47 m.	70°	66°

Effluent clear and colorless, and with very slight sediment.
Total effluent to end of month, 100,720 gallons.

Filter Tank No. 6 — Continued.

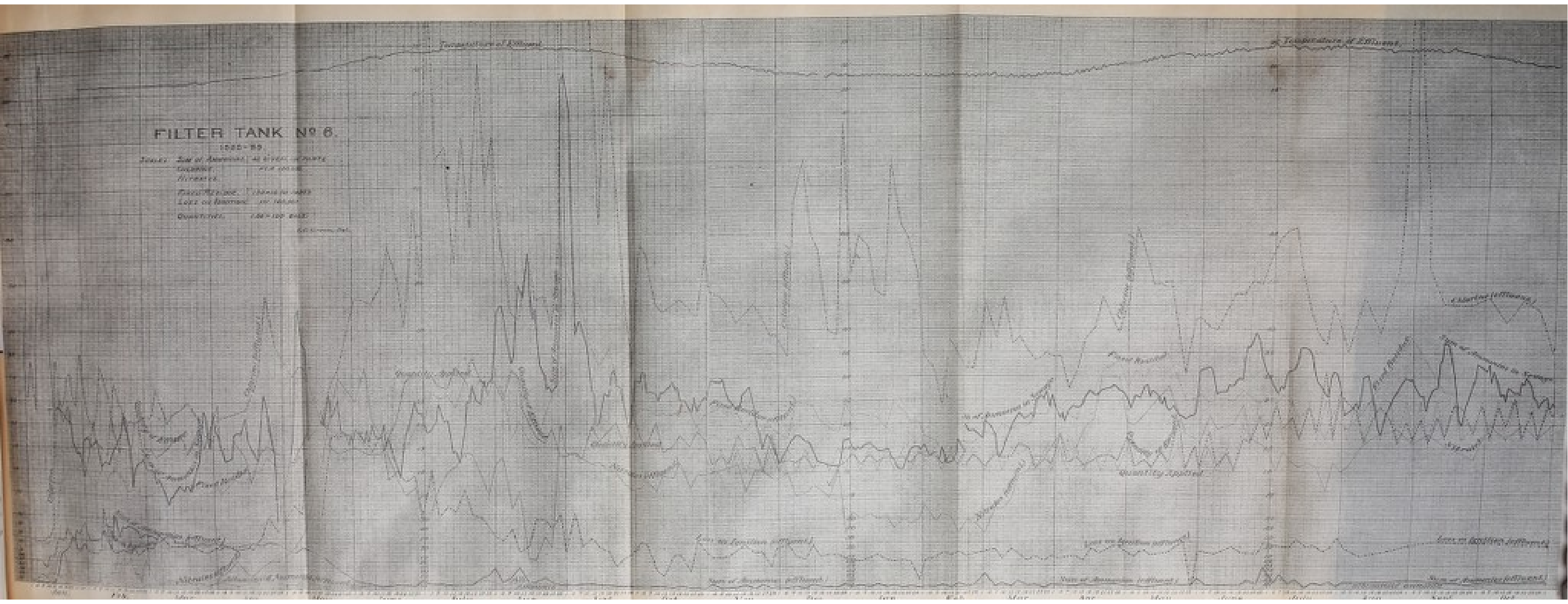
September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	42	-	-	-	-	-	-	-	-	-	-	-
2, .	-	17	-	-	-	-	-	-	-	-	-	-	68°
3, .	500	376	-	-	-	-	-	-	-	-	-	70°	67°
4, .	-	37	-	-	-	-	-	-	-	-	-	-	68°
5, .	500	418	-	-	-	-	-	-	-	-	45 m.	71°	67°
6, .	-	30	-	-	-	-	-	-	-	-	-	-	70°
7, .	500	400	-	-	.0050	.0116	.0166	5.32	1.8000	.0004	-	71°	66°
8, .	-	46	-	-	-	-	-	-	-	-	-	-	-
9, .	-	25	-	-	-	-	-	-	-	-	-	-	69°
10, .	500	388	-	-	-	-	-	-	-	-	46 m.	70°	67°
11, .	-	47	-	-	-	-	-	-	-	-	-	-	66°
12, .	500	429	-	-	-	-	-	-	-	-	48 m.	67°	66°
13, .	-	45	-	-	-	-	-	-	-	-	-	-	66°
14, .	500	521	2.6	26.6	.0032	.0110	.0142	4.53	1.5400	.0003	-	66°	67°
15, .	-	31	-	-	-	-	-	-	-	-	-	-	-
16, .	-	17	-	-	-	-	-	-	-	-	-	-	70°
17, .	500	396	-	-	-	-	-	-	-	-	-	68°	67°
18, .	-	50	-	-	-	-	-	-	-	-	-	-	67°
19, .	500	632	-	-	-	-	-	-	-	-	-	65°	66°
20, .	-	25	-	-	-	-	-	-	-	-	-	-	66°
21, .	500	431	-	-	.0018	.0114	.0132	4.51	1.4000	.0004	-	64°	66°
22, .	-	38	-	-	-	-	-	-	-	-	-	-	-
23, .	-	14	-	-	-	-	-	-	-	-	-	-	64°
24, .	500	398	-	-	-	-	-	-	-	-	-	59°	64°
25, .	-	27	-	-	-	-	-	-	-	-	-	-	-
26, .	500	437	-	-	.0016	.0070	.0086	4.52	1.2600	.0003	-	59°	63°
27, .	-	55	-	-	-	-	-	-	-	-	-	-	63°
28, .	500	433	-	-	-	-	-	-	-	-	47 m.	58°	62°
29, .	-	36	-	-	-	-	-	-	-	-	-	-	-
30, .	-	20	-	-	-	-	-	-	-	-	-	-	63°

Effluent clear and colorless, and free from sediment.

September 20. — Some effluent lost. September 25, 1.45 P.M., to September 26, 11.20 A.M., water backed up in underdrains.

Total effluent to end of month, 106,581 gallons.


FILTER TANK No 6.
Temperature of Effluent
Quantity Applied
Free Ammonia
Loss on Ignition (effluent)
Nitrates
Chlorine (effluent)

Filter Tank No. 6 — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	500	445	-	-	-	-	-	-	-	-	-	59°	61°
2, .	-	58	-	-	-	-	-	-	-	-	-	-	61°
3, .	500	428	-	-	.0060	.0060	.0120	4.67	2.0000	.0003	-	58°	60°
4, .	-	51	-	-	-	-	-	-	-	-	-	-	61°
5, .	500	426	-	-	-	-	-	-	-	-	48 m.	56°	60°
6, .	-	44	-	-	-	-	-	-	-	-	-	-	-
7, .	-	65	-	-	-	-	-	-	-	-	-	-	60°
8, .	500	476	-	-	-	-	-	-	-	-	-	55°	59°
9, .	-	49	-	-	-	-	-	-	-	-	-	-	58°
10, .	500	425	-	-	.0032	.0108	.0140	4.14	1.7000	.0010	-	51°	58°
11, .	-	47	-	-	-	-	-	-	-	-	-	-	56°
12, .	500	425	-	-	-	-	-	-	-	-	-	50°	57°
13, .	-	132	-	-	-	-	-	-	-	-	-	-	-
14, .	-	51	-	-	-	-	-	-	-	-	-	-	55°
15, .	500	425	-	-	-	-	-	-	-	-	-	49°	55°
16, .	-	39	-	-	-	-	-	-	-	-	-	-	55°
17, .	500	412	-	-	.0016	.0100	.0116	4.60	2.0000	.0001	-	48°	54°
18, .	-	32	-	-	-	-	-	-	-	-	-	-	55°
19, .	500	427	-	-	-	-	-	-	-	-	1 h. 3 m.	49°	53°
20, .	-	45	-	-	-	-	-	-	-	-	-	-	-
21, .	-	24	-	-	-	-	-	-	-	-	-	-	52°
22, .	500	434	-	-	-	-	-	-	-	-	-	48°	52°
23, .	-	49	-	-	-	-	-	-	-	-	-	-	52°
24, .	500	428	-	-	.0052	.0116	.0168	4.42	1.7000	.0000	-	48°	51°
25, .	-	51	-	-	-	-	-	-	-	-	-	-	52°
26, .	500	431	-	-	-	-	-	-	-	-	-	47°	52°
27, .	-	49	-	-	-	-	-	-	-	-	-	-	-
28, .	-	62	-	-	-	-	-	-	-	-	-	-	52°
29, .	500	534	-	-	-	-	-	-	-	-	-	49°	51°
30, .	-	60	-	-	-	-	-	-	-	-	-	-	51°
31, .	500	430	-	-	.0022	.0114	.0136	3.52	2.0000	.0000	1 h. 5 m.	48°	51°

Effluent clear and colorless, and free from sediment.
October 26. — Grass cut from one-half of surface.
Total effluent to end of month, 113,635 gallons.

Number of Bacteria in a Cubic Centimeter of Effluent from Filter Tank No. 6.

Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.
1888.		**1888** — Con.		**1888** — Con.		**1889** — Con.	
Jan. 3,	18	March 22,	4,426	Sept. 15,	56	March 12,	27
5,	36	24,	305	20,	20	19,	47
7,	130	27,	1,734	25,	81	26,	174
10,	49	29,	816	29,	584	April 2,	3
12,	63	31,	616	Oct. 2,	99	9,	16
14,	385	April 3,	404	6,	341	16,	9
17,	7,521	19,	378	11,	309	24,	14
19,	35,350	25,	127	16,	377	30,	4
21,	64,839	28,	210	20,	200	May 7,	2
24,	35,172	May 8,	5	25,	126	14,	2
26,	16,947	10,	90	30,	65	21,	3
28,	3,500	12,	12	Nov. 3,	64	28,	3
31,	1,724	19,	15	8,	320	June 4,	90
Feb. 2,	74	22,	4	13,	42	11,	90
4,	1,245	26,	21	19,	613	18,	38
7,	12,079	29,	3	23,	79	26,	70
9,	1,399	31,	3	28,	40	July 2,	76
11,	2,295	June 5,	4	Dec. 5,	37	9,	936
14,	2,615	9,	9	10,	14	16,	1,161
16,	199	14,	21	14,	6	23,	2,088
18,	9,081	21,	610	21,	5	30,	73
21,	13,350	26,	23	26,	28	Aug. 6,	21
23,	23,236	July 3,	400	**1889.**		12,	65
25,	1,197	7,	86	Jan. 2,	23	19,	63
28,	6,519	13,	245	8,	874	24,	2,782
March 1,	10,257	17,	18	15,	2,368	Sept. 2,	612
3,	6,370	21,	72	22,	3,612	10,	1,440
6,	654	Aug. 2,	145	29,	1,575	14,	2,030
8,	2,660	7,	400	Feb. 6,	2	24,	40
10,	690	11,	104	12,	1,200	Oct. 2,	55
15,	4,235	16,	114	19,	3	10,	950
17,	186	21,	452	27,	1	16,	36
20,	1,082	Sept. 11,	65	March 5,	234	25,	4

Number of Bacteria found in the Effluent of Tank No. 6 at different hours before and after applying Sewage.

Date.	Time of Collection.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.
1888.			
Dec. 15,	9.25 A.M.,	–	3
15,	8.35 A.M.,	–	1
15,*	9.37 to 9.54 A.M.,	–	–
15,	9.45 A.M.,	–	2
15,	9.55 A.M.,	–	2
15,	10.07 A.M.,	–	0
15,	10.37 A.M.,	84?	3
15,	10.52 A.M.,	1,262?	34
15,	11.07 A.M.,	1,262?	161
15,	11.22 A.M.,	2,271?	118
28,	4.32 P.M.,	–	13
29,	9.45 A.M.,	92	20
29,*	9.56 to 10.15 A.M.,	–	–
29,	10.15 A.M.,	94	13
29,	10.30 A.M.,	96	46
29,	11.15 A.M.,	5,160	719
29,	11.30 A.M.,	4,380	466
29,	11.45 A.M.,	3,640	356
29,	12.45 P.M.,	2,040	48
1889.			
April 16,	11.15 A.M.,	43	10
16,*	11.35 to 11.54 A.M.,	–	–
16,	2.04 P.M.,	2,160	28
16,	2.37 P.M.,	1,940	39
16,	5.05 P.M.,	1,000	37
17,	9.15 A.M.,	204	11
17,	4.45 P.M.,	120	5
30,	9.55 A.M.,	56	11
30,*	10.10 to 10.28 A.M.,	–	–
30,	11.50 A.M.,	1,152	165
30,	12.22 P.M.,	1,800	12
30,	5.14 P.M.,	820	156
May 1,	9.20 A.M.,	188	15

Date.	Time of Collection.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.
1889—Con.			
May 23,†	–	–	–
24,	8.20 A.M.,	186	12
24,	1.55 P.M.,	144	1
24,	5.08 P.M.,	124	0
25,	8.10 A.M.,	76	0
25,*	9.51 to 10.17 A.M.,	–	–
25,	2.05 P.M.,	1,600	1
25,	4.50 P.M.,	800	1
27,	8.10 A.M.,	100	7
28,*	10.24 to 10.38 A.M.,	–	–
28,	2.00 P.M.,	1,820	5
28,	5.00 P.M.,	820	1
29,	8.18 A.M.,	198	79
29,	2.15 P.M.,	144	1
30,	8.05 A.M.,	80	60
30,*	9.55 to 10.16 A.M.,	–	–
30,	2.00 P.M.,	1,520	8
30,	5.05 P.M.,	780	37
31,	8.05 A.M.,	174	112
31,	2.25 P.M.,	136	651
31,	5.05 P.M.,	128	11
June 1,	8.10 A.M.,	80	8
1,*	9.54 to 10.15 A.M.,	–	–
1,	2.00 P.M.,	1,540	104
3,	2.04 P.M.,	136	41
3,	5.14 P.M.,	120	123
4,	8.25 A.M.,	80	62
4,*	10.05 to 10.21 A.M.,	–	–
4,	1.58 P.M.,	1,720	490
4,	5.08 P.M.,	760	385
5,	8.05 A.M.,	220	115
5,	1.58 P.M.,	164	14
5,	5.08 P.M.,	140	3
6,	8.38 A.M.,	80	1
6,*	9.56 to 10.18 A.M.,	–	–

* Three hundred gallons of sewage applied. † Bacillus prodigiosus applied.

Number of Bacteria found in the Effluent of Tank No. 6 at different hours before and after applying Sewage — Continued.

Date.	Time of Collection.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.	Date.	Time of Collection.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.
1889—Con.				**1889**—Con.			
June 6, .	2.04 P.M., . .	1,560	63	June 18, .	5.04 P.M., . .	840	34
6, .	5.05 P.M., . .	760	65	19, .	7.58 A.M., . .	180	165
7, .	8.05 A.M., . .	184	1	19, .	2.10 P.M., . .	126	0
7, .	1.58 P.M., . .	140	2,640	19, .	5.03 P.M., . .	126	403
7, .	5.05 P.M., . .	124	0	20, .	8.07 A.M., . .	76	6
8, .	8.05 A.M., . .	76	112,000				
8,* .	10.02 to 10.22 A.M.,	-	-	July 2, .	10.00 A.M., . .	-	76
8, .	2.00 P.M., . .	1,560	1,333	2, .	12.10 P.M., . .	44	3,498
8, .	5.03 P.M., . .	840	1,363	2,† .	1.40 to 2.31 P.M.,	-	-
10, .	8.10 A.M., . .	88	29,744	2, .	2.38 P.M., . .	5,520	69,700
10, .	2.02 P.M., . .	766	9	2, .	2.50 P.M., . .	19,500	33,326
10, .	5.00 P.M., . .	66	69	2, .	5.05 P.M., . .	1,440	28,080
11, .	8.03 A.M., . .	52	117	3, .	10.00 A.M., . .	168	10,234
11,* .	10.09 to 10.25 A.M.,	-	-	3, .	3.00 P.M., . .	126	2,291
11, .	2.05 P.M., . .	1,720	667				
11, .	5.05 P.M., . .	800	66,000	9, .	5.00 A.M., . .	50	8
12, .	8.20 A.M., . .	156	254	9, .	6.00 A.M., . .	47	9
12, .	2.05 P.M., . .	144	168	9, .	7.00 A.M., . .	42	3
12, .	5.08 P.M., . .	116	47	9, .	7.35 A.M., . .	44	152
13, .	8.08 A.M., . .	76	97	9, .	8.05 A.M., . .	44	18
13,* .	10.07 to 10.31 A.M.,	-	-	9,† .	8.08 to 8.41 A.M.,	-	-
13, .	1.58 P.M., . .	1,420	5,610	9, .	9.05 A.M., . .	11,520	4,416
13, .	5.02 P.M., . .	760	14,352	9, .	9.28 A.M., . .	9,360	2,025
14, .	8.04 A.M., . .	180	14,487	9, .	10.08 A.M., . .	4,020	1,975
14, .	2.04 P.M., . .	124	36,540	9, .	11.03 A.M., . .	2,400	936
15, .	8.05 A.M., . .	76	35,400	9, .	1.00 P.M., . .	1,200	550
15,* .	9.59 to 10.22 A.M.,	-	-	9, .	3.35 P.M., . .	720	350
15, .	2.05 P.M., . .	1,240	2,523	9, .	4.30 P.M., . .	580	203
15, .	5.00 P.M., . .	723	44,116	9, .	5.15 P.M., . .	580	95
17, .	8.25 A.M., . .	76	394	9, .	7.00 P.M., . .	424	113
17, .	1.55 P.M., . .	64	12	9, .	9.00 P.M., . .	355	88
17, .	5.02 P.M., . .	64	9	10, .	8.15 A.M., . .	168	215
18, .	8.10 A.M., . .	48	126	11,‡ .	9.40 A.M., . .	72	101
18,† .	10.15 to 10.49 A.M.,	-	-	11,† .	9.45 to 10.17 A.M.,	-	-
18, .	2.04 P.M., . .	1,740	134	11, .	10.17 A.M., . .	-	1,749

* Three hundred gallons of sewage applied. † Five hundred gallons of sewage applied.
‡ Bottle touched outlet pipe while sample was collected.

Number of Bacteria found in the Effluent of Tank No. 6 at different hours before and after applying Sewage — Concluded.

Date.	Time of Collection.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.	Date.	Time of Collection.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.
1889—Con.				**1889**—Con.			
July 11,	10.22 A.M.,	-	972	July 20,	10.30 A.M.,	5,000	925
11,	10.26 A.M.,	3,120	330	20,	11.15 A.M.,	4,800	240
11,	10.30 A.M.,	8,880	824	20,	11.44 A.M.,	3,420	455
11,	10.36 A.M.,	13,650	1,850	20,	2.05 P.M.,	1,500	36
11,	10.58 A.M.,	12,000	1,575	20,	5.09 P.M.,	900	150
11,	12.05 P.M.,	1,740	264				
11,	2.04 P.M.,	1,480	18,240	25,	5.00 A.M.,	90	204
11,	2.10 P.M.,	880	2	25,	7.58 A.M.,	90	372
11,	3.05 P.M.,	1,040	1,450	25,*	8.00 to 8.31 A.M.,	-	-
11,	4.35 P.M.,	780	335	25,	8.41 A.M.,	800	638
11,	5.23 P.M.,	700	1,953	25,	8.44 A.M.,	3,120	572
11,	7.00 P.M.,	555	403	25,	8.48 A.M.,	5,520	1,161
11,	9.00 P.M.,	440	28	25,	8.51 A.M.,	9,120	952
12,	5.00 A.M.,?	225	96	25,	8.54 A.M.,	12,000	1,595
12,	7.58 A.M.,	216	590	25,	8.57 A.M.,	13,800	2,080
				25,	9.05 A.M.,	13,600	1,188
20,	5.00 A.M.,	75	891	25,	9.15 A.M.,	12,975	874
20,*	7.49 to 8.10 A.M.,	-	-	25,	9.30 A.M.,	9,480	1,230
20,	8.22 A.M.,	9,120	493	25,	10.00 A.M.,	4,980	975
20,	8.31 A.M.,	29,400	1,552	25,	10.17 A.M.,	4,080	870
20,	9.03 A.M.,	13,000	1,680	25,	10.30 A.M.,	3,660	648
20,	9.30 A.M.,	7,740	1,610	25,	11.00 A.M.,	2,720	700
20,	10.00 A.M.,	6,000	1,116				

* Five hundred gallons of sewage applied.

FILTER TANK No. 7.

The lower four feet in depth of this filter is of material like that of Tank No. 6.

The coarse and fine sand and fine gravel were brought from the same pit for Tanks No. 6, No. 7, and No. 8; and shovelfuls were thrown alternately into each of these tanks to make them as near alike as practicable. Tank No. 7 has, in addition to this material and resting upon it, ten inches in depth of yellow sandy loam, and above this, six inches of brown soil. The particles of each of the three kinds of material are of the following sizes: —

	Approximate Diameter of Grains, in Inches.	Sand and Gravel. Percentage.	Yellow Loam. Percentage.	Brown Soil. Percentage.
Coarser than sieve No. 2,	–	17	4	–
Between sieve No. 2 and No. 4,	–	10	4	1
Between sieve No. 4 and No. 10,	–	16	14	5
Between sieve No. 10 and No. 20,	–	25	17	16
Between sieve No. 20 and No. 40,	0.020 to 0.048	19	17	22
Between sieve No. 40 and No. 55,	0.012 to 0.020	5	8	9
Between sieve No. 55 and No. 70,	0.010 to 0.012	1	3	4
Between sieve No. 70 and No. 100,	0.008 to 0.010	2	4	4
Between sieve No. 100 and No. 140,	0.005 to 0.008	1	4	5
	0.003 to 0.005	1.8	10	7
	0.001 to 0.003	2.0	14	17
	0.000 to 0.001	0.2	1	10

The yellow loam and brown soil are both much finer than the sand beneath. The loam has 15 per cent. finer than 0.003 inch in diameter, and the soil has 27 per cent. finer than 0.003 inch, while the fine sand of No. 2 has but ten per cent. as fine, and No. 4. has 33 per cent. Although the loam has not so much fine material as No.

4, it has a little more organic matter, and the presence of alumina is evident from the soft feeling of the finest portion.

Its quartz grains and other material insoluble in acid, in two hours, amounted to 94.37 per cent. The soluble parts included 1.95 per cent. of alumina, and 1.31 per cent. of oxides of iron and manganese. The loss on heating to redness was 1.97 per cent.

The brown soil, which is above the loam and forms the surface of the filter, is not very different from the soil of Tank No. 5. It has not so much fine material, but it has more that is extremely fine; having 10 per cent. that has diameters of grains less than 0.001 inch.

The quartz grains and others insoluble in acid amount to 88.07 per cent. The soluble portion includes alumina, 2.44 per cent.; oxides of iron and manganese, 2.01 per cent.; and 0.05 of one per cent. of lime.

The amount lost in heating to redness, which is probably nearly all organic matter, forms 7.00 per cent. This large percentage no doubt softens when it is wet, expands, and fills the interstices between the grains more than the same amount of fine material would that was granular and unchanged by water.

It has been thought that soil was an essential part of a good filter. We have in the past two years found that a filter made entirely of soil as fine as that of Tank No. 5 was entirely unfit for purifying sewage, as no nitrification took place. In Tank No. 7 we have a filter the lower four feet of which contained material identical with No. 6; but it had in addition sixteen inches in depth of loam and soil, that the advantage or disadvantage of this addition may be determined by actual use.

Tables of the daily observations and the chemical analyses and bacteriological examinations of the effluent from this tank are given at the end of this section.

The results of chemical analysis are in all cases given in parts per 100,000.

For convenient reference the monthly averages of the analyses of sewage applied and of effluent from this tank are given in the following table, which includes also the average number of bacteria found in a cubic centimeter of the effluent, and the average quantity of sewage filtered daily. The latter quantity multiplied by 200 would give the equivalent quantity that would have been filtered on an acre.

Monthly Averages of Daily Results with Tank No. 7.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888.												
Jan. 1-14, . .	Effluent, .	67	.60	2.58	.0004	.0038	.0042	.24	.003	–	–	74
Jan. 14-20, .	Sewage, .	–	82.93	34.60	1.1567	1.0500	2.2067	2.94	.005	–	39°	–
Jan. 15-31, .	Effluent, .	133	1.53	5.29	.0008	.0062	.0070	1.73	.015	–	35°	11,670
	Per cent.,	–	2	15	.1of1	.6of1	.3of1	–	–	–	–	–
Jan. 21-Feb. 20,	Sewage, .	–	24.02	15.10	.9962	.5469	1.5431	2.38	.008	–	42°	–
February, . .	Effluent, .	129	1.68	9.16	.1761	.0202	.1963	2.62	.004	–	35°	7,335
	Per cent.,	–	7	61	18	4	13	–	–	–	–	–
Feb. 21-Mar. 28,	Sewage, .	–	19.68	23.61	.7555	.4135	1.1690	2.26	.007	–	54°	–
March, . .	Effluent, .	258	1.72	8.42	.2166	.0135	.2301	2.28	.006	.0005	35°	10,728
	Per cent.,	–	9	36	29	3	20	–	–	–	–	–
Mar. 29-Apr. 20,	Sewage, .	–	36.51	44.00	.9540	.7407	1.6947	3.17	.008	–	50°	–
April, . .	Effluent, .	193	1.63	10.02	.2091	.0143	.2234	2.78	.016	.0003	41°	5,769
	Per cent.,	–	4	23	22	1.9	13	–	–	–	–	–
Apr. 21-May 20,	Sewage, .	–	37.45	43.53	1.0867	1.2917	2.3784	3.46	.007	.0027	47°	–
May, . . .	Effluent, .	141	4.51	12.94	.2115	.0089	.2204	3.26	.273	.0031	50°	15
	Per cent.,	–	12	30	19	.7of1	9	–	–	–	–	–
May 21-June 9,	Sewage, .	–	28.45	33.06	1.3940	.6007	1.9947	4.40	.008	.0006	58°	–
June, . . .	Effluent, .	86	9.53	18.39	.1470	.0127	.1597	4.96	.874	.0062	60°	47
	Per cent.,	–	33	56	11	2.1	8	–	–	–	–	–
June 10-25, .	Sewage, .	–	15.85	22.70	1.2936	.2864	1.5800	4.27	.008	.0003	68°	–
July, . . .	Effluent, .	37	4.46	24.30	.1702	.0282	.1984	5.87	.017	.0002	69°	152
	Per cent.,	–	28	107	14	10	13	–	–	–	–	–
June 26-Aug. 17,	Sewage, .	–	43.98	46.92	2.3810	.9217	3.3027	6.57	.009	.0001	71°	–
August, . .	Effluent, .	100	4.99	19.48	.2331	.0242	.2573	5.76	.666	.0127	70°	157
	Per cent.,	–	11	42	10	2.6	8	–	–	–	–	–
Aug. 18-Sept. 12,	Sewage, .	–	67.95	82.80	2.5520	2.0587	4.6107	10.86	–	.0000	69°	–
September, .	Effluent, .	77	3.95	25.61	.1005	.0173	.1178	10.21	.441	.0293	66°	170
	Per cent.,	–	6	31	4	.8of1	3	–	–	–	–	–
Sept. 13-Oct. 11,	Sewage, .	–	26.44	41.84	1.9772	.6614	2.6386	6.84	–	.0000	59°	–
October, . .	Effluent, .	71	2.22	23.28	.0051	.0084	.0135	7.25	.840	.0069	56°	20
	Per cent.,	–	8	56	.3of1	1.3	.5of1	–	–	–	–	–
Oct. 12-Nov. 7, .	Sewage, .	–	17.56	28.15	2.3418	.4282	2.7700	4.83	–	.0000	49°	–
November, .	Effluent, .	54	1.40	18.92	.0011	.0079	.0090	5.00	.672	.0001	51°	7
	Per cent.,	–	8	67	.05of1	1.8	.3of1	–	–	–	–	–
Nov. 8-28, . .	Sewage, .	–	18.60	31.71	1.6944	.4189	2.1133	4.75	.008	.0000	46°	–
December, .	Effluent, .	40	.96	18.20	.0019	.0051	.0070	4.13	.739	.0000	42°	11
	Per cent.,	–	5	57	.1of1	1.2	.3of1	–	–	–	–	–
1889.												
Nov. 29, '88-Jan.												
1, '89.	Sewage, .	–	14.55	30.53	1.1245	.3364	1.4609	4.40	.011	.0000	44°	–
January, . .	Effluent, .	43	.67	16.12	.0011	.0048	.0059	4.11	.649	.0000	40°	6
	Per cent.,	–	5	53	.1of1	1.4	.4of1	–	–	–	–	–
Jan. 2-Jan. 28, .	Sewage, .	–	10.95	23.87	1.1458	.2550	1.4008	4.29	.031	.0045	44°	–
February, . .	Effluent, .	42	.93	14.86	.0012	.0055	.0067	3.66	.600	.0000	39°	3
	Per cent.,	–	8	62	.1of1	2.2	.5of1	–	–	–	–	–
Jan. 29-Mar. 2,	Sewage, .	–	9.64	18.06	1.0871	.2772	1.3643	3.67	.020	.0170	45°	–
March, . .	Effluent, .	46	.88	14.65	.0009	.0062	.0071	3.22	.615	.0000	40°	5
	Per cent.,	–	9	81	.1of1	2.2	.5of1	–	–	–	–	–
Mar. 3-Apr. 2, .	Sewage, .	–	13.66	25.06	1.5715	.4077	1.9792	4.65	.009	.0015	38°	–
April, . .	Effluent, .	49	.89	18.40	.0014	.0064	.0078	3.34	1.272	.0000	47°	6
	Per cent.,	–	7	73	.1of1	1.6	.4of1	–	–	–	–	–
Apr. 3-May 6, .	Sewage, .	–	13.04	25.29	2.0860	.4413	2.5273	5.31	.007	.0009	49°	–
May, . . .	Effluent, .	48	1.16	25.90	.0018	.0069	.0087	4.26	2.100	.0000	58°	6
	Per cent.,	–	9	102	.1of1	1.6	.3of1	–	–	–	–	–

Monthly Averages of Daily Results with Tank No. 7 — Concluded.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature.	Number of Bacteria per Cubic Centimeter.
1889 — Con.												
May 7-May 25, .	Sewage, .	–	15.12	25.18	1.8312	.4000	2.2312	4.55	.000	.0000	64°	–
June, . . .	Effluent, .	33	2.16	23.86	.0021	.0078	.0099	4.63	1.840	.0000	66°	9
	Per cent.,	–	14	95	.1of1	1.9	.4of1	–	–	–	–	–
May 26-July 20,	Sewage, .	–	23.94	33.68	2.3158	.6684	2.9842	6.23	.000	.0000	71°	–
July, . .	Effluent, .	52	2.06	22.15	.0017	.0074	.0091	5.07	1.300	.0001	68°	4
	Per cent.,	–	9	66	.1of1	1.1	.3of1	–	–	–	–	–
July 21-Aug. 17,	Sewage, .	–	21.97	40.01	1.9965	.5670	2.5635	4.81	.000	.0000	71°	–
August, . .	Effluent, .	53	1.60	22.40	.0006	.0066	.0072	4.35	1.462	.0000	68°	11
	Per cent.,	–	7	56	.03of1	1.2	.3of1	–	–	–	–	–
Aug. 18-Sept. 22,	Sewage, .	–	36.25	48.64	1.8867	.8904	2.7771	5.58	.000	.0002	69°	–
September, .	Effluent, .	80	1.65	27.50	.0004	.0076	.0080	5.38	1.440	.0001	66°	202
	Per cent.,	–	5	57	.02of1	.9of1	.3of1	–	–	–	–	–
Sept. 23-Oct. 26,	Sewage, .	–	27.70	28.90	2.0044	.8056	2.8100	4.98	.000	.0001	54°	–
October, . .	Effluent, .	135	–	–	.0008	.0107	.0115	4.60	1.494	.0003	57°	982
	Per cent.,	–	–	–	.04of1	1.3	.4of1	–	–	–	–	–

First Application of Sewage.

Water had been filtering through this tank about two months. Sewage was first applied on January 14, 1888. The next day, after 231 gallons had flowed out, the chlorine of the effluent had increased to two times the amount while city water was filtering, showing that some sewage had found its way through. The chlorine of the effluent gradually increased, until, ten days after the first application of sewage when 1,590 gallons had flowed out, it nearly equalled that of the sewage, — showing that sewage had to a great extent replaced the water previously in the sand. Although a small percentage — apparently about nine per cent. — of the effluent was from sewage on the second day, it has been estimated that the bulk of any sewage applied does not reach the outlet until 1,300 gallons have been pushed before it.

About 200 gallons of sewage were applied daily until January 21, and from January 24 till March 22, 150 gallons were applied daily. Till January 23, the effluent was 0.85 of the quantity applied, — the flow being somewhat impeded by frost. On January 24, the frost was twenty inches deep in the tank, and, in order that the applied sewage might flow down more readily, four holes were cut through the frost, and in these the sewage was applied, — generally at temperatures of from 38° to 43°, — till February 16. On February 18, the ice was all removed from the surface and the sewage run into a trench 2 inches deep and 18 inches wide, cut 18 inches from the edge of the tank; and, from this time until April 3, the sewage was heated to temperatures averaging 56° before application. After March 14, when all of the snow was again removed from the tank, there was little interference from frost and the sewage was more generally distributed through the upper layers of the tank.

To remove the frost more completely the quantity of sewage was, on March 23, increased to 500 gallons; and this quantity was applied daily for twelve days, till April 3, at an average temperature of 65°. The temperature of the effluent on March 23 was 34°; but it increased to 39° on April 2, and to 40° on April 3.

Immediately after sewage was first applied, and while it was coming through, mingled with the water previously in the sand, the nitrogen of the effluent as nitrates increased to 0.020 parts and continued for two weeks at an average of 0.016 parts; after which it decreased and remained as low as that in the sewage, averaging .004 parts per 100,000 in February and .006 parts in March. The temperature of the effluent averaged about 35° with a maximum of 37° for these two months. After April 2, when the temperature of the effluent reached 39°, the nitrogen as nitrates increased, and by the end of the month, when the temperature was 43°, reached .030 parts.

The ammonias of the effluent which had been 0.0044 parts per 100,000 while water was filtering, increased a little after sewage was applied, and averaged 0.0071 parts, or three-tenths of one per cent. of those of the sewage, till February 1. Thus in cold weather, with no nitrification, while 3,100 gallons of sewage entered the tank, nearly all of the ammonias were retained in the sand or escaped into the air. After February 5, they increased until they amounted to 0.4020 parts on February 26, with an average of 0.1963 parts for the month or 13 per cent. of the ammonias of the sewage. During this month the albuminoid ammonia increased from 0.0062 parts to 0.0400 parts, — which is the highest for several months, — and averaged 0.0202 parts or 4 per cent. of that of the sewage.

Increase in Nitrification.

Although the nitrates increased a little after April 2, when the temperature of the effluent rose above 39°, they did not begin to increase rapidly until the temperature of the effluent reached 50°; after which, in eighteen days, they rose from 0.200 parts to 1.500

parts on June 8, when the temperature was 59°. This rise in the nitrates, though very marked and rapid, was not as rapid as that in Tank No. 6, where the same change occurred in fourteen days from May 5 to 19, — twenty days earlier in the season, — and, while in No. 7 the nitrates immediately fell, and in one month were down to 0.010 parts, averaging for June 0.874 parts, those of No. 6 went on increasing to 3.200 parts on June 6, and averaged for the month 1.539 parts. The result is that Filter No. 6, without the covering of loam and soil, and receiving the same kind of sewage as No. 7, nitrified efficiently twenty days earlier in the season, and, in June, 1888, filtered two and one-half times as much sewage, with nitrates one and three-quarters times as high, and with ammonias averaging 0.0124 parts, when those of No. 7 were twelve times as high or 0.1597 parts.

By reference to the Diagram of Nitrates, page 125, it will be seen that No. 7 arrived at rapid nitrification later in the season than any of the tanks filled with sand except No. 2, which followed in about four days; but the nitrates of No. 2 became much higher than those of No. 7, and averaged for the month of June two and one-third times as high, or were 2.056 parts per 100,000.

The Surface becomes nearly Impervious, and Nitrification Ceases.

By referring again to the diagram, it will be seen that, unlike all of the sand tanks excepting No. 4, the nitrates of No. 7 fell rapidly immediately after reaching the maximum, and continued falling; and were, from July 5 to August 3, as low as those of the sewage. No nitrification was then taking place. The reason of this may be found in the condition of the surface and in the fact that the outlet was, through July, trapped by a glass tube so that no air could enter there. One hundred and fifty gallons of sewage were applied daily in May, except on six days, when none was applied. Early in June this quantity did not all disappear from the surface in twenty-four hours; and after June 14 the quantity applied was reduced, averaging 69 gallons daily for the remainder of the month; but an average of only 45 gallons came through. A part of the remainder evaporated, and a part accumulated on the surface. In the first 11 days of July an average of 45 gallons a day was applied; and the effluent averaged 22 gallons. There was a tough green covering on the surface of the soil, so nearly impervious that, with sewage accumulated on this surface to the depth of three inches, only 22 gallons passed through. After July 11, no sewage was applied until July 25, — in order to allow the sewage on the surface to disappear, which it did at the end of 12 days, and then to allow the surface to dry. While disappearing, with an average flow of only 20 gallons per day or at the rate of 4,000 gallons per acre per day, nitrification ceased.

Surface Cleaned and Nitrification Begins and is Continued by Reducing the Quantity of Sewage Applied.

On July 25, one-half inch in depth of the surface, including the green covering, was scraped off, and 100 gallons of sewage were applied, — which disappeared in 53 minutes. This quantity was applied daily for six weeks. At the end of ten days it disappeared from the surface in one hour and a half, and the nitrates began to increase. They increased from 0.003 parts, on August 2, to 1.100 parts on August 13 and 16. After the latter date sewage disappeared in much longer time, and some days not at all; and before the end of the month the nitrates had decreased to 0.625 parts.

The average quantity of effluent during August was 100 gallons a day, or 20,000 gallons per acre per day. This was evidently more than this filter could nitrify; although at the same time Tank No. 6 was satisfactorily purifying at the rate of 42,000 gallons per acre per day. After September 8 the quantity was reduced to 150 gallons applied three times a week, and the nitrates increased from 0.220 parts on September 10 to 1.050 parts on October 11; but even with this method of application, with long intermissions and an average quantity of effluent in October of 71 gallons a day, the surface was covered with sewage so much of the time that the nitrates decreased in the latter part of the month to 0.560 parts, averaging for the month 0.840 parts.

Early in November, the quantity was again reduced to 100 gallons applied on three days in a week; and the average quantity of effluent was 54 gallons a day, — being increased by the rainfall. The nitrates were quite constant and averaged 0.672 parts for the month.

On November 22, this tank was covered with canvas, and no rain or snow fell upon its surface until after March 13, 1889, when the canvas was removed.

During December, 1888, no rain falling upon the tank, the 100 gallons applied three times a week gave an effluent averaging 40 gallons a day or at the rate of 8,000 gallons per acre per day; and in this month, for the first time, did the nitrates of Tank No. 7 compare favorably with those of the sand tanks, — excepting No. 4. They averaged 0.739 parts. It is evident that with a larger quantity than this, nitrification will not be so complete as with the tanks having coarser material at the surface. At this time Tank No. 6 had nearly the same nitrates (0.790 parts), but was filtering three times as much sewage, and giving an effluent of about the same character.

During March and April, the nitrogen in the effluent as nitrites was low, averaging .0005 parts and .0003 parts for these two months. It increased in May, and in June reached .0110 parts; but again fell off, and in July was low, averaging but .0002 parts. It again increased in August and September, averaging .0127 parts and .0293 parts for those months. From the beginning of October, it rapidly decreased till, at the end of the month, it was but .0001 parts; and, for the next seven months, was very low, and generally none was found.

Now that the nitrates of the effluent, which have the most intimate relation with the condition of the surface of the filter, have been followed through the first year, we will return to the beginning of nitrification in April, and follow the changes which occurred in the ammonias.

Purification as Shown by the Ammonias of the Effluent.

As with most of the other filters, an increase in the nitrates is not accompanied by a decrease in ammonias, but such decrease follows some weeks later.

In March, 1888, when there was no nitrification, the ammonias were lower than in the latter part of February, and averaged 0.2301 parts, or 20 per cent. of those of the sewage. The albuminoid ammonia averaged 0.0135 parts, or 3 per cent. of that of the sewage. During April and May and until the middle of June, the sum of the ammonias continued nearly the same as in March, although, before the end of this time, the nitrates had risen to the highest for the year. The average of ammonias for April was 0.2234 parts, for May 0.2204 parts, and for the first half of June 0.2042 parts. In the latter half of June they were less, averaging 0.1152 parts. It is, however, to be noted that while the sum of ammonias was nearly constant for three months and a half, there was more removal of nitrogenous organic matter after nitrification began than before. The sewage in the three months grew continually stronger, and the percentage that the ammonias of the effluent were of those of the sewage decreased from 20 per cent. in March to 13 per cent. in April, and to 9 per cent. in May.

The albuminoid ammonia, which, in March, was 0.0135, or 3 per cent. of that in the sewage, averaged, in April, when there was slight nitrification, 0.0143 parts, — which was 1.9 per cent. of that of the sewage; and in May, when nitrification increased rapidly, it averaged 0.0089 parts, which was 0.7 of 1 per cent. of that in the sewage. In June, when nitrification reached its height and fell, the albuminoid ammonia changed in an opposite direction and averaged 0.0127, — which was 2.1 per cent. of the weaker sewage of this month.

The free ammonia was nearly constant through March, April and May, and to the middle of June, — averaging 0.2166 parts in March, 0.2091 parts in April, and 0.2115 parts in May; or 29 per cent., 22 per cent., and 19 per cent. of that of the sewage. In the first half of June, it averaged 0.1910 parts; and in the last half, 0.1030 parts; and was for the month 11 per cent. of that of the sewage.

By an examination of the diagram of results with Filter Tank No. 7, — which accompanies the table of chemical analyses and observations at the end of this section, — it will be seen, that, in July, when the nitrates had become nearly as low as those in the sewage, the sum of the ammonias of the effluent increased gradually until July 27; and then rapidly until August 2. When the nitrates began to increase the ammonias ceased increasing and began to decrease. The highest point that ammonias reached at this season was on August 2, when they were 0.4390 parts; to which they had risen in July from 0.0960 parts, averaging for the month of July 0.1984 parts, or 13 per cent. of those of the sewage. In August, they fell continually through the month to 0.1270 parts, averaging 0.2573 parts, which was higher than in July; but as the sewage was much stronger, this was but 8 per cent. of the amount in the sewage.

Through September, in which month the nitrates fell and rose again, the ammonias fell continually to 0.0178 parts, averaging 0.1178 parts, or 3 per cent. of those of the sewage.

The albuminoid ammonia, which in August averaged 0.0242 parts, fell in September from 0.0200 to 0.0098 parts, averaging 0 0173 parts, which, on account of some extremely strong sewage in the first part of the month, was but 0.8 of 1 per cent. of that in the sewage.

During October, 1888, with the higher nitrification and continued longer intermissions in the application, we have the first satisfactory purification by this filter. This was four months after Tank No. 6 — without the soil on the surface — began such purification. The average of the sum of ammonias for October was 0.0135 parts. They were still less in November, averaging 0.0090 parts; and in December averaged 0.0070; and were for these three months 0.5 of 1 per cent., 0.3 of 1 per cent. and 0.3 of 1 per cent., respectively, of those of the sewage.

The albuminoid ammonia was in October 0.0084 parts, in November 0.0079 parts, and in December 0.0051 parts; or 1.3 per cent., 1.8 per cent. and 1.2 per cent. of that in the sewage.

The free ammonia, which, in September, was 0.1005 parts, — the lowest of any month up to that time, — fell rapidly the last week in September, and averaged for October 0.0051 parts, for November 0.0011 parts, and for December 0.0019 parts; or 0.3 of 1 per cent., 0.05 of 1 per cent. and 0.1 of 1 per cent. of that of the sewage.

There is no check in the degree of purification as the cold weather comes on. We have found that this filter, with 100 gallons of sewage applied three times a week, which is the equivalent of 20,000 gallons applied to an acre three times a week, gives in December an effluent averaging 8,000 gallons per acre per day, from which has been removed more than $99\frac{1}{2}$ per cent. of the nitrogenous organic matter of the sewage.

Up to this time the effluent has had no color, except for ten days in the early part of August, when the color became as noticeable as that of Cochituate water. This was when the ammonias were the highest, after the period of no nitrification in July. Up to and including June there was very little sediment, and the effluent was nearly clear; but in July there was much brown flocculent sediment, and the turbidity was decided. The odor also was in this month sometimes strong.

In the first part of August these conditions were the same as in July; but as the nitrification increased and the ammonias decreased, the effluent became clear with no sediment and no odor.

In September there was very little to no sediment, very slight to no turbidity, and no color; but an odor could be distinguished. This odor continued into October; but afterward faded out and became imperceptible, and in the last three months of the year 1888 the effluent was clear, colorless, and with very little or no sediment. A bottle was filled December 17 and kept a year in a warm, light place. Upon being then examined, there were no bacteria and no microscopic organisms, but there was a thin deposit of very dark-brown sediment, which, under the microscope, appeared to be small inorganic feathery masses, much like rust. Upon shaking the bottle vigorously more than half of the sediment was disturbed, and some of it remained in suspension many days, giving a dark hue to the water. Chemical examination showed this sediment to be mainly black oxide of manganese, which amounted to 1.20 parts per 100,000; besides which there was 0.03 part per 100,000 of oxide of iron.

Purification in the Second Year.

For the following six months, January to the last of June, 1889, the same quantity of sewage was continued with the same intervals, giving an effluent equivalent to 9,000 gallons per acre per day.

In the latter part of January, 1889, about an inch in depth of frost was observed in the tank, and this increased in the colder month of February to four inches and one-half, which, however, had all disappeared on March 8; and only on one occasion, February 18, when sewage was applied, was there any of the sewage, previously applied, on the surface except in spots of ice. In the cold months the sewage was generally from two to three hours on the surface. At other times it disappeared in about an hour.

From the latter part of October, 1888, to the latter part of June, 1889, this filter was steadily removing as much as 99.6 per cent. of the nitrogenous organic matter of the sewage. The degree of nitrification at different seasons in the seventeen months, after nitrification commenced, is shown by the following table:—

Percentage of the Total Nitrogen applied in the Sewage that appears in the Effluent as Nitrates.

Date.	Total Nitrogen in Sewage.	Nitrates in Effluent, corrected for Quantity.	Per Cent.	Quantity of Effluent. Gals.	Temperature. Sewage.	Temperature. Effluent.
1888.						
May,	3.0192	.268	9	141	47°	50°
June,	2.1368	.594	28	86	58°	60°
July,	1.5387	.014	1	37	68°	69°
August,	3.4731	.642	18	100	71°	70°
September,	5.4689	.470	9	77	69°	66°
October,	2.7060	.944	35	71	59°	56°
November,	2.6225	.685	26	54	49°	51°
December,	2.0844	.952	46	40	46°	42°
1889.						
January,	1.4848	.665	45	43	44°	40°
February,	1.3933	.582	42	42	44°	39°
March,	1.3830	.621	45	46	45°	40°
April,	1.9678	1.434	73	49	38°	47°
May,	2.4422	2.087	85	48	49°	58°
June,	2.1576	2.293	106	33	64°	66°
July,	2.9951	1.436	48	52	71°	68°
August,	2.5670	1.994	78	53	71°	68°
September,	3.0075	1.380	46	80	69°	66°
October,	2.9649	1.490	50	135	54°	57°

Purification in the Winter of 1888–89.

During the four cold months, December, 1888, to March, 1889, when the temperature of the applied sewage averaged 45° and that of the effluent averaged 40°, the nitrogen in the effluent as nitrates averaged 44 per cent. of the total quantity of nitrogen applied in the sewage. The nitrification during this winter was more complete than in the previous two months, and eight-tenths as complete as the average of the nine months of steady purification. The sums of the ammonias were less than one-half of one per cent. of those of the sewage, — about the same as in the nine months.

The mean of the analyses for the four cold months was as follows: —

Daily quantity of effluent, 8,550 gallons per acre.

	Parts per 100,000.	
Loss on ignition, .	0.86,	or 6 per cent. of that of the sewage.
Fixed residue, .	15.96,	or 61 per cent. of that of the sewage.
Free ammonia, .	0.0013,	or 0.1 of 1 per cent. of that of the sewage.
Albuminoid ammonia,	0.0054,	or 1.8 per cent. of that of the sewage.
Sum of ammonias, .	0.0067,	or 0.4 of 1 per cent. of that of the sewage.
Chlorine, . . .	3.78,	or 90 per cent. of that of the sewage.
Nitrogen as nitrates, .	0.6510,	or 44 per cent. of the total nitrogen of the sewage.
Nitrogen as nitrites, .	0.0000.	

The loss on ignition, as stated elsewhere, should be reduced by a quantity, not definitely determined for all cases, but shown by many experiments to be from 0.5 to 0.7 parts per 100,000; but it is given as determined, without making this deduction.

The purification as shown by the ammonias is extremely satisfactory for these cold months; but the quantity filtered is smaller than it is desirable to be limited to, in practice, in any filtration area; and it will be seen that Filter No. 6 was at the same time removing more than 99 per cent. of the ammonias from three times as much sewage.

Stored Organic Matter removed from the Filter by Nitrification in the Spring and Early Summer.

By the table of the percentage of the total nitrogen found in nitrates, it will be seen that in Tank No. 7, as in the other tanks where nitrification was taking place, it became more complete as the growing season came on. From 45 per cent. in March, the nitrates increased to 73 per cent. in April, — with the average temperature of the effluent 47°, — to 85 per cent. in May and to 106 per cent. in June, when the temperature was 66°. In the latter month it is evident that nitrification was removing stored organic matter from the tank; and this was undoubtedly the case through the month of May, and possibly the case in the month of April: as we have before found in other tanks, when the nitrogen of the nitrates exceeded 50 to 75 per cent. of the total nitrogen applied, a part of this came from stored nitrogen in the tank.

The spring and early summer months and the month of August have proved to be the months when most of the filters were becoming purified by nitrification, or the burning up of their stored material in preparation for the work of the rest of the year.

The mean result of the comparatively constant condition of the effluent for the eight months, from Oct. 27, 1888, to June 27, 1889, is as follows: —

Daily quantity of effluent, 8,880 gallons.

	Parts per 100,000.	
Loss on ignition,	1.13,	or 8 per cent. of that of the sewage.
Fixed residue,	18.86,	or 73 per cent. of that of the sewage.
Free ammonia,	0.0014,	or 0.09 of 1 per cent. of that of the sewage.
Albuminoid ammonia,	0.0063,	or 1.7 per cent. of that of the sewage,
Sum of ammonias,	0.0077,	or 0.4 of 1 per cent. of that of the sewage.
Chlorine,	4.04,	or 88 per cent. of that of the sewage.
Nitrogen as nitrates,	1.0610.	
Nitrogen as nitrites,	0.0000.	

During the last six months the effluent was generally clear and colorless and without sediment or odor; it had the appearance of an excellent spring water.

Introduction of Sewage under the Soil by Means of Open-jointed Drain Pipe surrounded with Gravel.

The quality of the effluent for the last nine months had been excellent; but the quantity, being less than 10,000 gallons per acre per day, was so small that an effort was made to determine the result of introducing sewage under the soil into the sand by means of a pipe having open joints surrounded with gravel.

On June 25, 1889, a trench was cut in the tank three feet and a half deep and two feet wide, the outer edge being one foot and a half inside of the periphery of the tank.

Gravel, too coarse to go through a sieve whose meshes were three-quarters of an inch on a side, was filled into the trench to a depth of two feet. In the middle of the upper layers of this gravel was laid a six-inch drain pipe, with open joints once in two feet. The top of this drain pipe was level and even with the top of the gravel. Above this the trench was filled with one foot of yellow loam and five inches of brown soil as before.

A vertical four-inch pipe, connected with one end of the drain pipe, served for the entrance of sewage, which was applied, 50 gallons daily except Sundays, from June 29 to August 29; then 100 gallons on week days till September 29; after which it was continued at 150 gallons.

There was no falling off in the quality of the effluent from the change, nor from the subsequent increase in quantity.

Through July and August, with the quantity of effluent at 10,500 gallons per acre per day, the nitrogen of the nitrates was 63 per cent. of the total nitrogen of the sewage. The free ammonia was 0.0011 parts, or 0.05 of 1 per cent. of that of the sewage; the albuminoid ammonia was 0.0070 parts, or 1.2 per cent; and the sum of ammonias 0.0081 parts, or 0.3 of 1 per cent. of that of the sewage. With the increase in quantity filtered, through September, to 16,000 gallons per acre per day, the result was nearly identical with the last. With the further increase to 27,000 gallons per acre per day, continued through October, there was but little change. The free ammonia averaged 0.0008 parts, or 0.04 of 1 per cent.; the albuminoid ammonia, 0.0107 parts, or 1.3 per cent.; and the sum of the ammonias, 0.0115 parts, or 0.4 of 1 per cent. of those of the sewage. The nitrates were 50 per cent. of the total nitrogen of the sewage. The effluent continued entirely clear and colorless, and without sediment or odor.

Up to October 21, air could follow the sewage into the drain pipe through the entrance pipe. As this would not be the case in an extensive system of pipes used at intervals and cut off by gates, the entrance was changed by the insertion of a trap at the bottom of the vertical pipe, so arranged that the sewage could flow in both directions into the drain pipe circling around the tank, but no air could follow it; thus rendering it necessary that all air coming in contact with the sewage in the sand should come down through the soil. Up to the time of going to press, the same quantity — 27,000 gallons per acre per day — has been filtered. Through November and December the nitrates were higher than in most of the other good filters; but through the following months to April, 1890, they have been lower. The ammonias have slowly increased; and the average sum of ammonias for the month of March, 1890, was 0.0160 parts, which is 0.8 of 1 per cent. of those of the sewage. The nitrates during this month have averaged 0.6875 parts. Tank No. 4, filtering the same quantity, has the same sum of ammonias, but its nitrates are higher, being 1.25 parts. We have yet to see what may be the effect of the spring and summer nitrification before we can have a fair judgment upon the permanence of results from this method of application of sewage. By the method here introduced, of placing the sewage in pipes under the fine soil, we are enabled to filter three times as much sewage as it was possible to filter through the fine garden soil by applying sewage over the surface, with a chemical purification that has for five months continued very satisfactory.

Bacteria in the Effluent of Tank No. 7.

During the early part of January, 1888, while water was filtering, the number of bacteria found in a cubic centimeter of the effluent averaged 33. The number counted from time to time since January 1, 1888, may be found in a table at the end of this section.

Three days after sewage was applied, the number rose to 1,494; and four days later, to 42,384. Ten days after sewage was applied, when the chlorine indicated that the effluent was nearly all from sewage, the number was 5,100; and through the remaining week in January the number averaged 2,346. During this time of lower numbers the nitrates were a little higher than those of the sewage, being 0.016 parts.

On February 2 the number was exceptionally low, — 13; but in the next week it rose to 24,411 and on one other day was 21,960, but generally was much lower. These high numbers were probably due to a large amount of sewage being put into the tank by a single hole through the frost, which hole extended through the soil. The average number in February was 7,335, which is about one per cent. of the number applied in the sewage.

In March, while the application of 150 gallons was continued daily, the number averaged 4,367; but upon increasing the quantity to 500 gallons a day and continuing this quantity from March 23 to April 3, the number of bacteria increased, and on one day amounted to 68,564, and averaged 27,980 per cubic centimeter.

The usual quantity of 150 gallons was resumed on April 4 and continued thereafter, except that none was applied April 7 to 9. On April 19, when the next count of bacteria was made, the number was only 363. A week previous to this date nitrification commenced. The amount of the nitrates was small, being but 0.018 parts, but it was greater than it had been in March, when it averaged 0.006 parts. In the last ten days of April the number of bacteria averaged 195. In May, with moderate increase in nitrates, the first three weeks the number averaged 27; but before the end of the month, with the rapid increase in nitrates to 0.800 parts, the number was reduced to 5. The average for the month of May was 15.

In June, while the very high nitrification continued, the number continued small, although the ammonias remained high; but with the decrease in nitrates the number increased to 117 at the end of the month, averaging 47.

In July, with the decrease in the nitrates, the number increased at first to 1,071 on July 5, and averaged 293 in the first two weeks; but as no sewage was applied from July 12 to 24, the long time required for the passage, when but 20 gallons flowed out in a day, was evidently nearly if not quite fatal to them, as the number found in the latter half of the month averaged but 10, — and it is probable that these grew in the underdrains. In fact, the whole number found in the effluent of this tank after nitrification became active has been so small, and the time of passage when nitrates have at intervals been low has been so long, that it may be that none of these counted have come through the tank, but all have grown in the underdrains.

The number 1,071, just mentioned, was the highest number counted in the fifteen months in which sewage was applied to the surface of this tank after nitrification first became active; and this number was found on July 5, a few days after a glass trap had been put upon the outlet, which excluded air and flooded the outlet pipe. The counts in succession for the next two weeks were as follows: 1,071, 164, 100, 93, 8, 10. This result of a sudden increase after closing the outlet pipe, and a gradual decrease to the number when kept constantly open, was observed at Tank No. 5 under similar circumstances, and indicates that it is a local change in the underdrains or outlet pipe, and does not express an additional number coming through the filter. It may be due to floating from their resting places and taking into the current those that have grown on the moist parts of the outlet pipe or underdrains, which are flooded by the effluent held back.

The average number of bacteria per cubic centimeter counted in each month may be found in the table before given of Monthly Averages of Daily Results with Tank No. 7. The highest number there given, after nitrification began, while sewage was applied to the surface, was 170 for September, 1888. The ammonias were then quite high, amounting to 0.1178 parts per 100,000; and the nitrates were low, and — owing to the unusual amount of organic matter in the sewage then applied — contained but 9 per cent. of the nitrogen of the sewage.

In October, when the nitrates contained 35 per cent. of the nitrogen of the sewage, and the ammonias were much reduced, the average number of bacteria for the month was 20.

Probable Complete Removal of All Bacteria during Nitrification.

For the next eight months, when purification was satisfactory, the number of bacteria found in a cubic centimeter of the effluent averaged only 7, the highest monthly average being 11.

The smallness of this average number, 7, found in the effluent during satisfactory chemical purification, when the average number applied to the surface of the tank was 630,000, renders it extremely probable, that, under the conditions of nitrification then existing and the long time of twenty-nine days of the passage, no bacteria came down through the tank; but that these grew in the outlet pipe, in the underdrains, and on the gravel resting on the bottom of the tank, where they could get air from the outlet, and an extremely small quantity of food from the water.

We have reason to conclude that the material of this tank, with its upper layers of fine loam and soil, will filter for a long period 9,000 gallons of sewage per acre per day, with an effluent chemically purer than the water of good wells, and entirely exclude the bacteria of the sewage, thus rendering the effluent, as far as is known, an unobjectionable drinking water.

Change in Character of the Filter by applying Sewage beneath the Soil.

The trench that was dug on June 25, 1889, to within two feet of the bottom of the tank, and filled with coarse gravel up to the area to which sewage was to be applied, changed the character of the filter, especially in regard to its being a passage fatal to bacteria. Applying the sewage below the upper layers of fine material, and into a depth of two feet of coarse material, through which the liquid would rapidly flow, there remained, below this, scarcely two feet of material like that of Tank No. 6; so that the time of passage of the sewage in general, and the rapidity with which the advance particles of the sewage, applied after an interval, would reach the bottom, would be likely to render the passage of some of the bacteria more free and less fatal, and render the number more irregular than in the tanks of coarse sand already considered.

In the two months after the sewage was poured into the drain pipe, — 50 gallons on six days in the week, — there was no marked increase in the number of bacteria. The average number for July was 4, and for August was 11.

Four days after the daily quantity was increased to 100 gallons, — on September 2, — an hour after the sewage was applied, the effluent contained 4,256 bacteria per cubic centimeter; but on subsequent days in the month, the number, in a sample taken the same time after sewage was applied, was less, being 57 on September 14, and 13 on September 26. The number found in the morning before sewage was applied, was 23 on September 7, and 4 on September 24. On September 21, two hours and twenty minutes after application, the number was 6.

Increase in Number of Bacteria follows an Increase in Quantity of Sewage filtered, but the Number is again reduced when the Filter becomes adapted to the Increased Quantity.

On the last day of September the quantity was changed to 150 gallons; and this change, like that of the previous month, was accompanied by a marked increase in the number of bacteria, which, however, soon decreased. In October the number observed in samples taken about fifty minutes after sewage was applied was as follows: —

Day of Month.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.	Day of Month.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.
10, ...	4,200	7,800	24, ...	4,200	118
17, ...	4,920	8	31, ...	4,980	172

In samples taken about three hours and thirty minutes after sewage was applied, the number was as follows: —

Day of Month.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.	Day of Month.	Rate of Flow, Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.
2, ...	600	3,454	25, ...	750	33
10, ...	930	434	29, ...	900	58

and one sample taken October 16, before sewage was applied, contained 9 per cubic centimeter.

These results, as well as those in September, indicate that an increase in quantity of sewage applied makes a disturbance in the conditions of the tank by which more bacteria are able to live through the passage; but after a while, — in these cases about two weeks, — the conditions become nearly as fatal as when the previous smaller quantity was filtering.

By the chemical analyses we find a decrease in the nitrates in the first two weeks after the increase in quantity, followed by an increase in nitrates. Thus, on August 26, before the change to 100 gallons, which occurred August 30, the nitrates were 1 6100 parts. With the increase in quantity they fell, and were 1.4000 parts on September 2 and 7; but on September 14 they had again increased to 1.6000. Again, on September 26, they were 1.4000; but after the change to 150 gallons on September 30, they became, on October 3, 1.3400 parts; and on October 17 they had again increased, reaching 1.7500 parts.

There was an increase in the ammonias in October, after the increase in quantity, followed by a decrease in ammonias when the nitrates increased; but this change was not observable in September.

We find here, as in some of the other tanks that have been described, an adaptation to the changes in the work required of the filter; but some time is required in which to become adapted to the new conditions.

In general, the circumstances most favorable for the complete destruction of bacteria in fiiters are those most favorable for the complete removal of nitrogenous organic matter. The completeness with which the organic matter has been burned, and thus changed to mineral matter, may in a general way be taken as a measure of the destruction of bacteria; although the percentage of the organic matter remaining in the effluent, as shown by the sum of the ammonias, is generally greater than the percentage the number of bacteria remaining is of the number applied.

We have concluded that when sewage was applied to the surface of the soil during the eight months of nitrification, when the sum of the ammonias amounted to 0.4 of one per cent. of those of the sewage, no bacteria lived to get through; the number found in the effluent was one in 100,000 of the number in the sewage. After the sewage was introduced into coarse gravel below the soil, the number coming through has varied with the changing conditions, — at one time becoming as high as one per cent. of the number applied, but averaging a small fraction of one per cent.

In November, 1889, when the quantity applied was the same as through the previous month, and the chemical result was nearly constant and very satisfactory, the sum of ammonias was 0.4 of 1 per cent. of that of the sewage, and the number of bacteria, averaging 225 per cubic centimeter, was 0.04 of 1 per cent. of the number in the sewage. This very small percentage of the bacteria that survives the passage is probably limited to a few of the kinds that are to be found in the sewage; and whether any of these surviving are harmful, remains to be determined by further study of the species.

Microscopic Organisms in Effluent of Tank No. 7.

The only vegetable organism found in the effluent of Tank No. 7 has been Leptothrix, on five occasions, to the average number of 48 in a gallon.

Of animal forms, samples of Monas have been found twice, and of ciliata once. No microscopic organisms of any kind, except bacteria as above, have been found in the effluent since the early part of November, 1888.

Summary of Advantages and Disadvantages of Soil on a Filter Bed.

The results of our experiments upon the advantages and disadvantages of using, for filtering sewage, an area covered with a layer of soil, may be summarily stated as follows: —

The experiments have been limited to fine soils, quite retentive of water.

With a depth of five feet of soil no purification by nitrification occurred when the quantity filtered was only 7,500 gallons per acre per day; and the organic nitrogenous matter in the effluent was nearly as great as in the applied sewage. It is known, however, that for several months the average number of bacteria in the effluent was only one in 25,000 of the number applied to the filter; and it is probable that none lived to pass through the filter.

With the ordinary depth of soil resting on yellow loam, as it is often found in this State, and this underlaid by four feet of good filtering sand, we find that only about 9,000 gallons of sewage may be filtered upon an acre daily, with the result of removing 99.5 per cent. of the organic matter, and probably removing all of the bacteria; while, if the soil and loam be removed, the underlying sand may be able to filter three times as much, or 30,000 gallons per acre per day, giving an effluent as pure, chemically, as when covered with soil, but not removing so completely the bacteria, — allowing, ordinarily, a small fraction of one per cent. to pass through the filter.

For filtering sewage upon the margin of a drinking-water stream, a large area covered with fine soil, or a smaller area of very fine sand, would be preferable to a much smaller area of coarse sand or a mixed sand and gravel, in that the former could be so managed that no bacteria could pass through. For filtering sewage on any land that does not drain into a drinking-water stream, the covering of fine soil is a disadvantage. The quantity applied to it must be kept very small, or nitrification and purification will be prevented. The smaller areas of sand can be made to give as good an effluent chemically, with all the reduction in the number of bacteria that is necessary.

TABLES

OF

CHEMICAL ANALYSES OF THE EFFLUENT,

AND

DAILY OBSERVATIONS

Upon Filter Tank No. 7.

FILTER TANK No. 7.

January, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, . . .	40	72	–	–	–	–	–	–	–	–	–	–
2, . . .	50	72	–	–	–	–	–	–	–	–	–	–
3, . . .	50	90	.60	2.65	.0006	.0042	.0048	.23	.0000	.0000	–	–
4, . . .	70	72	–	–	–	–	–	–	–	–	–	–
5, . . .	50	53	.35	2.70	.0006	.0030	.0036	.26	.0030	Present.	–	–
6, . . .	90	51	.60	2.65	.0006	.0042	.0048	.23	.0030	.0000	–	–
7, . . .	88	51	–	–	–	–	–	–	–	–	–	–
8, . . .	80	60	–	–	–	–	–	–	–	–	–	–
9, . . .	60	69	.80	2.45	.0002	.0034	.0036	.25	.0000	Present	–	–
10, . . .	85	55	–	–	–	–	–	–	–	–	–	–
11, . . .	42	45	.65	2.45	.0002	.0042	.0044	.25	.0070	Present.	–	–
12, . . .	–	42	–	–	–	–	–	–	–	–	–	–
13, . . .	300	47	–	–	–	–	–	–	–	–	–	–
14, . . .	235	158	–	–	–	–	–	–	–	–	40°	–
15, . . .	216	223	.75	2.95	.0012	.0062	.0074	.50	.0200	.0005	40°	–
16, . . .	242	207	1.10	3.25	.0018	.0054	.0072	.74	.0200	.0020	40°	–
17, . . .	194	195	–	–	–	–	–	–	–	–	39°	–
18, . . .	260	155	1.05	3.85	.0014	.0052	.0066	1.02	.0180	Present.	39°	–
19, . . .	184	166	–	–	–	–	–	–	–	–	40°	–
20, . . .	162	143	1.20	4.80	.0004	.0066	.0070	1.40	.0090	.0001	38°	–
21, . . .	125	117	–	–	–	–	–	–	–	–	39°	–
22, . . .	90	86	1.90	5.15	.0004	.0052	.0056	1.70	.0100	.0000	38°	–
23, . . .	82	77	–	–	–	–	–	–	–	–	39°	–
24, . . .	150	168	2.35	5.55	.0004	.0072	.0076	2.58	.0180	Present.	38°	–
25, . . .	150	95	1.65	6.20	.0012	.0060	.0072	2.10	.0150	Present.	38°	–
26, . . .	150	97	–	–	–	–	–	–	–	–	37°	–
27, . . .	150	122	2.10	6.45	.0004	.0084	.0088	2.24	.0180	.0000	39°	–
28, . . .	150	102	–	–	–	–	–	–	–	–	39°	–
29, . . .	150	100	1.80	6.50	.0006	.0052	.0058	2.29	.0150	.0001	40°	–
30, . . .	150	101	–	–	–	–	–	–	–	–	40°	–
31, . . .	150	107	1.40	8 25	.0002	.0066	.0068	2.77	.0070	.0008	39°	35°

January 1. — Four inches of ice on surface. January 2 and 3. — Three inches of ice and water. January 4 and 5. — Three inches of ice. January 6 and 7. — Three and one-half inches. January 8. — Three and one-half inches of ice and water. January 9. — Four inches of ice. January 10 and 11. — Some. January 17. — One and one-half inches. January 24. — Twenty inches of frost. January 12. — Two circular trenches dug in surface of tank and filled with coarse sand. January 14. — First sewage applied. January 24 to 27. — Sewage applied in three or four holes cut through frost.

Total effluent to end of month, 2,419 gallons.

Filter Tank No. 7 — Continued.

February, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Effluent.	Temperature. Sewage.
1, .	150	103	1.30	7.85	.0022	.0062	.0084	2.37	.0080	.0005	-	40°	35°
2, .	150	146	-	-	-	-	-	-	-	-	-	37°	35°
3, .	150	120	2.80	7.60	.0502	.0108	.0610	1.88	.0080	.0005	-	43°	35°
4, .	150	136	-	-	-	-	-	-	-	-	-	38°	35°
5, .	150	170	1.35	7.20	.0348	.0128	.0476	1.98	.0150	.0040	-	-	35°
6, .	150	189	-	-	-	-	-	-	-	-	-	40°	35°
7, .	150	184	1.10	7.60	.1006	.0140	.1146	2.04	.0030	Present.	-	43°	35°
8, .	150	161	2.00	9.10	.1270	.0090	.1360	2.90	.0000	Present.	-	36°	-
9, .	150	152	-	-	-	-	-	-	-	-	-	39°	35°
10, .	150	123	2.20	11.90	.1550	.0120	.1670	4.13	.0080	.0000	-	43°	-
11, .	150	129	-	-	-	-	-	-	-	-	-	40°	35°
12, .	150	127	3.10	11.60	.1450	.0150	.1600	3.54	.0020	.0000	-	45°	-
13, .	150	127	-	-	-	-	-	-	-	-	-	42°	-
14, .	150	133	1.40	9.00	.2250	.0190	.2440	2.59	.0000	.0000	-	44°	35°
15, .	150	137	.90	9.90	.2420	.0250	.2670	2.44	.0000	.0000	-	44°	35°
16, .	150	87	-	-	-	-	-	-	-	-	-	43°	35°
17, .	-	80	-	-	-	-	-	-	-	-	-	-	-
18, .	150	38	-	-	-	-	-	-	-	-	-	68°	-
19, .	150	42	1.70	9.30	.1800	.0400	.2200	2.72	.0000	.0000	-	55°	-
20, .	150	51	-	-	-	-	-	-	-	-	-	44°	36°
21, .	150	80	2.20	10.90	.2000	.0400	.2400	3.52	.0000	Present.	-	47°	37°
22, .	150	121	-	-	-	-	-	-	-	-	-	51°	36°
23, .	150	159	-	-	-	-	-	-	-	-	-	50°	36°
24, .	150	180	-	-	-	-	-	-	-	-	-	47°	-
25, .	150	166	-	-	-	-	-	-	-	-	-	46°	35°
26, .	150	175	1.20	8.90	.3930	.0090	.4020	2.26	.0050	Present.	12 h.+	48°	36°
27, .	150	170	1.40	8.40	.3400	.0300	.3700	2.08	.0000	Present	-	46°	35°
28, .	150	122	.80	9.00	.2700	.0400	.3100	2.16	.0020	.0000	-	48°	35°
29, .	150	137	-	-	-	-	-	-	-	-	-	51°	35°

February 15. — Water all removed from holes through frost before applying sewage. February 18. — Trench 1½ feet wide cut through ice, 1½ feet from edge of tank, and coarse sand put in last month removed to a depth of 2 inches. Later in the day all ice removed from surface. February 19. — Ice and water removed. February 20. — Four inches of ice and water removed.

Total effluent to end of month, 6,164 gallons.

Filter Tank No. 7 — Continued.

March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	150	170	-	-	-	-	-	-	-	-	-	58°	35°
2, .	150	164	1.20	7.60	.2900	.0130	.3030	2.16	.0070	.0001	-	54°	-
3, .	150	168	-	-	-	-	-	-	-	-	-	54°	35°
4, .	150	131	-	-	-	-	-	-	-	-	-	47°	35°
5, .	150	134	2.00	8.70	.2400	.0230	.2630	2.22	.0050	.0002	-	52°	35°
6, .	150	122	-	-	-	-	-	-	-	-	-	50°	36°
7, .	150	172	1.20	8.80	.2600	.0230	.2830	2.32	.0050	.0002	-	56°	35°
8, .	150	161	-	-	-	-	-	-	-	-	-	53°	-
9, .	150	157	1.90	8.00	.1680	.0130	.1810	2.32	.0090	.0018	-	56°	35°
10, .	150	178	-	-	-	-	-	-	-	-	-	58°	36°
11, .	150	175	-	-	-	-	-	-	-	-	-	50°	36°
12, .	150	163	1.40	9.10	.2000	.0130	.2130	2.20	.0070	.0012	-	58°	35°
13, .	150	160	-	-	-	-	-	-	-	-	-	52°	-
14, .	150	176	1.40	9.50	.2080	.0110	.2190	2.20	.0080	.0004	-	55°	35°
15, .	150	167	-	-	-	-	-	-	-	-	-	52°	-
16, .	150	160	2.30	7.10	.1880	.0090	.1970	2.10	.0080	.0002	-	53°	35°
17, .	150	152	-	-	-	-	-	-	-	-	-	55°	35°
18, .	150	133	-	-	-	-	-	-	-	-	-	51°	35°
19, .	150	142	1.90	8.50	.2200	.0200	.2400	2.30	.0080	.0002	-	48°	35°
20, .	150	160	-	-	-	-	-	-	-	-	-	54°	35°
21, .	150	277	2.10	8.20	.2000	.0040	.2040	2.24	.0070	Present	-	53°	34°
22, .	150	199	-	-	-	-	-	-	-	-	2 h.	54°	35°
23, .	500	475	1.30	7.50	.1600	.0040	.1640	2.16	.0020	.0000	6 h.	71°	34°
24, .	500	443	-	-	-	-	-	-	-	-	6 h. 57 m.	60°	34°
25, .	500	495	-	-	-	-	-	-	-	-	-	60°	36°
26, .	500	520	2.20	8.50	.2120	.0140	.2260	2.56	.0020	.0003	6 h. 18 m.	65°	35°
27, .	500	613	-	-	-	-	-	-	-	-	7 h. 36 m.	60°	35°
28, .	500	582	2.10	8.80	.2300	.0150	.2450	2.50	.0010	.0001	8 h. 33 m.	63°	35°
29, .	500	516	-	-	-	-	-	-	-	-	8 h. 15 m.	60°	35°
30, .	500	487	1.40	9.20	.2400	.0140	.2540	3.32	.0030	.0003	5 h.	62°	36°
31, .	500	253	-	-	-	-	-	-	-	-	-	80°	-

Effluent colorless, clear or nearly so, and with very little or no sediment.
March 14. — Snow all removed from surface. March 31. — Outlet closed at 11.17 A.M. River high.
Total effluent to end of month, 14,169 gallons.

Filter Tank No. 7 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	500	675	1.80	8.70	.2400	.0240	.2640	2.38	.0050	.0001	–	68°	37°
2, .	500	644	.80	9.70	.2520	.0190	.2710	2.32	.0030	.0002	–	64°	39°
3, .	500	448	–	–	–	–	–	–	–	–	–	69°	40°
4, .	150	181	1.50	10.20	.1600	.0260	.1860	2.54	.0080	.0001	1 h. 50 m.	40°	40°
5, .	150	161	–	–	–	–	–	–	–	–	–	43°	40°
6, .	150	220	–	–	–	–	–	–	–	–	3 h. 38 m.	46°	41°
7, .	–	–	–	–	–	–	–	–	–	–	–	–	–
8, .	–	–	–	–	–	–	–	–	–	–	–	–	–
9, .	–	–	–	–	–	–	–	–	–	–	–	–	–
10, .	150	145	–	–	–	–	–	–	–	–	1 h. 1 m.	40°	41°
11, .	150	204	1.30	9.80	.2200	.0110	.2310	2.00	.0200	.0004	2 h. 22 m.	42°	41°
12, .	150	87	–	–	–	–	–	–	–	–	–	47°	42°
13, .	150	132	.60	10.20	.1720	.0060	.1780	2.55	.0180	.0003	2 h.	46°	41°
14, .	150	133	–	–	–	–	–	–	–	–	–	43°	41°
15, .	150	131	–	–	–	–	–	–	–	–	–	45°	41°
16, .	150	115	1.20	10.00	.1720	.0160	.1880	2.62	.0100	Present	2 h. 14 m.	41°	41°
17, .	150	111	–	–	–	–	–	–	–	–	2 h. 17 m.	43°	42°
18, .	150	129	1.80	9.70	.1840	.0110	.1950	2.83	.0180	.0004	–	45°	41°
19, .	150	128	–	–	–	–	–	–	–	–	1 h. 59 m.	42°	43°
20, .	150	132	1.30	10.10	.2000	.0110	.2110	2.66	.0200	.0006	2 h. 1 m.	43°	41°
21, .	300	278	–	–	–	–	–	–	–	–	–	42°	41°
22, .	–	89	–	–	–	–	–	–	–	–	–	–	–
23, .	150	68	2.90	9.30	.2000	.0110	.2110	3.24	.0250	.0005	–	43°	43°
24, .	150	121	–	–	–	–	–	–	–	–	–	44°	42°
25, .	150	121	1.70	11.50	.2680	.0060	.2740	3.59	.0200	.0003	–	42°	43°
26, .	150	131	–	–	–	–	–	–	–	–	–	45°	43°
27, .	150	131	3.00	11.00	.2320	.0160	.2480	3.83	.0300	.0004	–	43°	43°
28, .	300	257	–	–	–	–	–	–	–	–	–	46°	45°
29, .	–	49	–	–	–	–	–	–	–	–	–	–	–

Effluent colorless and generally nearly clear, and with from no sediment to considerable.

April 16 and 18.—A few organisms visible to naked eye in samples. April 1.—Outlet opened at 11.9 A.M. April 3, 7.58 A.M. to 1.36 P.M., and from 5.28 P.M. to April 4, 5.35 A.M.—Outlet closed. April 7, 5.21 A.M., to April 10, 8.12 A.M.—Outlet closed. River high in all cases. April 29, 6.50 P.M. —Outlet closed. River high.

Total effluent to end of month, 19,190 gallons.

Filter Tank No. 7 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	-	-	-	-	-	-	-	-	-	-	-	-
2, ...	-	-	-	-	-	-	-	-	-	-	-	-
3, ...	-	-	-	-	-	-	-	-	-	-	-	-
4, ...	150	100	2.90	13.50	.1800	.0060	.1860	2.95	.0600	.0022	46°	46°
5, ...	300	236	-	-	-	-	-	-	-	-	45°	46°
6, ...	-	73	-	-	-	-	-	-	-	-	-	-
7, ...	150	39	2.40	12.50	.1800	.0120	.1920	3.58	.0450	.0007	50°	-
8, ...	150	116	-	-	-	-	-	-	-	-	48°	48°
9, ...	150	199	-	-	-	-	-	-	-	-	50°	46°
10, ...	150	182	3.30	11.80	.2400	.0070	.2470	3.46	.0400	.0009	51°	47°
11, ...	150	135	-	-	-	-	-	-	-	-	51°	47°
12, ...	300	148	-	-	-	-	-	-	-	-	50°	48°
13, ...	-	-	-	-	-	-	-	-	-	-	-	-
14, ...	-	-	-	-	-	-	-	-	-	-	-	-
15, ...	-	-	-	-	-	-	-	-	-	-	-	-
16, ...	-	-	-	-	-	-	-	-	-	-	-	-
17, ...	150	535	2.50	10.00	.2560	.0140	.2700	3.20	.0900	.0010	49°	49°
18, ...	150	88	-	-	-	-	-	-	-	-	50°	51°
19, ...	300	212	-	-	-	-	-	-	-	-	50°	49°
20, ...	-	99	-	-	-	-	-	-	-	-	-	-
21, ...	150	51	4.40	11.10	.2120	.0080	.2200	2.88	.2000	.0034	52°	52°
22, ...	150	96	-	-	-	-	-	-	-	-	52°	50°
23, ...	150	102	-	-	-	-	-	-	-	-	53°	51°
24, ...	150	106	3.40	15.10	.2240	.0070	.2310	2.92	.3500	.0046	54°	52°
25, ...	150	112	-	-	-	-	-	-	-	-	55°	52°
26, ...	300	195	-	-	-	-	-	-	-	-	57°	51°
27, ...	-	78	-	-	-	-	-	-	-	-	-	-
28, ...	150	81	8.80	13.60	.2000	.0080	.2080	3.18	.6000	.0066	56°	52°
29, ...	150	153	-	-	-	-	-	-	-	-	56°	54°
30, ...	150	140	-	-	-	-	-	-	-	-	57°	54°
31, ...	150	116	8.40	15.90	.2000	.0090	.2090	3.88	.8000	.0057	57°	54°

Effluent colorless, generally clear and with very little sediment.

May 17.—Organisms in sample visible to naked eye. May 4.—7.44 A.M. Outlet opened. May 12, 8.55 P.M., to May 17, 7.45 A.M.—Outlet closed. River high. May 28.—Leak in measuring basin repaired. Total effluent to end of month, 22,582 gallons.

Filter Tank No. 7 — Continued.

June, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	150	107	–	–	–	–	–	–	–	–	24 h.	59°	55°
2, .	300	111	–	–	–	–	–	–	–	–	24 h.	59°	55°
3, .	–	111	–	–	–	–	–	–	–	–	24 h.	–	–
4, .	150	91	12.10	17.70	.1760	.0150	.1910	4.32	1.3000	.0044	24 h.	59°	56°
5, .	150	88	–	–	–	–	–	–	–	–	24 h.	61°	58°
6, .	150	101	–	–	–	–	–	–	–	–	24 h.	62°	59°
7, .	150	91	–	–	–	–	–	–	–	–	24 h.	64°	59°
8, .	150	86	13.00	15.80	.2000	.0150	.2150	4.50	1.5000	.0056	24 h.	65°	59°
9, .	300	138	–	–	–	–	–	–	–	–	24 h.	66°	60°
10, .	–	109	–	–	–	–	–	–	–	–	24 h.	–	–
11, .	150	72	10.10	15.70	.1880	.0110	.1990	4.67	1.1000	.0079	24 h.	68°	61°
12, .	150	84	–	–	–	–	–	–	–	–	24 h.	66°	61°
13, .	150	91	–	–	–	–	–	–	–	–	24 h.	66°	61°
14, .	150	93	11.00	16.10	.2000	.0120	.2120	4.82	1.0500	.0110	24 h.	66°	60°
15, .	80	98	–	–	–	–	–	–	–	–	24 h.	66°	61°
16, .	85	22	–	–	–	–	–	–	–	–	–	66°	–
17, .	–	–	–	–	–	–	–	–	–	–	–	–	–
18, .	100	2	7.60	23.80	.0920	.0080	.1000	5.18	.7200	.0048	–	68°	–
19, .	100	237	–	–	–	–	–	–	–	–	–	68°	61°
20, .	100	53	–	–	–	–	–	–	–	–	–	71°	64°
21, .	100	63	10.90	16.10	.1920	.0100	.2020	5.50	.5000	.0080	–	70°	63°
22, .	50	14	–	–	–	–	–	–	–	–	–	70°	65°
23, .	100	–	–	–	–	–	–	–	–	–	–	74°	–
24, .	–	–	–	–	–	–	–	–	–	–	–	–	–
25, .	75	61	7.20	22.20	.0360	.0140	.0500	5.17	.5800	.0070	24 h.	71°	–
26, .	80	84	–	–	–	–	–	–	–	–	–	71°	–
27, .	–	66	–	–	–	–	–	–	–	–	–	–	–
28, .	100	48	4.30	19.70	.0920	.0170	.1090	5.50	.2400	.0010	–	68°	–
29, .	60	–	–	–	–	–	–	–	–	–	–	67°	–
30, .	70	21	–	–	–	–	–	–	–	–	24 h.	66°	66°

Effluent colorless, from clear to distinctly turbid, and from very little to considerable sediment.

June 4. — Organisms visible to naked eye in sample. June 16, 11.0 A.M., to June 19, 11.0 A.M. — Outlet closed. June 22, 1.13 P.M., to June 25, 9.25 A.M. — Outlet closed. June 29. — Trap put in outlet pipe.

Total effluent to end of month, 24,724 gallons.

Filter Tank No. 7 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	21	-	-	-	-	-	-	-	-	24 h.	-	-
2, .	-	29	4.70	22.70	.0760	.0200	.0960	5.70	.0740	.0005	24 h.	-	66°
3, .	100	26	-	-	-	-	-	-	-	-	24 h.	66°	68°
4, .	100	30	-	-	-	-	-	-	-	-	24 h.	66°	67°
5, .	-	23	3.80	24.00	.1120	.0350	.1470	5.75	.0150	.0004	24 h.	-	69°
6, .	-	23	-	-	-	-	-	-	-	-	24 h.	-	69°
7, .	100	20	-	-	-	-	-	-	-	-	24 h.	70°	70°
8, .	-	18	-	-	-	-	-	-	-	-	24 h.	-	-
9, .	100	22	2.90	24.90	.1400	.0390	.1790	5.50	.0100	.0005	24 h.	69°	68°
10, .	-	19	-	-	-	-	-	-	-	-	24 h.	-	69°
11, .	100	15	-	-	-	-	-	-	-	-	24 h.	71°	71°
12, .	-	21	3.30	25.70	.1320	.0210	.1530	5.68	.0100	.0001	24 h.	-	68°
13, .	-	26	-	-	-	-	-	-	-	-	24 h.	-	67°
14, .	-	19	-	-	-	-	-	-	-	-	24 h.	-	70°
15, .	-	16	-	-	-	-	-	-	-	-	24 h.	-	-
16, .	-	19	3.00	26.60	.1600	.0310	.1910	6.31	.0050	.0000	24 h.	-	68°
17, .	-	17	-	-	-	-	-	-	-	-	24 h.	-	69°
18, .	-	19	-	-	-	-	-	-	-	-	24 h.	-	68°
19, .	-	17	5.80	27.80	.1920	.0200	.2120	5.68	.0050	.0000	24 h.	-	67°
20, .	-	14	-	-	-	-	-	-	-	-	-	-	71°
21, .	-	20	-	-	-	-	-	-	-	-	-	-	71°
22, .	-	19	-	-	-	-	-	-	-	-	-	-	-
23, .	-	44	5.70	24.30	.1600	.0190	.1790	6.25	.0070	.0000	-	-	69°
24, .	-	20	-	-	-	-	-	-	-	-	-	-	71°
25, .	100	30	-	-	-	-	-	-	-	-	-	72°	70°
26, .	100	57	4.80	23.90	.1920	.0270	.2190	5.58	.0030	.0000	53 m.	74°	70°
27, .	100	70	-	-	-	-	-	-	-	-	-	72°	68°
28, .	200	295	-	-	-	-	-	-	-	-	-	72°	67°
29, .	-	76	-	-	-	-	-	-	-	-	-	-	-
30, .	100	41	6.10	18.80	.3680	.0420	.4100	6.40	.0200	.0003	52 m.	71°	70°
31, .	100	55	-	-	-	-	-	-	-	-	-	72°	70°

Effluent colorless but generally decidedly turbid, and with very much brown, flocculent sediment.

July 2.— Iron in sample. July 16.— Hydrogen sulphide odor in sample upon adding acid. July 20.— Two hundred and forty gallons siphoned from surface. July 25.— One-half inch of material removed from surface. July 28.— Trap taken from outlet pipe. Effluent had an offensive odor and greasy appearance.

Total effluent to end of month, 25,865 gallons.

Filter Tank No. 7 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	100	101	-	-	-	-	-	-	-	-	1h.46m.	72°	69°
2, .	100	75	3.90	19.00	.4000	.0390	.4390	6.75	.0030	.0004	1h.56m.	73°	70°
3, .	100	69	-	-	-	-	-	-	-	-	1h.29m.	73°	70°
4, .	200	173	-	-	-	-	-	-	-	-	-	73°	71°
5, .	-	76	-	-	-	-	-	-	-	-	-	-	-
6, .	100	62	6.80	17.70	.3600	.0310	.3910	6.80	.2900	.0070	-	73°	70°
7, .	100	169	-	-	-	-	-	-	-	-	-	72°	70°
8, .	100	101	-	-	-	-	-	-	-	-	-	72°	69°
9, .	100	89	3.60	19.20	.3200	.0330	.3530	6.55	.7800	.0180	-	72°	71°
10, .	100	83	-	-	-	-	-	-	-	-	-	72°	71°
11, .	200	140	-	-	-	-	-	-	-	-	-	73°	69°
12, .	-	72	-	-	-	-	-	-	-	-	-	-	-
13, .	100	90	3.70	23.60	.2700	.0280	.2980	6.02	1.1000	.0240	-	70°	68°
14, .	100	259	-	-	-	-	-	-	-	-	12 h. +	69°	68°
15, .	100	110	-	-	-	-	-	-	-	-	7h.27m.	69°	69°
16, .	100	91	6.00	24.50	.2000	.0120	.2120	5.60	1.1000	.0100	5h.7m.	69°	72°
17, .	100	110	-	-	-	-	-	-	-	-	12 h. +	70°	69°
18, .	200	152	-	-	-	-	-	-	-	-	32 h.	70°	69°
19, .	-	109	-	-	-	-	-	-	-	-	-	-	-
20, .	100	64	6.80	19.10	.1400	.0240	.1640	5.31	.7000	.0120	4 h. 6 m.	71°	71°
21, .	100	72	-	-	-	-	-	-	-	-	3h.43m.	71°	70°
22, .	100	137	-	-	-	-	-	-	-	-	24 h.	71°	69°
23, .	100	112	4.80	17.80	.1520	.0160	.1680	5.17	.7000	.0070	24 h.	70°	69°
24, .	100	85	-	-	-	-	-	-	-	-	24 h.	70°	71°
25, .	200	83	-	-	-	-	-	-	-	-	24 h.	70°	71°
26, .	-	91	-	-	-	-	-	-	-	-	24 h.	-	-
27, .	100	61	4.00	18.30	.1400	.0240	.1640	5.00	.7000	.0140	24 h.	71°	70°
28, .	100	48	-	-	-	-	-	-	-	-	24 h.	70°	68°
29, .	100	55	-	-	-	-	-	-	-	-	24 h.	69°	70°
30, .	100	76	5.30	16.10	.1160	.0110	.1270	4.68	.6250	.0220	24 h.	69°	70°
31, .	100	79	-	-	-	-	-	-	-	-	24 h.	70°	69°

Color of effluent from 0 to 0.35, from distinct to no turbidity, and from much brown, flocculent sediment, to none.

After August 1. — Residue on evaporation obtained with sodium carbonate. August 6. — A very little iron in sample. August 14. — Sixty-two gallons siphoned from surface. August 22. — Fifty-five gallons. Some left.

Total effluent to end of month, 28,959 gallons.

Filter Tank No. 7 — Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	200	69	-	-	-	-	-	-	-	-	24 h.	71°	69°
2, .	-	62	-	-	-	-	-	-	-	-	24 h.	-	-
3, .	100	63	2.20	18.10	.1280	.0200	.1480	5.25	.4500	.0240	24 h.	70°	70°
4, .	100	68	-	-	-	-	-	-	-	-	24 h.	71°	68°
5, .	-	72	-	-	-	-	-	-	-	-	24 h.	-	70°
6, .	-	73	2.90	18.70	.1200	.0270	.1470	6.93	.3400	.0250	23 h. 46 m.	-	69°
7, .	-	48	-	-	-	-	-	-	-	-	-	-	67°
8, .	150	184	-	-	-	-	-	-	-	-	12 h.+	66°	68°
9, .	-	146	-	-	-	-	-	-	-	-	-	-	-
10, .	75	51	3.70	23.40	.1200	.0190	.1390	10.36	.2200	.0300	1 h. 30 m.	67°	69°
11, .	75	51	-	-	-	-	-	-	-	-	2 h.	66°	68°
12, .	75	111	-	-	-	-	-	-	-	-	12 h.+	66°	66°
13, .	75	89	4.50	24.10	.0840	.0160	.1000	11.36	.2400	.0350	4 h. 59 m.	66°	68°
14, .	75	63	-	-	-	-	-	-	-	-	5 h. 45 m.	64°	68°
15, .	150	81	-	-	-	-	-	-	-	-	23 h. 16 m.	64°	68°
16, .	-	73	-	-	-	-	-	-	-	-	-	-	-
17, .	150	43	4.10	30.20	.1120	.0220	.1340	11.95	.4700	.0150	36 h.+	65°	68°
18, .	-	106	-	-	-	-	-	-	-	-	-	-	66°
19, .	150	91	-	-	-	-	-	-	-	-	-	64°	65°
20, .	-	71	5.80	30.60	.0960	.0140	.1100	12.60	.3000	.0300	-	-	66°
21, .	150	73	-	-	-	-	-	-	-	-	27 h. 46 m.	63°	64°
22, .	-	105	-	-	-	-	-	-	-	-	-	-	66°
23, .	-	54	-	-	-	-	-	-	-	-	-	-	-
24, .	150	63	3.00	32.20	.0840	.0100	.0940	12.00	.8600	.0350	7 h.	59°	64°
25, .	-	65	-	-	-	-	-	-	-	-	-	-	64°
26, .	150	80	-	-	-	-	-	-	-	-	-	58°	62°
27, .	-	94	5.40	27.60	.0600	.0100	.0700	11.25	.6500	.0400	-	-	64°
28, .	150	68	-	-	-	-	-	-	-	-	36 h.+	57°	62°
29, .	-	71	-	-	-	-	-	-	-	-	-	-	61°
30, .	-	31	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, nearly clear and generally free from sediment.

September 17, 20 and 24. — Iron in samples. September 8. — First seventy-five gallons applied disappeared in one hour and fifty-four minutes. September 18. — One hundred and fifty gallons siphoned from surface. September 22. — Two hundred and twenty-six gallons. September 26. — Two hundred and sixty gallons. Some left. September 21. — Considerable water on surface before the regular application.

Total effluent to end of month, 31,278 gallons.

Filter Tank No. 7 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	150	43	4.80	25.80	.0080	.0098	.0178	9.95	.7700	.0200	2 h. 30 m.	53°	60°
2, .	-	97	-	-	-	-	-	-	-	-	-	-	61°
3, .	150	97	-	-	-	-	-	-	-	-	24 h.	53°	60°
4, .	-	104	2.50	25.50	.0118	.0086	.0204	9.35	1.0000	.0175	-	-	60°
5, .	150	71	-	-	-	-	-	-	-	-	12 h. +	51°	59°
6, .	-	86	-	-	-	-	-	-	-	-	-	-	59°
7, .	-	44	-	-	-	-	-	-	-	-	-	-	-
8, .	150	100	2.10	30.10	.0160	.0090	.0250	10.10	1.0000	.0100	36 h +	53°	57°
9, .	-	110	-	-	-	-	-	-	-	-	-	-	57°
10, .	150	71	-	-	-	-	-	-	-	-	45 h. 44 m.	52°	57°
11, .	-	66	2.40	23.40	.0040	.0094	.0134	7.05	1.0500	.0080	-	-	58°
12, .	150	60	-	-	-	-	-	-	-	-	-	51°	56°
13, .	-	58	-	-	-	-	-	-	-	-	-	-	56°
14, .	-	49	-	-	-	-	-	-	-	-	-	-	-
15, .	150	51	1.50	22.70	.0012	.0090	.0102	6.20	.9500	.0030	24 h.	51°	56°
16, .	-	51	-	-	-	-	-	-	-	-	24 h.	-	56°
17, .	150	50	-	-	-	-	-	-	-	-	36 h. +	50°	54°
18, .	-	53	2.20	21.70	.0008	.0070	.0078	5.65	.8600	.0010	-	-	54°
19, .	150	57	-	-	-	-	-	-	-	-	-	49°	55°
20, .	-	69	-	-	-	-	-	-	-	-	-	-	54°
21, .	-	66	-	-	-	-	-	-	-	-	-	-	-
22, .	150	82	1.60	20.30	.0016	.0078	.0094	5.47	.7000	.0010	12 h. +	51°	55°
23, .	-	81	-	-	-	-	-	-	-	-	-	-	53°
24, .	150	45	-	-	-	-	-	-	-	-	-	48°	52°
25, .	-	118	1.90	20.40	.0016	.0082	.0098	5.48	.6700	.0014	-	-	52°
26, .	150	89	-	-	-	-	-	-	-	-	29 h. 49 m.	47°	-
27, .	-	103	-	-	-	-	-	-	-	-	-	-	52°
28, .	-	66	-	-	-	-	-	-	-		-	-	-
29, .	150	60	1.00	19.60	.0008	.0070	.0078	5.99	.5600	.0001	24 h.	49°	53°
30, .	-	49	-	-	-	-	-	-	-	-	24 h.	-	53°
31, .	150	45	-	-	-	-	-	-	-	-	56 h. 36 m.	48°	54°

Effluent colorless, and generally clear and free from sediment.

October 18. — Manganese in sample. October 8. — Forty-five gallons siphoned from surface. October 18. — Two hundred and twenty-five gallons. Some left each day. October 25. — Twenty gallons siphoned off. October 15 and 24. — Water on surface before regular application. October 29. — Rain-water on surface disappeared at 7.15 A.M.

Total effluent to end of month, 33,469 gallons.

Filter Tank No. 7 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	53	2.40	17.60	.0014	.0094	.0108	5.40	.5300	.0000	-	-	56°
2, .	-	50	-	-	-	-	-	-	-	-	-	-	55°
3, .	-	50	-	-	-	-	-	-	-	-	-	-	55°
4, .	-	37	-	-	-	-	-	-	-	-	-	-	-
5, .	100	31	.90	19.60	.0014	.0080	.0094	5.39	.7000	.0000	-	49°	53°
6, .	-	34	-	-	-	-	-	-	-	-	-	-	54°
7, .	100	31	-	-	-	-	-	-	-	-	6 h. 6 m.	51°	53°
8, .	-	47	1.20	19.60	.0008	.0074	.0082	5.21	.6600	.0000	-	-	54°
9, .	100	48	-	-	-	-	-	-	-	-	72 h. 30 m.	51°	55°
10, .	-	108	-	-	-	-	-	-	-	-	-	-	53°
11, .	-	71	-	-	-	-	-	-	-	-	-	-	-
12, .	100	62	.80	19.40	.0004	.0074	.0078	5.14	.7800	.0000	-	48°	53°
13, .	-	65	-	-	-	-	-	-	-	-	-	-	52°
14, .	100	54	-	-	-	-	-	-	-	-	5 h. 36 m.	46°	53°
15, .	-	62	1.50	19.80	.0006	.0080	.0086	5.07	.7000	.0000	-	-	52°
16, .	100	106	-	-	-	-	-	-	-	-	12 h.+	45°	51°
17, .	-	98	-	-	-	-	-	-	-	-	-	-	50°
18, .	-	42	-	-	-	-	-	-	-	-	-	-	-
19, .	100	37	1.70	20.20	.0016	.0080	.0096	4.70	.6300	.0000	12 h.+	43°	50°
20, .	-	61	-	-	-	-	-	-	-	-	-	-	49°
21, .	100	49	-	-	-	-	-	-	-	-	-	43°	49°
22, .	-	42	.90	18.10	.0008	.0068	.0076	4.60	.7000	.0000	-	-	48°
23, .	100	32	-	-	-	-	-	-	-	-	-	46°	47°
24, .	-	48	-	-	-	-	-	-	-	-	-	-	48°
25, .	-	30	-	-	-	-	-	-	-	-	-	-	-
26, .	100	27	.60	18.40	.0010	.0078	.0088	4.47	.6500	.0001	12 h.+	45°	48°
27, .	-	47	-	-	-	-	-	-	-	-	-	-	46°
28, .	100	27	-	-	-	-	-	-	-	-	3 h. 40 m.	45°	48°
29, .	-	-	-	-	-	-	-	-	-	-	-	-	-
30, .	100	131	2.60	17.60	.0016	.0086	.0102	5.00	.7000	.0008	-	38°	45°

Effluent colorless, generally clear and free from sediment, or nearly so.

November 13. — One-fourth inch of ice on surface. November 22 to 24. — Thin ice in spots. November 22. — Canvas cover put over tank. November 28, 8.52 P.M., to November 30, 2.36 P.M. — Outlet closed. River high.

Total effluent to end of month, 35,049 gallons.

Filter Tank No. 7 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	52	-	-	-	-	-	-	-	-	-	-	44°
2, .	-	39	-	-	-	-	-	-	-	-	-	-	-
3, .	100	32	1.00	18.90	.0016	.0066	.0082	4.11	.7700	.0000	2 h. 2 m.	45°	44°
4, .	-	38	-	-	-	-	-	-	-	-	-	-	43°
5, .	100	40	-	-	-	-	-	-	-	-	2 h. 18 m.	44°	43°
6, .	-	46	.60	17.60	.0010	.0052	.0062	4.21	.7000	.0000	-	-	43°
7, .	100	41	-	-	-	-	-	-	-	-	2 h. 15 m.	45°	44°
8, .	-	52	-	-	-	-	-	-	-	-	-	-	44°
9, .	-	36	-	-	-	-	-	-	-	-	-	-	-
10, .	100	26	1.90	18.80	.0054	.0024	.0078	4.17	.8000	.0000	-	44°	43°
11, .	-	39	-	-	-	-	-	-	-	-	-	-	42°
12, .	100	45	-	-	-	-	-	-	-	-	-	45°	42°
13, .	-	56	1.00	18.10	.0008	.0052	.0060	4.10	.8000	.0000	-	-	41°
14, .	100	41	-	-	-	-	-	-	-	-	-	44°	39°
15, .	-	34	-	-	-	-	-	-	-	-	-	-	42°
16, .	-	25	-	-	-	-	-	-	-	-	-	-	-
17, .	100	24	.40	19.10	.0018	.0056	.0074	4.10	.7000	.0000	2 h. 30 m.	45°	44°
18, .	-	20	-	-	-	-	-	-	-	-	-	-	41°
19, .	-	-	-	-	-	-	-	-	-	-	-	-	-
20, .	-	-	-	-	-	-	-	-	-	-	-	-	-
21, .	100	102	-	-	-	-	-	-	-	-	2 h. 36 m.	46°	-
22, .	-	25	-	-	-	-	-	-	-	-	-	-	38°
23, .	-	20	-	-	-	-	-	-	-	-	-	-	-
24, .	100	20	-	-	-	-	-	-	-	-	-	42°	43°
25, .	-	22	-	-	-	-	-	-	-	-	-	-	-
26, .	100	38	-	-	-	-	-	-	-	-	4 h. 55 m.	46°	43°
27, .	-	58	1.00	17.00	.0012	.0058	.0070	4.12	.7000	.0000	-	-	40°
28, .	100	51	-	-	-	-	-	-	-	-	3 h. 33 m.	44°	41°
29, .	-	73	-	-	-	-	-	-	-	-	-	-	41°
30, .	-	35	-	-	-	-	-	-	-	-	-	-	-
31, .	100	29	.80	17.90	.0018	.0046	.0064	4.10	.7000	.0002	3 h. 30 m.	44°	43°

Effluent colorless, clear or nearly so, and free from sediment.

December 31. — Manganese in sample. December 15. — Thin ice in spots on surface. December 19. — Five-eighths of an inch of frost in tank. December 21. — Two inches. December 18, 5 P.M., to December 21, 7.50 A.M. — Outlet closed. River high.

Total effluent to end of month, 36,208 gallons.

Filter Tank No. 7 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	41	-	-	-	-	-	-	-	-	-	-	40°
2, .	100	39	-	-	-	-	-	-	-	-	2 h.35 m.	44°	40°
3, .	-	58	.90	17.70	.0002	.0040	.0042	4.08	.6000	.0000	-	-	40°
4, .	100	45	-	-	-	-	-	-	-	-	2 h.43 m.	44°	41°
5, .	-	53	-	-	-	-	-	-	-	-	-	-	39°
6, .	-	33	-	-	-	-	-	-	-	-	-	-	-
7, .	100	48	.50	16.30	.0010	.0064	.0074	4.01	.7700	.0000	2 h.	44°	40°
8, .	-	57	-	-	-	-	-	-	-	-	-	-	40°
9, .	100	48	-	-	-	-	-	-	-	-	1 h.51 m.	45°	41°
10, .	-	63	.80	17.20	.0006	.0054	.0060	4.10	.6200	.0000	-	-	40°
11, .	100	46	-	-	-	-	-	-	-	-	1 h.59 m.	44°	41°
12, .	-	60	-	-	-	-	-	-	-	-	-	-	39°
13, .	-	30	-	-	-	-	-	-	-	-	-	-	-
14, .	100	25	.90	15.80	.0022	.0056	.0078	4.02	.7800	.0000	1 h.40 m.	44°	41°
15, .	-	26	-	-	-	-	-	-	-	-	-	-	41°
16, .	100	35	-	-	-	-	-	-	-	-	1 h.52 m	45°	41°
17, .	-	46	.40	16.70	.0014	.0068	.0082	4.06	.6200	.0000	-	-	42°
18, .	100	58	-	-	-	-	-	-	-	-	2 h.8 m.	46°	42°
19, .	-	71	-	-	-	-	-	-	-	-	-	-	39°
20, .	-	33	-	-	-	-	-	-	-	-	-	-	-
21, .	100	23	1.10	15.10	.0012	.0040	.0052	4.05	.5500	.0001	-	44°	41°
22, .	-	25	-	-	-	-	-	-	-	-	-	-	40°
23, .	100	33	-	-	-	-	-	-	-	-	2 h.13 m.	45°	41°
24, .	-	54	.20	15.50	.0010	.0038	.0048	4.40	.6500	.0000	-	-	40°
25, .	100	45	-	-	-	-	-	-	-	-	-	44°	41°
26, .	-	59	-	-	-	-	-	-	-	-	-	-	40°
27, .	-	34	-	-	-	-	-	-	-	-	-	-	-
28, .	100	25	.20	16.00	.0010	.0028	.0038	4.17	.6500	.0000	5 h.10 m.	45°	41°
29, .	-	40	-	-	-	-	-	-	-	-	-	-	41°
30, .	100	36	-	-	-	-	-	-	-	-	3 h.53 m.	45°	40°
31, .	-	44	1.00	14.80	.0012	.0044	.0056	4.10	.6000	.0000	-	-	40°

Effluent colorless, clear or nearly so, and with very little or no sediment.

January 22. — One inch of frost in tank. January 26. — One-half inch. January 29. — A little frost around edges of tank. January 30. — Thin ice in spots on surface.

Total effluent to end of month, 37,541 gallons.

Filter Tank No. 7 — Continued.

February, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	100	39	-	-	-	-	-	-	-	-	-	46°	40°
2, .	-	58	-	-	-	-	-	-	-	-	-	-	39°
3, .	-	34	-	-	-	-	-	-	-	-	-	-	-
4, .	100	26	.90	15.40	.0016	.0038	.0054	4.00	.7000	.0001	-	44°	40°
5, .	-	29	-	-	-	-	-	-	-	-	-	-	39°
6, .	100	53	-	-	-	-	-	-	-	-	-	46°	41°
7, .	-	73	1.50	14.60	.0008	.0058	.0066	3.93	.6000	.0000	-	-	39°
8, .	100	41	-	-	-	-	-	-	-	-	-	44°	39°
9, .	-	40	-	-	-	-	-	-	-	-	-	-	40°
10, .	-	29	-	-	-	-	-	-	-	-	-	-	-
11, .	100	23	.50	15.40	.0018	.0052	.0070	3.83	.6000	.0000	-	44°	39°
12, .	-	31	-	-	-	-	-	-	-	-	-	-	39°
13, .	100	40	-	-	-	-	-	-	-	-	-	45°	39°
14, .	-	50	1.10	15.30	.0022	.0080	.0102	3.90	.6000	.0000	-	-	39°
15, .	100	41	-	-	-	-	-	-	-	-	24 h.	46°	41°
16, .	-	48	-	-	-	-	-	-	-	-	24 h.	-	40°
17, .	-	30	-	-	-	-	-	-	-	-	24 h.	-	-
18, .	100	44	.60	15.40	.0014	.0056	.0070	3.04	.6000	.0000	-	44°	39°
19, .	-	67	-	-	-	-	-	-	-	-	-	-	38°
20, .	100	50	-	-	-	-	-	-	-	-	12 h.+	46°	39°
21, .	-	61	1.30	14.60	.0002	.0058	.0060	3.57	.5000	.0000	-	-	38°
22, .	100	42	-	-	-	-	-	-	-	-	-	44°	40°
23, .	-	46	-	-	-	-	-	-	-	-	-	-	38°
24, .	-	33	-	-	-	-	-	-	-	-	-	-	-
25, .	100	23	1.00	13.80	.0010	.0052	.0062	3.57	.6000	.0001	-	44°	39°
26, .	-	29	-	-	-	-	-	-	-	-	-	-	39°
27, .	100	40	-	-	-	-	-	-	-	-	12 h.+	46°	40°
28, .	-	44	.50	14.40	.0002	.0048	.0050	3.45	.6000	.0001	-	-	40°

Effluent colorless, generally clear and with very slight sediment.

February 2 and 5. — One inch of frost in tank. February 7. — Two and one-half inches. February 9. — Three inches. February 14. — Three and one-quarter inches. February 20. — Three and one-half inches. February 25. — Four and one-half inches. Surface of tank generally more or less covered with thin ice for about one-half the days of the month.

Total effluent to end of month, 38,705 gallons.

Filter Tank No. 7 — Continued.

March, 1889.

Date	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	100	45	-	-	-	-	-	-	-	-	-	45°	40°
2, .	-	56	-	-	-	-	..	-	-	-	-	-	39°
3, .	-	24	-	-	-	-	..	-	-	-	-	-	-
4, .	100	36	.50	15.40	.0018	.0056	.0074	3.43	.5000	.0000	6 h.30 m.	35°	41°
5, .	-	45	-	-	-	-	-	-	-	-	-	-	38°
6, .	100	61	-	-	-	-	-	-	-	-	4 h.35 m.	36°	38°
7, .	-	65	.50	14.30	.0004	.0056	.0060	3.46	.4700	.0000	-	-	38°
8, .	100	53	-	-	-	-	-	-	-	-	2 h.30 m.	35°	39°
9, .	-	64	-	-	-	-	-	-	-	-	-	-	37°
10, .	-	31	-	-	-	-	-	-	-	-	-	-	-
11, .	100	32	.70	13.20	.0010	.0046	.0056	3.32	.6000	.0000	3 h.10 m.	34°	40°
12, .	-	39	-	-	-	-	-	-	-	-	-	-	39°
13, .	100	40	-	-	-	-	-	-	-	-	3 h.	37°	40°
14, .	100	59	1.50	14.80	.0000	.0058	.0058	3.18	.5000	.0000	-	-	39°
15, .	100	45	-	-	-	-	-	-	-	-	2 h.30 m.	38°	39°
16, .	-	57	-	-	-	-	-	-	-	-	-	-	40°
17, .	-	39	-	-	-	-	-	-	-	-	-	-	-
18, .	100	58	1.00	15.40	.0014	.0066	.0080	3.10	.6500	.0001	1 h.35 m.	38°	40°
19, .	-	81	-	-	-	-	-	-	-	-	-	-	40°
20, .	100	51	-	-	-	-	-	-	-	-	1 h.20 m.	39°	39°
21, .	-	63	1.40	14.90	.0010	.0078	.0088	3.15	.6000	.0000	-	-	38°
22, .	100	40	-	-	-	-	-	-	-	-	1 h.11 m.	37°	42°
23, .	-	50	-	-	-	-	-	-	-	-	-	-	41°
24, .	-	34	-	-	-	-	-	-	-	-	-	-	-
25, .	100	22	.70	14.40	.0010	.0070	.0080	3.10	.8000	.0000	52 m.	43°	42°
26, .	-	31	-	-	-	-	-	-	-	-	-	-	42°
27, .	100	32	-	-	-	-	-	-	-	-	1 h. 5 m.	42°	43°
28, .	-	44	.70	14.80	.0010	.0064	.0074	3.00	.8000	.0000	-	-	40°
29, .	100	32	-	-	-	-	-	-	-	-	-	-	43°
30, .	-	49	-	-	-	-	-	-	-	-	-	-	42°
31, .	-	35	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, generally clear and with very slight sediment.

March 1 and 4.—A little ice in spots on surface. March 4.—No frost in some parts of surface. Frost in other parts at a depth of from 1 inch to 3 inches to from 4 inches to 7 inches. March 8.—No frost in tank. March 13.—Canvas cover removed from tank.

Total effluent to end of month, 40,118 gallons.

Filter Tank No. 7 — Continued.

April, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1,	100	68	.50	16.60	.0006	.0054	.0060	2.96	.9000	.0000	-	-	42°
2,	-	115	-	-	-	-	-	-	-	-	-	-	40°
3,	100	81	-	-	-	-	-	-	-	-	2 h.	40°	40°
4,	-	79	.40	16.90	.0012	.0064	.0076	3.02	1.2000	.0000	-	-	40°
5,	100	41	-	-	-	-	-	-	-	-	2 h.	41°	43°
6,	-	49	-	-	-	-	-	-	-	-	-	-	43°
7,	-	39	-	-	-	-	-	-	-	-	-	-	-
8,	100	26	1.20	17.20	.0006	.0046	.0052	3.23	1.1500	.0000	1 h.32 m.	44°	44°
9,	-	24	-	-	-	-	-	-	-	-	-	-	47°
10,	100	25	-	-	-	-	-	-	-	-	1 h.24 m.	46°	47°
11,	-	34	.50	17.10	.0014	.0056	.0070	3.26	1.1000	.0000	-	-	45°
12,	100	29	-	-	-	-	-	-	-	-	-	46°	47°
13,	-	40	-	-	-	-	-	-	-	-	-	-	46°
14,	-	29	-	-	-	-	-	-	-	-	-	-	-
15,	100	27	.70	17.10	.0010	.0060	.0070	3.22	1.4000	.0000	54 m.	47°	48°
16,	-	20	-	-	-	-	-	-	-	-	-	-	47°
17,	100	21	-	-	-	-	-	-	-	-	-	47°	47°
18,	-	52	.50	18.70	.0010	.0066	.0076	3 30	1.3000	.0000	-	-	45°
19,	100	61	-	-	-	-	-	-	-	-	2 h.	50°	50°
20,	-	68	-	-	-	-	-	-	-	-	-	-	48°
21,	-	32	-	-	-	-	-	-	-	-	-	-	-
22,	100	23	.60	18.70	.0020	.0078	.0098	3.45	1.3000	.0000	-	53°	49°
23,	-	24	-	-	-	-	-	-	-	-	-	-	50°
24,	100	24	-	-	-	-	-	-	-	-	43 m.	51°	51°
25,	-	24	1.80	20.00	.0028	.0082	.0110	3.50	1.5000	.0000	-	-	52°
26,	100	90	-	-	-	-	-	-	-	-	48 m.	54°	52°
27,	-	197	-	-	-	-	-	-	-	-	-	-	48°
28,	-	48	-	-	-	-	-	-	-	-	-	-	-
29,	100	33	1.80	23.30	.0018	.0068	.0086	4.09	1.6000	.0000	-	55°	52°
30,	-	43	-	-	-	-	-	-	-	-	-	-	52°

Effluent colorless, clear or nearly so, and generally with a very slight sediment.
Total effluent to end of month, 41,584 gallons.

Filter Tank No. 7 — Continued.

May, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	100	30	-	-	-	-	-	-	-	-	1 h.40 m.	52°	52°
2, .	-	39	.70	25.30	.0004	.0050	.0054	4.07	1.8000	.0001	-	-	53°
3, .	100	26	-	-	-	-	-	-	-	-	1 h.30 m.	53°	52°
4, .	-	45	-	-	-	-	-	-	-	-	-	-	52°
5, .	-	24	-	-	-	-	-	-	-	-	-	-	-
6, .	100	25	2.50	24.90	.0018	.0070	.0088	4.30	2.0000	.0001	39 m.	55°	56°
7, .	-	22	-	-	-	-	-	-	-	-	-	-	55°
8, .	100	23	-	-	-	-	-	-	-	-	44 m.	58°	58°
9, .	-	35	-	-	-	-	-	-	-	-	-	-	58°
10, .	100	31	-	-	-	-	-	-	-	-	-	62°	60°
11, .	-	44	-	-	-	-	-	-	-	-	-	-	55°
12, .	-	29	-	-	-	-	-	-	-	-	-	-	-
13, .	100	24	.60	25.20	.0024	.0058	.0082	4.17	2.8000	.0000	38 m.	64°	59°
14, .	-	28	-	-	-	-	-	-	-	-	-	-	58°
15, .	100	77	-	-	-	-	-	-	-	-	1 h.30 m.	65°	58°
16, .	-	72	.80	25.70	.0012	.0080	.0092	4.16	2.0000	.0000	-	-	57°
17, .	100	35	-	-	-	-	-	-	-	-	44 m.	66°	62°
18, .	-	38	-	-	-	-	-	-	-	-	-	-	62°
19, .	-	25	-	-	-	-	-	-	-	-	-	-	-
20, .	100	57	1.30	25.60	.0030	.0078	.0108	4.15	2.0000	.0000	-	68°	62°
21, .	-	224	-	-	-	-	-	-	-	-	-	-	58°
22, .	100	119	-	-	-	-	-	-	-	-	-	67°	60°
23, .	-	70	-	-	-	-	-	-	-	-	-	-	60°
24, .	100	31	-	-	-	-	-	-	-	-	40 m.	65°	61°
25, .	-	39	-	-	-	-	-	-	-	-	-	-	61°
26, .	-	22	-	-	-	-	-	-	-	-	-	-	-
27, .	100	42	1.20	26.80	.0016	.0060	.0076	4.44	2.0000	.0000	1 h.30 m.	61°	58°
28, .	-	93	-	-	-	-	-	-	-	-	-	-	60°
29, .	100	43	-	-	-	-	-	-	-	-	43 m.	61°	61°
30, .	-	47	1.00	27.80	.0022	.0088	.0110	4.52	2.1000	.0000	-	-	60°
31, .	100	32	-	-	-	-	-	-	-	-	48 m.	62°	63°

Effluent colorless, generally clear and with very little or no sediment.
May 22. — Considerable grass and weeds on surface, principally near edge of tank.
Total effluent to end of month, 43,075 gallons.

Filter Tank No. 7 — Continued.

June, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	45	-	-	-	-	-	-	-	-	-	-	62°
2, .	-	84	-	-	-	-	-	-	-	-	-	-	-
3, .	100	87	.50	26.70	.0020	.0052	.0072	4.50	2.0000	.0000	1 h. 20 m.	65°	61°
4, .	-	76	-	-	-	-	-	-	-	-	-	-	61°
5, .	100	88	-	-	-	-	-	-	-	-	-	66°	61°
6, .	-	62	-	-	-	-	-	-	-	-	-	-	61°
7, .	100	33	-	-	-	-	-	-	-	-	38 m.	66°	63°
8, .	-	40	-	-	-	-	-	-	-	-	-	-	62°
9, .	-	16	-	-	-	-	-	-	-	-	-	-	-
10, .	100	20	4.00	24.20	.0016	.0068	.0084	4.55	1.7000	.0001	33 m.	67°	69°
11, .	-	47	-	-	-	-	-	-	-	-	-	-	65°
12, .	100	35	-	-	-	-	-	-	-	-	34 m.	69°	64°
13, .	-	40	-	-	-	-	-	-	-	-	-	-	65°
14, .	100	20	-	-	-	-	-	-	-	-	-	67°	68°
15, .	-	28	-	-	-	-	-	-	-	-	-	-	69°
16, .	-	4	-	-	-	-	-	-	-	-	-	-	-
17, .	100	14	-	-	-	-	-	-	-	-	20 m.	72°	68°
18, .	-	26	-	-	-	-	-	-	-	-	-	-	65°
19, .	100	31	-	-	-	-	-	-	-	-	1 h. 1 m.	70°	64°
20, .	-	40	2.10	22.70	.0014	.0092	.0106	4.60	2.4000	.0001	-	-	68°
21, .	100	22	-	-	-	-	-	-	-	-	30 m.	71°	70°
22, .	-	26	-	-	-	-	-	-	-	-	-	-	69°
23, .	-	14	-	-	-	-	-	-	-	-	-	-	-
24, .	100	14	1.20	24.30	.0020	.0088	.0108	4.72	1.5000	.0000	22 m.	70°	68°
25, .	-	16	-	-	-	-	-	-	-	-	-	-	68°
26, .	-	11	-	-	-	-	-	-	-	-	-	-	70°
27, .	-	8	3.00	21.40	.0034	.0090	.0124	4.77	1.6000	.0000	-	-	-
28, .	-	7	-	-	-	-	-	-	-	-	-	-	74°
29, .	50	35	-	-	-	-	-	-	-	-	-	72°	69°
30, .	-	8	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless and generally clear, and with very little or no sediment.

June 16. — Some effluent lost. June 25. — Trench 2 feet wide and 3½ feet deep, cut 1½ feet from edge of tank and filled to a depth of 2 feet with gravel too coarse to go through a sieve with ¾-inch meshes. Six-inch drain pipe laid with open joints in upper part of this gravel. One foot of yellow loam put upon gravel, and 5 inches of brown soil upon loam. Sewage to be applied through a 4-inch pipe connected with the open drain.

Total effluent to end of month, 44,072 gallons.

Filter Tank No. 7 — Continued.

July, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	50	34	1.80	22.80	.0034	.0078	.0112	4.80	1.4000	.0002	74°	69°
2, ...	50	46	-	-	-	-	-	-	-	-	73°	71°
3, ...	50	48	-	-	-	-	-	-	-	-	74°	68°
4, ...	50	55	-	-	-	-	-	-	-	-	73°	-
5, ...	50	45	2.00	19.80	.0032	.0076	.0108	5.73	.8500	.0000	74°	68°
6, ...	50	54	-	-	-	-	-	-	-	-	74°	68°
7, ...	-	8	-	-	-	-	-	-	-	-	-	-
8, ...	50	38	1.80	20.50	.0018	.0084	.0102	5.52	.8000	.0000	72°	69°
9, ...	50	45	-	-	-	-	-	-	-	-	73°	67°
10, ...	50	54	-	-	-	-	-	-	-	-	73°	67°
11, ...	50	51	-	-	-	-	-	-	-	-	72°	66°
12, ...	50	50	-	-	-	-	-	-	-	-	72°	68°
13, ...	50	51	-	-	-	-	-	-	-	-	72°	68°
14, ...	-	15	-	-	-	-	-	-	-	-	-	-
15, ...	50	35	2.10	24.50	.0014	.0080	.0094	5.95	1.2000	.0001	73°	65°
16, ...	50	43	-	-	-	-	-	-	-	-	71°	66°
17, ...	50	46	-	-	-	-	-	-	-	-	71°	66°
18, ...	50	52	1.80	24.60	.0014	.0086	.0100	5.14	1.8000	.0002	72°	69°
19, ...	50	51	-	-	-	-	-	-	-	-	72°	67°
20, ...	50	118	-	-	-	-	-	-	-	-	72°	66°
21, ...	-	43	-	-	-	-	-	-	-	-	-	-
22, ...	50	64	2.60	21.40	.0010	.0074	.0084	4.52	1.7000	.0000	73°	67°
23, ...	50	58	-	-	-	-	-	-	-	-	73°	66°
24, ...	50	71	-	-	-	-	-	-	-	-	71°	69°
25, ...	50	70	-	-	-	-	-	-	-	-	70°	70°
26, ...	50	59	1.60	22.30	.0006	.0060	.0066	4.53	1.6000	.0000	71°	69°
27, ...	50	59	-	-	-	-	-	-	-	-	70°	67°
28, ...	-	39	-	-	-	-	-	-	-	-	-	-
29, ...	50	71	2.80	21.30	.0006	.0058	.0064	4.37	1.1000	.0002	71°	72°
30, ...	50	62	-	-	-	-	-	-	-	-	72°	69°
31, ...	50	67	-	-	-	-	-	-	-	-	72°	69°

Effluent clear and colorless, and generally free from sediment.
Total effluent to end of month, 45,674 gallons.

Filter Tank No. 7 — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	50	125	-	-	-	-	-	-	-	-	72°	68°
2, ...	50	127	2.80	23.80	.0008	.0052	.0060	4.65	1.4000	.0000	72°	69°
3, ...	50	77	-	-	-	-	-	-	-	-	71°	68°
4, ...	-	21	-	-	-	-	-	-	-	-	-	-
5, ...	50	49	1.00	21.50	.0002	.0066	.0068	3.86	1.3000	.0000	70°	68°
6, ...	50	51	-	-	-	-	-	-	-	-	70°	69°
7, ...	50	51	-	-	-	-	-	-	-	-	70°	69°
8, ...	50	49	1.00	21.90	.0004	.0076	.0080	4.39	1.7000	.0002	70°	69°
9, ...	50	53	-	-	-	-	-	-	-	-	70°	69°
10, ...	50	50	-	-	-	-	-	-	-	-	70°	69°
11, ...	-	17	-	-	-	-	-	-	-	-	-	-
12, ...	50	34	-	-	-	-	-	-	-	-	70°	68°
13, ...	50	48	-	-	-	-	-	-	-	-	70°	68°
14, ...	50	47	-	-	-	-	-	-	-	-	69°	67°
15, ...	50	44	-	-	-	-	-	-	-	-	68°	68°
16, ...	50	47	-	-	-	-	-	-	-	-	67°	68°
17, ...	50	56	-	-	-	-	-	-	-	-	68°	68°
18, ...	-	18	-	-	-	-	-	-	-	-	-	-
19, ...	50	41	-	-	.0004	.0064	.0068	4.12	1.3000	.0000	68°	68°
20, ...	50	50	-	-	-	-	-	-	-	-	69°	64°
21, ...	50	49	-	-	-	-	-	-	-	-	68°	65°
22, ...	50	42	-	-	-	-	-	-	-	-	69°	67°
23, ...	50	60	-	-	-	-	-	-	-	-	70°	67°
24, ...	50	50	-	-	-	-	-	-	-	-	69°	67°
25, ...	-	15	-	-	-	-	-	-	-	-	-	-
26, ...	50	39	-	-	.0012	.0070	.0082	4.72	1.6100	.0000	69°	67°
27, ...	50	50	-	-	-	-	-	-	-	-	68°	69°
28, ...	50	50	-	-	-	-	-	-	-	-	68°	68°
29, ...	50	45	-	-	-	-	-	-	-	-	69°	67°
30, ...	100	89	-	-	-	-	-	-	-	-	69°	67°
31, ...	100	93	-	-	-	-	-	-	-	-	70°	71°

Effluent clear and colorless, and generally free from sediment.
Total effluent to end of month, 47,311 gallons.

Filter Tank No. 7 — Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	-	18	-	-	-	-	-	-	-	-	-	-
2, ...	100	76	.80	26.50	.0002	.0064	.0066	5.82	1.4000	.0000	71°	67°
3, ...	100	91	-	-	-	-	-	-	-	-	70°	68°
4, ...	100	100	-	-	-	-	-	-	-	-	71°	67°
5, ...	100	94	-	-	-	-	-	-	-	-	71°	67°
6, ...	100	93	-	-	-	-	-	-	-	-	72°	67°
7, ...	100	100	-	-	.0006	.0060	.0066	5.87	1.4000	.0002	71°	67°
8, ...	-	16	-	-	-	-	-	-	-	-	-	-
9, ...	100	76	-	-	-	-	-	-	-	-	72°	67°
10, ...	100	90	-	-	-	-	-	-	-	-	70°	67°
11, ...	100	96	-	-	-	-	-	-	-	-	68°	67°
12, ...	100	93	-	-	-	-	-	-	-	-	67°	67°
13, ...	100	88	-	-	-	-	-	-	-	-	66°	67°
14, ...	100	95	2.50	28.50	.0006	.0090	.0096	5.97	1.6000	.0000	66°	67°
15, ...	-	19	-	-	-	-	-	-	-	-	-	-
16, ...	100	71	-	-	-	-	-	-	-	-	68°	67°
17, ...	100	91	-	-	-	-	-	-	-	-	68°	67°
18, ...	100	94	-	-	-	-	-	-	-	-	68°	67°
19, ...	100	96	-	-	-	-	-	-	-	-	66°	66°
20, ...	100	91	-	-	-	-	-	-	-	-	65°	67°
21, ...	100	99	-	-	.0002	.0070	.0072	4.40	1.4000	.0000	64°	66°
22, ...	-	18	-	-	-	-	-	-	-	-	-	-
23, ...	100	82	-	-	-	-	-	-	-	-	60°	65°
24, ...	100	91	-	-	-	-	-	-	-	-	59°	64°
25, ...	100	98	-	-	-	-	-	-	-	-	68°	64°
26, ...	100	100	-	-	.0002	.0098	.0100	4.82	1.4000	.0001	59°	65°
27, ...	100	89	-	-	-	-	-	-	-	-	59°	64°
28, ...	100	91	-	-	-	-	-	-	-	-	58°	63°
29, ...	-	15	-	-	-	-	-	-	-	-	-	-
30, ...	150	125	-	-	-	-	-	-	-	-	58°	63°

Effluent clear and colorless, and free from sediment.
Total effluent to end of month, 49,707 gallons.

Filter Tank No. 7 — Continued.

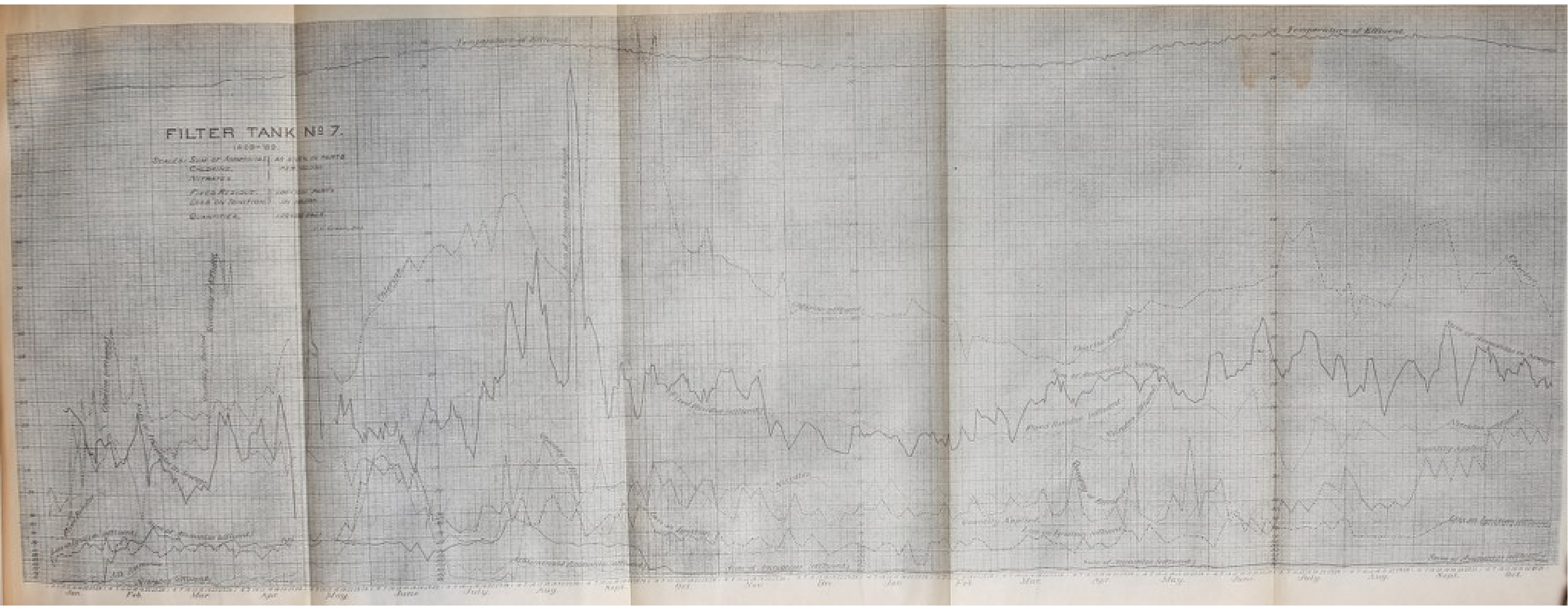
October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	150	136	-	-	-	-	-	-	-	-	59°	63°
2, ...	150	151	-	-	-	-	-	-	-	-	59°	62°
3, ...	150	141	-	-	.0020	.0110	.0130	4.82	1.3400	.0008	57°	62°
4, ...	150	142	-	-	-	-	-	-	-	-	57°	62°
5, ...	150	135	-	-	-	-	-	-	-	-	57°	61°
6, ...	-	19	-	-	-	-	-	-	-	-	-	-
7, ...	150	127	-	-	-	-	-	-	-	-	56°	58°
8, ...	150	157	-	-	-	-	-	-	-	-	54°	60°
9, ...	150	157	-	-	-	-	-	-	-	-	-	60°
10, ...	150	149	-	-	.0000	.0102	.0102	5.17	1.5400	.0007	51°	57°
11, ...	150	152	-	-	-	-	-	-	-	-	50°	59°
12, ...	150	151	-	-	-	-	-	-	-	-	50°	58°
13, ...	-	32	-	-	-	-	-	-	-	-	-	-
14, ...	150	187	-	-	-	-	-	-	-	-	49°	57°
15, ...	150	157	-	-	-	-	-	-	-	-	49°	57°
16, ...	150	151	-	-	-	-	-	-	-	-	48°	56°
17, ...	150	149	-	-	.0008	.0092	.0100	4.62	1.7500	.0001	48°	56°
18, ...	150	154	-	-	-	-	-	-	-	-	49°	56°
19, ...	150	151	-	-	-	-	-	-	-	-	49°	55°
20, ...	-	20	-	-	-	-	-	-	-	-	-	-
21, ...	150	133	-	-	-	-	-	-	-	-	49°	54°
22, ...	150	139	-	-	-	-	-	-	-	-	48°	54°
23, ...	150	151	-	-	-	-	-	-	-	-	48°	54°
24, ...	150	148	-	-	.0012	.0142	.0154	4.53	1.5000	.0001	47°	52°
25, ...	150	149	-	-	-	-	-	-	-	-	47°	52°
26, ...	150	149	-	-	-	-	-	-	-	-	47°	53°
27, ...	-	21	-	-	-	-	-	-	-	-	-	-
28, ...	150	144	-	-	-	-	-	-	-	-	48°	53°
29, ...	150	187	-	-	-	-	-	-	-	-	48°	52°
30, ...	150	189	-	-	-	-	-	-	-	-	47°	52°
31, ...	150	161	-	-	.0002	.0088	.0090	3.86	1.3400	.0000	48°	52°

Effluent clear and colorless, and free from sediment.

October 21. — Trap put in at bottom of vertical pipe through which sewage is applied. October 26. — Grass cut from one-half of surface.

Total effluent to end of month, 53,896 gallons.


FILTER TANK No 7.

Number of Bacteria found in a Cubic Centimeter of Effluent from Filter Tank No. 7.

Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.
1888.		**1888**—Con.		**1888**—Con.		**1889**—Con.	
Jan. 3,	27	March 24,	11,491	Aug. 21,	23	March 5,	0
5,	27	27,	9,372	Sept. 11,	753	12,	9
7,	156	29,	68,564	15,	41	19,	6
10,	1,567?	April 3,	22,491	20,	6	26,	7
12,	95	19,	363	25,	28	April 2,	6
14,	63	25,	105	29,	22	9,	12
17,	1,494	28,	116	Oct. 2,	98	16,	3
19,	25,670	May 8,	24	6,	7	30,	4
21,	42,384	10,	43	11,	4	May 7,	1
24,	5,100	19,	12	16,	12	14,	2
26,	1,435	22,	3	20,	6	21,	16
28,	2,145	26,	13	25,	3	28,	4
31,	3,459	29,	5	30,	7	June 4,	2
Feb. 2,	13	31,	5	Nov. 3,	8	11,	26
4,	8,187	June 5,	5	8,	10	18,	6
7,	12,624	9,	6	13,	14	26,	2
9,	24,411	14,	37	19,	0	July 2,	7
11,	1,048	21,	7	23,	1	9,	4
14,	21,960	26,	112	28,	8	16,	0
16,	659	29,	117	Dec. 5,	8	23,	2
18,	4,997	July 3,	39	10,	1	30,	8
21,	1,146	5,	1,071	14,	12	Aug. 6,	6
23,	5,727	7,	164	21,	1	12,	10
25,	867	10,	100	26,	34	19,	14
28,	6,379	13,	93	**1889.**		26,	12
March 1,	5,535	17,	8	Jan. 2,	3	Sept. 2,	5
3,	6,649	19,	10	8,	0	10,	736
6,	2,751	21,	14	15,	5	16,	63
8,	14,110	24,	10	22,	16	24,	4
10,	1,140	28,	9	29,	8	Oct. 2,	3,454
15,	3,693	Aug. 2,	83	Feb. 6,	6	10,	434
17,	1,804	7,	197	12,	2	16,	9
20,	1,428	11,	176	19,	3	25,	33
22,	2,196	16,	304	27,	3		

FILTER TANK No. 11.

This tank is one of the galvanized iron tanks, situated in the building, and has a horizontal area one hundredth of that of the large tanks which are in the field, or one twenty-thousandth of an acre.

Above the lower layer of sand and gravel common to all of the tanks, this tank is filled with 3.65 feet in depth of material like that of Tank No. 6, — making in all a depth of four feet of filtering material.

The whole tank contained 70 gallons of sand and gravel, in which were air spaces amounting to 25.4 gallons, or 37 per cent. of the whole volume. When saturated, it contained 25.4 gallons of water; and, after draining for two days, there still remained 7.6 gallons of water, with 17.8 gallons of air, or 11 per cent. and 26 per cent. respectively, of the whole volume of sand and gravel.

Effect of Sterilizing the Filtering Material.

The sand of this tank and its underdraining gravel were baked in a boiler heated to redness, in which the sand had been moved over the surface until it was supposed that every particle had come in contact with the red-hot iron.

The lower seven inches of gravel and sand were, after being heated, placed in the tank and then saturated with water at a temperature of 204° F. drawn from a boiler where it had been boiling.

This water was drawn out twice and replaced by boiled water. Then twelve gallons of boiled water at the temperature of 204° were added, and hot sand sprinkled into it at a temperature of 249°. Other water, amounting to 25 more gallons, was boiled and put in at the above temperature, and the hot sand added, causing the water to again boil in the tank. The tank was thus filled on February 4, and two days later all the water that would freely flow was drawn out of it, and the next day a sample that had collected in the bottom was found to contain 2,979 bacteria per cubic centimeter. On February 8 sewage was first applied, and the first water that was pushed through contained 62,400 bacteria. Later in the day more sewage was applied, amounting in all to 7.5 gallons, which must have replaced nearly all of the water held between the particles of sand. Three days later the number of bacteria in the effluent was 510,000. The number increased, and ten days after the first sewage was applied the number counted was 1,944,000, which was about five times the average number found in the sewage in the previous week.

Tank No. 6, filled with similar sand which was not baked and with water which was not boiled, allowed a maximum number of but five per cent. of the number of bacteria of the sewage applied the first week to come out with the effluent.

It is probable that the change due to heating the sand of No. 11 and to heating the water first applied was limited to the organic matter contained in the sand and water; and the resulting effect upon bacteria was through preparing this organic matter to be a better food for bacteria. This heating allowed one hundred times as many bacteria to live through the passage of No. 11 as came through No. 6 of like sand, and enabled the number applied in the first sewage to increase five-fold, while no sand that was not heated allowed more than 40 per cent. of the number applied to pass through. The effect of heating appeared to continue for more than three months, for there appears to be no other reason for the number of bacteria to continue through this long period nearly one hundred times as many as the number passing through No. 6.

This indicates that the food supply within the filter has a very important relation to the number of bacteria that can pass through.

General Results.

The chlorine of the effluent on the second day after sewage was applied indicated that the effluent was entirely from sewage. After this, for seven months, — February 9 to September 4, 1888, — the quantity of sewage applied daily (except on four short intervals) was 1.5 gallons; and the effluent averaged 1.47 gallons per day, — the equivalent of 29,400 gallons per acre per day.

The chemical analyses of the effluent and daily observations on this tank are given in tables at the end of this section. There may also be found a diagram of the daily results of analyses of the effluent, together with the sum of ammonias found in the sewage applied to this tank.

For immediate reference, the monthly averages of daily results of analyses of effluent and of the sewage from which it came, and the percentages of the latter, together with the daily quantity of effluent and the number of bacteria found in a cubic centimeter of the effluent, are given in the following table: —

Monthly Averages of Daily Results with Filter Tank No. 11.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	
1888.											
Feb. 8-22, . .	Sewage, .	–	21.84	12.85	1.2167	.4288	1.6455	3.06	.006	–	–
Feb. 8-29, . .	Effluent, .	1.86	5.18	10.74	.0119	.0326	.0445	3.05	.011	–	1,011,422
	Per cent.,	–	23	84	1	8	3	–	–	–	–
Feb. 23-Mar. 24,	Sewage, .	–	15.94	19.23	.5322	.3939	.9261	2.14	.007	.0027	–
March, . .	Effluent, .	1.48	2.02	9.46	.0375	.0127	.0502	2.05	.018	.0030	309,083
	Per cent.,	–	13	49	7	3	5	–	–	–	–
Mar. 25-Apr. 22,	Sewage, .	–	38.23	46.26	1.1370	.7230	1.8600	3.22	.007	–	–
April, . .	Effluent, .	1.48	3.11	13.00	.1547	.0151	.1698	3.07	.132	.0039	15,567
	Per cent.,	–	8	28	14	2.1	9	–	–	–	–
Apr. 23-May 24,	Sewage, .	–	42.09	47.27	1.1229	1.2980	2.4209	3.54	.008	.0024	–
May, . . .	Effluent, .	1.48	13.21	17.89	.3707	.0147	.3854	3.71	1.457	.0136	2,843
	Per cent.,	–	31	38	33	1.1	16	–	–	–	–
May 25-June 22,	Sewage, .	–	17.38	23.60	1.2819	.3643	1.6462	4.36	.007	.0006	–
June, . . .	Effluent, .	1.47	12.19	24.49	.0840	.0109	.0949	6.64	1.429	.0315	197
	Per cent.,	–	70	104	7	3	6	–	–	–	–
June 23-July 24,	Sewage, .	–	14.65	25.95	1.7304	.3632	2.0936	5.80	.009	.0002	–
July, . . .	Effluent, .	1.41	7.51	28.17	.0236	.0121	.0357	6.89	1.186	.0274	13,458
	Per cent.,	–	51	109	1	3	2	–	–	–	–
July 25-Aug. 27,	Sewage, .	–	50.74	51.25	2.7012	.9936	3.6948	6.53	.013	.0000	–
Aug. 1-Sept. 3, .	Effluent, .	1.48	4.12	32.77	.0129	.0105	.0234	7.13	1.483	.0040	3,757
	Per cent.,	–	8	64	.5 of 1	1.1	.6 of 1	–	–	–	–
Sept. 5, . .	Sewage, .	–	39.00	36.00	2.9600	1.1500	4.1100	7.00	–	.0000	–
Sept. 13-30, .	Effluent, .	.15	40.40	510.40	2.2080	.0832	2.2912	292.10	.034	.2684	3,279
	Sewage, .	–	–	–	–	–	–	–	–	–	–
October, . .	Effluent, .	.11	58.78	872.89	2.4944	.0867	2.5811	493.22	.044	.3861	535
	Sewage, .	–	–	–	–	–	–	–	–	–	–
November, .	Effluent, .	.09	62.75	1031.37	2.1375	.0612	2.1987	589.00	.562	.5875	67
	Sewage, .	–	–	–	–	–	–	–	–	–	–
December, .	Effluent, .	.10	81.00	1107.33	1.6300	.0647	1.6947	599.29	.739	1.1643	25
1889.											
January, . .	Effluent, .	.06	66.50	1080.67	1.4700	.0613	1.5313	589.50	.630	1.7750	112
February, . .	Effluent, .	.05	58.25	1029.00	1.4600	.0563	1.5163	563.00	.438	1.9250	5

When sewage first came through the tank, there was a slight nitrification which continued three or four days, the nitrates reaching 0.030 parts per 100,000; but, after this, nitrification ceased, and the nitrates of the effluent were no higher than those of the sewage, until March 5. During the remainder of March they were from 0.010 to 0.030 parts, averaging for the month 0.018 parts. There was an interval between March 31 and April 4, and another between April 7 and 10, when no sewage was applied.

On April 12 the nitrates had increased to 0.070 parts, and then continued increasing through the month to 0.260 parts, averaging for the month 0.132 parts. They then increased more rapidly, and on May 11 amounted to 2.000 parts, and averaged for the month of May 1.457 parts. In June the nitrates varied from 1.800 parts to 1.100 parts, averaging 1.429 parts. They continued high through July and August, averaging for July 1.186 parts, and for August 1.483 parts.

The percentages which the nitrogen of the nitrates, in the last four months, were of the total nitrogen of the sewage, are given in the following table: —

Percentage of the Total Nitrogen applied in the Sewage that appears in the Effluent of Tank No. 11 as Nitrates.

Date.	Total Nitrogen in Sewage.	Nitrates in Effluent corrected for Quantity.	Per Cent.	Quantity of Effluent. Gallons.	Temperature.	
					Sewage.	Effluent.
1888.						
May,	3.0599	1.440	47	1.48	48°	–
June,	1.6562	1.378	83	1.47	63°	66°
July,	2.0238	1.081	53	1.41	69°	69°
August 1 to September 3,	3.8575	1.460	39	1.48	71°	70°

The completeness of nitrification was almost identical with Tank No. 6 through May, June and July, but was decidedly greater in this tank in August.

In the First Months, Purification was Indicated by Decrease in Albuminoid Ammonia and Increase in Free Ammonia.

The free ammonia of the effluent, after the first ten days, increased continually until nearly a month after the nitrates became the highest, in May, and averaged in February 0.0119 parts; in March, 0.0375 parts, or seven per cent. of that of the sewage; in April, 0.1547 parts, or 14 per cent. of that of the sewage; and in May, 0.3707 parts, or 33 per cent. of that of the sewage.

The albuminoid ammonia, on the contrary, was highest when the sewage first came through the filter, amounting to 0.0556 parts, and decreased in percentage of that of the sewage in each month until the nitrates were at their height. It averaged, in February, 0.0326 parts, or eight per cent. of that of the sewage; in March, 0.0127 parts, or three per cent. of that of the sewage; in April, 0.0151 parts, or two per cent. of that of the sewage; and in May, 0.0147 parts, or one per cent. of that of the sewage.

More Complete Purification by Nitrification.

The purifying effects of the nitrification became evident, on the first of June, by the marked decrease of the amount of free ammonia, which, in May, averaged 0.3707 parts, and in June averaged only 0.0840 parts, or seven per cent. of that of the sewage.

The free ammonia continued decreasing through July and August, averaging, in July, 0.0236 parts, or one per cent. of that of the sewage; and in August, 0.0129 parts, or 0.5 of one per cent. of that of the sewage.

The albuminoid ammonia changed much less, and averaged in June, 0.0109 parts, or three per cent. of that of the sewage; in July, 0.0121 parts, or three per cent. of that of the sewage; in August, 0.0105 parts, or one and one-tenth per cent. of that of the sewage.

The sum of ammonias decreased in these three months from 0.0949 parts in June to 0.0234 parts in August, when they were six-tenths of one per cent. of the sum of ammonias of the sewage.

Nitrogen, as nitrites in the effluent of this tank, has been higher than in Tank No. 6. The average in March was 0.0030 parts; in April, 0.0039 parts; in May, 0.0136 parts; in June, 0.0315 parts; in July, 0.0274 parts; in August, 0.0400 parts. It was probably higher in the last two months than it would have been if there had not been a glass trap put upon the outlet June 20 and continued through July and August. The analyses of the effluent in August show more complete nitrification and a little better purification from organic matter than those of Tank No. 6, which was, however, filtering a larger quantity. Neither of these tanks had at this time reached the best result that could be expected of them. Tank No. 6 continued to improve rapidly in the following months; and the effluent of Tank No. 11 at this time compared favorably with the water flowing in the Merrimack River.

The Character of this Filter changed by covering the Surface with Peat.

In making investigations of the value of the Saugus Marshes for filtering the sewage of the Mystic River Valley, it became important to determine the effect of a layer of vegetable muck or peat upon a body of sand known to be a good filter. For this purpose Tank No. 11 was selected; and a section of peat, one foot in depth and just the diameter of this tank, was brought from the Saugus Marshes and thoroughly pulverized, like garden soil; and after saturating the sand with sewage on Sept. 5, 1888, this peat was on the next day placed on the top of the sand and saturated with 11 gallons of sewage. The top of the mass then stood 17.7 inches above the top of the sand, but in a few days it settled and became 14.5 inches deep.

The peat when pulverized, though it had appeared quite dry in the mass, was found to contain 59 per cent., by weight, of water; and when saturated and settled for twenty-four hours, it is estimated that 83 per cent. of the volume was water; at this rate the tank then contained, within the 14.5 inches in depth of peat, 16 gallons of water; and the four feet in depth of sand beneath it contained 13 gallons; so that one gallon of sewage applied to the surface daily, if it had to push before it all of the liquid contained in the material, would, if it went through, reach the bottom in twenty-nine days.

The Quantity of Sewage that will pass through the Peat too Small to render Filtration Practicable.

It was, however, soon found that a gallon of sewage would not go through the peat in a day. On September 10, a gallon was applied, and, with the outlet continually open, it did not disappear from the surface for a week. After this only 0.24 of a gallon was applied daily; and from September 13 to 30, only 0.15 of a gallon came through daily, the remainder evaporating.

In October, the same quantity was applied daily; but only 0.11 of a gallon came through. A part of the remainder evaporated, and a part accumulated on the surface, where it became, at the end of the month, 2.5 inches deep. The same quantity was applied until November 26; but as the amount accumulated on the surface came to be five inches deep, and nearly filled the tank, none was applied in the last four days of November. The average daily quantity that came through in the month was 0.09 of a gallon, — and this with a pressure of from three to five inches of sewage upon the surface. The quantity passing through was at the rate of only 1,800 gallons per acre per day, which is equal to less than one-half of the ordinary rainfall; thus showing that a body of sand covered with peat to the depth of a foot would be entirely useless for a filtering area.

During the month of December, 0.24 of a gallon of sewage was applied at intervals of from three to five days, sufficient to keep the sewage standing upon the surface to the depth of about five inches. The average quantity flowing through was 0.10 of a gallon daily.

In January and February the depth of sewage upon the surface remained about the same; but the quantity passing through decreased, averaging in January 0.06 of a gallon, and in February 0.05 of a gallon, daily, or the equivalent of only 1,000 gallons a day per acre. Up to the end of February only about 16 gallons of effluent had come through this tank in the six months since the layer of peat was put upon the sand.

Of the 11 gallons that were put into the peat on September 6, one gallon was drawn off the top and as many as three gallons were drawn down into the sand. At the same time 15.5 gallons had been drawn from the tank, leaving as much as 12 gallons of air within the sand, with probably six gallons of sewage that had been put into the sand before the peat was put on, and three or four gallons that had come down out of the peat.

Passage of Sewage through the Peat indicated by the Chlorine of the Effluent.

That some part of the liquid that had been in the peat came through the sand, without pushing out all of the water beneath, is shown by the chlorine of the effluent rising in three days from that of the sewage, which was 7.00 parts per 100,000, to 169.50 parts on September 13, when but one gallon had passed out after the three or four gallons above mentioned had left the sand. This rise in chlorine was due to the salt contained in the peat, which had been taken from a marsh frequently overflowed by the sea. Four days later the chlorine of the effluent was 258.5 parts, and at the end of the month 408 parts, averaging in September 292 parts per 100,000. It continued increasing through the next two months to 600 parts, averaging in October 493.22 parts, and in November 589.00 parts. It remained nearly constant through December and

January, and was a little lower in February. It averaged 599.29 parts in December, 589.51 parts in January, and 563.00 parts in February. From these amounts of chlorine we must conclude that a considerable part of the 16 gallons of effluent has filtered down through the peat as well as through the sand.

Little Purification except from Air entering Outlet Pipe.

When the first effluent was examined on Sept. 13, 1888, the nitrates were 0.0070 parts; they soon increased and continued at about 0.0300 parts until October 21; after which they increased rapidly to 0.1000 parts on October 29, averaging for the month of October 0.0440 parts; they continued increasing through November to 0.8500 parts, averaging for the month 0.5620 parts. On November 24, a glass trap was put upon the outlet intended to prevent the entrance of air; but on December 13 it was noticed that the effluent stopped running, and air was drawn into the tank through the trap, — hence the exclusion of air was not complete. On February 8 a trap 18 inches deep, with its outlet at the level of the bottom of the tank, replaced the former trap for the more complete exclusion of the air. The nitrates continued increasing until December 6, when they reached 1.0500 parts and afterwards decreased to 0.5000 parts, at the end of the month averaging 0.7390 parts. In January the nitrates averaged 0.6300 parts, and in February 0.4380 parts.

The nitrites were remarkably high in the effluent from this tank, particularly after the trap was put upon the outlet. They increased almost continually from the beginning of these experiments with peat upon the surface. On September 13 they amounted to .1000 parts, rising to .4000 parts at the end of the month, and averaging .2684 parts; in October they averaged .3861 parts; in November, .5875 parts; in December, 1.1643 parts; in January, 1.7750 parts; and in February, 1.9250 parts. In the last month the nitrites were the highest that have been found in the effluent from any of the tanks, and amounted to 45 per cent. of the total nitrogen of the sewage. At this time the nitrogen of the nitrites and nitrates amounted to 55 per cent. of the nitrogen of the sewage; and the nitrogen of the ammonias of the effluent amounted to 36 per cent. of the nitrogen of the sewage when applied.

The oxygen, that enabled the nitrates and nitrites to form, undoubtedly came through the outlet pipe; and, as the sand beneath the peat probably contained twice as much air as liquid, and the liquid was not changed more than two or three times in six months, this supply of oxygen appears adequate.

The free ammonia of the effluent was about eight-tenths of that of the sewage in September and October, averaging in the latter month 2.4944 parts. In November it decreased from 2.6000 parts to 1.6900 parts, and averaged 2.1375 parts. In December it was nearly constant, averaging 1.6300 parts. In January it averaged 1.4700 parts, and in February 1.4600 parts.

The albuminoid ammonia increased from 0.0500 parts on September 13 to 0.1300 parts at the end of the month, and averaged 0.0832 parts. In October, it averaged 0.0867 parts; in November, it decreased from 0.1100 parts to 0.0200 parts at the time the trap was put upon the outlet; after which it increased, and averaged for the month 0.0612 parts.

The sum of the ammonias decreased from 2 5811 parts in October to 1.5163 parts in February, when they were, after a passage of some months from the surface, 37 per cent. of the sum of the ammonias of the applied sewage.

In addition to the fact that the quantity of sewage that could filter through the peat was so small as to render it useless for a filter, the effluent after a trial of six months was unsatisfactory. Up to Jan. 1, 1889, the odor of the effluent was quite strong, but in the last two months it was scarcely noticeable.

Peat removed from the Surface, and a Solution of Peptone fully Nitrified.

On March 2, 1889, the one foot in depth of peat, which for six months had been upon the sand of Tank No. 11, was removed, and on March 4 city water was allowed to run through the sand for six hours, to wash out the salt which had come from the peat. The chlorine was thus reduced from 540 parts to about 10 parts per 100,000.

On March 9, instead of sewage, a solution of peptone was applied to this filter, consisting of three gallons of city water, in which was dissolved so much peptone that the solution had 1 part per 100,000 of albuminoid ammonia, or 1.5 parts of nitrogen, as determined by the Kjeldahl process. This peptone is an albuminoid compound which is soluble in water, and decomposes readily and completely. It contains hydrogen and nitrogen so combined with other constituents that they can be very readily separated as ammonia, with probably less liability to loss than the compounds in sewage which are expressed in analyses as albuminoid ammonia.

The object of experiments with this solution was to determine the relation of the nitrogen applied in a single nitrogenous substance of this character, of known composition, to the nitrogen of the effluent, expecting a more accurate comparison than could be made with the unknown and variable nitrogenous matter of sewage.

When the peptone was first dissolved in the water, the ammonia was nearly all in the form of albuminoid ammonia, but this so readily changed to free ammonia, that, in making an analysis immediately after dissolving the peptone, the free ammonia amounted to about 0.1700 parts; and at any subsequent time this amount of free ammonia would be found to be very much increased. This solution was made of the strength above given, and promptly applied to the sand, three gallons at a time daily, from March 9 until July 2, 1889. After July 2, there were applied solutions of chloride of ammonium with and without common salt. The details of these experiments, which were continued through the year, are given in the report of Professor Drown and Mr. Hazen, appended.

The general results of the application of peptone are as follows: The nitrates increased from 0.2500 parts to 1.0000 parts at the end of March. The free ammonia contained in the tank was reduced in the same time to 0.0028 parts, and the albuminoid ammonia to 0.0166 parts. The results obtained during the three following months are given in the table below.

	Free Ammonia.	Albuminoid Ammonia.	Nitrogen as		Total Nitrogen.
			Nitrates.	Nitrites.	
April,	0.0015	0.0157	1.1700	0.0011	1.20
May,	0.0020	0.0146	1.2800	0.0005	1.30
June,	0.0019	0.0126	1.5000	0.0003	1.52

The total nitrogen found in the effluent in April was 80 per cent. of that applied; in May, 87 per cent.; and in June it was equal to the amount applied, averaging for the three months 89 per cent. of the amount applied. A very much smaller per cent., if any, was lost than when sewage was applied.

The sum of ammonias was, in the three months, 1.6 per cent. of the sum of ammonias applied.

We find that this filter of sand four feet in depth, which in September, 1888, was removing more than 99 per cent. of the organic matter of the sewage applied to it, but which, when covered with a depth of one foot of peat, was able to remove but about 60 per cent. of the organic matter of the sewage, upon having the peat removed, again filters nitrogenous organic matter so effectually as to remove more than 98 per cent. of the nitrogenous matter as shown by the ammonias, and to transform it to mineral matter which appears in the effluent as nitrates.

A general view of the changes in the effluent from this filter to this time may be obtained from the diagram accompanying the tables of observations.

Experiments upon filtering a Solution of Ammonium Chloride with and without Salt.

Subsequent experiments from July 2 to Aug. 8, 1889, when there were applied daily three gallons of a solution of ammonium chloride (with its equivalent of soda) containing two parts of nitrogen per 100,000, showed that very nearly all of the ammonia was converted to nitrates, and that the latter were increased for several weeks by the removal of nitrogen which had previously been stored in the tank.

Applied in this form there appears to be very little if any loss of nitrogen into the air, or otherwise, in the nitrifying process.

The mean analysis of the effluent in the latter part of July and first of August was as follows: —

Free ammonia,	0.0018
Albuminoid ammonia,	0.0106
Chlorine,	5.42
Nitrates,	1.9500

After August 8, the same solution, with the addition of common salt, was applied daily until August 26, when the following analysis was obtained: —

Free ammonia,	1.9600
Albuminoid ammonia,	0.1400
Chlorine,	1291.0
Nitrates,	0.0000

This solution was about two-thirds as salt as sea-water, and its effect was to stop nitrification and allow the ammonia to come through the filter unchanged.

From August 27 to September 8, three gallons of the solution of ammonium chloride were applied daily without salt. In six days the nitrification was more than complete, — that is, it was removing stored nitrogen when the chlorine was 44.10 parts, and at the end of twelve days, when the chlorine was reduced to 7.46 parts, the following analysis was obtained: —

Free ammonia,	0.0080
Albuminoid ammonia,	0.0114
Chlorine,	7.46
Nitrates,	2.8000

Upon again adding salt so that the solution was about one-fourteenth as strong as sea-water, the nitrates decreased in ten days to 0.1500 parts; but upon continuing the same solution eight days longer the nitrates increased to 1.3400 parts. The chlorine was then 127.1 parts.

Upon increasing the quantity of salt daily for three weeks, until the chlorine amounted to 367.0 parts, the nitrates decreased to 0.2000 parts; but upon continuing to increase the quantity of salt the nitrates again increased; and when, on December 14, the chlorine had been gradually increased to 1306.0 parts, the nitrates formed 1.0000 parts. The analysis, in parts per 100,000, was as follows: —

Free ammonia,	.2500
Albuminoid ammonia,	.0220
Chlorine,	1306.0
Nitrates,	1.0000

Here we find that by gradually increasing the amount of salt in the solution to a little more than was applied in August at once, without time for a gradual adaptation of the filter to the work required of it, we find a very different result. In August the same quantity of salt caused nitrification to cease, and allowed the ammonia to come through the filter nearly unchanged. By the gradual application of the salt in increasing quantities, we now find that, when the same quantity is applied, the ammonias are reduced to about 12 per cent. of those which came through in August; and the nitrates, which were then zero, are now equal to one part per 100,000. From this we see that by properly preparing the filter, a solution of ammonia may be quite satisfactorily purified by nitrification, even when it is as salt as ordinary sea-water. Upon rapidly increasing the amount of salt, from Dec. 14 to Jan. 8, 1890, to about four times that which it contained on December 14, so that it was nearly three times as salt as ordinary sea-water, the nitrates were very much reduced. Obtained in the usual way they amounted to .0600 parts; but it is to be noted that the method of determining nitrates, when the solution contains these very large amounts of salt, gives results which are too low. From these results we may conclude that quite satisfactory nitrification may result when applying to a filtration area sewage containing a very large amount of salt, if only it be applied with reasonable regularity.

Bacteria in the Effluent of Tank No. 11.

A table of the number of bacteria found in a cubic centimeter of the effluent from this tank, during the two years, is given at the end of this section, following the tables of chemical analyses.

The enormous number of bacteria found in the effluent in the first two weeks after this tank was filled with baked sand and boiled water, attaining to five times the number applied in the sewage, as described on page 490, shows that there can be no serious mechanical impediment to the passage of bacteria through sand of this character; and we see no reason why the number should increase greatly while passing through this sand and decrease to only one per cent. as many when passing through identical sand in Tank No. 6, unless it be that baking the sand and boiling the first water that was applied prepared the organic matter of the sand and water to be particularly good food for the bacteria.

After February 18, when the number in the effluent amounted to 1,944,000, they decreased to 960,000 at the end of the month, and averaged, from February 9 to 28, 1,011,422 per cubic centimeter. The number continued to decrease till March 10, when it was 70,981; but it afterward increased to 891,600 on March 22, and a week later was 172,850. The average number for March was 309,083. In the middle of April the number was 26,610, but with the increase in nitrification in the latter part of the month it decreased to 4,524.

In May, with still higher nitrification, the number decreased from 6,000 in the first part of the month to 45 in the latter part, averaging for the month 2,843 per cubic centimeter.

During the three months of March, April and May, the number of bacteria that lived to pass through this sand averaged more than 100 times the number that passed through similar sand in Tank No. 6. The only known difference in character of the material is whatever may be due to heating the sand of No. 11 and the water first applied, in the early part of February.

In June the number of bacteria was low throughout the month, averaging 197 per cubic centimeter. In this month the nitrates of the effluent averaged 1.429 parts per 100,000, and contained 83 per cent. as much nitrogen as was applied in the sewage.

In July the number increased, in the latter part of the month, when the temperature of the effluent was 71° F., to 32,340, and averaged for the month 13,458 per cubic centimeter. The nitrates contained 53 per cent. of the nitrogen applied.

In August, with very constant condition of chemical constituents and with temperature of the effluent varying from 69° to 73° F., the number of bacteria varied from 10,148 in the early part of the month to 95 in the latter part, and averaged 3,757 per cubic centimeter, and the nitrates were 39 per cent. of the nitrogen of the sewage.

After nitrification became active the number of bacteria was very much less than before. The number was most reduced in June, when there was the most complete nitrification, and the nitrogen of the nitrates was equal to 83 per cent. of the total nitrogen of the sewage. Then the number in the effluent was 1 in 7,000 of the number applied in the sewage; but in the four months of nitrification the average number amounted to about one-third of one per cent. of the number in the sewage.

After the peat covered the sand, the number of bacteria in the effluent was less. In October, when the number of bacteria found in the sewage on top of the peat averaged 381,400 per cubic centimeter, the number found in the effluent was 535. In the following months the number was still smaller, being in November 67, in December 25, in January, 1889, 112, and in February 5.

In these latter months, the time required for any particle to pass from the surface to the bottom of the tank was many weeks.

When filtering Various Solutions, the Number of Bacteria decreased with Increase of Nitrates.

After the peat was removed from the surface of the sand and peptone was applied, the number of bacteria at first increased, being on March 12, 18,819; but as nitrification became more complete, the number decreased, and in the latter part of the month was but 18. Early in April, 1889, the number was 2,916, but decreased in the last of the month to 51, and averaged 928. During this month the nitrates were 78 per cent. of the total nitrogen applied.

In May, when the nitrates of the effluent contained 85 per cent. of the total nitrogen applied, the average number of bacteria was 10; and in June, when the nitrification was complete, the number of bacteria in the effluent averaged but 2. The number applied in the solution of peptone in the last four months was not determined.

The strong solution of ammonium chloride that was used upon this tank after July 2, 1889, was formed by boiling, and was undoubtedly sterile; and when put into the three gallons of city water it is most probable that the solution when applied to the filter contained no more bacteria than were in the city water at that time. The average number for the month of July was 87; and this is about the average number in the city water through the following six months. While the ammonium chloride was being applied alone and the nitrification was nearly complete through July and the first of August, the average number of bacteria found in the effluent was 4 per cubic centimeter.

A solution of salt as applied to this tank in three gallons of city water in the early part of November was found to contain about 1,500 bacteria per cubic centimeter.

After the addition of salt in large quantities, so that nitrification ceased and the ammonias of the effluent were equal to those applied, the number of bacteria increased to 2,208. Upon continuing the ammonium chloride without salt, — the nitrification becoming again complete and the ammonias very low, — the number of bacteria in the effluent was reduced to 11. Although salt was again applied in increasing quantities, the number counted did not reach 100 as long as nitrification continued active, and the ammonias were low; but when, on November 5, the nitrates contained but one-tenth of the total nitrogen applied, the bacteria increased to 1,679.

In the first three weeks of December, while the nitrates were increasing to 60 per cent. of the applied nitrogen, although the nitrogen of the ammonias increased to 40 per cent., the number of bacteria averaged only 47; but in the last week of the month, when the nitrogen of the nitrates decreased to 32 per cent. of the applied nitrogen, and the ammonias contained 48 per cent., the number of bacteria increased to 6,480, and continued high while the ammonias of the effluent were high, and the nitrates low.

We find here, with the application of ammonium chloride with and without salt, a decrease and near extinction of the bacteria when nitrification is very complete, as was found under like conditions when sewage was applied to the filter.

The solutions containing salt were examined only on one occasion, when about 1,500 per cubic centimeter were counted. Whether the number increased directly in proportion to the amount of salt was not determined. The appearance is that when salt was in the solution enough bacteria were added to account for the large number in the effluent, which varied, as when sewage was applied, inversely with the greater or less degree of nitrification.

TABLES

OF

CHEMICAL ANALYSES AND DAILY OBSERVATIONS

Upon Filter Tank No. 11.

February, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Sewage remained on Surface.	Temperature. Sewage.	Temperature. Effluent.
8, .	–	–	–	–	.0168	.0400	.0568	1.18	.0100	Present.	–	–	–
8, .	7.5	2.1	6.80	10.20	.0132	.0556	.0688	1.20	.0200	Present.	–	38°	–
9, .	1.5	7.2	9.70	10.90	.0180	.0500	.0680	3.20	.0250	Present.	–	44°	39°
10, .	1.5	2.1	6.60	13.10	.0170	.0530	.0700	4.50	.0300	Present.	1 m. 20 s.	44°	–
11, .	1.5	1.7	–	–	–	–	–	–	–	–	–	44°	–
12, .	1.5	2.3	8.60	12.40	.0030	.0410	.0440	4.22	.0090	Present.	1 m. 20 s.	44°	–
13, .	1.5	1.4	7.00	11.90	.0020	.0330	.0350	3.90	.0050	Present.	–	44°	–
14, .	1.5	1.4	4.60	11.60	.0010	.0370	.0380	3.36	.0050	Present.	1 m. 45 s.	44°	–
15, .	1.5	1.3	5.20	11.30	.0008	.0328	.0336	3.14	.0080	Present.	1 m. 55 s.	44°	–
16, .	1.5	1.1	4.00	10.40	.0006	.0376	.0382	2.80	.0080	Present.	1 m. 55 s.	44°	38°
17, .	1.5	1.8	–	–	–	–	–	–	–	–	–	44°	38°
18, .	1.5	2.3	–	–	–	–	–	–	–	–	–	43°	–
19, .	1.5	1.1	3.70	10.20	.0142	.0210	.0352	3.16	.0080	Present	–	43°	–
20, .	1.5	1.7	–	–	–	–	–	–	–	–	–	44°	–
21, .	1.5	1.1	2.60	9.60	.0178	.0174	.0352	2.52	.0050	Present.	–	44°	–
22, .	1.5	1.1	–	–	–	–	–	–	–	–	–	44°	44°
23, .	1.5	2.3	2.90	9.70	.0182	.0170	.0352	2.71	.0080	Present.	–	44°	44°
24, .	1.5	1.0	–	–	–	–	–	–	–	–	–	44°	41°
25, .	1.5	1.1	–	–	–	–	–	–	–	–	–	42°	41°
26, .	1.5	2.4	–	–	–	–	–	–	–	–	–	44°	–
27, .	1.5	1.5	2.30	9.60	.0240	.0136	.0376	2.54	.0070	Present	–	44°	40°
28, .	1.5	1.5	–	–	–	–	–	–	–	–	–	44°	37°
29, .	1.5	1.5	3.30	8.70	.0244	.0152	.0396	2.36	.0020	Present.	–	44°	–

February 8. — First sewage applied.
Total effluent to end of month, 41.0 gallons.

Filter Tank No. 11 — Continued.

March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1,	1.5	1.0	-	-	-	-	-	-	-	-	-	44°	38°
2,	1.5	1.1	2.10	8.50	.0302	.0130	.0432	1.90	.0080	Present.	-	44°	-
3,	1.5	2.4	-	-	-	-	-	-	-	-	-	44°	-
4,	1.5	1.4	-	-	-	-	-	-	-	-	-	44°	36°
5,	1.5	1.5	2.10	8.90	.0280	.0116	.0396	2.18	.0180	.0020	-	44°	-
6,	1.5	1.0	2.50	8.80	.0274	.0104	.0378	2.28	.0100	.0039	-	43°	36°
7,	1.5	1.1	-	-	-	-	-	-	-	-	-	42°	41°
8,	1.5	2.3	3.10	9.80	.0332	.0160	.0492	2.40	.0120	.0036	-	44°	40°
9,	1.5	1.5	-	-	-	-	-	-	-	-	-	42°	38°
10,	1.5	1.5	-	-	-	-	-	-	-	-	-	44°	40°
11,	1.5	1.4	1.90	10.00	.0360	.0166	.0526	2.02	.0100	.0026	-	44°	41°
12,	1.5	1.5	-	-	-	-	-	-	-	-	-	44°	41°
13,	1.5	1.4	-	-	-	-	-	-	-	-	-	44°	-
14,	1.5	1.5	2.30	9.40	.0352	.0122	.0474	1.98	.0300	.0053	-	44°	-
15,	1.5	1.6	2.20	9.50	.0320	.0094	.0414	2.00	.0250	.0063	-	44°	40°
16,	1.5	1.4	-	-	-	-	-	-	-	-	-	43°	-
17,	1.5	0.8	-	-	-	-	-	-	-	-	-	43°	40°
18,	1.5	2.2	2.10	9.50	.0344	.0106	.0450	2.12	.0100	.0019	-	44°	43°
19,	1.5	1.5	-	-	-	-	-	-	-	-	-	43°	43°
20,	1.5	1.5	1.60	9.40	.0400	.0096	.0496	2.00	.0220	.0022	-	44°	-
21,	1.5	0.8	-	-	-	-	-	-	-	-	-	44°	42°
22,	1.5	2.2	1.80	9.50	.0456	.0136	.0592	2.20	.0200	.0033	-	40°	-
23,	1.5	1.4	-	-	-	-	-	-	-	-	-	44°	-
24,	-	0.7	-	-	-	-	-	-	-	-	-	-	42°
25,	1.5	1.2	1.20	9.50	.0400	.0136	.0536	1.70	.0180	.0021	2 m. 50 s.	44°	41°
26,	1.5	2.5	-	-	-	-	-	-	-	-	2 m. 30 s.	44°	41°
27,	1.5	1.5	1.60	9.50	.0448	.0126	.0574	1.66	.0200	.0014	2 m. 50 s.	44°	40°
28,	1.5	0.8	-	-	-	-	-	-	-	-	-	44°	-
29,	1.5	2.2	1.80	10.70	.0608	.0152	.0760	2.20	.0250	.0020	-	43°	45°
30,	1.5	1.5	-	-	-	-	-	-	-	-	3 m. 10 s.	44°	47°
31,	1.5	.1	-	-	-	-	-	-	-	-	-	44°	-

Effluent colorless, generally clear and free from sediment, or very nearly so.
March 31. — Outlet closed at 11.35 A. M. River high.
Total effluent to end of month, 85.5 gallons.

Filter Tank No. 11 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Sewage remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	-	-	-	-	-	-	-	-	-	-	-	-
2, .	-	-	-	-	-	-	-	-	-	-	-	-	-
3, .	-	-	-	-	-	-	-	-	-	-	-	-	-
4, .	-	-	-	-	-	-	-	-	-	-	-	-	-
5, .	1.5	2.6	2.00	12.20	.0542	.0180	.0722	2.50	.0200	.0025	2 m. 25 s.	43°	39°
6, .	1.5	1.0	-	-	-	-	-	-	-	-	2 m. 30 s.	46°	-
7, .	-	-	-	-	-	-	-	-	-	-	-	-	-
8, .	-	-	-	-	-	-	-	-	-	-	-	-	-
9, .	-	-	-	-	-	-	-	-	-	-	-	-	-
10, .	-	-	-	-	-	-	-	-	-	-	-	-	-
11, .	1.5	1.9	-	-	-	-	-	-	-	-	2 m. 50 s.	44°	39°
12, .	1.5	1.7	1.80	11.50	.0632	.0134	.0766	2.26	.0700	.0030	2 m. 45 s.	40°	-
12, .	-	-	2.30	10.10	.0720	.0150	.0870	3.47	.0700	.0014	-	-	-
13, .	1.5	1.5	-	-	-	-	-	-	-	-	2 m. 40 s.	-	-
14, .	1.5	1.5	-	-	-	-	-	-	-	-	-	45°	-
15, .	1.5	1.5	2.90	10.50	.1220	.0164	.1384	2.64	.1500	.0021	-	45°	-
16, .	1.5	1.5	-	-	-	-	-	-	-	-	1 m. 50 s.	-	43°
17, .	1.5	1.5	2.50	11.80	.1320	.0130	.1450	3.06	.0450	.0030	-	42°	-
18, .	1.5	1.5	-	-	-	-	-	-	-	-	2 m. 20 s.	45°	43°
19, .	1.5	1.5	2.80	12.70	.1520	.0250	.1770	3.08	.2000	.0033	2 m. 20 s.	42°	-
20, .	1.5	1.5	-	-	-	-	-	-	-	-	-	43°	43°
21, .	3.0	2.7	3.80	14.30	.1800	.0100	.1900	3.04	.1300	.0033	-	43°	-
22, .	-	0.6	-	-	-	-	-	-	-	-	-	-	-
23, .	1.5	1.2	-	-	-	-	-	-	-	-	-	43°	-
24, .	1.5	1.4	3.80	16.30	.1880	.0080	.1960	3.74	.2000	.0040	-	42°	-
25, .	1.5	1.5	-	-	-	-	-	-	-	-	-	42°	-
26, .	1.5	1.5	5.20	15.60	.2840	.0120	.2960	3.63	.1800	.0080	-	46°	-
27, .	1.5	1.5	-	-	-	-	-	-	-	-	-	44°	-
28, .	3.0	2.7	4.00	15.00	.3000	.0200	.3200	3.28	.2600	.0080	-	46°	-
29, .	-	0.34	-	-	-	-	-	-	-	-	-	-	-
30, .	-	-	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, clear or nearly so, and generally with very little sediment.

April 5. — Outlet opened at 7.08 A.M. April 6. — 5.04 P.M. to April 11, 7.31 A.M., outlet closed. River high. April 21. — First 1.5 gallons applied disappeared in 2 minutes, 5 seconds. April 29. — Outlet closed at 6.36 P.M. River high.

Total effluent to end of month, 118.14.

Filter Tank No. 11 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	-	-	-	-	-	-	-	-	-	-	-	-
2, ...	-	-	-	-	-	-	-	-	-	-	-	-
3, ...	-	-	-	-	-	-	-	-	-	-	-	-
4, ...	1.5	1.1	-	-	-	-	-	-	-	-	45°	-
5, ...	3.0	3.0	10.40	15.10	.2500	.0170	.2670	3.45	.8000	.0200	45°	-
6, ...	-	0.5	-	-	-	-	-	-	-	-	-	-
7, ...	1.5	1.2	-	-	-	-	-	-	-	-	50°	-
8, ...	1.5	1.5	14.50	20.40	.3500	.0160	.3660	3.78	1.6000	.0180	48°	-
9, ...	1.5	1.5	-	-	-	-	-	-	-	-	50°	-
10, ...	1.5	1.5	-	-	-	-	-	-	-	-	51°	-
11, ...	1.5	1.5	16.60	17.50	.4250	.0150	.4400	3.27	2.0000	.0166	51°	-
12, ...	3.0	2.26	-	-	-	-	-	-	-	-	49°	-
13, ...	-	-	-	-	-	-	-	-	-	-	-	-
14, ...	-	-	-	-	-	-	-	-	-	-	-	-
15, ...	-	-	-	-	-	-	-	-	-	-	-	-
16, ...	-	-	-	-	-	-	-	-	-	-	-	-
17, ...	1.5	2.2	-	-	-	-	-	-	-	-	49°	-
18, ...	1.5	1.6	13.00	16.70	.4000	.0140	.4140	3.18	1.5000	.0133	49°	-
19, ...	3.0	2.8	-	-	-	-	-	-	-	-	50°	-
20, ...	-	0.5	-	-	-	-	-	-	-	-	-	-
21, ...	1.5	1.1	-	-	-	-	-	-	-	-	51°	-
22, ...	1.5	1.5	13.00	16.80	.4000	.0170	.4170	3.71	1.8000	.0072	52°	-
23, ...	1.5	1.4	-	-	-	-	-	-	-	-	53°	-
24, ...	1.5	1.5	-	-	-	-	-	-	-	-	55°	-
25, ...	1.5	1.4	14.70	18.40	.4200	.0120	.4320	3.89	1.3000	.0097	56°	-
26, ...	3.0	2.8	-	-	-	-	-	-	-	-	57°	-
27, ...	-	0.5	-	-	-	-	-	-	-	-	-	-
28, ...	1.5	1.1	-	-	-	-	-	-	-	-	57°	-
29, ...	1.5	1.6	-	-	-	-	-	-	-	-	56°	-
30, ...	1.5	1.5	-	-	-	-	-	-	-	-	57°	-
31, ...	1.5	1.5	10.30	20.30	.3500	.0120	.3620	4.72	1.2000	.0105	57°	-

Effluent colorless and generally clear, and with very little sediment.

May 4. — Outlet opened at 9.23 A.M. May 12. — 8.42 P.M. to May 17, 8.07 A.M., outlet closed. River high.

Total effluent to end of month, 155.20 gallons.

Filter Tank No. 11—Continued.

June, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	1.5	1.5	-	-	-	-	-	-	-	-	58°	-
2, ...	3.0	2.7	-	-	-	-	-	-	-	-	60°	-
3, ...	-	0.5	-	-	-	-	-	-	-	-	-	-
4, ...	1.5	1.1	-	-	-	-	-	-	-	-	59°	-
5, ...	1.5	1.5	12.50	20.20	.0800	.0170	.0970	4.64	1.8000	.0080	61°	-
6, ...	1.5	1.4	-	-	-	-	-	-	-	-	61°	-
7, ...	1.5	1.4	9.60	21.90	.1680	.0120	.1800	4.19	1.2000	.0500	64°	66°
8, ...	1.5	1.4	-	-	-	-	-	-	-	-	64°	65°
9, ...	3.0	2.8	-	-	-	-	-	-	-	-	66°	65°
10, ...	-	0.5	-	-	-	-	-	-	-	-	-	-
11, ...	1.5	1.1	12.70	19.90	.1200	.0130	.1330	4.89	1.7000	.0650	65°	66°
12, ...	1.5	1.4	-	-	-	-	-	-	-	-	65°	65°
13, ...	1.5	1.4	-	-	-	-	-	-	-	-	64°	65°
14, ...	1.5	1.4	14.30	21.40	.0920	.0040	.0960	6.05	1.8000	.0250	65°	61°
15, ...	1.5	1.5	-	-	-	-	-	-	-	-	65°	62°
16, ...	3.0	2.9	-	-	-	-	-	-	-	-	66°	-
17, ...	-	0.5	-	-	-	-	-	-	-	-	-	-
18, ...	1.5	1.1	10.90	24.90	.0640	.0060	.0700	6.40	1.4600	.0320	68°	-
19, ...	1.5	1.5	-	-	-	-	-	-	-	-	68°	68°
20, ...	1.5	1.4	-	-	-	-	-	-	-	-	70°	67°
21, ...	1.5	1.4	14.70	24.80	.0480	.0050	.0530	6.65	1.2500	.0180	69°	-
22, ...	1.5	1.5	-	-	-	-	-	-	-	-	69°	67°
23, ...	3.0	2.8	-	-	-	-	-	-	-	-	73°	73°
24, ...	-	0.4	-	-	-	-	-	-	-	-	-	-
25, ...	1.5	.9	11.80	34.40	.0600	.0160	.0760	11.83	1.1200	.0300	71°	67°
26, ...	1.5	.85	-	-	-	-	-	-	-	-	69°	67°
27, ...	1.5	-	-	-	-	-	-	-	-	-	69°	-
28, ...	1.5	1.3	11.00	28.40	.0400	.0140	.0540	8.45	1.1000	.0240	68°	-
29, ...	1.5	1.0	-	-	-	-	-	-	-	-	66°	63°
30, ...	3.0	2.8	-	-	-	-	-	-	-	-	67°	66°

Effluent colorless and generally clear, and with very little sediment.
June 26.—Trap put in outlet-pipe. 26.—5.30 P.M., to 28, 10.03 A.M., outlet closed.
Total effluent to end of month, 197.15 gallons.

Filter Tank No. 11 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, .	-	0.4	-	-	-	-	-	-	-	-	-	-
2, .	1.5	1.2	12.40	26.20	.0400	.0080	.0480	6.98	1.2500	.0400	65°	-
3, .	1.5	1.5	-	-	-	-	-	-	-	-	65°	67°
4, .	1.5	1.1	-	-	-	-	-	-	-	-	67°	70°
5, .	1.5	1.8	9.00	25.70	.0360	.0110	.0470	6.46	1.1500	.0150	68°	70°
6, .	1.5	1.4	-	-	-	-	-	-	-	-	68°	70°
7, .	3.0	2.8	-	-	-	-	-	-	-	-	70°	74°
8, .	-	-	-	-	-	-	-	-	-	-	-	-
9, .	1.5	1.5	6.70	27.70	.0480	.0190	.0670	6.62	1.0000	.0600	69°	68°
10, .	1.5	1.4	-	-	-	-	-	-	-	-	69°	71°
11, .	1.5	1.2	-	-	-	-	-	-	-	-	69°	72°
12, .	1.5	1.9	7.00	28.60	.0200	.0150	.0350	7.03	1.0000	.0400	69°	68°
13, .	1.5	1.4	-	-	-	-	-	-	-	-	69°	65°
14, .	3.0	2.9	-	-	-	-	-	-	-	-	69°	69°
15, .	-	-	-	-	-	-	-	-	-	-	-	-
16, .	1.5	1.4	6.10	28.90	.0110	.0170	.0280	6.67	1.0200	.0350	69°	66°
17, .	1.5	1.4	-	-	-	-	-	-	-	-	69°	69°
18, .	1.5	0.9	-	-	-	-	-	-	-	-	71°	67°
19, .	1.5	2.0	10.10	28.20	.0210	.0080	.0290	7.79	1.1800	.0225	71°	66°
20, .	1.5	1.6	-	-	-	-	-	-	-	-	70°	71°
21, .	3.0	2.8	-	-	-	-	-	-	-	-	71°	72°
22, .	-	-	-	-	-	-	-	-	-	-	-	-
23, .	1.5	1.6	6.40	28.20	.0110	.0090	.0200	6.60	1.6500	.0150	72°	71°
24, .	1.5	1.43	-	-	-	-	-	-	-	-	72°	-
25, .	1.5	0.73	-	-	-	-	-	-	-	-	73°	70°
26, .	1.5	2.11	9.20	27.20	.0134	.0104	.0238	6.40	1.2000	.0100	73°	70°
27, .	1.5	1.40	-	-	-	-	-	-	-	-	72°	-
28, .	3.0	2.79	-	-	-	-	-	-	-	-	72°	65°
29, .	-	0.39	-	-	-	-	-	-	-	-	-	-
30, .	1.5	1.21	11.00	28.80	.0120	.0118	.0238	7.47	1.2200	.0090	71°	69°
31, .	1.5	1.51	-	-	-	-	-	-	-	-	72°	-

Effluent clear and colorless, and generally free from sediment.
Total effluent to end of month, 240.92 gallons.

Filter Tank No. 11 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	1.5	1.42	–	–	–	–	–	–	–	–	73°	72°
2, ...	1.5	1.47	4.10	30.20	.0130	.0112	.0242	6.33	1.2700	.0030	73°	71°
3, ...	1.5	1.45	–	–	–	–	–	–	–	–	73°	73°
4, ...	3.0	2.90	–	–	–	–	–	–	–	–	74°	72°
5, ...	–	0.39	–	–	–	–	–	–	–	–	–	–
6, ...	1.5	.99	–	–	–	–	–	–	–	–	74°	70°
7, ...	1.5	1.63	3.50	31.40	.0126	.0108	.0234	7.10	1.4500	.0080	72°	69°
8, ...	1.5	1.53	–	–	–	–	–	–	–	–	72°	69°
9, ...	1.5	1.48	2.70	28.80	.0154	.0128	.0282	5.90	1.3700	.0010	73°	71°
10, ...	1.5	1.48	–	–	–	–	–	–	–	–	72°	73°
11, ...	3.0	2.82	–	–	–	–	–	–	–	–	73°	69°
12, ...	–	0.37	–	–	–	–	–	–	–	–	–	–
13, ...	1.5	1.16	2.60	34.50	.0110	.0104	.0214	5.77	1.8000	.0080	70°	65°
14, ...	1.5	1.46	–	–	–	–	–	–	–	–	–	68°
15, ...	1.5	1.51	–	–	–	–	–	–	–	–	69°	68°
16, ...	1.5	1.54	4.00	30.50	.0102	.0086	.0188	5.52	1.5400	.0060	69°	71°
17, ...	1.5	1.48	–	–	–	–	–	–	–	–	70°	72°
18, ...	3.0	2.92	–	–	–	–	–	–	–	–	71°	73°
19, ...	–	0.38	–	–	–	–	–	–	–	–	–	–
20, ...	1.5	1.15	6.10	30.00	.0134	.0126	.0260	5.49	1.4000	.0040	71°	–
21, ...	1.5	1.43	–	–	–	–	–	–	–	–	71°	70°
22, ...	1.5	1.56	–	–	–	–	–	–	–	–	70°	69°
23, ...	1.5	1.43	4.20	29.20	.0126	.0094	.0220	5.78	1.8000	.0026	70°	68°
24, ...	1.5	1.54	–	–	–	–	–	–	–	–	70°	69°
25, ...	3.0	2.90	–	–	–	–	–	–	–	–	70°	73°
26, ...	–	0.42	–	–	–	–	–	–	–	–	–	–
27, ...	1.5	1.10	7.30	28.00	.0136	.0112	.0248	6.00	1.3000	.0030	71°	73°
28, ...	1.5	1.42	–	–	–	–	–	–	–	–	70°	67°
29, ...	1.5	1.49	–	–	–	–	–	–	–	–	69°	69°
30, ...	1.5	1.49	3.00	34.60	.0138	.0080	.0218	8.22	1.4000	.0016	70°	69°
31, ...	1.5	1.52	–	–	–	–	–	–	–	–	70°	72°

Effluent colorless, free from sediment and generally clear.
After August 1. — Residue on evaporation was obtained with sodium carbonate.
Total effluent to end of month, 286.75.

Filter Tank No. 11 — Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Depth of Sewage on Surface. Inches.	Temperature. Sewage.	Temperature. Effluent.
1, .	3.0	2.90	-	-	-	-	-	-	-	-	-	71°	72°
2, .	-	0.36	-	-	-	-	-	-	-	-	-	-	-
3, .	1.5	1.13	3.7	50.5	.0130	.0100	.0230	15.1	1.5000	.0030	-	70°	68°
4, .	1.5	4.19	-	-	-	-	-	-	-	-	-	71°	66°
5, .	31.49	15.58	-	-	-	-	-	-	-	-	-	70°	-
6, .	21.26	17.36	-	-	-	-	-	-	-	-	-	68°	-
7, .	-	8.69	-	-	-	-	-	-	-	-	-	-	-
8, .	-	5.48	-	-	-	-	-	-	-	-	-	-	61°
9, .	-	0.43	-	-	-	-	-	-	-	-	-	-	-
10, .	1.00	.30	-	-	-	-	-	-	-	-	-	67°	69°
11, .	-	.26	-	-	-	-	-	-	-	-	.2	-	67°
12, .	-	.23	-	-	-	-	-	-	-	-	.2	-	-
13, .	-	.20	20.0	277.0	1.8000	.0500	1.8500	169.5	.0070	.1000	.3	-	66°
14, .	-	.18	-	-	-	-	-	-	-	-	-	-	64°
15, .	-	.28	-	-	-	-	-	-	-	-	-	-	64°
16, .	-	.07	-	-	-	-	-	-	-	-	-	-	-
17, .	-	.19	38.0	443.0	2.0000	.0760	2.0760	258.5	.0700	.2750	-	-	67°
18, .	0.24	.16	-	-	-	-	-	-	-	-	-	65°	-
19, .	0.24	.14	-	-	-	-	-	-	-	-	-	64°	63°
20, .	0.24	.18	70.0	548.0	2.2100	.1100	2.3200	304.5	.0300	.3000	-	64°	61°
21, .	0.24	.13	-	-	-	-	-	-	-	-	-	63°	62°
22, .	0.24	.14	-	-	-	-	-	-	-	-	-	61°	62°
23, .	-	.12	-	-	-	-	-	-	-	-	-	-	-
24, .	.24	.13	18.0	628.0	2.5400	.0500	2.5900	348.0	.0250	.2670	-	58°	61°
25, .	.24	.13	-	-	-	-	-	-	-	-	-	58°	59°
26, .	.24	.11	-	-	-	-	-	-	-	-	-	58°	58°
27, .	.24	.12	56.0	656.0	2.4900	.1300	2.6200	380.0	.0400	.4000	.6	58°	61°
28, .	.24	.12	-	-	-	-	-	-	-	-	.7	57°	-
29, .	.24	.11	-	-	-	-	-	-	-	-	.7	55°	55°
30, .	-	.11	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless and nearly clear, but with considerable white sediment.

Sept. 5. — Trap removed from outlet pipe and 2.43 gallons effluent drawn. Sept. 6. — Tank filled by forcing 10.1 gallons sewage through faucet at outlet. One hundred and forty-seven pounds eight ounces of muck from Saugus Marshes put in top of tank and saturated with sewage, which was applied till within 1¾ inches of rim of tank. Sept. 10. — Surface of muck 5 inches below rim of tank. Sept. 18. — Five and seven-sixteenths inches. Sept. 24 and 27. — Magnesium carbonate in samples. Sept. 27. — Organisms visible to the naked eye in sample. Sept. 20 to 26. — Surface continually covered with sewage.

Total effluent to end of month, 346.28 gallons.

Filter Tank No. 11 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Depth of Sewage on Surface. Inches.	Temperature. Sewage.	Temperature. Effluent.
1, .	0.24	0.15	50.0	732.0	2.6400	.1000	2.7400	408.0	.0300	.4000	.7	53°	-
2, .	.24	.12	-	-	-	-	-	-	-	-	.8	53°	-
3, .	.24	.12	-	-	-	-	-	-	-	-	.9	51°	56°
4, .	.24	.12	58.0	792.0	2.3700	.0800	2.4500	430.0	.0350	.3500	1.0	50°	55°
5, .	.24	.13	-	-	-	-	-	-	-	-	1.1	50°	-
6, .	.24	.11	-	-	-	-	-	-	-	-	1.1	50°	-
7, .	-	.13	-	-	-	-	-	-	-	-	-	-	-
8, .	.24	.15	57.0	836.0	2.5800	.0900	2.6700	471.0	.0300	.4000	1.2	52°	55°
9, .	.24	.12	-	-	-	-	-	-	-	-	1.2	51°	-
10, .	.24	.11	-	-	-	-	-	-	-	-	1.2	49°	52°
11, .	.24	.11	50.0	847.0	2.4700	.1100	2.5800	483.0	.0300	.3000	1.3	49°	54°
12, .	.24	.12	-	-	-	-	-	-	-	-	1.4	47°	54°
13, .	.24	.11	-	-	-	-	-	-	-	-	1.5	47°	-
14, .	-	.11	-	-	-	-	-	-	-	-	-	-	-
15, .	.24	.12	90.0	873.0	2.6400	.1000	2.7400	492.0	.0300	.3250	1.5	47°	56°
16, .	.24	.13	-	-	-	-	-	-	-	-	1.6	47°	-
17, .	.24	.12	-	-	-	-	-	-	-	-	1.6	48°	55°
18, .	.24	.12	25.0	934.0	2.6000	.0600	2.6600	512.0	.0200	.3000	1.7	47°	-
19, .	.24	.11	-	-	-	-	-	-	-	-	1.9	46°	51°
20, .	.24	.11	-	-	-	-	-	-	-	-	1.9	47°	-
21, .	-	.10	-	-	-	-	-	-	-	-	-	-	-
22, .	.24	.10	47.0	956.0	2.5900	.0700	2.6600	530.0	.0500	.4000	1.9	45°	52°
23, .	.24	.10	-	-	-	-	-	-	-	-	1.9	45°	-
24, .	.24	.10	-	-	-	-	-	-	-	-	2.1	45°	53°
25, .	.24	.10	67.0	940.0	2.8500	.0500	2.9000	551.0	.0700	.5000	2.2	45°	53°
26, .	.24	.11	-	-	-	-	-	-	-	-	2.2	45°	-
27, .	.24	.10	-	-	-	-	-	-	-	-	2.4	46°	53°
28, .	-	.10	-	-	-	-	-	-	-	-	-	-	-
29, .	.24	.10	87.0	946.0	1.7100	.1200	1.8300	562.0	.1000	.5000	2.4	46°	54°
30, .	.24	.10	-	-	-	-	-	-	-	-	2.4	46°	-
31, .	.24	.10	-	-	-	-	-	-	-	-	2.5	45°	54°

Color, none, or less than 0.1. Little or no turbidity, but more or less white sediment.

October 3. — Microscopical animal growth in sewage on surface. No vegetable growth. October 4, 15, 18, 22, 25 and 29. — Magnesium carbonate in samples.

October 4. — Organisms visible to naked eye in sample. October 19. — Hole drilled in side of tank 3 inches below top of muck.

Total effluent to end of month, 349.81 gallons.

Filter Tank No. 11 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Depth of Sewage on Surface. Inches.	Temperature. Sewage.	Temperature. Effluent.
1, .	0.24	.10	90.	973.	2.6000	.1100	2.7100	558.0	.3700	.4750	2.6	47°	-
2, .	.24	.11	-	-	-	-	-	-	-	-	2.7	46°	-
3, .	.24	.07	-	-	-	-	-	-	-	-	2.8	48°	-
4, .	-	.13	-	-	-	-	-	-	-	-	-	-	-
5, .	.24	.10	60.	1050.	2.2400	.0700	2.3100	582.0	.4500	.6000	2.8	48°	-
6, .	.24	.09	-	-	-	-	-	-	-	-	2.9	49°	-
7, .	.24	.10	-	-	-	-	-	-	-	-	3.1	50°	-
8, .	.24	.09	60.	1037.	2.5300	.0400	2.5700	589.0	.4500	.5250	3.1	49°	-
9, .	.24	.10	-	-	-	-	-	-	-	-	3.2	49°	-
10, .	.24	.09	-	-	-	-	-	-	-	-	3.3	48°	-
11, .	-	.08	-	-	-	-	-	-	-	-	-	-	-
12, .	.24	.10	60.	1040.	2.1800	.1000	2.2800	590.0	.5300	.6000	3.4	45°	-
13, .	.24	.08	-	-	-	-	-	-	-	-	3.4	43°	-
14, .	.24	.09	-	-	-	-	-	-	-	-	3.6	43°	-
15, .	.24	.08	63.	1027.	2.2000	.0500	2.2500	597.0	.5000	.6000	3.7	42°	-
16, .	.24	.09	-	-	-	-	-	-	-	-	3.8	42°	-
17, .	.24	.08	-	-	-	-	-	-	-	-	3.9	42°	-
18, .	-	.08	-	-	-	-	-	-	-	-	-	-	-
19, .	.24	.09	63.	1037.	1.9600	.0300	1.9900	594.0	.6500	.6500	3.9	40°	-
20, .	.24	.07	-	-	-	-	-	-	-	-	4.1	40°	-
21, .	.24	.08	-	-	-	-	-	-	-	-	4.1	38°	-
22, .	.24	.08	53.	993.	1.7000	.0200	1.7200	602.0	.7000	.6500	4.2	45°	-
23, .	.24	.08	-	-	-	-	-	-	-	-	4.3	44°	-
24, .	.24	.07	-	-	-	-	-	-	-	-	4.4	45°	-
25, .	-	.09	-	-	-	-	-	-	-	-	-	-	-
26, .	.24	.08	53.	1094.	1.6900	.0700	1.7600	600.0	.8500	.6000	4.4	45°	-
27, .	-	.10	-	-	-	-	-	-	-	-	4.7	-	-
28, .	-	.03	-	-	-	-	-	-	-	-	4.7	-	-
29, .	-	-	-	-	-	-	-	-	-	-	-	-	-
30, .	-	-	-	-	-	-	-	-	-	-	-	-	-

Color, none, or less than 0.1. Very slight turbidity, and more or less white sediment. Magnesium carbonate in samples throughout the month.

November 24. — Trap put on outlet. Nov. 28. — Outlet closed at 4.30 P.M. River high.

Total effluent to end of month, 352.24 gallons.

Filter Tank No. 11 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Depth of Sewage on Surface. Inches.	Temperature. Sewage.	Temperature. Effluent.
1, .	0.24	0.30	-	-	-	-	-	-	-	-	4.4	44°	-
2, .	-	.08	-	-	-	-	-	-	-	-	-	-	-
3, .	.24	.07	97.	1113.	1.8000	.0500	1.8500	605.0	.8000	.8000	4.5	44°	-
4, .	-	.09	-	-	-	-	-	-	-	-	4.6	-	-
5, .	-	.07	-	-	-	-	-	-	-	-	4.6	-	-
6, .	.24	.06	93.	1060.	1.5900	.0500	1.6400	598.0	1.0500	.9000	4.5	46°	-
7, .	.24	.07	-	-	-	-	-	-	-	-	4.6	45°	-
8, .	-	.09	-	-	-	-	-	-	-	-	4.7	-	-
9, .	-	.07	-	-	-	-	-	-	-	-	-	-	-
10, .	-	.08	63.	1103.	1.5600	.0580	1.6180	601.0	.8500	1.1000	4.6	-	-
11, .	.24	.06	-	-	-	-	-	-	-	-	4.6	45°	-
12, .	-	.01	-	-	-	-	-	-	-	-	4.7	-	-
13, .	-	.10	-	-	-	-	-	598.0	.7000	1.2000	4.6	-	-
14, .	-	-	-	-	-	-	-	-	-	-	4.6	-	-
15, .	.24	.16	-	-	-	-	-	-	-	-	4.4	45°	-
16, .	-	.08	-	-	-	-	-	-	-	-	-	-	-
17, .	.24	.10	70.	1157.	1.6600	.0710	1.7310	601.0	.5500	1.3000	4.5	41°	-
18, .	-	.03	-	-	-	-	-	-	-	-	4.8	-	-
19, .	-	-	-	-	-	-	-	-	-	-	-	-	-
20, .	-	-	-	-	-	-	-	-	-	-	-	-	-
21, .	-	.26	-	-	-	-	-	-	-	-	-	-	-
22, .	.24	.10	-	-	-	-	-	-	-	-	4.4	45°	-
23, .	-	.08	-	-	-	-	-	-	-	-	-	-	-
24, .	.24	.10	-	-	-	-	-	-	-	-	4.4	42°	-
25, .	.24	.12	-	-	-	-	-	-	-	-	4.6	45°	-
26, .	-	.11	-	-	-	-	-	-	-	-	4.7	-	-
27, .	-	.12	73.	1124.	1.5100	.0490	1.5590	600.0	.7200	1.3500	4.6	-	-
28, .	-	.09	-	-	-	-	-	-	-	-	4.6	-	-
29, .	-	.08	-	-	-	-	-	-	-	-	4.5	-	-
30, .	-	.08	-	-	-	-	-	-	-	-	-	-	-
31, .	.24	.08	90.	1087.	1.6600	.1100	1.7700	592.0	.5000	1.5000	4.4	45°	-

Effluent generally colorless, nearly clear, and with some white sediment.

December 1. — Outlet opened at 8.17 A.M. December 6. — Magnesium carbonate in sample. December 14. — Outlet thawed out. December 14, 15 and 22. — A thin coating of ice on surface. December 18, 3.40 P.M., to December 21, 1.58 P.M. — Outlet closed. River high.

Total effluent to end of month, 354.98 gallons.

Filter Tank No. 11 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Depth of Sewage on Surface. Inches.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Sewage.	Effluent.
1, .	-	0.07	-	-	-	-	-	-	-	-	4.5	-	-
2, .	0.24	.08	-	-	-	-	-	-	-	-	4.4	45°	-
3, .	-	.06	40.	1090.	1.5800	.0550	1.6350	597.0	.5500	1.6000	4.6	-	-
4, .	.24	.07	-	-	-	-	-	-	-	-	4.5	45°	-
5, .	-	07	-	-	-	-	-	-	-	-	4.6	-	-
6, .	-	06	-	-	-	-	-	-	-	-	-	-	-
7, .	-	.06	57.	1086.	1.5000	.0750	1.5750	593.0	.7000	1.7000	4.6	-	-
8, .	-	.06	-	-	-	-	-	-	-	-	4.6	-	-
9, .	.24	.06	-	-	-	-	-	-	-	-	4.5	45°	-
10, .	-	.06	72.	1051.	1.5600	.0570	1.6170	592.0	.7000	1.7000	4.6	-	-
11, .	-	.05	-	-	-	-	-	-	-	-	4.6	-	-
12, .	-	.01	-	-	-	-	-	-	-	-	4.5	-	-
13, .	-	.13	-	-	-	-	-	-	-	-	-	-	-
14, .	.24	.04	83.	1087.	1.5600	.0640	1.6240	591.0	.7000	2.0000	4.3	44°	-
15, .	.24	.05	-	-	-	-	-	-	-	-	4.4	45°	-
16, .	-	.12	-	-	-	-	-	-	-	-	4.6	-	-
17, .	-	.05	-	-	-	-	-	-	-	-	4.6	-	-
18, .	-	.05	-	-	-	-	-	-	-	-	4.5	-	-
19, .	.24	.01	-	-	-	-	-	-	-	-	4.4	44°	-
20, .	-	.13	-	-	-	-	-	-	-	-	-	-	-
21, .	-	.05	60.	1097.	1.3400	.0660	1.4060	590.0	.6800	1.9000	4.5	-	-
22, .	.24	.01	-	-	-	-	-	-	-	-	4.4	44°	-
23, .	-	.00	-	-	-	-	-	-	-	-	4.6	-	-
24, .	-	.08	-	-	-	-	-	-	-	-	4.5	-	-
25, .	.24	.06	-	-	-	-	-	-	-	-	4.4	44°	-
26, .	-	.03	-	-	-	-	-	-	-	-	4.6	-	-
27, .	-	.08	-	-	-	-	-	-	-	-	-	-	-
28, .	-	.05	87.	1073.	1.2800	.0510	1.3310	574.0	.4500	1.7500	4.6	-	-
29, .	-	.06	-	-	-	-	-	-	-	-	4.5	-	-
30, .	.24	.00	-	-	-	-	-	-	-	-	4.4	46°	-
31, .	-	.10	-	-	-	-	-	-	-	-	4.6	-	-

Effluent generally colorless and nearly clear, but with considerable white sediment.
January 3. — Much manganese in sample.
Total effluent to end of month, 356.79 gallons.

Filter Tank No. 11 — Continued.

February, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation: Loss on Ignition.	Residue on Evaporation: Fixed.	Ammonia: Free.	Ammonia: Albuminoid.	Ammonia: Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Depth of Sewage on Surface. Inches.	Temperature: Sewage.	Temperature: Effluent.
1, .	-	.05	-	-	-	-	-	-	-	-	4.6	-	-
2, .	-	.06	-	-	-	-	-	-	-	-	4.5	-	-
3, .	-	.02	-	-	-	-	-	-	-	-	-	-	-
4, .	.24	.05	80.	1013.	1.4200	.0610	1.4810	565.0	.6000	1.9000	4.4	44°	-
5, .	-	.07	-	-	-	-	-	-	-	-	4.5	-	-
6, .	-	.02	-	-	-	-	-	-	-	-	4.5	-	-
7, .	-	.00	-	-	-	-	-	-	-	-	4.5	-	-
8, .	.24	.01	-	-	-	-	-	-	-	-	4.4	44°	-
9, .	-	.16	-	-	-	-	-	-	-	-	4.6	-	-
10, .	-	.02	-	-	-	-	-	-	-	-	-	-	-
11, .	-	.06	53.	1040.	1.5100	.0590	1.5690	558.0	.5000	2.0000	4.4	-	-
12, .	.24	.05	-	-	-	-	-	-	-	-	4.4	46°	-
13, .	-	.06	-	-	-	-	-	-	-	-	4.6	-	-
14, .	-	.03	-	-	-	-	-	-	-	-	4.6	-	-
15, .	-	.05	-	-	-	-	-	-	-	-	4.5	-	-
16, .	.12	.08	-	-	-	-	-	-	-	-	4.4	45°	-
17, .	-	.05	-	-	-	-	-	-	-	-	-	-	-
18, .	-	.05	40.	1033.	1.4200	.0450	1.4650	577.0	.3000	1.8000	4.6	-	-
19, .	-	.03	-	-	-	-	-	-	-	-	4.5	-	-
20, .	.24	.00	-	-	-	-	-	-	-	-	4.4	45°	-
21, .	-	.00	-	-	-	-	-	-	-	-	4.6	-	-
22, .	-	.13	-	-	-	-	-	-	-	-	4.5	-	-
23, .	-	.01	-	-	-	-	-	-	-	-	4.5	-	-
24, .	-	.00	-	-	-	-	-	-	-	-	-	-	-
25, .	.24	.00	60.	1030.	1.4900	.0600	1.5500	552.0	.3500	2.0000	4.4	45°	-
26, .	-	.10	-	-	-	-	-	-	-	-	4.5	-	-
27, .	.24	.14	-	-	-	-	-	-	-	-	4.4	45°	-
28, .	-	.06	-	-	-	-	-	-	-	-	4.6	-	-

Effluent generally colorless and nearly clear, but with considerable white sediment.
Total effluent to end of month, 358.15 gallons.

Filter Tank No. 11 — Continued.

March, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.
1,	-	.06	-	-	-	-	-	-	-	-	-	-
2,	-	.06	67.00	983.00	1.3700	.0570	1.4270	540.00	.3000	1.8000	-	-
3,	-	.06	-	-	-	-	-	-	-	-	-	-
4,	-	-	-	-	-	-	-	-	-	-	-	-
5,	-	-	-	-	-	-	-	-	-	-	-	-
6,	3.00	2.69	-	-	-	-	-	-	-	-	35°	44°
7,	3.00	3.03	3.20	30.10	.0700	.0220	.0920	9.52	.2500	.0100	35°	44°
8,	3.00	2.99	-	-	-	-	-	-	-	-	34°	44°
9,	3.00	2.96	-	-	-	-	-	-	-	-	40°	41°
10,	-	.38	-	-	-	-	-	-	-	-	-	-
11,	3.00	2.66	3.00	27.90	.0200	.0200	.0400	4.00	.5000	.0050	40°	43°
12,	3.00	2.99	-	-	-	-	-	-	-	-	40°	42°
13,	3.00	3.03	-	-	-	-	-	-	-	-	41°	43°
14,	3.00	3.00	3.20	19.40	.0600	.1100	.1700	1.03	.6500	.0030	39°	46°
15,	3.00	2.98	-	-	-	-	-	-	-	-	40°	44°
16,	3.00	2.99	-	-	-	-	-	-	-	-	39°	44°
17,	-	.38	-	-	-	-	-	-	-	-	-	-
18,	3.00	2.65	0.90	19.00	.0120	.0170	.0290	.72	.8000	.0040	41°	44°
19,	3.00	3.02	-	-	-	-	-	-	-	-	43°	45°
20,	3.00	2.98	-	-	-	-	-	-	-	-	41°	45°
21,	3.00	3.02	2.40	15.90	.0040	.0230	.0270	.65	1.0000	.0030	42°	43°
22,	3.00	3.03	-	-	-	-	-	-	-	-	40°	46°
23,	3.00	2.97	-	-	-	-	-	-	-	-	41°	47°
24,	-	.41	-	-	-	-	-	-	-	-	-	-
25,	3.00	2.60	1.70	17.00	.0050	.0280	.0330	.50	.9000	-	43°	47°
26,	3.00	2.96	-	-	-	-	-	-	-	-	40°	46°
27,	3.00	2.98	-	-	-	-	-	-	-	-	44°	46°
28,	3.09	2.94	2.10	15.00	.0028	.0166	.0194	.40	1.0000	.0015	43°	47°
29,	3.00	3.01	-	-	-	-	-	-	-	-	45°	47°
30,	3.00	2.94	-	-	-	-	-	-	-	-	40°	45°
31,	-	.38	-	-	-	-	-	-	-	-	-	-

Effluent was generally colorless, nearly clear, and with very slight sediment.

March 2. — Peat from Saugus Marshes, put on in September, 1888, removed from surface of sand. 4. — Sand washed by running city water through the tank. 6 to 8. — Sewage applied. 9 to 31. — City water with peptone was applied. The solution contained 1.00 part per 100,000 of albuminoid ammonia, or 1.50 parts of nitrogen. Total effluent to end of month, 421.30 gallons.

Filter Tank No. 11 — Continued.

April, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	3.00	2.57	1.10	16.00	.0018	.0138	.0156	0.33	.9000	.0014	40°	43°
2, ...	3.00	2.98	-	-	-	-	-	-	-	-	41°	43°
3, ...	3.00	2.92	-	-	-	-	-	-	-	-	43°	45°
4, ...	3.00	2.93	1.10	13.90	.0024	.0156	.0180	0.30	1.1000	.0010	43°	45°
5, ...	3.00	3.04	-	-	-	-	-	-	-	-	41°	47°
6, ...	3.00	3.00	-	-	-	-	-	-	-	-	41°	46°
7, ...	-	.38	-	-	-	-	-	-	-	-	-	-
8, ...	3.00	2.60	2.10	14.80	.0014	.0162	.0176	0.32	1.0000	.0024	44°	47°
9, ...	3.00	3.03	-	-	-	-	-	-	-	-	43°	49°
10, ...	3.00	2.98	-	-	-	-	-	-	-	-	43°	50°
11, ...	3.00	3.04	1.00	15.20	-	-	-	0.28	1.2000	.0007	45°	-
12, ...	3.00	3.04	-	-	-	-	-	-	-	-	50°	53°
13, ...	3.00	2.95	-	-	-	-	-	-	-	-	45°	53°
14, ...	-	.36	-	-	-	-	-	-	-	-	-	-
15, ...	3.00	2.60	1.20	14.00	.0010	.0152	.0162	0.28	1.2000	.0012	45°	48°
16, ...	3.00	2.99	-	-	-	-	-	-	-	-	46°	48°
17, ...	3.00	3.09	-	-	-	-	-	-	-	-	47°	48°
18, ...	3.00	3.00	3.10	14.20	.0010	.0146	.0156	0.24	1.1500	.0008	46°	48°
19, ...	3.00	3.08	-	-	-	-	-	-	-	-	53°	55°
20, ...	3.00	2.99	-	-	-	-	-	-	-	-	45°	-
21, ...	-	.39	-	-	-	-	-	-	-	-	-	-
22, ...	3.00	2.57	2.00	15.40	.0018	.0184	.0202	0.34	1.2000	.0010	45°	51°
23, ...	3.00	2.95	-	-	-	-	-	-	-	-	48°	-
24, ...	3.00	3.02	-	-	-	-	-	-	-	-	47°	52°
25, ...	3.00	3.02	0.70	16.00	.0012	.0162	.0174	0.27	1.4000	.0004	52°	56°
26, ...	3.00	3.00	-	-	-	-	-	-	-	-	52°	56°
27, ...	3.00	2.97	-	-	-	-	-	-	-	-	51°	54°
28, ...	-	.39	-	-	-	-	-	-	-	-	-	-
29, ...	3.00	2.65	2.70	14.40	.0014	.0158	.0172	0.31	1.4000	.0007	54°	56°
30, ...	3.00	3.01	-	-	-	-	-	-	-	-	53°	56°

Effluent colorless and generally clear, with very little or no sediment.
The solution applied contained 1.00 part per 100,000 of albuminoid ammonia to 1.50 parts nitrogen.
Total effluent to end of month, 498.75 gallons.

Filter Tank No. 11 — Continued.

May, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	3.00	2.99	-	-	-	-	-	-	-	-	51°	53°
2, ...	3.00	3.03	1.40	13.20	.0008	.0144	.0152	0.30	1.2000	.0004	52°	55°
3, ...	3.00	2.97	-	-	-	-	-	-	-	-	50°	-
4, ...	3.00	3.01	-	-	-	-	-	-	-	-	52°	54°
5, ...	-	.39	-	-	-	-	-	-	-	-	-	-
6, ...	3.00	2.66	-	-	.0026	.0144	.0170	0.24	1.2000	.0004	51°	58°
7, ...	3.00	2.94	-	-	-	-	-	-	-	-	51°	57°
8, ...	3.00	3.05	-	-	-	-	-	-	-	-	52°	59°
9, ...	3.00	3.02	2.20	13.80	.0014	.0158	.0172	0.32	1.4000	.0002	54°	63°
10, ...	3.00	3.04	-	-	-	-	-	-	-	-	57°	65°
11, ...	3.00	2.92	-	-	-	-	-	-	-	-	54°	64°
12, ...	-	.38	-	-	-	-	-	-	-	-	-	-
13, ...	3.00	2.68	2.20	14.70	.0032	.0154	.0186	0.35	1.4000	.0006	56°	62°
14, ...	3.00	2.93	-	-	-	-	-	-	-	-	55°	60°
15, ...	3.00	3.03	-	-	-	-	-	-	-	-	58°	63°
16, ...	3.00	3.08	2.10	13.10	.0012	.0162	.0174	0.27	1.2000	.0002	58°	63°
17, ...	3.00	2.98	-	-	-	-	-	-	-	-	59°	66°
18, ...	3.00	3.04	-	-	-	-	-	-	-	-	63°	69°
19, ...	-	.38	-	-	-	-	-	-	-	-	-	-
20, ...	3.00	2.58	2.60	14.00	.0030	.0150	.0180	0.33	1.4000	.0012	58°	66°
21, ...	3.00	3.01	-	-	-	-	-	-	-	-	60°	65°
22, ...	3.00	3.04	-	-	-	-	-	-	-	-	62°	65°
23, ...	3.00	2.98	-	-	-	-	-	-	-	-	60°	63°
24, ...	3.00	3.00	-	-	-	-	-	-	-	-	60°	62°
25, ...	3.00	2.95	-	-	-	-	-	-	-	-	60°	63°
26, ...	-	.35	-	-	-	-	-	-	-	-	-	-
27, ...	3.00	2.59	2.10	12.70	.0010	.0126	.0136	0.32	1.2000	.0004	57°	55°
28, ...	3.00	3.02	-	-	-	-	-	-	-	-	61°	61°
29, ...	3.00	2.97	-	-	-	-	-	-	-	-	59°	61°
30, ...	3.00	3.00	-	-	.0028	.0128	.0156	0.32	1.2000	.0005	59°	60°
31, ...	3.00	3.05	-	-	-	-	-	-	-	-	62°	65°

Effluent colorless, and generally clear and free from sediment.
The solution applied contained 1.00 part per 100,000 of albuminoid ammonia, or 1.50 parts nitrogen.
Total effluent to end of month, 579.81 gallons.

Filter Tank No. 11 — Continued.

June, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	3.00	2.96	-	-	-	-	-	-	-	-	61°	66°
2, ...	-	.38	-	-	-	-	-	-	-	-	-	-
3, ...	3.00	2.61	-	-	-	-	-	-	-	-	60°	66°
4, ...	3.00	2.95	-	-	-	-	-	-	-	-	60°	65°
5, ...	3.00	2.98	-	-	-	-	-	-	-	-	62°	66°
6, ...	3.00	2.95	2.60	14.20	.0016	.0060	.0076	.33	1.4000	.0003	61°	67°
7, ...	3.00	2.97	-	-	-	-	-	-	-	-	61°	64°
8, ...	3.00	2.93	-	-	-	-	-	-	-	-	60°	64°
9, ...	-	.40	-	-	-	-	-	-	-	-	-	-
10, ...	3.00	2.63	2.30	14.40	.0028	.0120	.0148	.35	1.4000	.0005	65°	71°
11, ...	-	.39	-	-	-	-	-	-	-	-	-	73°
12, ...	3.00	2.36	-	-	-	-	-	-	-	-	64°	-
13, ...	3.00	3.15	-	-	-	-	-	-	-	-	71°	71°
14, ...	3.00	2.98	-	-	-	-	-	-	-	-	66°	73°
15, ...	3.00	3.01	-	-	-	-	-	-	-	-	64°	73°
16, ...	-	.38	-	-	-	-	-	-	-	-	-	-
17, ...	3.00	2.57	-	-	-	-	-	-	-	-	69°	72°
18, ...	3.00	2.84	-	-	-	-	-	-	-	-	63°	65°
19, ...	3.00	2.93	-	-	-	-	-	-	-	-	63°	64°
20, ...	3.00	3.01	2.30	12.80	.0010	.0138	.0148	.36	1.5000	.0002	65°	70°
21, ...	3.00	2.99	-	-	-	-	-	-	-	-	67°	75°
22, ...	3.00	2.93	-	-	-	-	-	-	-	-	66°	73°
23, ...	-	.38	-	-	-	-	-	-	-	-	-	-
24, ...	3.00	2.52	2.50	13.20	.0018	.0148	.0166	.36	2.1000	.0003	65°	68°
25, ...	3.00	2.96	-	-	-	-	-	-	-	-	66°	67°
26, ...	3.00	2.99	-	-	-	-	-	-	-	-	67°	68°
27, ...	3.00	2.97	2.80	11.60	.0022	.0164	.0186	.43	1.1000	.0002	71°	72°
28, ...	3.00	2.99	-	-	-	-	-	-	-	-	69°	74°
29, ...	3.00	2.99	-	-	-	-	-	-	-	-	70°	75°
30, ...	-	.35	-	-	-	-	-	-	-	-	-	-

Effluent colorless, and generally clear and free from sediment.
The solution applied contained 1.00 part per 100,000 of albuminoid ammonia, or 1.50 parts nitrogen.
Total effluent to end of month, 651.26 gallons.

Filter Tank No. 11 — Continued.

July, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.
1, ...	3.00	2.54	2.30	14.50	.0046	.0150	.0196	.44	1.6500	.0004	71°	76°
2, ...	3.00	2.95	-	-	-	-	-	-	-	-	69°	73°
3, ...	3.00	3.00	-	-	-	-	-	-	-	-	70°	74°
4, ...	3.00	2.99	-	-	-	-	-	-	-	-	72°	73°
5, ...	3.00	2.84	1.90	28.80	.0052	.0144	.0196	5.17	2.1000	.0005	71°	72°
6, ...	3.00	2.94	-	-	-	-	-	-	-	-	71°	74°
7, ...	-	.37	-	-	-	-	-	-	-	-	-	-
8, ...	3.00	2.49	1.70	31.00	.0060	.0138	.0198	5.73	2.4000	.0012	72°	73°
9, ...	3.00	2.92	-	-	-	-	-	-	-	-	70°	70°
10, ...	3.00	2.93	-	-	-	-	-	-	-	-	68°	68°
11, ...	3.00	3.01	-	-	.0037	.0118	.0155	-	2.7667	.0005	67°	66°
12, ...	3.00	2.88	-	-	-	-	-	-	-	-	71°	70°
13, ...	3.00	3.00	-	-	-	-	-	-	-	-	73°	73°
14, ...	-	.35	-	-	-	-	-	-	-	-	-	-
15, ...	3.00	2.49	2.40	32.40	.0040	.0118	.0158	5.69	2.7000	.0008	65°	65°
16, ...	3.00	2.98	3.10	32.00	.0032	.0116	.0148	5.52	2.8000	.0004	67°	67°
17, ...	3.00	2.95	-	-	-	-	-	-	-	-	69°	67°
18, ...	3.00	2.95	1.60	31.60	.0032	.0126	.0158	5.54	2.7000	.0002	70°	70°
19, ...	3.00	2.94	-	-	-	-	-	-	-	-	70°	72°
20, ...	3.00	2.81	-	-	-	-	-	-	-	-	67°	69°
21, ...	-	.37	-	-	-	-	-	-	-	-	-	-
22, ...	3.00	2.60	2.60	30.60	-	-	-	5.54	2.2000	.0004	70°	71°
23, ...	3.00	2.85	-	-	-	-	-	-	-	-	69°	71°
24, ...	3.00	2.95	-	-	-	-	-	-	-	-	68°	70°
25, ...	3.00	2.94	-	-	-	-	-	-	-	-	70°	68°
26, ...	3.00	2.97	2.40	28.80	.0020	.0082	.0102	5.42	2.1000	.0004	70°	72°
27, ...	3.00	2.90	-	-	-	-	-	-	-	-	69°	68°
28, ...	-	.40	-	-	-	-	-	-	-	-	-	-
29, ...	3.00	2.68	-	-	-	-	-	-	-	-	72°	75°
30, ...	3.00	2.95	-	-	-	-	-	-	-	-	72°	74°
31, ...	3.00	2.96	-	-	-	-	-	-	-	-	70°	73°

Effluent colorless, and generally clear and free from sediment.

A solution of ammonium chloride, containing 2.00 parts per 100,000 of nitrogen, with its equivalent of sodium carbonate, applied.

Total effluent to end of month, 730.16 gallons.

Filter Tank No. 11 — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, . . .	3.00	2.96	-	-	-	-	-	-	-	-	71°	-
2, . . .	3.00	3.00	2.20	28.00	.0016	.0130	.0146	5.42	1.8000	.0002	70°	74°
3, . . .	3.00	2.95	-	-	-	-	-	-	-	-	70°	73°
4, . . .	-	.38	-	-	-	-	-	-	-	-	-	-
5, . . .	3.00	2.54	-	-	-	-	-	-	-	-	69°	69°
6, . . .	3.00	2.96	-	-	-	-	-	-	-	-	70°	71°
7, . . .	3.00	2.93	-	-	-	-	-	-	-	-	70°	71°
8, . . .	3.00	2.86	2.10	36.80	.0012	.0074	.0086	9.72	2.2500	.0004	69°	70°
9, . . .	3.00	3.65	-	-	-	-	-	-	-	-	69°	72°
10, . . .	3.00	2.95	-	-	-	-	-	-	-	-	70°	73°
11, . . .	-	.34	-	-	-	-	-	-	-	-	-	-
12, . . .	3.00	2.50	-	-	-	-	-	-	-	-	68°	68°
13, . . .	3.00	2.97	12.00	2028.00	1.0000	.0400	1.0400	1133.00	.0100	.0004	69°	68°
14, . . .	3.00	2.91	-	-	-	-	-	-	-	-	66°	67°
15, . . .	3.00	2.96	-	-	-	-	-	-	-	-	66°	65°
16, . . .	3.00	2.99	-	-	-	-	-	-	-	-	68°	68°
17, . . .	3.00	3.12	-	-	-	-	-	-	-	-	68°	68°
18, . . .	-	.35	-	-	-	-	-	-	-	-	-	-
19, . . .	3.00	2.65	-	-	1.5000	.0400	1.5400	1291.00	.0400	.0003	68°	68°
20, . . .	3.00	3.00	-	-	-	-	-	-	-	-	69°	69°
21, . . .	3.00	2.98	-	-	-	-	-	-	-	-	68°	70°
22, . . .	3.00	2.98	-	-	-	-	-	-	-	-	70°	71°
23, . . .	3.00	2.87	-	-	-	-	-	-	-	-	69°	70°
24, . . .	3.00	3.08	-	-	-	-	-	-	-	-	67°	69°
25, . . .	-	.36	-	-	-	-	-	-	-	-	-	-
26, . . .	3.00	2.60	-	-	1.9600	.1400	2.1000	1291.00	.0000	.0016	68°	68°
27, . . .	3.00	3.02	-	-	-	-	-	-	-	-	68°	68°
28, . . .	3.00	3.00	-	-	-	-	-	-	-	-	68°	66°
29, . . .	3.00	2.93	-	-	1.2200	.1000	1.3200	449.00	.0000	.2400	67°	66°
30, . . .	3.00	2.97	-	-	-	-	-	-	-	-	69°	65°
31, . . .	3.00	2.92	-	-	-	-	-	-	-	-	69°	70°

Effluent clear and colorless, and generally free from sediment.

The solution applied contained 2.00 parts per 100,000 of nitrogen, and from August 8 to August 26 some common salt was added. The amount is shown by the chlorine of the effluent.

Total effluent to end of month, 810.84 gallons.

Filter Tank No. 11 — Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	-	.37	-	-	-	-	-	-	-	-	-	-
2, ...	3.00	2.56	3.20	125.20	.1100	.0500	.1600	44.10	2.2000	.0650	67°	69°
3, ...	3.00	3.00	-	-	-	-	-	-	-	-	69°	70°
4, ...	3.00	2.92	-	-	-	-	-	-	-	-	69°	70°
5, ...	3.00	2.93	-	-	.0160	.0108	.0268	11.49	3.3000	.0020	69°	69°
6, ...	3.00	2.94	-	-	-	-	-	-	-	-	70°	74°
7, ...	3.00	2.90	-	-	-	-	-	-	-	-	68°	70°
8, ...	-	.32	-	-	-	-	-	-	-	-	-	-
9, ...	3.00	2.59	-	-	.0080	.0114	.0194	7.46	2.8000	.0003	67°	69°
10, ...	3.00	2.94	-	-	-	-	-	-	-	-	68°	67°
11, ...	3.00	2.93	-	-	.0074	.0090	.0164	73.20	.9500	.0040	66°	65°
12, ...	3.00	2.94	-	-	-	-	-	-	-	-	67°	66°
13, ...	3.00	3.05	-	-	.0116	.0082	.0198	123.70	.6000	.0004	67°	65°
14, ...	3.00	2.98	-	-	-	-	-	-	-	-	67°	67°
15, ...	-	.35	-	-	-	-	-	-	-	-	-	-
16, ...	3.00	2.62	18.00	252.00	.0138	.0078	.0216	124.20	.2500	.0004	70°	71°
17, ...	3.00	2.97	-	-	-	-	-	-	-	-	69°	72°
18, ...	3.00	2.90	-	-	.0096	.0116	.0212	125.30	.1500	.0004	68°	68°
19, ...	3.00	2.92	-	-	-	-	-	-	-	-	64°	62°
20, ...	3.00	2.97	-	-	-	-	-	-	-	-	65°	62°
21, ...	3.00	2.89	-	-	-	-	-	-	-	-	66°	62°
22, ...	-	.33	-	-	-	-	-	-	-	-	-	-
23, ...	3.00	2.56	-	-	.0066	.0062	.0128	125.70	.9000	.0003	62°	59°
24, ...	3.00	2.98	-	-	-	-	-	-	-	-	62°	60°
25, ...	3.00	3.00	-	-	-	-	-	-	-	-	64°	61°
26, ...	3.00	2.98	-	-	.0054	.0066	.0120	127.10	1.3400	.0002	64°	63°
27, ...	3.00	2.93	-	-	-	-	-	-	-	-	63°	60°
28, ...	3.00	2.92	-	-	.0054	.0096	.0150	143.00	1.2000	.0004	61°	60°
29, ...	-	.35	-	-	-	-	-	-	-	-	-	-
30, ...	3.00	2.60	-	-	-	-	-	-	-	-	62°	60°

Effluent clear and colorless, and generally free from sediment.

The solution applied contained 2.00 parts per 100,000 of nitrogen, and after September 9 some common salt was added, the amount of the latter being regularly increased, as shown by the chlorine of the effluent.

Total effluent to end of month, 884.48 gallons.

Filter Tank No. 11 — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	3.00	2.97	–	–	–	–	–	–	–	–	63°	62°
2, ...	3.00	2.90	–	–	–	–	–	–	–	–	62°	61°
3, ...	3.00	2.95	–	–	–	–	–	–	–	–	60°	59°
4, ...	3.00	2.96	–	–	–	–	–	–	–	–	62°	60°
5, ...	3.00	2.87	–	–	.0052	.0084	.0136	218.	1.2600	.0002	59°	55°
6, ...	–	.38	–	–	–	–	–	–	–	–	–	–
7, ...	3.00	2.57	–	–	–	–	–	–	–	–	58°	58°
8, ...	3.00	2.91	–	–	–	–	–	–	–	–	58°	55°
9, ...	3.00	2.95	–	–	–	–	–	–	–	–	58°	54°
10, ...	3.00	2.90	–	–	–	–	–	–	–	–	57°	53°
11, ...	3.00	2.97	–	–	–	–	–	–	–	–	55°	53°
12, ...	3.00	2.97	–	–	.0048	.0120	.0168	295.	.9000	.0000	57°	54°
13, ...	–	.35	–	–	–	–	–	–	–	–	–	–
14, ...	3.00	2.54	–	–	–	–	–	–	–	–	54°	49°
15, ...	3.00	2.99	–	–	–	–	–	–	–	–	56°	53°
16, ...	3.00	2.93	–	–	–	–	–	–	–	–	55°	51°
17, ...	3.00	2.96	–	–	–	–	–	–	–	–	55°	52°
18, ...	3.00	2.96	–	–	–	–	–	–	–	–	55°	53°
19, ...	3.00	2.94	–	–	.0058	.0104	.0162	367.	.2000	.0001	54°	53°
20, ...	–	.38	–	–	–	–	–	–	–	–	–	–
21, ...	3.00	2.55	–	–	–	–	–	–	–	–	54°	51°
22, ...	3.00	2.93	–	–	–	–	–	–	–	–	53°	54°
23, ...	3.00	2.97	–	–	–	–	–	–	–	–	52°	48°
24, ...	3.00	2.99	–	–	–	–	–	–	–	–	52°	47°
25, ...	3.00	3.02	–	–	–	–	–	–	–	–	53°	49°
26, ...	3.00	2.95	–	–	.0516	.0094	.0610	452.	.5500	.0010	53°	51°
27, ...	–	.38	–	–	–	–	–	–	–	–	–	–
28, ...	3.00	2.63	–	–	–	–	–	–	–	–	54°	54°
29, ...	3.00	2.93	–	–	–	–	–	–	–	–	53°	51°
30, ...	3.00	2.97	–	–	.0470	.0130	.0600	477.	.2500	.0010	51°	50°
31, ...	3.00	3.01	–	–	–	–	–	–	–	–	53°	52°

Effluent clear and colorless, and generally free from sediment. The solution applied contained 2.00 parts per 100,000 of nitrogen, and an amount of common salt increased regularly, as shown by the chlorine of the effluent.

Total effluent to end of month, 964.16 gallons.

Filter Tank No. 11 — Continued.

November, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.
1, ...	3.00	2.96	-	-	-	-	-	-	-	-	52°	52°
2, ...	3.00	3.05	-	-	.0212	.0090	.0302	545.	.2000	.0006	53°	53°
3, ...	-	.38	-	-	-	-	-	-	-	-	-	-
4, ...	3.00	2.60	-	-	-	-	-	-	-	-	53°	53°
5, ...	3.00	2.95	-	-	-	-	-	-	-	-	51°	49°
6, ...	3.00	2.95	-	-	-	-	-	-	-	-	52°	48°
7, ...	3.00	3.02	-	-	-	-	-	-	-	-	50°	51°
8, ...	3.00	3.00	-	-	-	-	-	-	-	-	53°	51°
9, ...	3.00	3.03	24.0	1036.0	.0236	.0074	.0310	606.	.1800	.0002	53°	52°
10, ...	-	.37	-	-	-	-	-	-	-	-	-	-
11, ...	3.00	2.60	-	-	-	-	-	-	-	-	53°	52°
12, ...	3.00	3.00	-	-	-	-	-	-	-	-	54°	53°
13, ...	3.00	3.01	-	-	-	-	-	-	-	-	53°	54°
14, ...	3.00	3.02	-	-	-	-	-	-	-	-	56°	57°
15, ...	3.00	2.86	-	-	-	-	-	-	-	-	51°	50°
16, ...	3.00	2.98	-	-	.0650	.0080	.0730	678.	.7000	.0010	49°	48°
17, ...	-	.38	-	-	-	-	-	-	-	-	-	-
18, ...	3.00	2.56	-	-	-	-	-	-	-	-	50°	48°
19, ...	3.00	2.99	-	-	-	-	-	-	-	-	50°	49°
20, ...	3.00	3.05	-	-	-	-	-	-	-	-	51°	50°
21, ...	3.00	3.01	-	-	-	-	-	-	-	-	51°	51°
22, ...	3.00	2.98	-	-	-	-	-	-	-	-	50°	51°
23, ...	3.00	2.99	-	-	.0260	.0090	.0350	752.	.8000	.0001	50°	51°
24, ...	-	.40	-	-	-	-	-	-	-	-	-	-
25, ...	3.00	2.59	-	-	-	-	-	-	-	-	50°	50°
26, ...	3.00	3.00	-	-	-	-	-	-	-	-	48°	48°
27, ...	3.00	3.01	-	-	-	-	-	-	-	-	45°	46°
28, ...	3.00	3.03	-	-	-	-	-	-	-	-	49°	48°
29, ...	3.00	2.95	-	-	-	-	-	-	-	-	47°	48°
30, ...	3.00	2.95	-	-	.0256	.0096	.0352	846.	.6500	.0002	46°	44°

Effluent clear and colorless, and free from sediment.

The solution applied contained 2.00 parts per 100,000 of nitrogen, and an amount of common salt increased regularly, as shown by the chlorine of the effluent.

Total effluent to end of month, 1041.83 gallons.

Filter Tank No. 11 — Continued.

December, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	-	.40	-	-	-	-	-	-	-	-	-	-
2, ...	3.00	2.63	-	-	-	-	-	-	-	-	46°	45°
3, ...	3.00	2.96	-	-	-	-	-	-	-	-	47°	46°
4, ...	3.00	2.98	-	-	-	-	-	-	-	-	42°	40°
5, ...	3.00	3.03	-	-	-	-	-	-	-	-	44°	40°
6, ...	3.00	3.04	-	-	-	-	-	-	-	-	44°	43°
7, ...	3.00	3.01	-	-	.0910	.0125	.1035	934.	1.1500	.0018	44°	45°
8, ...	-	.41	-	-	-	-	-	-	-	-	-	-
9, ...	3.00	2.68	-	-	-	-	-	-	-	-	52°	48°
10, ...	3.00	2.96	-	-	-	-	-	-	-	-	46°	47°
11, ...	3.00	3.00	-	-	-	-	-	-	-	-	47°	47°
12, ...	3.00	2.97	-	-	-	-	-	-	-	-	44°	44°
13, ...	3.00	3.01	-	-	-	-	-	-	-	-	42°	43°
14, ...	3.00	2.95	-	-	.2500	.0220	.2720	1306.	1.0000	.0014	40°	39°
15, ...	-	.42	-	-	-	-	-	-	-	-	-	-
16, ...	3.00	2.66	-	-	-	-	-	-	-	-	43°	43°
17, ...	3.00	3.02	-	-	-	-	-	-	-	-	43°	43°
18, ...	3.00	3.04	-	-	-	-	-	-	-	-	44°	43°
19, ...	3.00	3.09	-	-	-	-	-	-	-	-	46°	46°
20, ...	3.00	3.02	-	-	-	-	-	-	-	-	45°	46°
21, ...	3.00	3.06	-	-	.9000	.0400	.9400	1540.	1.2000	.0030	48°	48°
22, ...	-	.38	-	-	-	-	-	-	-	-	-	-
23, ...	3.00	2.55	-	-	-	-	-	-	-	-	42°	43°
24, ...	3.00	3.08	-	-	-	-	-	-	-	-	42°	42°
25, ...	3.00	3.14	-	-	-	-	-	-	-	-	41°	-
26, ...	3.00	3.00	-	-	-	-	-	-	-	-	42°	45°
27, ...	3.00	3.01	-	-	-	-	-	-	-	-	45°	44°
28, ...	3.00	2.90	-	-	1.0800	.0400	1.1200	1561.	.6400	.0050	42°	42°
29, ...	-	.40	-	-	-	-	-	-	-	-	-	-
30, ...	3.00	2.55	-	-	-	-	-	-	-	-	41°	44°
31, ...	3.00	3.00	-	-	-	-	-	-	-	-	-	41°

Effluent clear and colorless, and free from sediment.

The solution applied contained 2.00 parts per 100,000 of nitrogen, and an amount of common salt increased regularly, as shown by the chlorine of the effluent.

Total effluent to end of month, 1120.18 gallons.

Filter Tank No. 11 — Continued.

January, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	3.00	2.90	-	-	2.0000	.1000	2.1000	2780.	.2200	.0030	42°	42°
2, ...	3.00	3.08	-	-	-	-	-	-	-	-	52°	48°
3, ...	3.00	3.00	-	-	-	-	-	-	-	-	46°	47°
4, ...	3.00	2.77	110.	4930.	2.6000	.1200	2.7200	4650.	.0400	.0010	44°	44°
5, ...	-	.38	-	-	-	-	-	-	-	-	-	-
6, ...	3.00	2.73	-	-	-	-	-	-	-	-	45°	43°
7, ...	3.00	3.20	-	-	-	-	-	-	-	-	-	45°
8, ...	3.00	3.17	-	-	3.1000	.1100	3.2100	5180.	.0600	.0016	48°	45°
9, ...	3.00	3.04	-	-	-	-	-	-	-	-	39°	40°
10, ...	3.00	2.98	-	-	-	-	-	-	-	-	40°	36°
11, ...	3.00	3.03	-	-	.8700	.0700	.9400	1340.	.0600	.0040	41°	37°
12, ...	-	.45	-	-	-	-	-	-	-	-	-	-
13, ...	3.00	2.71	-	-	-	-	-	-	-	-	43°	43°
14, ...	3.00	3.04	-	-	-	-	-	-	-	-	42°	43°
15, ...	3.00	3.01	-	-	-	-	-	-	-	-	39°	41°
16, ...	3.00	3.05	-	-	-	-	-	-	-	-	45°	44°
17, ...	3.00	2.90	-	-	-	-	-	-	-	-	38°	39°
18, ...	3.00	3.13	-	-	1.1000	.0700	1.1700	1040.	.2400	.0800	40°	40°
19, ...	-	.45	-	-	-	-	-	-	-	-	-	-
20, ...	3.00	2.66	-	-	-	-	-	-	-	-	40°	47°
21, ...	3.00	3.00	-	-	-	-	-	-	-	-	38°	45°
22, ...	3.00	2.97	-	-	1.1200	.0500	1.1700	674.	.7500	.0900	-	39°
23, ...	3.00	3.02	-	-	-	-	-	-	-	-	38°	37°
24, ...	3.00	2.91	-	-	-	-	-	-	-	-	38°	39°
25, ...	3.00	3.04	-	-	.5000	.0600	.5600	564.	.6000	.1100	37°	37°
26, ...	-	.37	-	-	-	-	-	-	-	-	-	-
27, ...	3.00	2.68	-	-	-	-	-	-	-	-	40°	41°
28, ...	3.00	2.97	-	-	-	-	-	-	-	-	38°	36°
29, ...	3.00	3.17	-	-	.4800	.1000	.5800	581.	.6000	.1200	42°	41°
30, ...	3.00	2.96	-	-	-	-	-	-	-	-	42°	40°
31, ...	3.00	3.31	-	-	.4500	.0600	.5100	580.	.7000	.1200	40°	39°

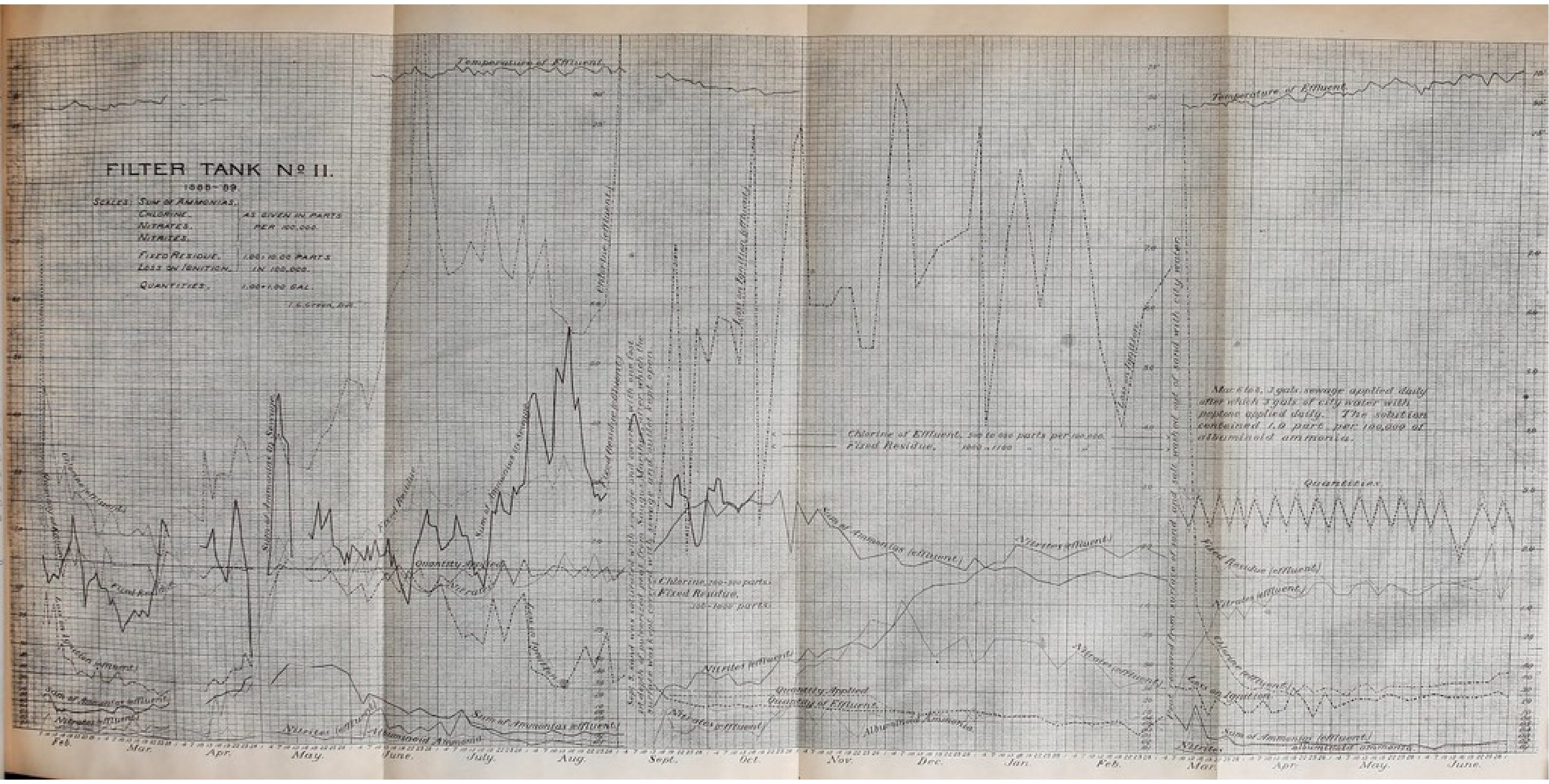
Effluent clear and generally colorless, and free from sediment.

The solution applied contained 2.00 parts per 100,000 of nitrogen, and an amount of common salt increased regularly till January 7, after which less was added, as shown by the chlorine of the effluent.

Total effluent to end of month, 1202.26 gallons.

Number of Bacteria found in a Cubic Centimeter of Effluent from Tank No. 11.

Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.
1888.		**1888**—Con.		**1888**—Con.		**1889**—Con.	
Feb. 7, .	2,979	May 22, .	1,974	Nov. 16, .	66	June 28, .	0
9, .	62,400	26, .	581	21, .	189	July 2, .	3
11, .	510,000	29, .	45	26, .	65	9, .	14
14, .	264,000	June 2, .	178	Dec. 7, .	37	16, .	2
16, .	1,852,500	7, .	81	17, .	12	23, .	0
18, .	1,944,000	12, .	173	**1889.**		30, .	7
21, .	1,584,000	16, .	49	Jan. 2, .	146	Aug. 6, .	2
23, .	710,900	23, .	75	8, .	175	12, .	0
25, .	1,215,000	29, .	626	29, .	16	19, .	17
28, .	960,000	July 5, .	1,202	Feb. 6, .	6	26, .	2,208
March 1, .	792,000	24, .	32,340	19, .	4	Sept. 2, .	64
3, .	196,800	26, .	9,216	March 12, .	18,819	10, .	11
6, .	164,310	28, .	11,076	19, .	13,377	16, .	12
10, .	70,981	Aug. 4, .	10,148	23, .	60	24, .	19
15, .	157,896	14, .	4,722	26, .	18	Oct. 2, .	94
17, .	237,600	18, .	65	April 2, .	2,916	10, .	83
20, .	279,000	23, .	95	9, .	1,479	16, .	32
22, .	891,600	Sept. 22, .	5,365	16, .	179	25, .	3
24, .	127,795	27, .	1,194	24, .	15	Nov. 5, .	1,679
29, .	172,850	Oct. 4, .	778	30, .	51	16, .	83
April 19, .	26,610	9, .	851	May 7, .	18	21, .	247
25, .	42,240?	13, .	537	14, .	10	Dec. 4, .	12
28, .	4,524	23, .	199	21, .	7	10, .	48
May 8, .	6,000	27, .	311	28, .	4	17, .	81
10, .	7,920	Nov. 1, .	49	June 4, .	1	28, .	6,480
12, .	1,330	6, .	3	11, .	4		
19, .	2,048	10, .	33	18, .	4		



FILTER TANK No. II.
SCALES: SUM OF AMMONIAS.
CHLORINE.
NITRATES.
NITRITES.
AS GIVEN IN PARTS PER 100,000.
FIXED RESIDUE.
LOSS ON IGNITION.
QUANTITIES.
Temperature of Effluent
Chlorine (effluent)
Fixed Residue (effluent)
Loss on Ignition (effluent)
Quantity Applied
Quantity of Effluent
Sum of Ammonias (effluent)
Sum of Ammonias in Sewage
Nitrates (effluent)
Nitrites (effluent)
Albuminoid Ammonia
Chloride of Effluent
Fixed Residue
Quantities
after which 3 gals of city water with peptone applied daily. The solution contained 1.0 part per 100,000 of albuminoid ammonia.
Feb.
Mar.
Apr.
May.
June.
July.
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May.
June.

FILTER TANK No. 3.

PEAT.

This was one of the large tanks in the field, having an area of one two-hundredth of an acre. It had underdrains, with the usual depth of about seven inches of gravel and coarse sand; above which it was filled with a depth of five feet of peat taken from a cultivated field. This peat was nearly all vegetable matter, but contained a little mud. The top of the peat-bed which had been cultivated was removed, and the tank filled to the depth of four feet from the undisturbed lower layers; after which one foot in depth of the original top layer was put on. This material was at first completely saturated with water, by cutting it up fine, and sprinkling it into water standing in the tank. The space occupied by the peat and water was about 8,500 gallons.

After the outlet was opened, in one week about 700 gallons of water flowed out of the peat, which settled into the space of about 8,000 gallons. The peat then contained probably as much as 6,000 gallons of water.

The quantity flowing out decreased in a month to about 25 gallons a day, or at the rate of 5,000 gallons per acre per day, although the surface was kept covered with water. At the end of one and a half months, on Dec. 26, 1887, sewage was applied, and, through the following twenty-two months, was nearly all the time kept continually on the surface.

Before sewage was applied, the chlorine of the effluent was, at one time, 1.46 parts per 100,000, — from salt which was originally in the peat; but, when 1,600 gallons of water had been drawn out of the peat, the chlorine was reduced to 1.18 parts per 100,000, — which was the amount of chlorine when sewage was first applied to the tank. The chlorine was no higher than this five months later, —

at the end of May, — when about 1,500 gallons of effluent had flowed from the tank after sewage was first applied. From this time forward the chlorine of the effluent increased slowly; though it was not until the latter part of August, 1889, twenty months after sewage was first applied, that the chlorine of the effluent became equal to that of the chlorine of the sewage first applied. At this time a little more than 5,000 gallons of effluent had flowed from the tank after the first application of sewage.

Up to this time it is evident that a large but decreasing fraction of the effluent was from the water with which the peat was saturated when filled into the tank; and that, although a very little less than one per cent. of the effluent came from sewage at the end of five months after its application, it was about eighteen months after it was first applied before the effluent could be said to be coming from the sewage; that is, this bed of saturated peat, five feet in depth, and completely underdrained, when kept continually covered with sewage, was so nearly impervious to liquid that it required about eighteen months for any body of sewage applied to the surface to reach the outlet. The rate of flow through the outlet during this time varied from about 13 gallons a day to 6.5 gallons, or from 2,600 gallons per acre per day to 1,300 gallons per acre per day; and the average quantity, for the whole twenty-two months in which sewage was applied, was about 1,700 gallons per acre per day, — which is only about one-half of the average daily rainfall upon the same surface.

Chemical analyses of the effluent were made once a week, or oftener, during the first year, and have been continued at longer intervals during the second year. As the quality of the effluent varied but little through the whole time, it is thought to be unnecessary to give the tables of daily observations, with the weekly analyses; but there have been placed, in the following table, the monthly averages of the results of analyses of the effluent, together with the average daily quantity of effluent, and the number of bacteria found in a cubic centimeter of the effluent.

Monthly Averages of Daily Results with Tank No. 3.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Bacteria.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888.												
Dec. 27 and 29, '87,	First Sewage, .	–	20.20	21.50	1.5100	.6000	2.1100	3.56	.006	.0000	–	–
January, . .	Effluent,	13.3	2.99	10.89	.0056	.0260	.0316	1.15	.018	–	–	16
February, . .	Effluent,	6.5	3.30	13.41	.0023	.0238	.0261	1.08	.009	–	42½°	22
March, . .	Effluent,	8.1	3.46	11.98	.0071	.0246	.0317	1.20	.039	.0004	44°	19
April, . .	Effluent,	10.2	3.37	12.90	.0210	.0292	.0502	1.17	.018	.0004	44°	49
May, . . .	Effluent,	10.1	4.12	14.40	.0103	.0299	.0402	1.25	.031	.0004	53°	226
June, . . .	Effluent,	9.8	4.25	13.67	.0054	.0259	.0313	1.48	.030	.0002	63½°	51
July, . . .	Effluent,	8.7	4.22	14.58	.0026	.0252	.0278	1.56	.024	.0000	68°	20
August, . .	Effluent,	9.2	3.97	14.58	.0031	.0249	.0280	1.65	.021	.0000	69½°	24
September, .	Effluent,	8.8	3.52	17.54	.0051	.0295	.0346	1.61	.022	.0000	64°	8
October, . .	Effluent,	7.9	2.83	17.67	.0084	.0281	.0365	1.70	.020	.0000	57°	21
November, .	Effluent,	7.5	2.64	17.56	.0138	.0296	.0434	1.81	.048	.0000	53°	23
December, .	Effluent,	8.3	2.43	18.37	.0155	.0284	.0439	1.97	.048	.0000	44½°	2
1889.												
January, . .	Effluent,	8.9	3.17	18.07	.0120	.0294	.0414	2.00	.099	.0000	44°	47
February, . .	Effluent,	7.8	3.03	16.95	.0088	.0278	.0366	2.31	.072	.0000	42°	3
March, . .	Effluent,	7.8	3.50	16.40	.0060	.0250	.0310	2.65	.080	.0000	44°	32
April, . .	Effluent,	7.3	4.40	17.80	.0036	.0278	.0314	2.48	.070	.0000	49½°	6
May, . . .	Effluent,	6.4	3.10	17.00	.0040	.0294	.0334	2.66	.080	.0001	60°	5
June, . . .	Effluent,	6.5	5.45	15.10	.0115	.0354	.0469	3.02	.053	.0000	67°	80
July, . . .	Effluent,	8.3	4.50	16.15	.0046	.0305	.0351	3.24	.033	.0001	69°	9
August, . .	Effluent,	10.5	4.00	18.00	.0035	.0345	.0380	3.50	.070	.0090	68°	11
September, .	Effluent,	11.0	4.80	18.95	.0092	.0409	.0501	4.50	.058	.0000	65°	167
October, . .	Effluent,	8.4	–	–	.0035	.0342	.0377	4.90	.037	.0001	55°	9

During the first year the nitrates increased from 0.018 parts to 0.048 parts. The free ammonia varied, in the first four months, from 0.0023 parts to 0.0210 parts, and was, at the end of the year, 0.0155 parts; averaging, for the year, 0.0083 parts. The albuminoid ammonia was nearly constant throughout the first year, varying from 0.0238 parts to 0.0299 parts, and averaging, for the year, 0.0271 parts.

In the second year the results changed gradually — as shown by the table — from those just given to the following, which are the mean results during the last three months, when the effluent may be regarded as coming from the sewage. In these months the nitrates varied from 0.070 parts in August to 0.037 parts in October, and averaged 0.055 parts. The free ammonia averaged 0.0054 parts, the albuminoid ammonia averaged 0.0365 parts; and the sum of the ammonias averaged 0.0419 parts, — which is two per cent. of the sum of the ammonias of the sewage first applied.

From these results we see that about 98 per cent. of the nitrogenous organic matter of the sewage has been removed from the effluent; but, as there is little nitrification, and this probably takes place in the sand beneath the peat by contact with air entering the outlet, there can be no doubt that the larger part of the nitrogenous matter of the sewage is being stored within the tank. But, whatever be the proportion remaining there, it is evident that the organic matter of the sewage is removed to a less degree than with any of the filters of sand; and, as the conditions do not warrant us to expect any increase in nitrification, these results do not give promise of more efficient filtration in future.

The quantity of sewage that could pass through this material is so small, that it renders the material entirely unfit for a filtering area. If a bed of it were surrounded by a bank, so that the rain falling upon it could not flow off over the surface, the surface would remain covered with water, from rain alone, in all of those months when the evaporation did not exceed one-half of the rainfall; so that, during about two-thirds of the year, it would be incapable of receiving any sewage.

We must regard such an area as entirely worthless for filtration of sewage.

Bacteria of Effluent from Tank No. 3.

The number of bacteria found in the effluent from Tank No. 3 has generally been very small, being in seven of the months less than ten, and averaging for the whole time thirty-nine. It is not probable that the conditions of so long a passage as has been stated would allow the continued existence of bacteria coming from the surface; and there seems to be little doubt that those found grew in the sand and gravel on the bottom of the tank, or in the underdrains and outlet pipe.

FILTER TANKS Nos. 15, 16, 17 AND 18.

Peat and Sand from Saugus Marshes.

These tanks were of galvanized iron, placed within the building, having an area equal to one twenty-thousandth of an acre. In the bottom of each tank was placed a layer of coarse gravel, upon which was a layer of fine gravel and then one of coarse sand, forming a depth of about six inches of material, which served as an underdrain to the filtering material above it. The filtering material consisted of a depth of five feet of sand and peat taken from the Saugus Marshes.

In Tank No. 15 this filtering material consisted of two and one-half feet of peat, overlying peaty sand and sand.

In Tank No 16 there was a depth of one and one-half feet of peat from the surface down, with peaty sand and clear sand in the lower three and one-half feet.

Tank No. 17 contained three and one-half feet of peat, underlaid with peaty sand and sand; and Tank No. 18 contained five feet in depth of peat, mixed with some very fine sand and some clay.

These tanks were prepared for the purpose of determining the ability of different sections of the Saugus Marshes for filtering sewage; and the results of the first six months of their use are contained in the report of the State Board of Health upon the sewerage of the Mystic and Charles River Valleys, published in Senate Document No. 2, January, 1889.

A summary of the results obtained in the earlier months of their use will be taken from that report.

As these materials were all found to be quite worthless for the filtration of sewage, it is not thought valuable to present the tables of daily results of analyses and observations; but the monthly averages of these results are contained in the following tables.

Monthly Averages of Daily Results with Filter Tank No. 15.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Number of Bacteria per Cubic Centimeter.
1888.											
May 5, . . .	Sewage,	-	22.4	26.8	1.6200	.6600	2.2800	4.3	.0050	.0000	-
May, . . .	Effluent,	1.96	-	-	.2582	.0287	.2869	532.2	.0055	.0000	5,125
June, . . .	Effluent,	1.50	143.7	613.7	.2717	.0354	.3071	356.8	.0053	.0001	68
July, . . .	Effluent,	1.35	18.8	289.5	.3606	.0640	.4246	149.1	.0066	.0000	194
August, . .	Effluent,	1.87	21.8	89.1	.1916	.1992	.3908	32.1	.0132	.0003	329
September, . .	Effluent,	.56	14.1	80.4	.3750	.1312	.5062	28.6	-	.0000	1,270
October, . .	Effluent,	.59	10.9	88.1	.6200	.1287	.7487	32.5	.0100	.0000	91
November, . .	Effluent,	.65	12.8	77.8	.9075	.1472	1.0547	23.6	.0100	.0000	70
December, . .	Effluent,	.65	8.1	67.3	1.0067	.1067	1.1134	15.4	.0090	.0000	257
1889.											
January, . .	Effluent,	.61	6.1	62.1	1.1975	.0967	1.2942	14.2	.0090	.0000	2,823
February, . .	Effluent.	.66	6.8	47.1	.9325	.0965	1.0290	10.4	.0072	.0000	10
March, . . .	Effluent,	.68	8.3	48.0	.8150	.1310	.9460	9.3	.0125	.0000	1,485
April, . . .	Effluent,	.41	14.8	41.6	.8600	.1580	1.0180	7.4	-	-	1,231

Monthly Averages of Daily Results with Filter Tank No. 16.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Number of Bacteria per Cubic Centimeter.
1888.											
May 5, . . .	Sewage,	-	22.4	26.8	1.6200	.6600	2.2800	4.3	.0050	.0000	-
May, . . .	Effluent,	1.67	-	-	.0440	.0202	.0642	751.2	.0057	.0000	2,058
June, . . .	Effluent,	.78	18.1	223.1	.0169	.0211	.0380	145.5	.0049	.0001	2,229
July, . . .	Effluent,	.42	5.8	144.7	.0017	.0765	.0782	64.5	.0067	.0000	1,304
August, . .	Effluent,	.21	17.2	124.4	.0120	.1462	.1582	44.7	.0133	.0000	326
September, . .	Effluent,	.20	11.0	107.3	.0090	.1380	.1470	34.1	-	.0000	665
October, . .	Effluent,	.28	10.3	98.6	.0527	.1033	.1560	29.1	-	.0000	378
November, . .	Effluent,	.28	9.2	141.6	.2022	.0523	.2545	31.5	.0433	.0046	82
December, . .	Effluent,	.29	7.1	127.9	.3843	.0547	.4390	22.4	.0090	.0000	8
1889.											
January, . .	Effluent,	.07	8.0	129.2	.3970	.0390	.4360	14.3	.0125	.0000	28
February, . .	Effluent,	.05	10.4	125.4	.3180	.0425	.3605	14.7	.0057	.0000	4
March, . . .	Effluent,	.04	24.6	183.4	.3940	.0435	.4375	14.1	.0075	.0041	51
April, . . .	Effluent,	.04	-	-	-	-	-	-	-	-	24

Monthly Averages of Daily Results with Filter Tank No. 17.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	
1888.											
May 25, . .	Sewage,	–	38.4	34.6	1.0300	.7200	1.7500	4.1	.0040	.0000	–
June, . . .	Effluent,	.67	812.3	3202.6	.0639	.0369	.1008	1823.1	.0076	.0000	53
July, . . .	Effluent,	.33	671.4	3034.3	.0523	.0429	.0952	1754.6	.0057	.0000	16,642
August, . .	Effluent,	.27	198.0	2262.0	.0162	.0464	.0626	1316.4	.0080	.0000	5,348
September, . .	Effluent,	.18	95.0	1558.7	.0092	.0440	.0532	826.0	.0125	.0000	7,981
October, . .	Effluent,	.20	40.5	785.0	.0020	.0625	.0645	435.0	.0112	.0000	12,667
November, . .	Effluent,	.15	25.5	457.0	.0060	.1400	.1460	248.0	.0285	.0000	26
December, . .	Effluent,	.17	52.7	350.7	.0147	.4323	.4470	173.7	.0175	.0000	42
1889.											
January, . .	Effluent,	.12	65.2	299.0	.0640	.8225	.8865	127.1	–	.0000	9
February, . .	Effluent,	.11	61.2	270.7	.0425	.9550	.9975	102.6	–	.0000	41
March, . . .	Effluent,	.10	68.0	224.0	.0600	1.0850	1.1450	84.1	–	.0000	1,937
April, . . .	Effluent,	.10	70.0	218.0	.0700	1.4000	1.4700	63.5	–	–	2,225

Monthly Averages of Daily Results with Filter Tank No. 18.

1888.											
May 25, . .	Sewage,	–	38.4	34.6	1.0300	.7200	1.7500	4.1	.0040	.0000	–
June, . . .	Effluent,	.16	995.0	4467.3	.5746	.0725	.6471	2505.1	.0050	.0002	13,150
July, . . .	Effluent,	.15	1098.6	4578.6	.5743	.0814	.6557	2654.3	.0069	.0000	31,909
August, . .	Effluent,	.14	606.0	4468.0	.5640	.0814	.6454	2625.5	0088	.0000	35,355
September, . .	Effluent,	.07	276.7	4640.0	.6067	.0770	.6837	2638.5	.0067	.0000	21,438
October, . .	Effluent,	.01	190.0	4570.0	.4930	.1120	.6050	2619.3	.0100	.0000	–
November, . .	Effluent,	.01	320.0	4485.0	.5300	.2100	.7400	2595.3	.0150	.0000	–
December, . .	Effluent,	.01	250.0	4680.0	.6200	.0600	.6800	2570.7	–	.0000	–

Tank No. 15, which allowed sewage to pass through it most freely, had sewage applied first on May 5, 1888, and was treated with sewage at the rate of 30,000 gallons per acre per day for three months, which flowed through with the slight decrease attributable to evaporation. This quantity did not keep the surface continuously covered. The quantity was increased to 60,000 gallons, which disappeared for three days and then began to accumulate upon the surface, and in the next two weeks an average flow of 45,000 gallons ensued; but the quantity flowing was growing less, and 30,000 gallons applied accumulated upon the surface. Then for two weeks 20,000 gallons — applied daily — accumulated; and all application of sewage was stopped until that upon the surface should disappear, which occurred in seven days (Sept. 5 to 11, 1888), in which time the average flow was at the rate of 15,600 gallons per acre per day. During the next week the rate of 11,400 gallons per acre did not keep the surface continually covered; but a daily application in the next four weeks of 12,860 gallons per acre kept the surface continually covered; and the effluent was at the rate of 12,000 gallons per acre per day. The same quantity was continued for the next five months (November, 1888, through March, 1889), keeping the surface covered nearly all the time; but in April, 1889, 10,000 gallons per acre kept the surface covered, and the amount of effluent was reduced to 8,200 gallons per acre per day.

The chlorine dissolved out of the salt marsh material was at first in the effluent 600 parts in 100,000. This decreased rapidly, until in August it averaged but 32 parts; after which it decreased more gradually, and became at the end of the year, in April, 1889, 7.4 parts, or but little higher than that of the sewage which had been applied.

The sum of the ammonias of the effluent increased in the first month from 0.10 parts to 0.30 parts, and continued increasing until in January, 1889, they amounted to 1.29 parts. After this they were somewhat lower, but averaged, in the three following months, one part per 100,000, and were, during the last six months, at about 50 per cent. of the sum of ammonias of the sewage.

The albuminoid ammonia increased from 0.0287 parts in May, 1888, to 0.1472 parts in November, and averaged in the last six months 0.1227 parts; being the highest at the last, in April, when it was 0.1580 parts.

The free ammonia increased from 0.2582 parts, in May, 1888, to 1.1975 parts in January, 1889; and averaged for the last six months 0.9532 parts.

The nitrates have been low throughout, and have varied from 0.0055 parts in May to 0.0132 parts in August, 1888; and for the last six months averaged 0.0095 parts. There have been no nitrites.

From the experiments with this material, continued through nearly a year, those of the last six months indicate that, with the application of 12,000 gallons a day to an acre, of this material, we may expect no nitrification; and the organic matter of the effluent, as indicated by the ammonias, will be as much as one-half of the organic matter of the sewage applied. From which we see that, while the quantity that can be filtered through an area of such material as this is so small as to make it undesirable for use in any filtering area, the resulting purification is also unsatisfactory.

FILTER TANK No. 16.

This tank of material from the Saugus Marshes had one and a half feet in depth of peat near the surface, with peaty sand and clear sand below.

Sewage was first applied on May 5, 1888. In the first week the quantity of the effluent was about seven-tenths of the quantity of sewage applied, and was the equivalent of 40,000 gallons per acre per day. In the last ten days of May the effluent amounted to three-fourths of the amount of sewage applied, and was equivalent to 22,000 gallons per acre per day.

During the month of June the surface of the tank was continually covered with sewage, increasing in depth from day to day, until it became about five inches deep. The quantity passing through decreased from the equivalent of 22,000 gallons to the equivalent of 6,000 gallons to an acre, averaging for the month about 16,000 gallons.

During the month of July enough sewage was applied to keep about five inches in depth upon the surface, and the quantity of effluent for the month averaged 8,400 gallons.

During August no sewage was applied for twenty-eight days, giving time for the five inches in depth upon the surface to disappear. The average quantity of effluent during this month was equivalent to 4,200 gallons per acre per day.

During September the quantity of sewage applied in the first three weeks was not quite sufficient to keep the surface continually covered, that there might be produced the effect of intermittent filtration. The quantity of effluent during this time was nearly constant, and amounted to the equivalent of 1,500 gallons per acre per day; but in the latter part of the time the peat near the surface shrank away from the sides of the tank, and allowed sewage to pass down through the crack, which was about one-eighth of an inch wide around nearly two-thirds of the circumference of the tank.

The quantity of sewage applied was increased, and at first about nine-tenths of it came through; but, the crack gradually closing up by the swelling peat and the deposit of slime, the quantity coming through was reduced to but one-fifth of that applied, and at the end of the month was the equivalent of 2,600 gallons per acre per day. This shrinking of the surface, forming cracks through which the sewage could flow without filtration or purification, rendered it impossible to continue intermittent filtration with this material; and during the month of October the surface was kept covered with sewage to the depth of from two to five inches. The quantity flowing through was the equivalent of 5,600 gallons per acre per day. Nearly the same quantity continued through November and December.

During January, 1889, sufficient sewage was applied to keep the surface covered about one inch in depth, and the quantity of effluent averaged but 1,400 gallons per acre per day; and, with the same depth upon the surface in the three following months, the quantity of effluent became still smaller, and averaged for the four months, from January to April, 1889, 1,000 gallons per acre per day,— which is equal to about one-third of the ordinary rainfall upon the same area.

An area of such material, after being used nine months for the filtration of sewage, becomes so nearly impervious that it would be unable to absorb the rain that would fall upon it, and would have no value for a filtration area.

The effluent which first came through contained 1,226 parts per 100,000 of chlorine; but at the end of May this quantity was reduced to 240 parts, averaging for the month 751 parts.

In June the chlorine formed but 145 parts, and in July was reduced to 64 parts; after which it decreased gradually to 22 parts in December, 1888, and in the three months in 1889 averaged 14.4 parts per 100,000.

The nitrates have generally been low, averaging, in the first four months, 0.0076 parts; but they increased for a short time in November to 0.0600 parts, but soon fell off, and in December averaged 0.0090 parts, and in the three months of 1889 averaged but 0.0086 parts.

The nitrites during 1888 were generally absent, except in the month of November, when, on one occasion, they rose to 0.0150 parts; but disappeared in the next month, and continued absent through January and February, and were 0.0041 parts in March, 1889.

The sum of ammonias of the effluent increased from an average of 0.0642 parts in May to 0.4390 parts in December, 1888; after which time they continued nearly constant, averaging, for the three months of 1889, 0.4113 parts.

The free ammonia was variable; but low from June through September, averaging 0.0099 parts. After this it increased rapidly to 0.3843 parts in December, and continued in the next three months at nearly the same quantity.

The albuminoid ammonia increased from 0.0202 parts in May to 0.1462 parts in August; after which it decreased to 0.0547 parts in December, and averaged 0.0417 parts in the first three months of 1889.

We have in this tank, after nine months of application of sewage, no nitrification, and very unsatisfactory removal of organic matter, there still remaining in the effluent about one-fifth of the organic matter of the sewage; and the quantity filtering is so extremely small as to render this material worthless for filtration.

FILTER TANK No. 17.

Filter Tank No. 17 contained three and a half feet of peat, underlaid with one and a half feet of peaty sand and sand.

Sewage was first applied May 25, 1888; and thereafter continually covered the surface, excepting on a few days in August. The quantity of sewage which settled into the peat is very small; and the water, that had been held by the material, which flowed out from the bottom, amounted to the following rates per acre per day: in June, 13,400 gallons; in July, 6,600 gallons; in August, 5,400 gallons; in September, 3,600 gallons; in October, 4,000 gallons; in November, 3,000 gallons; and in December, 3,400 gallons. In the first four months of 1889 it decreased to 2,000 gallons, and averaged 2,150 gallons per acre per day.

The chlorine amounted to 1,823 parts per 100,000 in June; and its constancy through the month indicated that no sewage reached the bottom from the surface. In the latter part of July a reduction of chlorine to 1,550 parts indicated that, at that time, about one-sixth part of the effluent was from sewage. In September the chlorine indicated that about one-half of the effluent was from sewage; and in December the sewage formed about nine-tenths of the effluent. After this the chlorine continued to decrease, being 127 parts in January and 63 parts in April.

The nitrates increased from 0.0076 parts in June to 0.0285 parts in November; and decreased to 0.0175 parts in December; after which time they were not observed. There were no nitrites at any time.

When sewage began to reach the outlet in small quantities, the sum of ammonias of the effluent began to increase, and continued increasing for the next nine months through which observations were continued, until they amounted to 1.4700 parts per 100,000, which was about three-fourths of the sum of ammonias of the sewage which had been applied.

In this tank the free ammonia was generally much lower than in the other tanks of material from the Saugus Marshes. It decreased from 0.0639 parts in June, 1888, to 0.0020 parts in October, and then increased; and in the first four months of 1889 averaged 0.0591 parts, being the highest in the last month, when it was 0.0700 parts.

The albuminoid ammonia, on the other hand, continued increasing, — throughout the time of using the tank, — from 0.0369 parts in June, 1888, to 1.4000 parts in April, 1889, and averaged, for the four months of 1889, 1.0606 parts.

This material also proved to be entirely unsatisfactory as a filter, both from the small quantity of sewage that would pass through it, — being considerably less than the annual rainfall upon its surface, — and from the very large part of the organic matter from the sewage which remained in the effluent.

FILTER TANK No. 18.

Filter Tank No. 18 contained five feet in depth of peat mixed with some very fine sand and some clay, from the Saugus Marshes. Sewage was first applied to this tank on May 25, 1888.

The chlorine of the effluent was very high, as this material was obtained from near the edge of the marsh, where it was continually saturated with sea water, and frequently overflowed. At first the chlorine of the effluent amounted to 2,290 parts; but this increased before the end of June to 2,632 parts; and continued increasing till the sixth of July, when it amounted to 2,682 parts. After this it was nearly constant for four months, continuing above 2,600 parts. In November the chlorine amounted to 2,595 parts; and in December, 2,570 parts; and averaged, for the seven months, 2,601 parts.

The nitrates were very low, but increased from 0.0050 parts in June to 0.0150 parts in November, averaging 0.0087 parts; and there were no nitrites.

During June and July the surface was kept continually covered with sewage, and the effluent averaged the equivalent of 3,200 gallons per acre per day, in June, and 3,000 gallons in July.

On August 1 sewage was about two inches deep upon the surface; and none was applied until this disappeared, on August 12. For the next two weeks only sufficient sewage was applied to keep the surface covered about half of the time. The quantity of effluent during this month averaged 2,800 gallons per acre per day. During the month of September the sewage applied was not quite sufficient to keep the surface continually covered, and the amount of effluent averaged 1,400 gallons per acre per day; but in the three following months, October to December, with the surface covered from one-half inch to one and three-fourths inches in depth, the quantity of effluent averaged but 200 gallons per acre per day.

The sum of ammonias of the effluent slightly increased during the seven months, from 0.6471 parts in June to 0.6800 parts in December, averaging 0.6653 parts. The free ammonia was nearly constant, and averaged 0.5661 parts. The albuminoid ammonia varied from 0.0600 parts to 0.2100 parts, and averaged 0.0992 parts.

The quantity of sewage that can be passed through five feet in depth of this material, when it is completely underdrained, being but one-fifteenth of the quantity of rain that would fall upon this surface, rendered it entirely useless for filtration.

The conclusions in regard to filtering through peat, made by the Board when these experiments were about half finished, are fully supported by the results obtained on concluding the experiments. These conclusions were as follows: —

The experiments upon this material prove to the Board that an area of sand covered with peat to the depth of even one foot is unsuitable to be used for a filtration area. They indicate that, if so used, the surface will become covered with a slime which will prove a nuisance; that sewage applied to such an area in winter will have to remain so long upon the surface that it will freeze, and the whole become inoperative; that, under the most favorable circumstances, the quantity of sewage which can flow through the peat is so small, and the effluent so little improved by passing, that it is not expedient to use it for this purpose; and that the only way to render such an area suitable for filtration is to remove the peat entirely from the sand, and apply the sewage directly to the sand.

Bacteria in the Effluent of Tanks No. 15, 16, 17 and 18.

A table of the number of bacteria counted in effluent from these tanks may be found at the end of this section. The monthly averages of these counts are in the table near the beginning of this section.

When the water that came through the sand was draining from these tanks, the number of bacteria was at first high, excepting in that from Tank No. 18, which at first was low, but rapidly increased.

The number at first in the effluent from Tank No. 15 was 18,480; from Tank No. 16, 7,392; and from Tank No. 17, 1,584; but these numbers immediately decreased. In the effluent from Tank No. 15, after the first few weeks, the average number for the eleven months was 712; being less than a hundred in four of the months, and in the coldest month — February — the number was 10 per cubic centimeter.

The number of bacteria that exists in the sewage remaining upon the top of the tanks is generally much reduced from the number in the sewage when it is first applied. Sometimes one-half of the original number may be found, and sometimes a smaller fraction.

The average number found during the whole time in the effluent from Tank No. 15 may be taken as about 1 in 500 of the number in the sewage upon the surface; and, whether any of these came through the peat from the surface, or grew in the underdrains, we have no means of distinguishing.

In the effluent from Filter Tank No. 16 the number found in the first two months was about 2,000. The number decreased, until, in November, 1888, it averaged but 82; and in the five following months the average number was 23 per cubic centimeter. It appears probable that, in the last five months, none of the bacteria of the applied sewage survived the long passage; but that the small number found in the effluent grew in the underdrains, where there was an abundance of food in the large amount of nitrogenous matter then in the effluent.

In the effluent from Tank No. 17 the number at first counted was 1,584; but this number was immediately reduced, and averaged for June, 1888, 53. The chlorine of the effluent in July indicated that a small quantity of sewage, perhaps four per cent. of the effluent, then reached the outlet; and the number of bacteria increased in the first half of the month to 33,682, after which the number decreased, and averaged for the month 16,642. The number remained high through August, September and October, averaging for the four months, July to October, 10,660.

At the end of this time the chlorine of the effluent indicated that about five-sixths of it was from sewage. After this the number of bacteria immediately decreased to very small numbers, and averaged 26 for November; and for the four months, November to February, 1889, the average number was but 29. In March, on one day, the number found was 3,780, and the average for the month was 1,937. In April, on one day, 8,890 were found; on three other days the number was but four.

In the effluent of Tank No. 18 the number increased, in two weeks, from 20 at the first count to 28,800; and averaged for the month of June, 13,150. In the four months from June to September the average number was 25,463; and, as there was no diminution in the chlorine of the effluent during these months, it is quite certain that no sewage came from the surface of the tank, and consequently that no bacteria came down from the surface; and these large numbers must have grown either in the sand in the lower part of the tank, or in the gravel and underdrains at the bottom.

The increase from the very small number at first to large numbers at the end of two weeks, when no liquid could have come down from the surface, indicates that the conditions for growth of bacteria were favorable in the lower part of this tank or its underdrains; and, there being a larger number in the effluent from this tank than from either of the other tanks containing peat, renders it quite probable that the bacteria found in the effluent from each of these tanks grew near the bottom, where they could receive air from the outlet pipes, and did not come down through the filter, after the liquid had drained out which was originally in the filtering material.

Number of Bacteria found in the Effluent from Tanks Nos. 15, 16, 17 and 18.

Date.	Number of Bacteria per Cubic Centimeter.			
	Tank No. 15.	Tank No. 16.	Tank No. 17.	Tank No. 18.
1888.				
May 10, . .	18,480	7,392	–	–
12, . .	4,242	96	–	–
19, . .	–	575	–	–
22, . .	2,589	2,016	–	–
26, . .	312	1,496	1,584	–
29, . .	0	774	37	20
June 2, . .	–	932	–	5,425
7, . .	–	274	23	8,352
12, . .	158	9,840	98	28,800
16, . .	9	57	50	71
29, . .	38	40	42	23,100
July 5, . .	–	1,480	5,431	4,410
10, . .	39	3,724	–	37,270
14, . .	278	1,912	33,682	76,345
19, . .	–	440	–	–
24, . .	–	183	20,736	–
28, . .	265	86	6,720	9,610
Aug. 4, . .	272	135	4,890	11,742
14, . .	243	180	5,807	–
18, . .	406	664	–	58,968
23, . .	397	–	–	–
Sept. 13, . .	298	642	3,482	6,122
18, . .	1,072	1,490	–	–
22, . .	912	321	9,660	17,391
27, . .	2,798	208	10,800	40,800
Oct. 4, . .	408	272	50,657	–
9, . .	24	467	–	–
13, . .	16	377	0	–
23, . .	4	469	9	–
27, . .	1	307	2	–
Nov. 1, . .	148	317	7	–
6, . .	12	5	4	–
10, . .	41	22	2	–
16, . .	55	12	3	–
1888—Con.				
Nov. 21, . .	4	9	–	–
26, . .	163	126	114	–
Dec. 7, . .	7	0	118	–
12, . .	3	9	–	–
17, . .	198	17	5	–
26, . .	819	7	4	–
1889.				
Jan. 2, . .	3,520	40	4	–
8, . .	576	2	0	–
15, . .	798	49	0	–
22, . .	9,216	19	–	–
29, . .	7	32	33	–
Feb. 6, . .	22	1	–	–
12, . .	8	4	1	–
19, . .	8	9	–	–
27, . .	2	1	82	–
Mar. 5, . .	4	3	–	–
12, . .	1,365	70	3,780	–
19, . .	2,352	3	95	–
26, . .	2,220	130	–	–
April 2, . .	1,764	–	–	–
9, . .	3,255	0	8,890	–
16, . .	820	30	5	–
24, . .	28	0	5	–
30, . .	289	66	2	–
May 7, . .	121	9	15,768	–
14, . .	41	22	7	–
21, . .	0	7	3,770	–
28, . .	9	0	1	–
June 4, . .	13	61	1	–
11, . .	9	2	1	–
18, . .	33	10	8	–
26, . .	4	2	0	–

FILTER TANK No. 15A.

Very Coarse, Clean Gravel.

The peat and sand which had been used as a filter in Tank No. 15, from May, 1888, to June, 1889, were, on June 28, removed from the tank; and, after being washed, the tank was filled with gravel, none of the stones of which were less than three-fourths of an inch in diameter, nor more than one and one-fourth inches. The filter thereafter being of entirely different material, will be designated as Tank No. 15A. This gravel had been carefully washed, so that there should be no sand attached to the stones. It was then spread out, that the water might drain from it, and was put into the tank damp. After standing ten days, with the outlet open, the outlet was closed, and the gravel which occupied the space of 90 gallons was filled with 33 gallons of sewage. The sewage then occupied 37 per cent. of the space. After standing twenty-four hours, the tank was drained, and 31 gallons flowed out within half an hour, and in the next twenty-four hours one-half a gallon more dropped slowly from the outlet. The tank was again filled with 31.44 gallons of sewage, 31 gallons of which flowed out rapidly in fifteen minutes; and in the course of the next week a sufficient quantity dropped out to make the whole quantity drained from the tank 31.52 gallons. From this time, July 23, 1889, one-half gallon of sewage was applied to the tank daily, — except Sundays, — until August 16; after which the quantity was doubled.

It appears, from the filling and draining of the tank, that a little more than 1.5 gallons of liquid is held by the stones, after being thoroughly drained, and that all but two gallons will run out in a short time after being applied. When sewage was applied every day, the amount applied went into the tank containing 90 gallons of gravel, in which were 31 gallons of air and two gallons of liquid.

No analyses of the effluent were made until August 5, when, as stated above, sewage had filled the tank twice, and then had been allowed to drain from the tank for about two weeks, and had afterward been applied at the rate of one-half gallon a day, on twelve days. The first analysis was as follows : —

Free ammonia,	0.3400
Albuminoid ammonia,	0.0320
Chlorine,	4.53
Nitrates,	4.2500
Nitrites,	0.0600

It will be seen that at this time the ammonias were high, and the nitrates very high ; but, as this effluent contains nearly twice as much nitrogen as was contained in the sewage at any time since its application began, and the amount of nitrogen which came out in the effluent in the next eleven days is greater than the whole amount applied up to that time since the one-half gallon began to be regularly applied on July 23, we must conclude that the nitrogen at this time being removed must be in part from the organic matter held back by the gravel, when it was saturated, on July 9 and 12, with sewage which on the two days amounted to sixty-four gallons. There being so much nitrogen stored in the tank at this time, it is probable that the nitrification began but a few days before this first analysis. We can, however, safely conclude that it began within three weeks of the time of first applying sewage to the gravel.

The results of chemical analyses of the effluent, and the daily observations upon this tank, are given in tables at the end of this section.

The monthly averages of the chemical analyses of the effluent and of the sewage applied to this tank are given in the following table, which contains also the daily quantity of effluent and its temperature and the number of bacteria found in a cubic centimeter : —

Monthly Averages of Daily Results with Tank No. 15 A.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1889.												
July 27–Aug. 12,	Sewage, .	–	23.25	43.82	2.0858	.5975	2.6833	4.94	.0000	.0000	71°	–
Aug. 1–16, . .	Effluent, .	.44	3.13	37.00	.1426	.0214	.1640	4.31	5.1100	.0215	–	78
	Per cent.,	–	13	84	7	4	6	–	–	–	–	–
Aug. 13–Oct. 3, .	Sewage, .	–	30.83	42.01	1.8892	.8536	2.7428	5.41	.0000	.0001	–	–
Aug. 17–Oct. 6, .	Effluent, .	.81	2.20	30.00	.0818	.0398	.1216	5.98	2.2778	.0011	67°	6,125
	Per cent.,	–	7	71	4	5	4	–	–	–	–	–
Oct. 4–29, . .	Sewage, .	–	–	–	1.8833	.7472	2.6305	4.73	.0007	.0002	–	–
Oct. 7–31, . .	Effluent, .	.88	–	–	.1217	.0356	.1573	6.60	31.0125	.0047	52°	80
	Per cent.,	–	–	–	6	5	6	–	–	–	–	–
Oct. 30–Nov. 28,	Sewage, .	–	25.00	25.97	2.0812	.6050	2.6862	5.65	.0000	.0000	–	–
November, .	Effluent, .	.89	9.40	84.40	.5620	.0644	.6264	6.16	1.1100	.0022	50°	64
	Per cent.,	–	38	325	27	11	23	–	–	–	–	–
Nov. 29–Dec. 28,	Sewage, .	–	–	–	1.1559	.4694	1.6253	5.15	.0071	.0006	–	–
December, .	Effluent, .	.87	–	–	.9000	.0575	.9575	5.76	.3325	.0015	44°	341
	Per cent.,	–	–	–	78	12	59	–	–	–	–	–
1890.												
Dec. 29–Jan. 29,	Sewage, .	–	32.79	23.91	1.4378	.6248	2.0626	4.74	.0000	.0000	–	–
January, . .	Effluent, .	.79	9.40	106.60	1.1900	.0760	1.2660	5.26	.1520	.0015	42°	608
	Per cent.,	–	29	447	83	12	61	–	–	–	–	–
Jan. 30–Feb. 26,	Sewage, .	–	–	–	1.5950	.8337	2.4287	4.55	.0000	.0001	–	–
February, . .	Effluent, .	.89	–	–	1.5000	.0700	1.5700	4.49	.0825	.0015	42°	880
	Per cent.,	–	–	–	94	8	65	–	–	–	–	–

After August 16 the quantity of sewage applied daily was increased to one gallon. This was continued through the year. The nitrates, which were then 4.7000 parts, decreased to 3.0000 parts at the end of the month, and in the month of September continued decreasing, till they formed but 1.0000 parts; but on October 5 they again increased to 2.1000 parts. The free ammonia decreased from 0.3400 parts at the first analysis to 0.0470 parts on August 16; after which it increased to 0.1670 parts on September 7, and again decreased to 0.0040 parts on September 23; after which it rose to 0.0264 parts on October 5. The albuminoid ammonia decreased from 0.0320 parts at the first analysis to 0.0130 parts on August 16; after which it increased, but varied from 0.0280 parts to 0.0700 parts on September 18; after which it was lower, and on October 5 was 0.0300 parts. During the last two weeks of this time, the sum of ammonias of the effluent averaged but one per cent. of those of the sewage, and the nitrates averaged 1.6000 parts per 100,000.

There was, after two and a half months' application of sewage to this coarse gravel, a very satisfactory purification, and a good degree of nitrification.

Saltpetre added to the Sewage applied.

For the five days after October 7, saltpetre was dissolved in the sewage, in sufficient quantity to give 72 parts of nitrogen per 100,000. In two days the nitrates increased to 27 parts per 100,000, and on the third and fourth days were 64 parts per 100,000. This saltpetre was discontinued after the fifth day, and, twelve days after the first was applied, the nitrates had fallen to 15 parts per 100,000.

Sulphuric Acid added to the Sewage.

From Oct. 22, 1889, to the end of the observations, sulphuric acid was added to the sewage in sufficient quantity to equal 22.54 parts per 100,000 of sulphuric acid in the solution. This was done to see whether nitrification would continue with the sewage which contained an excess of acid. It was begun when the nitrates of the effluent from the saltpetre, which had been previously added, amounted to about 10 parts per 100,000; and they of course rapidly decreased, and by the end of November were 0.4000 parts. From this time they have been continually decreasing, except for a short time in December, when they increased to 0.4900 parts, and again decreased to 0.1000 parts at the last of January, 1890, and to 0.0700 parts at the last of February.

The free ammonia increased quite steadily to 0.6000 parts in the last of November, and became 1.0000 parts the last of December, from which it increased to 1.6000 parts in January, and averaged 1.5000 parts in February.

The albuminoid ammonia increased and decreased, averaging 0.0644 parts in November, 0.0575 parts for December, 0.0760 parts for January, and 0.0700 parts for February. The sum of ammonias increased until in February they became about two-thirds of the sum of ammonias of the sewage; but the albuminoid ammonia of the effluent was then but one-twelfth of that of the sewage.

Although Nitrification was checked by Acid in Sewage, Marked Purification continued.

For four months nitrification continued in decreasing amount, with a strongly acid solution of sewage. The amount of acid evidently interfered seriously with the purification of the sewage; but the part of the sewage which can putrefy — the albuminoid ammonia —

decreased to only eight per cent.; so that, while nitrification was checked, a very decided step in the purification of the sewage continued.

We learn from this experiment that sewage containing a large percentage of sulphuric acid may have a large part of its organic matter removed by intermittent filtration for a considerable time; so that we may not expect an unfavorable result if sewage having an excess of acid be occasionally applied to a filtration area; but, if it is to be constantly applied, it should be neutralized by lime or some alkali.

Bacteria in the Effluent of Tank No. 15 a.

A table of bacteria follows the table of chemical analyses. The monthly averages may be found in a previous table.

In the first half of August, 1889, when the ammonias were high and the nitrates very high, the number of bacteria in the effluent averaged but 81. In the latter part of the month, when the ammonias were lower, and the nitrates, though lower, were still high, the average number found was 5,640. In September, with a varying but fair degree of purification, the number of bacteria averaged 9,967 per cubic centimeter.

While applying saltpetre in large quantities to the tank in October, the number found in the effluent was 31. At this time the nitrates of the effluent were 64 per 100,000. A week later the number was 168. Three days after sulphuric acid was first applied, the number in the effluent was 40; and, while continuing to apply the acid through November, the average number was 64. With the acid in the effluent somewhat stronger in December, the number of bacteria counted averaged 341. In January the number was 608, and in February 880. During the four months in which the acid was applied with the sewage, the number of bacteria in the sewage averaged 500,000, and the average number in the effluent was equal to about one in 1,000 of those applied. During this time, while the ammonias were very high and the nitrates low, the addition of acid appeared to be an unfavorable condition for the existence of bacteria; but during the last two months, when the nitrates became very low and the ammonias nearly as high as those of the sewage, there was an increase in the number of bacteria in the effluent, reaching on one day as high as one per cent. of the number in the sewage, but generally being less than one-tenth of one per cent.

CHEMICAL ANALYSES OF THE EFFLUENT,

AND

DAILY OBSERVATIONS

Upon Filter Tank No. 15A.

July, 1889.

The quantity of sewage applied and effluent from tank in gallons were as follows: —

Date.	Quantity Applied.	Quantity of Effluent.	Date.	Quantity Applied.	Quantity of Effluent.	Date.	Quantity Applied.	Quantity of Effluent.
9, ...	32.76	-	17, ...	-	.04	25, ...	.50	.47
10, ...	.32	31.42	18, ...	-	.04	26, ...	.50	.47
11, ...	-	.15	19, ...	-	.03	27, ...	.50	.45
12, ...	31.27	-	20, ...	-	.04	28, ...	-	.19
13, ...	.17	31.02	21, ...	-	.01	29, ...	.50	.35
14, ...	-	.17	22, ...	-	.03	30, ...	.50	.49
15, ...	-	.08	23, ...	.50	.10	31, ...	.50	.51
16, ...	-	.06	24, ...	.50	.36			

Total effluent to end of month, 66.48 gallons.

Filter Tank No. 15 A — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	.50	.51	–	–	–	–	–	–	–	–	72°	–
2, ...	.50	.57	–	–	–	–	–	–	–	–	72°	–
3, ...	.50	.52	–	–	–	–	–	–	–	–	72°	–
4, ...	–	.25	–	–	–	–	–	–	–	–	–	–
5, ...	.50	.28	2.20	35.30	.3400	.0320	.3720	4.53	4.2500	.0600	71°	–
6, ...	.50	.47	–	–	–	–	–	–	–	–	–	–
7, ...	.50	.50	–	–	–	–	–	–	–	–	71°	–
8, ...	.50	.47	–	–	–	–	–	–	–	–	72°	–
9, ...	.50	.47	3.60	37.80	.1340	.0220	.1560	4.31	5.5000	.0190	71°	–
10, ...	.50	.49	3.60	37.80	.1100	.0200	.1300	4.22	5.7000	.0220	71°	–
11, ...	–	.22	–	–	–	–	–	–	–	–	–	–
12, ...	.50	.26	–	–	–	–	–	–	–	–	70°	–
13, ...	.50	.52	–	–	–	–	–	–	–	–	–	–
14, ...	.50	.47	–	–	.0820	.0200	.1020	4.23	5.4000	.0040	68°	–
15, ...	.50	.47	–	–	–	–	–	–	–	–	65°	–
16, ...	.50	.52	–	–	.0470	.0130	.0600	4.27	4.7000	.0024	68°	–
17, ...	1.00	.98	–	–	–	–	–	–	–	–	69°	–
18, ...	–	.24	–	–	–	–	–	–	–	–	–	–
19, ...	1.00	.74	–	–	–	–	–	–	–	–	68°	69°
20, ...	1.00	.98	–	–	–	–	–	–	–	–	–	72°
21, ...	1.00	.92	–	–	.0790	.0510	.1300	4.51	3.2000	.0025	69°	70°
22, ...	1.00	.98	–	–	–	–	–	–	–	–	70°	73°
23, ...	1.00	.99	–	–	–	–	–	–	–	–	70°	70°
24, ...	1.00	.71	–	–	–	–	–	–	–	–	71°	69°
25, ...	–	.25	–	–	–	–	–	–	–	–	–	–
26, ...	1.00	.77	–	–	–	–	–	–	–	–	70°	68°
27, ...	1.00	.86	–	–	–	–	–	–	–	–	–	67°
28, ...	1.00	.94	–	–	.0700	.0430	.1130	6.71	3.0000	.0010	71°	67°
29, ...	1.00	.94	–	–	–	–	–	–	–	–	70°	67°
30, ...	1.00	.91	–	–	–	–	–	–	–	–	71°	70°
31, ...	1.00	.93	–	–	–	–	–	–	–	–	72°	72°

Effluent colorless, from clear to decidedly turbid, and with little or no sediment.
Total effluent to end of month, 85.61 gallons.

Filter Tank No. 15 A—Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	-	.25	-	-	-	-	-	-	-	-	-	-
2, ...	1.00	.74	-	-	-	-	-	-	-	-	71°	70°
3, ...	1.00	1.00	2.20	30.00	.1360	.0280	.1640	5.76	2.8000	.0006	-	71°
4, ...	1.00	.95	-	-	-	-	-	-	-	-	-	72°
5, ...	1.00	.96	-	-	-	-	-	-	-	-	72°	69°
6, ...	1.00	.99	-	-	-	-	-	-	-	-	71°	74°
7, ...	1.00	.94	-	-	.1670	.0540	.2210	5.57	2.4000	.0014	72°	70°
8, ...	-	.22	-	-	-	-	-	-	-	-	-	-
9, ...	1.00	.73	-	-	-	-	-	-	-	-	72°	69°
10, ...	1.00	.92	-	-	-	-	-	-	-	-	-	66°
11, ...	1.00	.95	-	-	.1580	.0460	.2040	6.70	2.5000	.0012	70°	64°
12, ...	1.00	.95	-	-	-	-	-	-	-	-	68°	66°
13, ...	1.00	.97	-	-	-	-	-	-	-	-	68°	66°
14, ...	1.00	.96	-	-	-	-	-	-	-	-	67°	67°
15, ...	-	.23	-	-	-	-	-	-	-	-	-	-
16, ...	1.00	.80	-	-	-	-	-	-	-	-	68°	73°
17, ...	1.00	.97	-	-	-	-	-	-	-	-	-	72°
18, ...	1.00	.93	-	-	.0800	.0700	.1500	5.91	1.8000	.0010	69°	68°
19, ...	1.00	.88	-	-	-	-	-	-	-	-	-	62°
20, ...	1.00	.98	-	-	-	-	-	-	-	-	-	65°
21, ...	1.00	.98	-	-	-	-	-	-	-	-	-	63°
22, ...	-	.28	-	-	-	-	-	-	-	-	-	-
23, ...	1.00	.68	-	-	.0040	.0146	.0186	5.52	1.7000	.0004	-	61°
24, ...	1.00	.98	-	-	-	-	-	-	-	-	-	63°
25, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	62°
26, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	65°
27, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	61°
28, ...	1.00	.98	-	-	.0162	.0212	.0374	6.03	1.0000	.0006	-	57°
29, ...	-	.28	-	-	-	-	-	-	-	-	-	-
30, ...	1.00	.73	-	-	-	-	-	-	-	-	-	61°

Effluent colorless, with from slight to great turbidity and little or no sediment.

After September 19, one-half of the sewage applied was put on in the forenoon and one-half in the afternoon.

Total effluent to end of month, 109.84 gallons.

Filter Tank No. 15 A — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	63°
2, ...	1.00	.97	-	-	-	-	-	-	-	-	-	59°
3, ...	1.00	.98	-	-	-	-	-	-	-	-	-	59°
4, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	60°
5, ...	1.00	.93	-	-	.0264	.0300	.0564	7.09	2.1000	.0014	-	55°
6, ...	-	.30	-	-	-	-	-	-	-	-	-	-
7, ...	1.00	.75	-	-	-	-	-	-	-	-	-	57°
8, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	54°
9, ...	1.00	1.02	-	-	.0996	.0300	.1296	6.67	27.0000	.0050	-	53°
10, ...	1.00	1.00	-	-	.1110	.0410	.1520	6.62	64.0000	.0030	-	53°
11, ...	1.00	1.00	-	-	.1380	.0480	.1860	6.55	64.0000	.0100	-	53°
12, ...	1.00	.99	-	-	.1420	.0360	.1780	6.37	60.0000	.0100	-	54°
13, ...	-	.27	-	-	-	-	-	-	-	-	-	-
14, ...	1.00	.71	-	-	-	-	-	-	-	-	-	49°
15, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	53°
16, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	53°
17, ...	1.00	1.01	-	-	-	-	-	-	-	-	-	54°
18, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	55°
19, ...	1.00	1.01	-	-	.0740	.0220	.0960	5.97	15.0000	.0020	-	53°
20, ...	-	.30	-	-	-	-	-	-	-	-	-	-
21, ...	1.00	.73	-	-	-	-	-	-	-	-	-	50°
22, ...	1.00	1.01	-	-	-	-	-	-	-	-	-	51°
23, ...	1.00	1.03	-	-	.0700	.0270	.0970	6.22	9.5000	.0016	-	47°
24, ...	1.00	1.01	-	-	-	-	-	-	-	-	-	47°
25, ...	1.00	1.05	-	-	-	-	-	-	-	-	-	50°
26, ...	1.00	1.04	-	-	.1940	.0520	.2460	6.72	5.0000	.0016	-	52°
27, ...	-	.30	-	-	-	-	-	-	-	-	-	-
28, ...	1.00	.79	-	-	-	-	-	-	-	-	-	54°
29, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	51°
30, ...	1.00	1.01	-	-	.1450	.0290	.1740	7.67	3.6000	-	-	49°
31, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	51°

Effluent colorless, from clear to decidedly turbid, and generally with slight sediment.

October 7 to October 12. — Potassium nitrate (saltpetre) added to sewage, equivalent to 72 parts of nitrogen per 100,000. After October 22. — Sulphuric acid added to sewage, equivalent to 22.5 parts per 100,000.

Total effluent to end of month, 137.14 gallons.

Filter Tank No. 15 A — Continued.

November, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	1.00	1.01	-	-	-	-	-	-	-	-	-	52°
2, ...	1.00	1.05	-	-	.3300	.0420	.3720	7.12	2.2000	.0012	-	52°
3, ...	-	.31	-	-	-	-	-	-	-	-	-	-
4, ...	1.00	.74	-	-	-	-	-	-	-	-	-	54°
5, ...	1.00	.98	-	-	-	-	-	-	-	-	-	48°
6, ...	1.00	1.01	-	-	-	-	-	-	-	-	-	47°
7, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	52°
8, ...	1.00	1.05	-	-	-	-	-	-	-	-	-	52°
9, ...	1.00	1.04	9.40	84.40	.5300	.1400	.6700	6.02	1.3000	.0010	-	52°
10, ...	-	.31	-	-	-	-	-	-	-	-	-	-
11, ...	1.00	.89	-	-	-	-	-	-	-	-	-	51°
12, ...	1.00	1.04	-	-	-	-	-	-	-	-	-	53°
13, ...	1.00	1.04	-	-	-	-	-	-	-	-	-	54°
14, ...	1.00	1.05	-	-	-	-	-	-	-	-	-	56°
15, ...	1.00	.94	-	-	-	-	-	-	-	-	-	49°
16, ...	1.00	.98	-	-	.6000	.0500	.6500	5.87	.9000	.0014	-	47°
17, ...	-	.30	-	-	-	-	-	-	-	-	-	-
18, ...	1.00	.76	-	-	-	-	-	-	-	-	-	48°
19, ...	1.00	1.01	-	-	-	-	-	-	-	-	-	49°
20, ...	1.00	1.06	-	-	-	-	-	-	-	-	-	50°
21, ...	1.00	1.04	-	-	-	-	-	-	-	-	-	51°
22, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	50°
23, ...	1.00	1.04	-	-	.7500	.0300	.7800	5.57	.7500	.0016	-	50°
24, ...	-	.32	-	-	-	-	-	-	-	-	-	-
25, ...	1.00	.76	-	-	-	-	-	-	-	-	-	49°
26, ...	1.00	.98	-	-	-	-	-	-	-	-	-	47°
27, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	45°
28, ...	1.00	1.04	-	-	-	-	-	-	-	-	-	47°
29, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	48°
30, ...	1.00	.96	-	-	.6000	.0600	.6600	6.22	.4000	.0060	-	42°

Effluent colorless, with from very slight to great turbidity, and generally no sediment.
Total effluent to end of month, 163.94 gallons.

Filter Tank No. 15 A—Continued.

December, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1,	-	.27	-	-	-	-	-	-	-	-	-	-
2,	1.00	.80	-	-	-	-	-	-	-	-	-	44°
3,	1.00	1.00	-	-	-	-	-	-	-	-	-	44°
4,	1.00	1.00	-	-	-	-	-	-	-	-	-	40°
5,	1.00	1.04	-	-	-	-	-	-	-	-	-	42°
6,	1.00	1.06	-	-	-	-	-	-	-	-	-	43°
7,	1.00	1.06	-	-	.6500	.0600	.7100	5.43	.2500	.0006	-	45°
8,	-	.30	-	-	-	-	-	-	-	-	-	-
9,	1.00	.78	-	-	-	-	-	-	-	-	-	49°
10,	1.00	1.00	-	-	-	-	-	-	-	-	-	46°
11,	1.00	1.01	-	-	-	-	-	-	-	-	-	46°
12,	1.00	1.03	-	-	-	-	-	-	-	-	-	44°
13,	1.00	1.04	-	-	-	-	-	-	-	-	-	45°
14,	1.00	1.00	-	-	1.0000	.0800	1.0800	5.23	.3000	.0018	-	40°
15,	-	.31	-	-	-	-	-	-	-	-	-	-
16,	1.00	.79	-	-	-	-	-	-	-	-	-	43°
17,	1.00	1.04	-	-	-	-	-	-	-	-	-	43°
18,	1.00	1.04	-	-	-	-	-	-	-	-	-	43°
19,	1.00	1.07	-	-	-	-	-	-	-	-	-	47°
20,	1.00	1.03	-	-	-	-	-	-	-	-	-	47°
21,	1.00	1.04	-	-	.9500	.0400	.9900	5.50	.4900	.0020	-	49°
22,	-	.32	-	-	-	-	-	-	-	-	-	-
23,	1.00	.74	-	-	-	-	-	-	-	-	-	43°
24,	1.00	1.04	-	-	-	-	-	-	-	-	-	44°
25,	1.00	1.15	-	-	-	-	-	-	-	-	-	-
26,	1.00	.97	-	-	-	-	-	-	-	-	-	46°
27,	1.00	.98	-	-	-	-	-	-	-	-	-	43°
28,	1.00	1.05	-	-	1.0000	.0500	1.0500	6.87	.2900	.0016	-	44°
29,	-	.34	-	-	-	-	-	-	-	-	-	-
30,	1.00	.86	-	-	-	-	-	-	-	-	-	44°
31,	1.00	.88	-	-	-	-	-	-	-	-	44°	42°

Effluent colorless, generally clear or nearly so, and with no sediment or some white flocculent.
Total effluent to end of month, 190.98 gallons.

Filter Tank No. 15 A — Continued.

January, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	1.00	.95	–	–	–	–	–	–	–	–	–	43°
2, ...	1.00	1.07	–	–	–	–	–	–	–	–	–	50°
3, ...	1.00	1.00	–	–	–	–	–	–	–	–	–	46°
4, ...	1.00	.99	9.40	106.60	.9500	.0700	1.0200	6.30	.2500	.0030	–	44°
5, ...	–	.32	–	–	–	–	–	–	–	–	–	–
6, ...	1.00	.72	–	–	–	–	–	–	–	–	–	44°
7, ...	1.00	1.00	–	–	–	–	–	–	–	–	–	44°
8, ...	1.00	1.01	–	–	–	–	–	–	–	–	–	45°
9, ...	1.00	.98	–	–	–	–	–	–	–	–	–	39°
10, ...	1.00	1.00	–	–	–	–	–	–	–	–	–	36°
11, ...	1.00	1.06	–	–	1.0000	.0700	1.0700	6.67	.1400	.0012	–	36°
12, ...	–	.34	–	–	–	–	–	–	–	–	–	–
13, ...	1.00	.79	–	–	–	–	–	–	–	–	–	43°
14, ...	1.00	1.00	–	–	–	–	–	–	–	–	–	44°
15, ...	1.00	1.03	–	–	–	–	–	–	–	–	–	41°
16, ...	1.00	1.04	–	–	–	–	–	–	–	–	–	44°
17, ...	1.00	1.00	–	–	–	–	–	–	–	–	–	38°
18, ...	1.00	1.01	–	–	1.0000	.0600	1.0600	4.44	.1500	.0006	–	41°
19, ...	–	.35	–	–	–	–	–	–	–	–	–	–
20, ...	.50	.40	–	–	–	–	–	–	–	–	–	47°
21, ...	.50	.48	–	–	–	–	–	–	–	–	–	46°
22, ...	.50	.50	–	–	–	–	–	–	–	–	–	46°
23, ...	.50	.53	–	–	–	–	–	–	–	–	–	37°
24, ...	.50	.51	–	–	–	–	–	–	–	–	42°	38°
25, ...	.50	.53	–	–	1.4000	.1300	1.5300	4.47	.1200	.0010	40°	37°
26, ...	–	.25	–	–	–	–	–	–	–	–	–	–
27, ...	1.00	.73	–	–	–	–	–	–	–	–	40°	39°
28, ...	1.00	.99	–	–	–	–	–	–	–	–	45°	35°
29, ...	1.00	1.07	–	–	–	–	–	–	–	–	43°	40°
30, ...	1.00	.91	–	–	–	–	–	–	–	–	39°	39°
31, ...	1.00	.98	–	–	1.6000	.0500	1.6500	4.42	.1000	.0018	38°	39°

Effluent colorless, generally nearly clear, and with no sediment or some white flocculent.
Total effluent to end of month, 215.52 gallons.

Filter Tank No. 15 A — Concluded.

February, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	1.00	1.00	-	-	-	-	-	-	-	-	43°	41°
2, ...	-	.26	-	-	-	-	-	-	-	-	-	-
3, ...	1.00	.77	-	-	-	-	-	-	-	-	-	43°
4, ...	1.00	1.05	-	-	-	-	-	-	-	-	-	41°
5, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	47°
6, ...	1.00	.98	-	-	-	-	-	-	-	-	-	40°
7, ...	1.00	1.04	-	-	1.1000	.0800	1.1800	4.50	.1000	.0010	-	40°
8, ...	1.00	1.02	-	-	-	-	-	-	-	-	-	44°
9, ...	-	.29	-	-	-	-	-	-	-	-	-	-
10, ...	1.00	.73	-	-	-	-	-	-	-	-	-	-
11, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	42°
12, ...	1.00	1.04	-	-	-	-	-	-	-	-	-	44°
13, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	44°
14, ...	1.00	1.04	-	-	1.9000	.0600	1.9600	4.40	.0900	.0016	-	43°
15, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	46°
16, ...	-	.30	-	-	-	-	-	-	-	-	-	-
17, ...	1.00	.89	-	-	-	-	-	-	-	-	-	44°
18, ...	1.00	1.00	-	-	-	-	-	-	-	-	-	40°
19, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	39°
20, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	39°
21, ...	1.00	1.02	-	-	1.5000	.0700	1.5700	4.88	.0700	.0014	-	34°
22, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	35°
23, ...	-	.29	-	-	-	-	-	-	-	-	-	-
24, ...	1.00	.84	-	-	-	-	-	-	-	-	-	43°
25, ...	1.00	1.04	-	-	-	-	-	-	-	-	-	43°
26, ...	1.00	1.07	-	-	-	-	-	-	-	-	-	46°
27, ...	1.00	1.03	-	-	-	-	-	-	-	-	-	45°
28, ...	1.00	1.01	-	-	1.5000	.0700	1.5700	4.18	.0700	.0020	-	45°

Effluent generally colorless, with from slight to distinct turbidity, and with little or no sediment.
Total effluent to end of month, 240.32 gallons.

Bacteria found in a Cubic Centimeter of Effluent from Tank No. 15 A.

Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.
1889.		**1889** – Con.		**1889** – Con.		**1890** – Con.	
July 30, .	693	Sept. 24, .	38,500	Dec. 4, .	495	Jan. 21, .	5
Aug. 6, .	101	Oct. 2, .	667	10, .	247	28, .	1,518
12, .	56	10, .	31	17, .	282	Feb. 4, .	52
19, .	85	16, .	168	**1890.**		8, .	3,828
27, .	1,050	25, .	40	Jan. 1, .	288	11, .	81
Sept. 2, .	83	Nov. 5, .	41	7, .	198	14, .	215
10, .	2,387	16, .	147	14, .	1,029	18, .	226
16, .	105	21, .	3				

FILTER TANK No. 16A.

Small, Clean Gravel Stones.

After removing the peat and sand from the Saugus Marshes which had been in Tank No. 16 up to June 28, 1889, this tank was filled with gravel. The bottom was covered to the depth of two inches with stones that would not go through a screen having meshes three-fourths of an inch square. The remaining depth of five feet and five inches was filled with gravel that would not go through a screen having a mesh one-eighth of an inch square, but would go through one having a mesh three-eighths of an inch square. The gravel was wet when sewage was first applied, as it had been washed to remove all particles of sand before being put into the tank.

Sewage was first applied on July 9, and the 90 gallons of wet gravel was filled by 29.5 gallons of sewage, and, upon being drained, this quantity flowed out. The amount of air space was then 29.5 gallons, or 33 per cent. of the whole space occupied by the gravel. The amount of water held upon and between the stones was not measured.

The results of chemical analyses of the effluent and the daily observations upon this tank are given in tables at the end of this section.

The monthly averages of the chemical analyses of the effluent and of the sewage applied are given in the following table, which contains also the daily quantity of effluent and its temperature, and the number of bacteria found in a cubic centimeter: —

Monthly Averages of Daily Results with Tank No. 16 A.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature.	Number of Bacteria per Cubic Centimeter.
1889.												
July 25–Aug. 9,	Sewage, .	–	22.20	39.62	2.1217	.5258	2.6475	5.05	.0000	.0000	71°	–
Aug. 1–16, . .	Effluent, .	.43	3.40	34.15	.1140	.0117	.1257	3.80	4.7750	.0169	–	9
	Per cent.,	–	15	86	5	2.2	5	–	–	–	–	–
Aug. 10–Sept. 14,	Sewage, .	–	33.31	47.06	1.9300	.8488	3.7788	5.61	.0000	.0002	–	–
Aug. 17–Sept. 18,	Effluent, .	.82	1.90	32.50	.0371	.0206	.0577	5.64	3.2333	.0007	70°	221
	Per cent.,	–	6	69	1.9	2.4	2.1	–	–	–	–	–
Sept. 15–Oct. 20,	Sewage, .	–	–	–	1.9348	.8304	2.7652	4.86	.0004	.0001	–	–
Sept. 19–Oct. 22,	Effluent, .	1.71	–	–	.0100	.0230	.0330	6.22	1.3320	.0004	57°	5,154
	Per cent.,	–	–	–	.5	2.8	1.2	–	–	–	–	–
Oct. 21–Nov. 29,	Sewage, .	–	26.21	28.06	1.9522	.6287	2.5809	5.32	.0000	.0000	–	–
Oct. 23–Nov. 30,	Effluent, .	3.67	2.80	25.40	.0364	.0360	.0724	5.53	1.1067	.0017	50°	6,325
	Per cent.,	–	11	91	1.9	6	2.8	–	–	–	–	–
Nov. 30–Dec. 30,	Sewage, .	–	–	–	1.1694	.4706	1.6400	5.12	.0067	.0006	–	–
December, .	Effluent, .	3.40	–	–	.0058	.0300	.0358	5.58	1.1380	.0009	44°	2,661
	Per cent.,	–	–	–	.5	6	2.2	–	–	–	–	–
1890.												
Dec. 31–Jan. 30,	Sewage, .	–	32.79	23.91	1.4465	.6191	2.0656	4.76	.0000	.0000	–	–
January, . .	Effluent, .	3.44	2.30	24.40	.0187	.0331	.0518	4.96	.9500	.0007	42°	3,825
	Per cent.,	–	7	102	1.3	5	2.5	–	–	–	–	–
Jan. 31–Feb. 27,	Sewage, .	–	–	–	1.5669	.8381	2.4050	4.42	.0000	.0001	–	–
February, . .	Effluent, .	3.53	–	–	.0985	.0609	.1594	4.29	1.0500	.0031	42°	5,412
	Per cent.,	–	–	–	6	7	7	–	–	–	–	–

No analyses of the effluent were made until August 5, although one-half gallon of sewage had been applied daily since July 23. The first analysis was as follows: —

Free ammonia, ...	.2200
Albuminoid ammonia, ...	.0180
Chlorine, ...	3.66
Nitrates, ...	4.2000
Nitrites, ...	0.0440

It will be seen that nitrification was then very active, four weeks after the application of the first sewage. The ammonias were, however, still high, but they rapidly decreased, while the nitrates increased to 5 parts per 100,000 on August 16. After this date the quantity of sewage was increased to 1 gallon per day. This quantity was continued to September 18, when the effluent gave the following analysis: —

Free ammonia, ...	.0140
Albuminoid ammonia, ...	.0210
Nitrates, ...	2.4000
Nitrites, ...	.0004

At this time the sum of the ammonias was 2 per cent. of the sum of ammonias of the sewage.

From September 19 until October 22, the quantity of sewage applied daily was 2 gallons. This was at first applied, one gallon in the morning and one gallon in the evening; and the analysis continued for three weeks nearly the same as on September 18. After October 7 about one-ninth of the quantity was applied hourly for nine hours of the day. This was continued for two weeks, in which time the ammonias were much reduced, and the nitrates also fell, but afterwards increased. The last analysis was as follows: —

Free ammonia,	.0118
Albuminoid ammonia,	.0148
Nitrates,	1.2500

The purification at this time was more complete, the sum of ammonias of the effluent being but one-half of one per cent. of those of the sewage. After October 22 the quantity was still further increased to 4 gallons a day, on six days of the week, one-ninth of which was applied hourly. For the first two weeks after the increase in quantity, the ammonias increased, and became about three per cent. of those of the sewage. The nitrates also increased to 1.3000 parts. The ammonias continued to decrease until the middle of December, when the effluent gave the following analysis: —

Free ammonia,	.0012
Albuminoid ammonia,	.0278
Nitrates,	1.0000
Nitrites,	.0004

and the sum of ammonias was about 2 per cent. of the sum of ammonias of the sewage. After this, for the next two months and a half, the nitrification continued high, averaging 1.0500 parts. The free ammonia and albuminoid ammonia increased, and on the last of February the effluent gave the following analysis: —

Free ammonia,	.0648
Albuminoid ammonia,	.0508
Nitrates,	1.3000
Nitrites,	.0026

At this time the sum of ammonias of the effluent amounted to 7 per cent. of the sum of ammonias of the sewage.

During these four months, in which the quantity filtered has been at the average rate of 70,000 gallons per acre per day, the nitrates have averaged 1.0612 parts, and the percentage of the sum of ammonias of the sewage in the effluent has been for the several months 2.8 per cent., 2.2 per cent., 2.5 per cent. and 7 per cent.

Up to Feb. 1, 1890, the surface of the gravel appeared clean, but since that date there has been some deposit of organic matter.

This filter of small gravel-stones, containing no sand, has for four months had sewage applied to the depth of about one-third of an inch on its surface at hourly intervals for nine hours of the day, and has given an effluent, colorless and generally clear or with slight turbidity, and with slight odor; and having for three months 97 per cent. and for the last month 93 per cent. of the organic matter of the sewage removed.

The increase of impurity in the effluent during the last month indicates that this quantity of 70,000 gallons per acre daily is more than this material can continue to purify, although it is not improbable that this amount of impurity may increase through the month of March, after which the increased nitrification of the spring months may remove stored impurity from the gravel, so that it may afterward go on purifying more completely for several months.

Bacteria in the Effluent from Tank No. 16 A.

A table of the number of bacteria found in the effluent of this tank may be found following the tables of chemical analyses; and the monthly averages of the number may be found in the preceding table of monthly averages.

While one-half a gallon of sewage was being applied daily, the number of bacteria in the effluent averaged 9 per cubic centimeter. After the quantity was increased to one gallon, the average number was 270. When 2 gallons a day, or the equivalent of 40,000 gallons per acre per day, were being filtered, the number averaged 5,120; and during the last four months, when the quantity filtered on week days was at the rate of 80,000 gallons per acre per day, the average number of bacteria found in the effluent has been 4,675, which is nearly 1 per cent. of the number of bacteria found in the applied sewage.

Note. — After the increased nitrification in the spring of 1890 the deposit was consumed, and the quality of the effluent was so much improved that the daily quantity was increased to 100,000 gallons per acre, with excellent results through the summer.

Purification by Nitrification not Dependent upon Fine Straining.

The results obtained with these small gravel stones, as well as with the coarser stones of Tank No. 15 A, enable us to comprehend, more clearly than when considering the results with sand, that the purification of sewage by nitrification, and the removal of bacteria, is not to any essential degree mechanical. It is not a straining through fine pores. In fact, the passing of sewage through filter paper in the laboratory which has pores so fine that the process has been regarded as removing from a liquid all matter not in solution, removes from our sewage but 11 per cent. of the sum of ammonias, and about 80 per cent. of the bacteria; while the slow moving of the sewage in thin films over and between stones as large as the ball of one's thumb causes the removal, for months at a time, of 97 per cent. of the sum of ammonias, and of 99 per cent. of the bacteria. The removal is not a mechanical one of holding back these substances, but a chemical change, in which these organic substances are burned, forming products of mineral matter which pass off daily in the purified liquid.

TABLES

OF

CHEMICAL ANALYSES OF THE EFFLUENT,

AND

DAILY OBSERVATIONS

Upon Filter Tank No. 16A.

July, 1889.

The quantity of sewage applied and effluent from tank in gallons were as follows: —

Date.	Quantity Applied.	Quantity of Effluent.	Date.	Quantity Applied.	Quantity of Effluent.	Date.	Quantity Applied.	Quantity of Effluent.
9, ...	29.04	–	17, ...	–	.11	25, ...	.50	.43
10, ...	.47	29.40	18, ...	–	.10	26, ...	.50	.50
11, ...	–	.23	19, ...	–	.05	27, ...	.50	.43
12, ...	28.95	–	20, ...	–	.07	28, ...	–	.20
13, ...	.32	29.00	21, ...	–	.06	29, ...	.50	.37
14, ...	–	.17	22, ...	–	.06	30, ...	.50	.49
15, ...	–	.15	23, ...	.50	.16	31, ...	.50	.54
16, ...	–	.12	24, ...	.50	.42			

Total effluent to end of month, 63.06 gallons.

Filter Tank No. 16 A — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	.50	.53	-	-	-	-	-	-	-	-	72°	-
2, ...	.50	.47	-	-	-	-	-	-	-	-	72°	-
3, ...	.50	.48	-	-	-	-	-	-	-	-	72°	-
4, ...	-	.22	-	-	-	-	-	-	-	-	-	-
5, ...	.50	.29	2.60	32.30	.2200	.0180	.2380	3.66	4.2000	.0440	71°	-
6, ...	.50	.43	-	-	-	-	-	-	-	-	-	-
7, ...	.50	.47	-	-	-	-	-	-	-	-	71°	-
8, ...	.50	.47	-	-	-	-	-	-	-	-	72°	-
9, ...	.50	.50	4.20	36.00	.1300	.0110	.1410	3.91	4.8000	.0180	71°	-
10, ...	.50	.39	-	-	-	-	-	-	-	-	71°	-
11, ...	-	.22	-	-	-	-	-	-	-	-	-	-
12, ...	.50	.28	-	-	-	-	-	-	-	-	70°	-
13, ...	.50	.61	-	-	-	-	-	-	-	-	-	-
14, ...	.50	.52	-	-	.0600	.0100	.0700	3.82	5.1000	.0040	68°	-
15, ...	.50	.49	-	-	-	-	-	-	-	-	68°	-
16, ...	.50	.50	-	-	.0460	.0080	.0540	3.82	5.0000	.0018	68°	-
17, ...	1.00	.97	-	-	-	-	-	-	-	-	69°	-
18, ...	-	.21	-	-	-	-	-	-	-	-	-	-
19, ...	1.00	.75	-	-	-	-	-	-	-	-	68°	70°
20, ...	1.00	.97	-	-	-	-	-	-	-	-	-	71°
21, ...	1.00	.94	-	-	.0520	.0210	.0730	4.17	4.6000	.0020	69°	68°
22, ...	1.00	.97	-	-	-	-	-	-	-	-	70°	72°
23, ...	1.00	1.02	-	-	-	-	-	-	-	-	70°	70°
24, ...	1.00	.72	-	-	-	-	-	-	-	-	71°	70°
25, ...	-	.24	-	-	-	-	-	-	-	-	-	-
26, ...	1.00	.80	-	-	-	-	-	-	-	-	70°	68°
27, ...	1.00	.88	-	-	-	-	-	-	-	-	-	68°
28, ...	1.00	.98	-	-	.0490	.0210	.0700	5.56	3.4000	.0010	71°	67°
29, ...	1.00	.97	-	-	-	-	-	-	-	-	70°	67°
30, ...	1.00	.83	-	-	-	-	-	-	-	-	71°	71°
31, ...	1.00	.95	-	-	-	-	-	-	-	-	72°	72°

Effluent colorless, generally clear or nearly so, and with very little or no sediment.
Total effluent to end of month, 82.13 gallons.

Filter Tank No. 16 A — Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	–	.25	–	–	–	–	–	–	–	–	–	–
2, ...	1.00	.70	–	–	–	–	–	–	–	–	71°	70°
3, ...	1.00	.97	1.90	32.50	.0440	.0260	.0700	5.87	3.0000	.0002	–	72°
4, ...	1.00	.96	–	–	–	–	–	–	–	–	–	73°
5, ...	1.00	.98	–	–	–	–	–	–	–	–	72°	71°
6, ...	1.00	.99	–	–	–	–	–	–	–	–	71°	75°
7, ...	1.00	.95	–	–	.0134	.0164	.0298	5.69	3.0000	.0004	72°	70°
8, ...	–	.25	–	–	–	–	–	–	–	–	–	–
9, ...	1.00	.72	–	–	–	–	–	–	–	–	72°	68°
10, ...	1.00	.95	–	–	–	–	–	–	–	–	–	66°
11, ...	1.00	.94	–	–	.0500	.0180	.0680	6.25	3.0000	.0005	70°	65°
12, ...	1.00	.99	–	–	–	–	–	–	–	–	68°	66°
13, ...	1.00	1.13	–	–	–	–	–	–	–	–	68°	66°
14, ...	1.00	1.09	–	–	–	–	–	–	–	–	67°	68°
15, ...	–	.36	–	–	–	–	–	–	–	–	–	–
16, ...	1.00	.79	–	–	–	–	–	–	–	–	68°	72°
17, ...	1.00	1.03	–	–	–	–	–	–	–	–	–	72°
18, ...	1.00	.95	–	–	.0140	.0210	.0350	6.32	2.4000	.0004	69°	68°
19, ...	2.00	1.92	–	–	–	–	–	–	–	–	–	61°
20, ...	2.00	1.95	–	–	–	–	–	–	–	–	–	63°
21, ...	2.00	1.93	–	–	–	–	–	–	–	–	–	63°
22, ...	–	.50	–	–	–	–	–	–	–	–	–	–
23, ...	2.00	1.51	–	–	.0170	.0265	.0435	5.64	1.2600	.0004	–	61°
24, ...	2.00	2.02	–	–	–	–	–	–	–	–	–	62°
25, ...	2.00	2.03	–	–	–	–	–	–	–	–	–	62°
26, ...	2.00	2.04	–	–	–	–	–	–	–	–	–	64°
27, ...	2.00	1.96	–	–	–	–	–	–	–	–	–	60°
28, ...	2.00	1.96	–	–	.0122	.0280	.0402	6.24	.9000	.0004	–	57°
29, ...	–	.38	–	–	–	–	–	–	–	–	–	–
30, ...	2.00	1.56	–	–	–	–	–	–	–	–	–	61°

Effluent colorless and generally free from sediment, with from slight to decided turbidity. September 19 to October 6. — One-half of sewage applied was put on in the forenoon, and one-half in the afternoon.

Total effluent to end of month, 116.89 gallons.

Filter Tank No. 16 A — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	2.00	2.02	-	-	-	-	-	-	-	-	-	63°
2, ...	2.00	1.99	-	-	-	-	-	-	-	-	-	60°
3, ...	2.00	1.98	-	-	-	-	-	-	-	-	-	59°
4, ...	2.00	2.01	-	-	-	-	-	-	-	-	-	60°
5, ...	2.00	1.94	-	-	.0160	.0310	.0470	7.32	2.4000	.0008	-	55°
6, ...	-	.37	-	-	-	-	-	-	-	-	-	-
7, ...	2.03	1.75	-	-	-	-	-	-	-	-	-	57°
8, ...	2.03	2.02	-	-	-	-	-	-	-	-	-	54°
9, ...	2.03	2.01	-	-	-	-	-	-	-	-	-	53°
10, ...	2.03	2.02	-	-	-	-	-	-	-	-	-	53°
11, ...	2.03	2.05	-	-	-	-	-	-	-	-	-	55°
12, ...	2.03	2.09	-	-	.0032	.0144	.0176	5.92	.8500	.0002	-	54°
13, ...	-	.43	-	-	-	-	-	-	-	-	-	-
14, ...	2.03	1.57	-	-	-	-	-	-	-	-	-	49°
15, ...	2.03	2.09	-	-	-	-	-	-	-	-	-	52°
16, ...	2.03	2.03	-	-	-	-	-	-	-	-	-	53°
17, ...	2.03	2.06	-	-	-	-	-	-	-	-	-	54°
18, ...	2.03	1.96	-	-	-	-	-	-	-	-	-	53°
19, ...	2.03	1.93	-	-	.0018	.0148	.0166	6.00	1.2500	.0001	-	52°
20, ...	-	.35	-	-	-	-	-	-	-	-	-	-
21, ...	2.03	1.65	-	-	-	-	-	-	-	-	-	51°
22, ...	2.03	2.07	-	-	-	-	-	-	-	-	-	50°
23, ...	4.07	4.10	-	-	-	-	-	-	-	-	-	49°
24, ...	4.07	4.09	-	-	-	-	-	-	-	-	-	46°
25, ...	4.07	4.09	-	-	-	-	-	-	-	-	-	48°
26, ...	4.07	4.18	-	-	.0488	.0448	.0936	5.17	.9000	.0020	-	52°
27, ...	-	.26	-	-	-	-	-	-	-	-	-	-
28, ...	4.07	4.09	-	-	-	-	-	-	-	-	-	53°
29, ...	4.07	4.25	-	-	-	-	-	-	-	-	-	50°
30, ...	4.07	4.17	-	-	-	-	-	-	-	-	-	50°
31, ...	4.07	4.18	-	-	-	-	-	-	-	-	-	50°

Effluent colorless, generally clear or nearly so, and with little or no sediment. After October 7, the sewage was put on in nine applications daily.

Total effluent to end of month, 188.69 gallons.

Filter Tank No. 16 A — Continued.

November, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	4.07	4.16	-	-	-	-	-	-	-	-	-	50°
2, ...	4.07	4.09	-	-	.0720	.0320	.1040	6.14	.8000	.0020	-	53°
3, ...	-	.26	-	-	-	-	-	-	-	-	-	-
4, ...	4.07	4.02	-	-	-	-	-	-	-	-	-	52°
5, ...	4.07	4.16	-	-	-	-	-	-	-	-	-	48°
6, ...	4.07	4.18	-	-	-	-	-	-	-	-	-	47°
7, ...	4.07	4.28	-	-	-	-	-	-	-	-	-	50°
8, ...	4.07	4.20	-	-	-	-	-	-	-	-	-	51°
9, ...	4.07	4.23	2.80	25.40	.0740	.0420	.1160	6.22	1.3000	.0040	-	52°
10, ...	-	.20	-	-	-	-	-	-	-	-	-	-
11, ...	4.07	4.01	-	-	-	-	-	-	-	-	-	51°
12, ...	4.07	4.20	-	-	-	-	-	-	-	-	-	53°
13, ...	4.07	4.24	-	-	-	-	-	-	-	-	-	54°
14, ...	4.07	4.23	-	-	-	-	-	-	-	-	-	57°
15, ...	4.07	4.14	-	-	-	-	-	-	-	-	-	50°
16, ...	4.07	4.15	-	-	.0042	.0390	.0432	5.12	1.1000	.0006	-	47°
17, ...	-	.18	-	-	-	-	-	-	-	-	-	-
18, ...	4.07	3.93	-	-	-	-	-	-	-	-	-	47°
19, ...	4.07	4.29	-	-	-	-	-	-	-	-	-	49°
20, ...	4.07	4.29	-	-	-	-	-	-	-	-	-	50°
21, ...	4.07	4.22	-	-	-	-	-	-	-	-	-	52°
22, ...	4.07	4.25	-	-	-	-	-	-	-	-	-	50°
23, ...	4.07	4.22	-	-	.0154	.0300	.0454	5.55	1.5000	.0012	-	51°
24, ...	-	.20	-	-	-	-	-	-	-	-	-	-
25, ...	4.07	4.07	-	-	-	-	-	-	-	-	-	48°
26, ...	4.07	4.18	-	-	-	-	-	-	-	-	-	47°
27, ...	4.07	4.23	-	-	-	-	-	-	-	-	-	44°
28, ...	4.07	4.58	-	-	-	-	-	-	-	-	-	47°
29, ...	4.07	4.14	-	-	-	-	-	-	-	-	-	47°
30, ...	4.07	4.19	-	-	.0040	.0280	.0320	4.97	1.0400	.0006	-	44°

Effluent colorless, nearly clear, and generally free from sediment.
Total effluent to end of month, 298.41 gallons.

Filter Tank No. 16 A— Continued.

December, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	-	.20	-	-	-	-	-	-	-	-	-	-
2, ...	4.07	4.04	-	-	-	-	-	-	-	-	-	45°
3, ...	4.07	4.06	-	-	.0056	.0310	.0366	5.10	1.1000	.0010	-	44°
4, ...	4.07	4.17	-	-	-	-	-	-	-	-	-	41°
5, ...	4.07	4.06	-	-	-	-	-	-	-	-	-	40°
6, ...	4.07	4.20	-	-	-	-	-	-	-	-	-	43°
7, ...	4.07	4.20	-	-	.0102	.0270	.0372	4.22	.9600	.0020	-	44°
8, ...	-	.21	-	-	-	-	-	-	-	-	-	-
9, ...	4.07	4.08	-	-	-	-	-	-	-	-	-	49°
10, ...	4.07	4.21	-	-	-	-	-	-	-	-	-	47°
11, ...	4.07	4.24	-	-	-	-	-	-	-	-	-	47°
12, ...	4.07	4.19	-	-	-	-	-	-	-	-	-	44°
13, ...	4.07	4.13	-	-	-	-	-	-	-	-	-	44°
14, ...	4.07	3.71	-	-	.0012	.0278	.0290	5.32	1.0000	.0004	-	39°
15, ...	-	.22	-	-	-	-	-	-	-	-	-	-
16, ...	4.07	4.01	-	-	-	-	-	-	-	-	-	42°
17, ...	4.07	4.20	-	-	-	-	-	-	-	-	-	43°
18, ...	4.07	4.20	-	-	-	-	-	-	-	-	-	43°
19, ...	4.07	4.28	-	-	-	-	-	-	-	-	-	46°
20, ...	4.07	4.21	-	-	-	-	-	-	-	-	-	46°
21, ...	4.07	4.17	-	-	.0034	.0366	.0400	4.90	1.3300	.0006	-	48°
22, ...	-	.22	-	-	-	-	-	-	-	-	-	-
23, ...	4.07	3.95	-	-	-	-	-	-	-	-	-	42°
24, ...	4.07	4.19	-	-	-	-	-	-	-	-	-	42°
25, ...	4.07	4.23	-	-	-	-	-	-	-	-	-	-
26, ...	4.07	4.14	-	-	-	-	-	-	-	-	-	45°
27, ...	4.07	4.15	-	-	-	-	-	-	-	-	-	43°
28, ...	4.07	4.16	-	-	.0086	.0274	.0360	8.37	1.3000	.0006	-	42°
29, ...	-	.23	-	-	-	-	-	-	-	-	-	-
30, ...	3.16	2.93	-	-	-	-	-	-	-	-	-	44°
31, ...	2.26	2.29	-	-	-	-	-	-	-	-	-	41°

Effluent colorless, clear or nearly so, and free from sediment.
Total effluent to end of month, 403.89 gallons.

Filter Tank No. 16 A — Continued.

January, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Sewage.	Effluent.
1, ...	4.07	4.13	-	-	-	-	-	-	-	-	-	42°
2, ...	4.07	4.22	-	-	-	-	-	-	-	-	-	50°
3, ...	4.07	4.15	-	-	-	-	-	-	-	-	-	47°
4, ...	4.07	4.11	2.30	24.40	.0044	.0290	.0334	7.50	.9000	.0006	-	44°
5, ...	-	.25	-	-	-	-	-	-	-	-	-	-
6, ...	4.07	3.90	-	-	-	-	-	-	-	-	-	43°
7, ...	4.07	4.12	-	-	-	-	-	-	-	-	-	45°
8, ...	4.07	4.12	-	-	-	-	-	-	-	-	-	44°
9, ...	4.07	4.10	-	-	-	-	-	-	-	-	-	39°
10, ...	4.07	4.11	-	-	-	-	-	-	-	-	-	36°
11, ...	4.07	4.13	-	-	.0164	.0272	.0436	5.04	1.0000	.0006	-	38°
12, ...	-	.28	-	-	-	-	-	-	-	-	-	-
13, ...	4.07	3.89	-	-	-	-	-	-	-	-	-	43°
14, ...	4.07	4.09	-	-	-	-	-	-	-	-	-	44°
15, ...	4.07	4.17	-	-	-	-	-	-	-	-	-	40°
16, ...	4.07	4.11	-	-	-	-	-	-	-	-	-	44°
17, ...	4.07	4.11	-	-	-	-	-	-	-	-	-	39°
18, ...	4.07	4.10	-	-	.0094	.0272	.0366	3.64	.9000	.0004	-	41°
19, ...	-	.31	-	-	-	-	-	-	-	-	-	-
20, ...	2.71	2.59	-	-	-	-	-	-	-	-	-	47°
21, ...	3.16	3.14	-	-	-	-	-	-	-	-	-	43°
22, ...	4.07	4.03	-	-	-	-	-	-	-	-	-	39°
23, ...	4.07	4.10	-	-	-	-	-	-	-	-	-	37°
24, ...	3.16	2.63	-	-	-	-	-	-	-	-	-	-
25, ...	4.07	3.76	-	-	.0320	.0370	.0690	4.47	.9500	.0008	-	-
26.	-	.29	-	-	-	-	-	-	-	-	-	-
27, ...	3.16	3.03	-	-	-	-	-	-	-	-	-	41°
28, ...	4.52	4.57	-	-	-	-	-	-	-	-	-	36°
29, ...	4.07	4.10	-	-	-	-	-	-	-	-	-	39°
30, ...	4.07	4.15	-	-	-	-	-	-	-	-	-	40°
31, ...	4.07	4.00	-	-	.0312	.0454	.0766	4.17	1.0000	.0012	-	39°

Effluent colorless, clear or slightly turbid, and generally free from sediment.
Total effluent to end of month, 510.68 gallons.

Filter Tank No. 16 A — Concluded.

February, 1890.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Sewage.	Temperature. Effluent.
1, ...	4.52	4.53	-	-	-	-	-	-	-	-	-	41°
2, ...	-	.28	-	-	-	-	-	-	-	-	-	-
3, ...	4.07	3.86	-	-	-	-	-	-	-	-	-	43°
4, ...	4.07	4.08	-	-	-	-	-	-	-	-	-	44°
5, ...	4.07	4.10	-	-	-	-	-	-	-	-	-	47°
6, ...	4.07	4.07	-	-	-	-	-	-	-	-	-	41°
7, ...	4.07	3.88	-	-	.1175	.0610	.1785	4.12	1.0000	.0020	-	38°
8, ...	4.07	4.24	-	-	-	-	-	-	-	-	-	43°
9, ...	-	.31	-	-	-	-	-	-	-	-	-	-
10, ...	4.07	3.80	-	-	-	-	-	-	-	-	-	-
11, ...	4.07	4.07	-	-	-	-	-	-	-	-	-	42°
12, ...	4.07	4.11	-	-	-	-	-	-	-	-	-	45°
13, ...	4.07	4.10	-	-	-	-	-	-	-	-	-	43°
14, ...	4.07	4.13	-	-	.1300	.0740	.2040	4.74	.9000	.0040	-	43°
15, ...	4.07	4.00	-	-	-	-	-	-	-	-	-	45°
16, ...	-	.35	-	-	-	-	-	-	-	-	-	-
17, ...	4.07	3.88	-	-	-	-	-	-	-	-	-	43°
18, ...	4.07	4.07	-	-	-	-	-	-	-	-	-	41°
19, ...	4.07	4.09	-	-	-	-	-	-	-	-	-	41°
20, ...	4.07	4.12	-	-	-	-	-	-	-	-	-	39°
21, ...	4.07	4.06	-	-	.0815	.0580	.1395	4.79	1.0000	.0040	-	36°
22, ...	4.07	4.07	-	-	-	-	-	-	-	-	-	37°
23, ...	-	.35	-	-	-	-	-	-	-	-	-	-
24, ...	4.07	3.91	-	-	-	-	-	-	-	-	-	43°
25, ...	4.07	4.11	-	-	-	-	-	-	-	-	-	42°
26, ...	4.07	4.18	-	-	-	-	-	-	-	-	-	45°
27, ...	4.07	4.10	-	-	-	-	-	-	-	-	-	45°
28, ...	3.61	4.11	-	-	.0648	.0508	.1156	3.50	1.3000	.0026	-	44°

Effluent colorless, generally nearly clear, and with very slight or no sediment.
Total effluent to endof month, 609.64 gallons.

Table of the Number of Bacteria found in a Cubic Centimeter of the Effluent from Tank No. 16 A.

Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.
1889.		**1889** — Con.		**1889** — Con.		**1890** — Con.	
July 30, .	9	Oct. 2, .	2,325	Dec. 4, .	2,508	Jan. 21, .	260
Aug. 6, .	14	10, .	9,200	10, .	658	28, .	8,448
12, .	4	16, .	3,936	17, .	4,818	Feb. 4, .	6,468
19, .	25	25, .	11,172	**1890.**		8, .	4,950
28, .	648	Nov. 5, .	4,704	Jan. 1, .	2,610	11, .	4,950
Sept. 2, .	11	16, .	8,400	7, .	4,224	14, .	3,960
10, .	394	21, .	1,025	14, .	3,584	18, .	6,734
16, .	29						

A GENERAL VIEW OF RESULTS.

We have now filtered sewage intermittently through clean gravel stones, larger than robins' eggs, through filters made of various grades of gravel and of sand, to a sand whose particles average but 0.004 inch in diameter, — a fine granular dust, — as well as through soils and through peat.

With the gravels and sands, from the coarsest to the finest, we find that purification by nitrification takes place in all, when the quantity of sewage is adapted to their ability, and the surface is not allowed to become clogged by organic matter to the exclusion of air.

With fine soils, containing, in addition to their sand grains, two or three per cent. of alumina and oxide of iron and manganese, and six or seven per cent. of organic matter, we find that, when only six inches in depth, resting upon fine, sandy material, they retain water so long that the quantity that can be applied is so small, and the interval in which this must settle and dry away to allow air to enter the filter is so long, that the amount of sewage that can be purified is very small. When the quantity applied is adapted to its ability, such a filter may give an excellent effluent, quite free from bacteria.

With greater depth of soil the quantity that can be filtered will evidently become less; and, with the depth of five feet of such a soil, we have found nitrification did not take place; and, although it was probable that no bacteria came through, the organic matter in the effluent was at the end of two years nearly as great as in the sewage. This soil remained continually so nearly saturated that, when only 5,000 gallons per acre were being filtered daily, although free to drain over every square foot of the bottom, sufficient air could not be taken in to produce any nitrification; and the chemical result with this material was, throughout the two years of its trial, nearly the same as would be expected if the filtration had been made continuous, instead of intermittent.

With peat upon the surface of a filtration area, even to the depth of only one foot, its imperviousness to liquid and the quantity that it will retain until it evaporates, renders intermittent filtration impracticable; and a sand area thus covered with peat can be rendered efficient for filtration only by the removal of the peat from the surface.

The truths in regard to filtration of sewage that have been made manifest by the experiments of the State Board of Health in the past two years can be appreciated only by a careful study of the results which have been presented. No statement of general conclusions can convey all that these experiments have made known; but, to one who has carefully considered the results in detail, it may be useful to group the results and bring out some of the general truths with more clearness.

The experiments with gravel-stones give us the best illustration of the essential character of intermittent filtration of sewage. In these, without straining the sewage sufficiently to remove even the coarser suspended particles, the slow movement of the liquid in thin films over the surface of the stones, with air in contact, caused to be removed for some months 97 per cent. of the organic nitrogenous matter, a large part of which was in solution, as well as 99 per cent. of the bacteria, which were of course in suspension, and enabled these organic matters to be oxidized or burned, so that there remained in the effluent but three per cent. of the decomposable organic matter of the sewage, the remainder being converted into harmless mineral matter.

The mechanical separation of any part of the sewage by straining through sand is but an incident, which, under some conditions, favorably modifies the result; but the essential conditions are very slow motion of very thin films of liquid over the surface of particles having spaces between them sufficient to allow air to be continually in contact with the films of liquid.

With these conditions it is essential that certain bacteria should be present to aid in the process of nitrification. These, we have found, come in the sewage at all times of the year; and the conditions just mentioned appear to be most favorable for their efficient action, and at the same time most destructive to them and to all kinds of bacteria that are in the sewage.

In grouping the results of our experiments, it will be best to refer to the general diagram of nitrates, of ammonias and of bacteria, given at page 125. There are graphically presented these elements for the sewage and for most of the tanks that have been used.*

As nitrification, or the burning up of organic matter, is the essential step in purification of sewage by intermittent filtration, we will first follow by the diagram the rise and fall of the nitrates.

The nitrates of the sewage were nearly zero from beginning to end.

Passing the slight nitrification in January, 1888, in nearly all of the tanks when sewage was first applied, we have through February and March a season of no nitrification. During these months the temperature of the effluents had been about 36° Fah. When the temperature of the effluent rose to 39° or 40° in the several tanks, a slight increase in the nitrates was observed, which continued slowly rising until about 50° was reached.

This was true of all of the filters represented, except No. 5, which was filled with garden soil, in which no appreciable nitrification occurred during the two years. Filter No. 3, not represented, which was composed of peat, also did not nitrify. Of those represented, the first to nitrify are those presented by heavy lines, No. 1, No. 14, No. 13 and No. 12. These were all of coarse, open sand, like No. 1, which would allow air to enter it most freely; and those began first and burned most rapidly in which the most organic matter had been stored.

Filters started at other seasons of the year have shown us that nitrification does not become active until there is an accumulation of organic matter that may be burned.

Following those filters of the most open sand, in nitrification, came the mixed sands of No. 6 and No. 11, which allowed air to penetrate them less freely. These were followed by the finest sand, No. 4, the fine sand of No. 2, and the soil-covered filter No. 7,— the latter being more than a month later than the earliest.

Nitrification was highest in all of these filters in the rapidly growing months of May and June. In the second year the highest nitrates were in general at the same season, but began earlier, in the latter half of April, and continued through May. With the excep-

* In order to bring the widely varying quantities within the limits of a single plate, and at the same time to indicate the changes that take place when the quantities are very small, it has been necessary to sacrifice the presentation of relative magnitudes to the eye, and adopt for each diagram varying scales, which must be regarded in order to have any just appreciation of the relative magnitudes presented.

tion of the increased activity of nitrification in the spring months, when in several of the filters more nitrogen came away in the effluent — principally as nitrates — than was being applied in the sewage, the nitrates of the effluent rise and fall, in the several filters which are purifying the sewage, with the rise and fall of the ammonias in the sewage; so that, in the winter months of 1888-89, while the nitrates of the effluent were lower than at other times, we find that the sum of ammonias of the sewage was also lower, and that nitrification at that time was quite as complete as in the previous months.

Before following the varying and exceptional condition of nitrification in some of the filters, we will turn to the diagram of ammonias, and see how they were in general affected by nitrification.

Upon first applying sewage, some of the impurities were held back by the sand by the straining process; and, so far as this occurred, the finer sands held back for a longer time than the coarser. With the coarser sands of No. 1 and No. 6 there was a considerable increase in ammonias soon after the chlorine indicated that liquid from sewage had reached the outlet. With No. 7, No. 2 and No. 4, there was but little increase in the ammonias for some weeks after the original water in the sand had been expelled, and liquid from sewage had permeated all parts of the filter.

All, however, gave an effluent at some time before nitrification began, which contained from 20 to 40 per cent. as much free and albuminoid ammonia as the sewage. But during this time, in the cold months of a very cold winter, there was an important step in purification going on. This was the conversion of albuminoid ammonia to free ammonia; or, to state the case more definitely, it was the burning up of a part of the organic matter by the combination of oxygen with some of the carbon, producing carbonic acid, and leaving the nitrogen and hydrogen that were combined with this carbon to form ammonia, and thus reducing the amount of combined nitrogen which in our analyses appears as albuminoid ammonia. This is as complete a destruction of organic matter, as far as it goes, as if the free ammonia were again oxidized, forming nitric acid or nitrates; but this process seldom if ever carries the destruction of the organic impurities of sewage to such an extent that the resulting liquid contains so little impurity as when nitrification takes place. We find, further, that this process of reducing the albuminoid ammonia is not so destructive to bacteria as the more complete process of nitrification. It is, however, a process of purification; and the conditions of intermittent filtration are those most favorable to this step in purification.

During the three cold months previous to the beginning of nitrification in April, 1888, we have, under very unfavorable circumstances, the large filters in the field filtering intermittently and purifying without nitrification. The sum of ammonias were — though generally lower — at some time from 20 to 40 per cent. of the sum of ammonias of the sewage applied; but this does not express the degree of the destruction of organic impurities. We are unable to say, in regard to this short period, how much was destroyed; for a considerable part of that which was in solid form — in suspension — was without doubt held back, and may have been accumulating in the sand. If we compare the albuminoid ammonia of the effluent from the several tanks in the field with the albuminoid ammonia of the sewage, we find that but about five per cent. was coming through the filter; but, if we suppose that all that was in suspension in the sewage was mechanically held back by the sand, we still find that the albuminoid ammonia of the effluent was only twenty per cent. of the albuminoid ammonia that was in solution in the sewage; that is, in the process of intermittent filtration previous to the beginning of nitrification, there was going on within the filter a chemical change by which a considerable part of the organic impurities were burned up, thus reducing the combined nitrogen that was in solution in the sewage by 80 per cent. This occurred in winter, when frost was in the upper layers of the filters, and the effluents were at the temperature of about 36° Fah.

When the frost had been melted in the tanks in the field, and the temperature of the effluent in each had reached 39° or 40°, nitrification began in all of the filters composed of sand. The sum of ammonias, however, did not immediately decrease; in fact, it generally increased in the coarser sands for two or three weeks, and in the finest sand for two months. The time when it began to decrease and the rapidity with which the filter reached a condition of established purification, appears to depend upon the freedom with which air can penetrate the filter, and upon the amount of organic impurity that has been stored in the filter.

The order in which the several filters reached an established condition of purification by nitrification was as follows: No. 14, No. 1, No. 13, No. 6, No. 12, No. 11, No. 2, No. 7 and No. 4.

The coarse-sand filters reached this condition in from one to five weeks after nitrification first reached its height. The fine sand of No. 2 required two months, and No. 7 and No. 4 a much longer time; but they were probably delayed by receiving at first too much sewage, and having the surface clogged.

The degree of purification which the several tanks attained for the month following their reaching an established condition of purification, as expressed by the percentage which the sum of ammonias of the effluent bore to the sum of ammonias of the sewage, and the percentage which the number of bacteria in the effluent bore to the number in the sewage, was as follows: —

Number of Filter.	Quantity Filtering, in Gallons per Acre per Day.	Percentage the Sum of Ammonias of Effluent was of the Sum of Ammonias of the Sewage.	Percentage the Number of Bacteria in the Effluent was of the Number in the Sewage.	Number of Filter.	Quantity Filtering, in Gallons per Acre per Day.	Percentage the Sum of Ammonias of Effluent was of the Sum of Ammonias of the Sewage.	Percentage the Number of Bacteria in the Effluent was of the Number in the Sewage.
14, . . .	120,000	1.0	3.	11, . . .	30,000	0.6	1.
13, . . .	60,000	0.7	0.005	2, . . .	19,000	0.3	0.01
1, . . .	43,000	0.9	0.3	4, . . .	14,000	0.8	0.001
12, . . .	28,000	0.8	0.15	7, . . .	11,000	0.3	0.001
6, . . .	45,000	0.7	0.02				

All of these sand filters were at these times burning up the nitrogenous impurities of the sewage, and thus removing from 99 to 99.7 per cent. thereof, and giving effluents containing less organic impurities, as shown by chemical analyses, than most of the drinking-water supplies of the State.

At the same time the number of bacteria in a cubic centimeter of the sewage was from 340,000 to 1,400,000; and the number of bacteria found in the effluent averaged, for these months, from 3 per cent. in that from the open sand filtering the largest quantity to a fraction of one per cent. in that from the other open sands, and to 0.001 of one per cent. in the finest sand and in the sand covered with soil.

The coarser sands, though presenting conditions so unfavorable for bacteria to live through the passage of five feet in depth, — which required from one and a half to seven days, — that only the small percentages given survived, yet allowed more to pass through than are found in good drinking waters. The finer sands, however, of No. 2 and No. 4, and the soil-covered sand of No. 7, with their passages of from three to five weeks, did not allow as many to survive as are found in good drinking waters. It is most probable that none came through the sand, but that the small numbers of from 4 to 30 per cubic centimeter, found in the effluent from these three filters, grew in the gravel on the bottom of the tanks or in the underdrains.

Most of these filters continued filtering the quantity of sewage that they were found adapted to purify for from a year to a year and a half after they reached the established condition of purification which has just been presented. We will now consider the results obtained in the latter part of this time.

The average results of purification for periods of from three to eight months, mostly in the second year of filtration, are given in the following table : —

Number of Filter.	Quantity Filtering, in Gallons per Acre per Day.	Percentage the Sum of Ammonias of Effluent was of the Sum of Ammonias of the Sewage.	Percentage the Number of Bacteria in the Effluent was of the Number in the Sewage.	Number of Filter.	Quantity Filtering, in Gallons per Acre per Day.	Percentage the Sum of Ammonias of Effluent was of the Sum of Ammonias of the Sewage.	Percentage the Number of Bacteria in the Effluent was of the Number in the Sewage.
14, . . .	117,000	1.4	3.	2, . . .	25,700	0.4	0.003
13, . . .	60,000	0.4	0.02	4, . . .	13,400	0.6	0.002
1, . . .	55,400	2.5	0.19	7, . . .	8,880	0.4	0.001
6, . . .	42,600	0.5	0.08				

The first given in this table, No. 14, of coarse sand like No. 1, filtered the above quantity for three months; after which the quantity was increased, and averaged for five months 177,000 gallons per acre per day. The purification was less complete for the first month after the change, but in the second and third months it was more complete than with the quantity given above. The fourth and fifth months, however, gave less satisfactory results, — showing that the filter was becoming overburdened; the surface became much clogged with organic matter, and the sum of ammonias of the effluent increased to 2.7 per cent. of those of the sewage; but the bacteria in the effluent decreased to 0.1 of one per cent. of the number in the sewage. This filter was evidently doing more than it could continue to do indefinitely. The other filters, filtering quantities decreasing with their perviousness from 60,000 gallons per acre per day to 9,000 gallons, indicated that they would continue giving as good results indefinitely. In all cases, except that of No. 1, they gave an effluent containing about one-half of one per cent. of the nitrogenous organic matter of the sewage, as shown by the sum of the ammonias; and from 0.08 to 0.001 of one per cent. of the number of bacteria in the sewage. It is probable that the three less pervious materials allowed no bacteria to be brought down from the sewage, but that the numbers of one or two or three in 100,000 of the number in the sewage grew in the underdrains.

The nitrogen in the effluents as nitrates, during the periods covered by the last table, amounted to about 50 per cent. of the nitrogen of the sewage. During these periods the effluents were generally colorless, clear, bright waters, having the appearance of good spring waters.

While the results given in the table may fairly be taken as the average results for each filter, it is to be noted that with the coarser sands there is a short time, an hour or more, soon after the flow of the effluent is increased by the application of sewage, when a small percentage of the newly applied sewage reaches the bottom before it has had time to be much changed chemically, or to have the bacteria killed. It is mixed to some degree with liquid that has been longer in the filter, and for the short time mentioned it produces an effluent that contains more organic matter and a greater number of bacteria than through the rest of the day. The most marked result of this temporary increase in impurity of effluent was observed with the open sand of Tank No. 1, in April, 1889, when the impurities, as shown by the sum of ammonias, increased from 1.5 per cent. to 8 per cent. of those of the sewage, and the number of bacteria increased from 0.01 of one per cent. to 2 per cent. of the number in the sewage. Ordinarily the increase was very much less than this with the sand of Tank No. 1, and still less, though observable, with the mixed sand of Tank No. 6. Very little if any such effect was produced upon applying sewage to the fine sand of Tank No. 2, and none with the sand of Tank No. 4 or with the soil-covered Tank No. 7.

Effect on Filtration of Exclusion of Air.

The essential difference between intermittent filtration and continuous filtration of sewage is, that in the former air is allowed to enter the filter during the intermissions, and in the latter air is excluded from the filter.

If from any cause the surface becomes impervious to air, by the material becoming so retentive of water that no air can enter between the applications of sewage, the result is similar to that when filtration is continuous; no nitrification takes place, and the effluent gradually grows to contain as much organic matter as the sewage. This was the result with the garden soil of Tank No. 5 throughout the two years. It was the case for a short time with Tank No. 7, covered with garden soil, which, in June, 1888, was receiving 17,000 gallons of sewage per acre per day. This proved to be more than would readily enter; and a green layer of organic matter formed on the surface, that was so retentive of water that no air could enter the filter; and the result is shown upon the Diagram of Nitrates in the rapid decrease in the nitrates, until nitrification ceased on July 10, and so continued till August 2, in which time the sum of ammonias increased from 0.10 parts to 0.44 parts. This condition was changed by removing, on July 25, one-half inch in depth of the surface, allowing the air to enter, and causing the nitrates to increase in eleven days from 0.003 parts to 1.100 parts; but purification by nitrification was not well established until the quantity applied was reduced to 14,000 gallons per acre per day. With 9,000 gallons daily per acre it was continued very satisfactorily — as given in the above table — for eight months.

A similar result was obtained with Tank No. 11, which, in August, 1888, was purifying sewage very satisfactorily, removing 99.4 per cent. of the nitrogenous organic matter; when, upon covering the surface with one foot in depth of pulverized peat, which became saturated with sewage, and so retentive that no air could enter through it, nitrification ceased, and the ammonias soon became equal to those of the sewage. After a while nitrates and nitrites were found in the effluent; but these undoubtedly were formed from air entering the coarse sand through the outlet pipe in sufficient quantity to oxidize the extremely small quantity of sewage that could pass through the peat. For six months the ammonias were nearly equal to those of the sewage; and then, upon removing the peat from the surface and applying a solution of organic matter intermittently, purification became satisfactory. Other examples of purification ceasing when air was excluded are shown by the action of Tank No. 14, when, in the spring of 1889, a tight cover was put upon the tank, and sewage was introduced without air. This was followed by an extremely rapid burning up of stored organic matter when a current of air was drawn through the filter. Again, while covered, nitrification was made very active by adding a very small quantity of air daily, and keeping the air within the tank circulating through the sand.

But the most striking effect of the difference between intermittent and continuous filtration is given in the account of Tank No. 12, and is illustrated by the diagram facing page 184. This filter, acting intermittently, removed 99.2 per cent. of the sum of ammonias. Upon filling the tank with sewage and keeping the surface covered, drawing off daily the same amount that had flowed through in intermittent filtration, nitrification ceased in less than a month; at which time the sum of ammonias began to increase, and continued increasing, until, after three months, they were greater than the sum of ammonias of the sewage. In this period the albuminoid ammonia of the effluent was much less than that of the sewage, in the last month averaging only twelve per cent.; but from the subsequent action it appears that the albuminoid ammonia, although in solution, was in large part stored in the sand; for, upon draining the tank and resuming intermittent filtration, the nitrates far exceeded in amount those from any of the other tanks; and the amount of nitrogen which came off, principally as nitrates, was fifty per cent. more than was applied. In the three months after intermittent filtration was resumed, the impurities that had been stored in the tank during continuous filtration had been removed by nitrification, — that is, had been burned up; and the sum of ammonias of the effluent had been reduced to 0.7 of one per cent. of those of the sewage, and were only 0.0151 parts per 100,000, or less than in the average of the public drinking waters of the State.

Effect of Continuous Filtration on Bacteria.

The effect upon the number of bacteria in changing from intermittent to continuous filtration was, in No. 12, to increase and then to decrease it. In June, 1888, the number was 166. Through July, with a glass trap on the outlet, the number averaged 891. On July 27, the tank was filled with sewage, and continuous filtration commenced. In a week the number of bacteria in a cubic centimeter of the effluent was 55,900, in three weeks it had gradually decreased to 3,540, and in two weeks more it was only 64. In the next two months, while continuous filtration continued and nitrification ceased, the number averaged less than 100. During this time there was no nitrification to kill them, but they were unable to survive the long passage of three weeks through the sand without oxygen.

Upon drawing sewage out of the tank on November 28, and resuming intermittent filtration, the number of bacteria, when the first liquid from the top — being one week on its passage — reached the outlet, was 10,416, and in two days the number fell off to 34; and in the next three weeks, while the nitrates were increasing from 0.1200 to 1.0200 parts, the number averaged 82.

When nitrification ceased in No. 7, due to the surface becoming impervious to air, the quantity of water that could enter was so small that about two months were required to pass through the sand; and so long a passage without air was undoubtedly the cause of the number of bacteria being very small, although there was no nitrification.

General Effect of Intermittent Filtration of Sewage upon the Bacteria which are growing in it.

The sewage pumped from the sewer at the Experiment Station generally contained about 700,000 bacteria per cubic centimeter. If it was allowed to stand in an open vessel, the number would increase for a few days to three or four times the original number, and then generally decrease to a fraction of the original number.

When sewage was first applied to the sand filters, the number of bacteria found in the effluents, while the sewage was mingling with water that was previously in the sand, rose from the small numbers that had been in the water to appreciable percentages of the number that was in the sewage, and, in the case of Tank No. 11, exceeded that number.

The maximum percentages of the number in the sewage found in the effluents at such times were as follows: No. 1, 31 per cent.; No. 12, 83 per cent.; No. 13, 40 per cent.; No. 14, 26 per cent.; No. 6, 5 per cent.; No. 11, 487 per cent.; No 2, 14 per cent.; No. 4, 5 per cent.; No. 7, 5 per cent.

The sand of No. 11 had been heated, and the water of both No. 11 and No. 12 had been boiled and put into the sand when hot; and, though the heating of the sand and the boiling of the water probably sterilized each for the time, these processes may have prepared the organic matter in each to be better food for the bacteria afterwards brought in by the sewage, and caused the number to be greater than would have ordinarily existed. Omitting these in the discussion until we have opportunity to give them especial attention, the coarse sands, like No. 1, allowed from 26 to 40 per cent. of the bacteria to pass through; the mixed sand of No. 6 allowed 5 per cent. to pass; the fine sand of No. 2 allowed 14 per cent.; and the still finer sand of No. 4 and the soil-covered sand of No. 7 allowed 5 per cent. to pass through. It is not probable that the five feet in depth of soil in No. 5, or the same depth of peat in No. 3, allowed any to pass through.

These results show us that it is mechanically possible for bacteria to be carried through the several filters of sand in large numbers, and with varying percentages of loss; and that, when the number brought through is far below the percentages above given, we must conclude that some other condition, not merely mechanical, is unfavorable to their passage.

Immediately after the water that had been in the sand of the several filters had been pushed out by the incoming sewage, so that all of the liquid that was in the sand was from sewage, the number of bacteria decreased; and, in two or three weeks from the time of the maximum number in the effluents just given, the percentage of the number in the sewage decreased to a minimum on a single day as follows: No. 1, from 31 per cent. to 0.24 of one per cent.; No. 12, from 83 per cent. to one per cent.; No. 13, from 40 per cent. to 0.01 of one per cent.; No. 14, from 26 per cent. to 0.03 of one per cent.; No. 6, from 5 per cent. to 0.01 of one per cent.; No. 11, from 487 per cent. to 6 per cent.; No. 2, from 14 per cent. to 0.001 of one per cent.; No. 4, from 5 per cent. to 0.001 of one per cent.; No. 7, from 5 per cent. to 0.001 of one per cent.

The conditions under which these great changes occurred, which are common to all of the filters, were these: when the sewage was first applied, with its half-million of bacteria in each cubic centimeter, it mingled with water in the sand which contained some absorbed oxygen and some oxygen brought down mechanically from the surface; and with this supply of oxygen, and there being no known burning up of organic matter, from five to forty per cent. of the bacteria appear to have been able to survive the passage of from two to five days through the coarse sands, and from ten to twenty days through the finer sands. But, when sewage took possession of the tank, there was no absorbed oxygen in the liquid, and the amount of oxygen taken in mechanically was used up to a considerable extent in combining with the carbon of the organic matter; and it appears that there was not enough left to support more than a small fraction of one per cent. of the bacteria on the passage through the sand.

It may be that, after the first great reduction in numbers, there came more bacteria of the kinds that could survive the passage; for, during the next two months with the large tanks, and a shorter time with the smaller tanks, while there was no nitrification, although there was a great reduction of organic nitrogen, which indicates an oxidation of carbonaceous matter, the number of bacteria was higher than the very small number to which they first fell. During this period of partial purification without nitrification the average percentages of the number of bacteria in the sewage that appeared in the effluents were as follows: No. 1, 5 per cent.; No. 12, 7 per cent.; No. 13, 0.1 of one per cent.; No. 14, 0.08 of one per cent.; No. 6, 0.6 of one per cent.; No. 11, 26 per cent.; No. 2, 0.26 of one per cent.; No. 4, 0.27 of one per cent.; No. 7, 1.03 per cent. During this time the sum of ammonias averaged about 0.30 parts. Here, omitting No. 11 and No. 12 as before, we have in the effluents an average of a little more than one per cent. of the number of bacteria in the sewage.

After this, nitrification began, and increased, in about one month, from 0.01 parts to 0.15 parts; and the sum of the ammonias increased from about 0.21 parts to about 0.42 parts. In this time the numbers of bacteria in the effluents of the several filters were the following percentages of the numbers in the applied sewage: No. 1, 0.29 of one per cent.; No. 12, 0.59 of one per cent.; No. 13, 0.08 of one per cent.; No. 14, 0.07 of one per cent.; No. 6, 0.017 of one per cent.; No. 11, 2.52 per cent.; No. 2, 0.035 of one per cent.; No. 4, 0.037 of one per cent.; and No. 7, 0.008 of one per cent. Omitting, as before No. 11 and No. 12, these average 0.077 of one per cent.

Immediately after this time, generally in May, 1888, the nitrates increased rapidly, — in a little more than two weeks, — from 0.15 parts to about 2.42 parts, while the sum of ammonias decreased from about 0.42 parts to 0.29 parts. In this time the numbers of bacteria were the following percentages of the numbers in the applied sewage: Filter No. 1, 0.10 of one per cent.; No. 12, 0.08 of one per cent.; No. 13, 0.008 of one per cent.; No. 14, 0.05 of one per cent.; No. 6, 0.002 of one per cent.; No. 11, 0.29 of one per cent.; No. 2, 0.001 of one per cent.; No. 4, 0.001 of one per cent.; and No. 7, 0.001 of one per cent. Here No. 11 is the only exceptional one; omitting this, the others average 0.03 of one per cent.

After the nitrates reached the maximum, when they contained nearly as much and in some cases more nitrogen than was in the sewage applied, — in which cases stored nitrogenous matter was being burned out of the sand, — the nitrates decreased, in varying times, from about 2.42 parts to about 0.90 parts, while the sum of ammonias was decreasing from about 0.27 parts to an established low condition, averaging about 0.018 parts.

While this change to an established condition of purification of the effluent was going on, the numbers of bacteria were the following percentages of the numbers in the applied sewage: Filter No. 1, 0.26 of one per cent.; No. 12, 0.013 of one per cent.; No. 13, 0.004 of one per cent.; No. 14, 0.39 of one per cent.; No. 6, 0.001 of one per cent.; No. 11, 0.07 of one per cent.; No. 2, 0.017 of one per cent.; No. 4, 0.003 of one per cent.; and No. 7, 0.002 of one per cent. Omitting No. 11, as before, and No. 14, which was filtering an exceptionally large quantity, we have an average of 0.060 of one per cent. of the number in the sewage.

We now reach the condition in which the several effluents were in well-established purification through nitrification. Selecting the first month of each, when the nitrates averaged 1.032 parts and the sum of ammonias averaged 0.014 parts, the percentages of the number of bacteria of the sewage found in the several effluents are given on page 582. Omitting, as before, No. 11 and No. 14, the average percentage is 0.070 of one per cent.

Finally, after the filters had been filtering sewage for a year or more, the average conditions of the effluents are to be found on page 583, where the average, taken like the last, gives us 0.050 of one per cent. of the numbers in the sewage.

Arranging all of the preceding results, so that we may compare the number of bacteria found in the several effluents at the different periods, in terms of the percentage of the numbers in the applied sewage, we have the following table: —

Percentages the Number of Bacteria in the Effluents were of Those in the Sewage at Different Periods.

NUMBER of FILTER.	Maximum Percentages when Sewage First Applied was mingling with Water in the Filter.	Minimum Percentages soon after Water was Expelled from the Filter.	Average Percentages during Partial Purification without Nitrification.	Average Percentages when Nitrates were slowly Increasing from 0.01 to 0.15 Parts, and Ammonias were from 0.21 to 0.42 Parts.	Average Percentages when Nitrates were rapidly Increasing from 0.15 to 2.26 Parts, and Ammonias were from 0.42 to 0.29 Parts.	Average Percentages when Nitrates were Decreasing from 2.26 to 0.30 Parts, and Ammonias were from 0.27 to 0.018 Parts.	Average Percentages during the First Month after Established Purification.	Average Percentages from Three to Eight Months, generally in the Second Year of Filtration.
1, . .	31.	0.24	5.	0.29	0.10	0.26	0.3	0.19
12, . .	83.	1.	7.	0.59	0.08	0.13	0.15	-
13, . .	40.	0.01	0.1	0.08	0.008	0.004	0.005	0.02
14, . .	26.	0.03	0.08	0.07	0.05	0.39	3.	3.
6, . .	5.	0.01	0.6	0.017	0.002	0.001	0.02	0.08
11, . .	487.	6.	26.	2.52	0.29	0.07	1.	-
2, . .	14.	0.001	0.26	0.035	0.001	0.017	0.01	0.003
4, . .	5.	0.001	0.27	0.037	0.001	0.003	0.001	0.002
7, . .	5.	0.001	1.03	0.008	0.001	0.002	0.001	0.001
Average,* .	18.	0.042	1.05	0.077	0.030	0.060	0.070	0.050

* Omitting the exceptional.

From this summary we find from the average results of the filters, — omitting those which have exceptional conditions, — that, under the most favorable conditions, from 5 to 40 per cent. of the bacteria applied lived to get through the filters, the smaller number being through fine material and the larger number being through coarse sand, the average amounting to 18 per cent. This was before the liquid in the tank was all from sewage; and, being a condition that is never found after a filter has been used some months for sewage, it is of interest only in showing that it is mechanically possible for bacteria to pass through these materials, under favorable conditions, with a loss of from 60 to 95 per cent.

The minimum number found on a single day, when the conditions, without nitrification, were exceptionally unfavorable, — given in the third column, and averaging but 0.042 of one per cent., — are significant, but may be passed to consider the more general condition given in the fourth column of the average in the large tanks numbered from 1 to 7, for two months or more, and in the others for a much shorter time, when there was a marked reduction in the organic matter by the burning up of carbonaceous matter, but resulting in only a partial purification with no nitrification. At this time there survived the passage from 0.08 of one per cent. to 5 per cent., averaging 1.05 per cent. of the number in the sewage.

We must, from the result, regard the conditions at this time as unfavorable to the passage of bacteria through the sands far beyond that due to mechanical obstruction. Nearly 99 per cent. died where there was apparently an abundance of food, and no destruction by the formation of nitric acid or nitrates. Carbonic acid was formed; and probably the oxygen was in some part of the passage all used up in combining with the carbon.

We may suppose that their general destruction at this time, and in the previous time soon after sewage took possession of the tank, was due to the character of the food met with, and to being deprived of oxygen.

The marked difference in the conditions of the liquid passing through the sand in the periods giving the results in the second and third columns, is an abundance of oxygen in the former and little or none in the latter. The results in the fourth column are also obtained at a time when the oxygen that was not used in burning up the carbonaceous matter must have been in small quantity.

That the character of the food met with has an important effect upon the result, is illustrated by the exceptional results obtained up to this time in Filter No. 11, when compared with identical sand in No. 6; and in Filter No. 12, when compared with identical sand in No. 1.

The sands of No. 6 and No. 1 were in natural condition, as they had been taken from the pit; but that of No. 11 was, when put into the tank, passed in thin layers over red-hot iron, by which its organic matter — less than one per cent. of the whole — was probably partly burnt and partly baked; and the water which was first put into the tank was boiled and poured in upon the hot sand, which caused it to boil again in the tank. In this way the sand and water were freed from bacteria, or were sterilized, and the organic material they contained was burned or cooked. This appears to have so prepared it that it was particularly favorable for the support of bacteria on their passage through this sand. Ten days after the tank was filled and after the first sewage was applied, the number of bacteria in the effluent was nearly five times the number in the applied sewage, and nearly one hundred times as many as came through like sand in Tank No. 6, which had not been heated; and for more than three months the number continued nearly one hundred times as many as in No. 6, and did not decrease to equal No. 6 until nitrification had been high for a month.

When Tank No. 12 was filled, the water that was first poured into it was boiled, and put into the sand hot; and nine days later, after sewage had been passing through daily, the number of bacteria in the effluent was 83 per cent. of the number applied in the sewage, and nearly three times as many as came through like sand in Tank No. 1. The excess in No. 12 over No. 1 continued about two months.

To determine if boiled water would support bacteria in greater numbers than unboiled water, the following experiment was made. A quart of water from the city service pipe was boiled in a clean flask with a return condenser for one hour, and thus sterilized. After cooling, it was mixed with ten per cent. of unboiled city water.

Another clean flask was filled with unboiled city water; and both flasks, covered with inverted beakers, were set aside together, where each would have the same temperature, on May 14, 1890. The numbers of bacteria found in a cubic centimeter of each were as follows: —

Date.	City Water. Number of Bacteria.	City Water Boiled. Number of Bacteria.	Date.	City Water. Number of Bacteria.	City Water Boiled. Number of Bacteria.
May 14, ...	196	3	June 4, ...	12	103,486
17, ...	79	74,880	7, ...	-	63,140
21, ...	31	162,864	10, ...	-	128,040
27, ...	759	90,000	13, ...	-	530

A similar experiment, made to determine if turning boiling water through sand would cause the sand to support more bacteria while cold water was afterwards passing through it, gave the following result: —

Sand like that of Tank No. 1 was put into two glass funnels. On May 14, 500 cubic centimeters of cold city water were poured through one, and the same amount of boiling city water was poured through the other. On the following days 100 cubic centimeters of cold city water were poured through each, and the numbers of bacteria counted in a cubic centimeter of the effluent were as follows: —

Date.	Sand which had not been heated. Number of Bacteria.	Sand which had been heated. Number of Bacteria.	Date.	Sand which had not been heated. Number of Bacteria.	Sand which had been heated. Number of Bacteria.
1889.			**1889.**		
May 15, ...	141	17	May 17, ...	225	6,912
16, ...	4,756	120	21, ...	285	27,612

A like increase in the number of bacteria followed heating the sand in Tank No. 13, by boiling water as given on page 155.

Bacteria decrease with Completeness of Nitrification independently of the Sum of Ammonias.

We have seen that it is mechanically possible for from 5 to 40 per cent., averaging 18 per cent., of the number of bacteria applied in the sewage to pass through the several filters; but that, after intermittent filtration is established and no nitrification is taking place,—although there is a destruction of organic matter by the burning up of some of the carbonaceous matter,—the number of bacteria that survived the passage was from 0.08 of one per cent. to five per cent., averaging 1.05 per cent. In this condition of partial purification 99 per cent. of the bacteria are destroyed; but, when nitrification begins, the number surviving the passage suddenly decreases to only 0.08 of one per cent., and a still further decrease to about 0.03 of one per cent. when nitrification becomes complete.

During each of these stages there appears to be no lack of food for bacteria; for both free and albuminoid ammonia are abundant, their sum averaging from 0.2 to 0.4 parts per 100,000 of the effluent.

In the stages which follow, a decrease in the sum of ammonias is not accompanied with a further decrease in the number of bacteria. In the seventh column we have a decrease in the sum of ammonias, from 0.270 parts to 0.018 parts, accompanying a decrease in nitrates from 2.42 parts to 0.90 parts, but a much higher average condition of nitrates than in the previous columns; but the number of bacteria is higher, and, when the sum of ammonias is maintained at the very small amount of 0.0140 parts, or about one-half of one per cent. of the sum of ammonias of the sewage, the average percentage of the number of bacteria continues about the same; viz., 0.07 and 0.05 of one per cent. of the number in the sewage.

We do not here find that the number of bacteria, after nitrification begins, decreases with the decrease in the sum of the ammonias; but it does decrease with the completeness of the nitrification.

Bacteria also independent of the Albuminoid Ammonia.

As free ammonia is generally an indication of organic matter that previously existed, it may be that in these effluents it is not, even when abundant, in a form that serves as food or support to bacteria; and, as the changes noted in regard to the sum of ammonias are in great part changes in free ammonia, it will be useful to examine the actual amounts of albuminoid ammonia in the effluents at the several periods. These are given in the following table: —

Percentage of the Number of Bacteria in the Sewage that are found in the Effluents.	Amount of Albuminoid Ammonia in the Effluents, in Parts per 100,000.	Percentage of the Number of Bacteria in the Sewage that are found in the Effluents.	Amount of Albuminoid Ammonia in the Effluents, in Parts per 100,000.	Percentage of the Number of Bacteria in the Sewage that are found in the Effluents.	Amount of Albuminoid Ammonia in the Effluents, in Parts per 100,000.
18.	0.0180	0.077	0.0180	0.070	0.0110
0.042	0.0110	0.023	0.0150	0.050	0.0110
1.05	0.0220	0.060	0.0140		

Here we find the albuminoid ammonias, at the several periods, nearly constant at two or three per cent. of the albuminoid ammonia of the sewage, and in amount and in variation as usually found in drinking water supplies; but there appears to be no relation between the number of bacteria and the amount of albuminoid ammonia. For example, we find the same amount of albuminoid ammonia when the number of bacteria in the effluents averaged 18 per cent. of the number in the sewage as when the number was only 0.077 of one per cent.; hence we cannot ascribe the difference in number in the latter case to be due to the want of albuminoid ammonia for food. It is, however, possible that the albuminoid ammonia remaining in the effluent when nitrification was active expressed a quality of organic matter very difficult to decompose, and not as well adapted to support bacteria as that in the effluent before nitrification began.

The Same Conclusions reached if Fine Sand Filters are not included.

We have been considering all of the filters of the table that did not present conditions that were evidently exceptional; but, as we have found strong ground for concluding that no bacteria live to pass through the fine sand and soil covered filters after nitrification was established, it will be necessary to see the effect of the different conditions of the effluent in the coarse sand filters, No. 1, No. 13 and No. 6. Upon taking the mean from the several columns of the table for these tanks, we find the same order of change as in the mean for all of the tanks, the means for these coarse sand tanks being from 1.5 to 2 times the means for all; hence the same conclusions would be reached in regard to the destructive effect of nitrification and the independence of the result upon the greater or less amount of the sum of ammonias.

Probable Destruction of Bacteria by Oxidation.

Although the number of bacteria in the effluent was relatively small, being but one per cent. of the number in the sewage, when carbonic acid was formed in the burning up of carbon in organic matter, and the number was decreasing as the process continued, yet it was very much smaller, being from 0.03 to 0.07 of one per cent. when nitric acid was formed in the burning up of nitrogen derived from organic matter of the sewage; and the least number was when this oxidation of nitrogen was most complete. It would follow, in a permanently established condition of nitrification, that, when nitrification was most complete, the amount of the ammonias in the effluent would be the least; but in the varying condition of the sewage applied, and the storing and subsequent giving off of ammonias from the sand, we have sometimes found the highest nitrification and the smallest number of bacteria when there was a large supply of the ammonias in the effluent. This would indicate that the most complete destruction of bacteria was not due to a failure of food, so far as that may be supplied by the free or albuminoid ammonia of these effluents, but was rather due to the process of the formation of nitrates, — the burning process. We have thought that their destruction might be due to being deprived of oxygen that was used in the oxidation of other organic matter; but it may be due to their own oxidation, — to their being burned.

The Effluents from the Filters not adapted to support Bacteria.

We have found that, if food that has been proved to be well adapted to the growth of bacteria be applied to one of these filters, when the sewage ordinarily applied is being very completely nitrified, the number of bacteria will for a time be greatly increased, and continue high until this food has passed out or is becoming nitrified; from which we may conclude that the free and albuminoid ammonias, — although quite high in an effluent, — when they are the residue of a much larger amount that has been burned, indicate substances that are much less able to support bacterial life than fresh organic substances, that would give the same amount of free and albuminoid ammonia in a solution.

Examinations have been made of the number of bacteria in the effluent from Tanks No. 1, No. 2, No. 4 and No. 6, from hour to hour, while filling and after standing two or three days in the measuring basins, to determine whether bacteria would increase in numbers in these effluents, when exposed to the air under circumstances probably more favorable to their growth than if turned into a drinking-water stream.

In some cases there was an increase in numbers on standing, and in others a decrease; but in no case did the growth of bacteria in these effluents indicate that the remaining organic matter was well adapted to support bacteria.

May the Filtered Effluent be used for Drinking?

We now come to the important question of the character, as regards healthfulness of the effluents obtained by filtering sewage intermittently through five feet in depth of sand, after the sand has filtered sewage for a year or more without being cleaned.

We have found that the sum of ammonias, which have been taken to indicate the amount of nitrogenous organic matter, has been reduced to about one-half of one per cent. of those in the sewage, and is less than the sum of ammonias of most of the public drinking-water supplies of the State.

The chlorine and nitrates are higher than in the public drinking waters. They indicate in these effluents, as their excess above the normal does in the drinking waters, that the water which contains them came from sewage; but, in the absence of the ammonias, they indicate that, though the water came from sewage, the organic impurities have been destroyed, and these are merely mineral constituents which remain after that destruction. They are principally common salt and saltpetre, which, in the quantities found in any of the effluents, are regarded as entirely harmless.

Judging by the chemical analyses, there is nothing in the effluents known, or even suspected by chemists, to be harmful.

Although nearly all of the bacteria that were in the sewage did not live to pass through the filters, there have been found in the effluents from filters of coarse sand more bacteria than are found in the public drinking supplies, and some of these evidently come from the sewage; and, until we learn that disease-producing bacteria are not among those that come through, we must assume that they may be among them; and, although reduced in numbers to such an extent that they may do no harm, we yet know that bacteria in general increase with enormous rapidity when under favorable conditions, and we do not yet know enough to allow us to assume that the very small number of one or two in a thousand of the number in the sewage that come through may not increase in the human body or under other conditions to such numbers as to be harmful.

From this cause we are not able to assume that the effluent from the coarse sand filters five feet in depth is suitable for drinking water.

The effluent from the extremely fine sand filter, No. 4, and that from the soil-covered filter, No. 7, and a part of the time from the fine sand, No. 2, we have strong ground for concluding contained no bacteria from the sewage. The numbers that were found in the effluents were smaller than are usually found in public drinking supplies; and we have good reason for concluding that they all grew in the gravel and underdrains beneath the filters. If these conclusions are correct, there is no known reason why these effluents may not be used with safety for drinking.

The effluent from No. 2 has been frequently used for drinking by a number of people, without any noticeable effect; but none of them have been used continuously by a large number sufficiently to prove their safety. In the absence of such positive evidence, we have made the following comparisons.

The city of Lawrence is provided with a public water supply from the river; but there are a dozen or more wells scattered about the city, on the sides of streets, that have been used for many years for watering horses, and are still used for this purpose, or for supplying drinking water to families in the neighborhood, and particularly are used by the public for a cool draught of water in the summer, when it is much more refreshing than the city reservoir water.

The water from ten of these wells has been analyzed and examined for bacteria, and the results obtained from seven of them are arranged below, with the average result obtained by analysis of the filtered sewage from six of our filters, covering from two to eight months, after most of them had been in use a year or more.

Comparison of the Effluent from Several of the Filters filtering Sewage, with Water from Wells in Common Use.

Average Effluent from	Ammonias.			Chlorine.	Nitrogen as		Bacteria per Cubic Centimeter.
	Free.	Albuminoid.	Sum.		Nitrates.	Nitrites.	
Tank No. 1, for two months,	.0313	.0272	.0585	4.83	1.78	.0008	549
Well water, Atlantic Street,	.1410	.0155	.1565	8.08	2.37	.0024	4,370
Tank No. 13, for six months,	.0011	.0105	.0116	7.28	1.25	.0004	76
Well water, Hampshire Street,	.0078	.0118	.0196	7.51	2.00	.0007	128
Tank No. 6, for three months,	.0036	.0104	.0140	4.98	1.66	.0002	678
Well water, Andover Street,	.0184	.0046	.0230	2.79	1.50	.0018	46
Tank No. 6, for six months,	.0014	.0074	.0088	4.51	1.11	.0001	319
Well water, Mechanic Street,	.0016	.0076	.0092	5.29	4.20	.0000	240
Tank No. 4, for two months,	.0025	.0108	.0133	3.72	0.75	.0002	20
Well water, Salem Street,	.0070	.0086	.0156	7.67	1.40	.0014	447
Tank No. 2, for four months,	.0007	.0065	.0072	3.98	0.71	.0000	17
Well water, Lowell Street,	.0012	.0070	.0082	7.11	2.10	.000	27
Tank No. 7, for eight months,	.0014	.0063	.0077	4.04	1.06	.0000	7
Well water, Haverhill Street,	.0022	.0050	.0072	2.44	0.55	.0016	344

Here we find, for each of the filters filtering sewage, a well the water of which is used for drinking by many people, but is in fact sewage not so well purified as the effluent from the filter with which it is associated. This is not presented to show that the effluent from the filters is good for drinking, for we have no reason to so regard those at least in the upper half of the table, and we should without hesitation pronounce the well waters in the upper half of the table as unsafe to drink; but we present this comparison to show that waters in every way as impure and as certainly derived from sewage as the effluents from the several sewage filters are being used daily, and have been used for years by multitudes of people, without their knowing that they were harmed by them.

Every one of these wells should be regarded as unsafe, some of them dangerous in their present condition, and others unsafe because of what they may change to from day to day.

If these wells contained unpolluted water, the chlorine would be about 0.36, while it is from seven to twenty-two times this amount; the nitrates would be about 0.01 or 0.02, while they are from 0.55 to 4.20.

The latter show that a large amount of organic matter, generally more than there is in sewage in a sewer, has been burned out of these waters, and the high chlorines show that this organic matter was of the same character as that in sewage. From the amounts in most of these well waters we must conclude that their previous condition was worse — that is, more polluted — than ordinary sewage in sewers, and that on its way to some of the wells it has by intermittent filtration through the ground been purified to such an extent that they may not in their present condition be harmful; and, where the numbers of bacteria are continually small and the ammonias low, they probably are not harmful; but, where the numbers of bacteria are large and the ammonias are large, although the waters have been previously much worse than at present, and have to a considerable degree been purified, their present condition indicates that the material through which they have filtered has not been able to exclude bacteria nor to burn up all of the food they live on; hence, if disease germs get into their source, some of them will probably get into these wells. Such of the wells as are included in this latter class should be filled with earth, and never used again. Others, if examined from time to time, and always found with low ammonias and small number of bacteria, would probably be harmless; and we should have the same ground for concluding that the effluent from sewage at those fine sand or soil-covered filters through which no bacteria come from the sewage would also be harmless for drinking.

These comparisons have been made, not to advise drinking any of the well waters that have been cited, nor any of the effluents from the sewage filters, but to show that, as people are drinking such waters with impunity, with which the effluents from the filters of fine sand compare favorably in every respect, there can be no doubt that the effluents from sewage filtration through such filters can be turned into a drinking-water stream, where they will be much diluted, without risk of injury to those who drink from it.

INTERMITTENT FILTRATION OF WATER.

In November and December, 1887, the large filtering tanks in the field were used for the intermittent filtration of water taken from the service pipes of the city of Lawrence.

The results of those experiments were given in the nineteenth annual report of the State Board of Health, pages 46 to 64. The general result with tanks No. 1, No. 2, No. 6, No. 7 and No. 8, when filtering from 300 gallons to 4,000 gallons a day, during those two months, was the removal of about four-fifths of the nitrogenous organic matter, as shown by the sum of ammonias; but, as there was no nitrification, — in fact, the nitrates were reduced in nearly the same proportion as the ammonias, — it is evident that the impurities removed from the water during those two months must have been in large part retained by the sand. There was no indication of any burning process, by which the organic matter could be changed to mineral matter.

While the effluents were of very good quality, — the free ammonia of the city water, being 0.0025 parts, was reduced to 0.0003 parts, and the albuminoid ammonia from 0.0134 was reduced to 0.0028 parts, — and there was no decrease in quality by the continuance of the filtration, still, the time was too short to enable conclusions to be reached in regard to the result that would be obtained if the filtration should be continued indefinitely. All these tanks, except No. 8, were after the first two months used for the filtration of sewage.

FILTER TANK No. 8.

Tank No. 8 has been continued filtering water for two years with very satisfactory results. This tank was filled with the same kind of materials as Tank No. 7, which has been previously described; but on Jan. 13, 1888, the six inches in depth of brown soil at the surface, and two inches in depth of yellow loam, which underlaid it, were replaced by six inches in depth of the material like that under the yellow loam; so that, after Jan. 13, 1888, Tank No. 8 was filled as follows: —

The lower seven inches, in which were the underdrains, were made up of a layer of stones, about one inch by two inches, covering the bottom of the tank, upon which were stones of smaller size, followed by layers of fine gravel, and by two or three inches of coarse sand like that of Tank No. 1. Above the lower seven inches were three feet and eight inches in depth of fine gravel and coarse and fine sand. Above this was a depth of eight inches of yellow, sandy loam, and this was covered with a depth of six inches of fine gravel and coarse and fine sand like that beneath the loam. The percentages of grains of different sizes in the two kinds of material are given in the following table: —

	Approximate Diameter of Grains, in Inches.	Sand and Gravel. Percentage.	Yellow Loam. Percentage.
Coarser than sieve No. 2,	–	17	4
Between sieve No. 2 and No. 4,	–	10	4
Between sieve No. 4 and No. 10,	–	16	14
Between sieve No. 10 and No. 20,	–	25	17
Between sieve No. 20 and No. 40,	0.020 to 0.048	19	17
Between sieve No. 40 and No. 55,	0.012 to 0.020	5	8
Between sieve No. 55 and No. 70,	0.010 to 0.012	1	3
Between sieve No. 70 and No. 100,	0.008 to 0.010	2	4
Between sieve No. 100 and No. 140,	0.005 to 0.008	1	4
	0.003 to 0.005	1.8	10
	0.001 to 0.003	2.0	14
	0.000 to 0.001	0.2	1

The yellow loam has 15 per cent. finer than 0.003 inch in diameter, and the soft feeling of the finest portion indicates that there is some alumina present. The loss on heating to redness was 1.97 per cent., which was probably nearly all organic matter. The quartz grains and other material, insoluble in acid, when exposed two hours, amounted to 94.37 per cent. The soluble parts included 1.95 per cent. of alumina and 1.31 per cent. of oxide of iron and manganese.

The presence of these small amounts of alumina, iron and organic matter in this loam may be the cause of results in filtration through this filter quite different from those obtained through sand.

Tables of Analyses.

The chemical analyses of the city water, and of the effluent from Tank No. 8, made once a week or oftener, during the past two years, may be found in the tables at the end of this section. The tables also contain the quantity of water applied, and of the effluent, together with their temperatures. The results of chemical analysis are expressed in parts per 100,000.

Monthly averages of the analyses of both city water and effluent, and the percentage which the constituents of the latter are of the former, and the number of bacteria found in a cubic centimeter of the city water, and of the effluent from this tank, are given in the following tables: —

Monthly Averages of Results with Tank No. 8, filtering City Water.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1887.												
Nov. 23-26, .	City water,	–	1.35	2.95	.0016	.0104	.0120	0.28	.0180	.0000	45°	–
Nov. 26-30, .	Effluent, .	375	0.42	3.42	.0004	.0031	.0035	0.34	.0000	.0000	–	128
	Per cent., .	–	31	116	25	30	29	–	–	–	–	–
Nov. 27-Dec. 27,	City water,	–	1.28	2.98	.0024	.0134	.0158	0.29	.0182	.0000	44°	70
December, .	Effluent, .	453	0.41	2.61	.0004	.0031	.0035	0.26	.0044	–	–	55
	Per cent., .	–	32	88	17	23	22	–	–	–	–	–
1888.												
Dec. 28, '87-Jan. 23, '88, . .	City water,	–	1.25	2.80	.0029	.0131	.0160	0.17	.0130	.0000	41°	224
January, . .	Effluent, .	221	0.45	2.53	.0010	.0026	.0036	0.25	.0120	–	35°	40
	Per cent., .	–	36	90	34	20	22	–	92	–	–	–
Jan. 24-Feb. 27,	City water,	–	1.14	2.99	.0032	.0116	.0148	0.22	.0141	.0001	35°	143
February, . .	Effluent, .	188	0.47	2.54	.0005	.0029	.0034	0.22	.0095	–	35°	19
	Per cent., .	–	41	85	16	25	23	–	67	–	–	–

Monthly Averages of Results with Tank No. 8, filtering City Water — Continued.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888 — Con.												
Feb. 28-Mar. 23,	City water,	–	1.27	2.81	.0034	.0106	.0140	0.20	.0212	–	36°	221
March, . .	Effluent, .	362	0.74	2.45	.0014	.0029	.0043	0.21	.0190	.0000	36°	47
	Per cent., .	–	58	87	41	26	31	–	90	–	–	–
Mar. 24-Apr. 20,	City water,	–	0.86	2.41	.0023	.0112	.0135	0.20	.0140	–	37°	146
April, . .	Effluent, .	174	0.49	2.66	.0020	.0036	.0056	0.18	.0200	–	41°	19
	Per cent., .	–	57	110	87	32	41	–	–	–	–	–
Apr. 21-May 22,	City water,	–	1.07	2.58	.0008	.0099	.0107	0.13	.0203	.0002	45°	45
May, . . .	Effluent, .	174	1.32	2.49	.0009	.0034	.0043	0.18	.0550	–	50°	16
	Per cent., .	–	123	97	112	34	40	–	–	–	–	–
May 23-June 27,	City water,	–	1.17	2.40	.0007	.0095	.0102	0.17	.0144	.0001	58°	50
June, . .	Effluent, .	182	0.83	3.11	.0009	.0037	.0046	0.20	.0617	.0000	62°	12
	Per cent., .	–	71	130	129	39	45	–	–	–	–	–
June 28-July 30,	City water,	–	0.90	3.05	.0024	.0110	.0134	0.27	.0220	.0001	67°	81
July, . . .	Effluent, .	649	0.46	2.70	.0009	.0037	.0046	0.35	.0276	.0000	70°	12
	Per cent., .	–	51	89	37	34	34	–	–	–	–	–
July 31-Aug. 30,	City water,	–	1.76	2.46	.0008	.0114	.0122	0.28	.0224	.0000	69°	114
August, . .	Effluent, .	897	1.12	2.10	.0006	.0038	.0044	0.31	.0235	.0000	72°	16
	Per cent., .	–	64	85	75	33	36	–	–	–	–	–
Aug. 31-Sept. 28,	City water,	–	1.55	2.97	.0012	.0118	.0130	0.25	.0228	.0000	67°	283
September, .	Effluent, .	876	0.31	3.02	.0003	.0027	.0030	0.26	.0217	.0000	68°	18
	Per cent., .	–	20	102	25	23	23	–	–	–	–	–
Sept. 29-Oct. 30,	City water,	–	1.45	2.50	.0012	.0144	.0156	0.22	.0220	.0000	56°	109
October, . .	Effluent, .	905	0.52	2.37	.0002	.0027	.0029	0.22	.0216	.0000	55°	11
	Per cent., .	–	36	95	17	19	19	–	–	–	–	–
Oct. 31-Nov. 28,	City water,	–	1.29	2.83	.0005	.0114	.0119	0.24	.0222	.0000	49°	84
November, .	Effluent, .	1,060	0.50	2.05	.0000	.0030	.0030	0.23	.0227	.0000	49°	61
	Per cent., .	–	39	72	0	26	25	–	–	–	–	–
Nov. 29-Dec. 30,	City water,	–	1.06	2.85	.0008	.0092	.0100	0.23	.0260	.0000	40°	55
December, .	Effluent, .	1,160	0.67	2.31	.0003	.0034	.0037	0.22	.0282	.0000	40°	75
	Per cent., .	–	63	81	37	37	37	–	–	–	–	–
1889.												
Dec. 31, '88-Jan. 30, '89, . .	City water,	–	1.04	2.71	.0003	.0099	.0102	0.23	.0260	.0000	38°	87
January, . .	Effluent, .	1,370	0.52	2.27	.0002	.0045	.0047	0.22	.0270	.0000	38°	12
	Per cent., .	–	50	84	67	46	46	–	–	–	–	–
Jan. 31-Feb. 27,	City water,	–	1.01	2.66	.0007	.0084	.0091	0.24	.0232	.0000	36°	37
February, . .	Effluent, .	1,307	0.56	2.28	.0003	.0035	.0038	0.22	.0242	.0000	36°	7
	Per cent., .	–	55	86	43	42	42	–	–	–	–	–
Feb. 28-Mar. 30,	City water,	–	0.65	2.85	.0012	.0089	.0101	0.23	.0225	.0000	37°	49
March, . .	Effluent, .	1,318	0.37	2.54	.0002	.0030	.0032	0.21	.0252	.0000	40°	6
	Per cent., .	–	57	89	17	34	32	–	–	–	–	–
Mar. 31-Apr. 29,	City water,	–	0.78	2.61	.0009	.0097	.0106	0.17	.0175	.0000	43°	25
April, . .	Effluent, .	1,299	0.60	2.45	.0004	.0046	.0050	0.16	.0262	.0001	49°	9
	Per cent., .	–	77	94	44	47	47	–	–	–	–	–
Apr. 30-May 30,	City water,	–	1.12	2.36	.0004	.0102	.0106	0.14	.0134	.0000	55°	31
May, . . .	Effluent, .	1,320	0.57	2.64	.0006	.0044	.0050	0.14	.0260	.0000	62°	7
	Per cent., .	–	51	112	150	43	47	–	–	–	–	–
May 31-June 28,	City water,	–	1.56	2.53	.0007	.0131	.0138	0.16	.0167	.0000	63°	67
June, . . .	Effluent, .	1,231	0.66	2.53	.0004	.0049	.0053	0.16	.0412	.0000	69°	9
	Per cent., .	–	42	100	57	37	38	–	–	–	–	–
June 29-July 30,	City water,	–	1.27	2.81	.0011	.0133	.0144	0.19	.0160	.0000	70°	87
July, . . .	Effluent, .	1,315	0.70	2.52	.0008	.0053	.0061	0.18	.0254	.0000	73°	11
	Per cent., .	–	55	90	73	40	42	–	–	–		–

Monthly Averages of Results with Tank No. 8, filtering City Water — Concluded.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1889 — Con.												
July 31-Aug. 30,	City water,	–	1.97	4.06	.0007	.0158	.0165	0.19	.0192	.0000	69°	28
August, . .	Effluent, .	1,277	1.56	2.74	.0003	.0049	.0052	0.19	.0237	.0000	71°	88
	Per cent., .	–	79	67	43	31	32	–	–	–	–	–
Aug. 31-Sept. 28,	City water,	–	1.42	3.33	.0015	.0139	.0154	0.25	.0180	.0000	67°	91
September, .	Effluent, .	1,217	0.87	3.08	.0004	.0051	.0055	0.24	.0248	.0000	68°	6
	Per cent., .	–	61	92	27	37	36	–	–	–	–	–
Sept. 29-Oct. 30,	City water,	–	1.70	2.94	.0015	.0151	.0166	0.21	.0108	.0000	56°	124
October, . .	Effluent, .	1,274	1.55	2.42	.0003	.0060	.0063	0.21	.0160	.0000	55°	6
	Per cent., .	–	91	82	20	40	38	–	–	–	–	–
Oct. 31-Nov. 29,	City water,	–	1.37	2.63	.0010	.0144	.0154	0.21	.0097	.0000	49°	170
November, .	Effluent, .	1,206	0.93	2.60	.0003	.0060	.0063	0.21	.0145	.0000	49°	11
	Per cent., .	–	68	99	30	42	41	–	–	–	–	–
Nov. 30-Dec. 30,	City water,	–	1.57	2.60	.0013	.0127	.0140	0.18	.0124	.0000	43°	66
December, .	Effluent, .	1,114	1.07	2.63	.0005	.0061	.0066	0.19	.0188	.0000	40°	7
	Per cent., .	–	68	101	38	48	47	–	–	–	–	–

The data of the tables of daily observations upon the applied water and upon the effluent from this tank are also presented by a diagram following the tables.

Upon first applying water to Tank No. 8, the result, in common with that of all the other tanks to which water was applied, was at first a general reduction of the ammonias and of the nitrates. For the three months from December, 1887, to February, 1888, the effluent from Tank No. 8 contained but 22 per cent. of the ammonias of the water applied, and 57 per cent. of the nitrates. In these three months the total nitrogen that came from the tank was but 32 per cent. of the total nitrogen applied in the water. If the city water had been filtered through filter paper, there would have been removed about 5 per cent. of the total nitrogen that it contained, — that is, 95 per cent. of its total nitrogen was in solution; and we find that, in these three months, 66 per cent. of the nitrogen that was in solution in the city water was retained by the filtering material. In what way the sand retains any considerable part of the nitrogenous matter that is in solution in the liquid applied, is not clear; but the fact that it is so retained is shown by the results of nearly all the efficient filters with which we have experimented. In the fourth month, March, the ammonias of the effluent were 31 per cent. of those in the applied water, and the nitrates were 90 per cent. of the nitrates of the water. In April the nitrates of the effluent began to increase when the temperature of the effluent reached 40° Fah.; and the average nitrates of the effluent for the month were 43 per cent. higher than the nitrates of the water. The sum of the ammonias of the effluent for this month were 41 per cent. of those of the water applied.

In May the nitrates increased from 0.0300 parts per 100,000 to 0.0750 parts, and averaged 0.0550 parts, while the nitrates of the applied water were 0.0203 parts. During this month the nitrogen in the nitrates of the effluent amounted to 147 per cent. of the nitrogen of the water applied; and the total nitrogen of the effluent was 164 per cent. of the total nitrogen of the water applied; that is, there was, during this month, removed from the filtering material, some of the organic matter which it had retained in the previous five months. The percentage which the nitrogen of nitrates in the effluent bears to the total nitrogen of the applied water for the several months is given in the following table: —

Percentage of the Total Nitrogen of the applied Water that appears in the Effluent as Nitrates.

Date.	Total Nitrogen in Applied City Water.	Nitrates in Effluent.	Per Cent.	Quantity of Effluent. Gals.	Temperature.	
					City Water.	Effluent.
1887.						
Nov. 26-30,	.0364	.0000	0	375	45°	–
December,	.0421	.0044	10	453	44°	–
1888.						
January,	.0369	.0120	33	221	41°	35°
February,	.0358	.0095	27	188	35°	35°
March,	.0414	.0190	46	362	36°	36°
April,	.0343	.0200	58	174	37°	41°
May,	.0374	.0550	147	174	45°	50°
June,	.0307	.0617	201	182	58°	62°
July,	.0421	.0276	66	649	67°	70°
August,	.0417	.0235	56	897	69°	72°
September,	.0431	.0217	50	876	67°	68°
October,	.0466	.0216	46	905	56°	55°
November,	.0413	.0227	55	1,060	49°	49°
December,	.0417	.0282	68	1,160	40°	40°

Percentages of the Total Nitrogen of the applied Water that appears in the Effluent as Nitrates — Concluded.

Date.	Total Nitrogen in Applied City Water.	Nitrates in Effluent.	Per Cent.	Quantity of Effluent. Gals.	Temperature. City Water.	Temperature. Effluent.
1889.						
January,	.0425	.0270	64	1,370	38°	38°
February,	.0375	.0242	65	1,307	36°	36°
March,	.0381	.0252	66	1,318	37°	40°
April,	.0341	.0262	77	1,299	43°	49°
May,	.0305	.0260	85	1,320	55°	62°
June,	.0388	.0412	106	1,231	63°	69°
July,	.0387	.0254	66	1,315	70°	73°
August,	.0457	.0237	52	1,277	69°	71°
September,	.0420	.0248	59	1,217	67°	68°
October,	.0368	.0160	43	1,274	56°	55°
November,	.0341	.0145	43	1,206	49°	49°
December,	.0343	.0188	55	1,114	43°	40°

In June, 1888, the nitrates were still higher than in May, reaching 0.0800 parts, and averaging 0.0617 parts, while those of the water were 0.0144 parts. The nitrates of the effluent contained 201 per cent. as much nitrogen as was applied in the city water; and the total nitrogen which came away from the tank in the effluent was 223 per cent. of the amount applied in the city water. In these two months of May and June, the amount of the nitrogen which came away in the effluent, in excess of the amount which was applied, was nearly equal to the excess of the nitrogen applied in the city water in the previous three months, over the amount which then came through in the effluent. And, as we have found in other filter tanks that some of the applied nitrogen escapes, — probably into the air, — it is probable that all of the nitrogen which had been stored in this tank in the previous five months, during which water had been applied, was removed by the nitrification of these two months, May and June.

In July the nitrates of the effluent averaged 0.0276 parts, while those of the applied water were 0.0220 parts. The nitrates in the effluent, during this month, amounted to 66 per cent. of the total nitrogen of the applied water; and, as this is the percentage which we have found in the effluent from other tanks, when no organic matter was being stored in the filtering material, it is probable that none was being stored in this tank at this time. The total nitrogen of the effluent during this month amounted to 82 per cent. of the total nitrogen of the applied water.

In the next four months, August to November, 1888, the nitrates of the effluent averaged 0.0223 parts, and were equal to those of the applied water. There was, during this time, then, no nitrification. The total nitrogen which came away in the effluent was, during these four months, 64 per cent. of the total nitrogen applied.

In the four cold months, December, 1888, to March, 1889, the nitrates of the effluent averaged 0.0261 parts, which was 8 per cent. more than the nitrates of the applied water, which averaged 0.0244 parts. The nitrogen of the nitrates in the effluent, during these months, bore a very constant relation to the total nitrogen of the applied water, varying only from 68 per cent. to 64 per cent., averaging 66 per cent. This indicates that during these four cold months very little, if any, of the nitrogenous matter of the water was stored in the filter. The total nitrogen of the effluent, during these four months, averaged 80 per cent. of the total nitrogen of the applied water. The temperature of the effluent varied from 35 degrees to 43 degrees, and averaged 39 degrees. In the month of February it averaged 36 degrees, and the nitrates were in this month 4 per cent. higher than those of the water.

In April the nitrates of the effluent averaged 0.0262 parts, and were 50 per cent. higher than those of the water, which averaged 0.0175 parts. They amounted to 77 per cent. of the total nitrogen of the applied water.

In May the nitrates were 0.0260 parts, which was 94 per cent. more than the nitrates of the water, which averaged 0.0134 parts. The nitrogen of the nitrates in this month amounted to 85 per cent. of the total nitrogen of the applied water.

In June the nitrates were still higher, averaging 0.0412 parts, or 247 per cent. of the nitrates of the water, which averaged 0.0167 parts. The nitrogen of the nitrates in this month amounted to 106 per cent. of the total nitrogen of the applied water, and the total nitrogen of the effluent was 28 per cent. in excess of the total nitrogen of the applied water.

In the three months, April, May and June, in which the high nitrates are found, the total nitrogen of the effluent was continually greater than the total nitrogen of the applied water, and averaged for the three months 13 per cent. greater. Nitrogen stored in the filtering material was then being removed. Up to the end of this period, 82 per cent. of all of the nitrogen that had been applied to the tank had come through in the effluent.

During the next six months, to the end of the year 1889, the nitrates of the effluent varied from 123 to 159 per cent. of those of the applied water, and averaged 143 per cent. During this time the nitrogen in the nitrates of the effluent averaged 53 per cent. of the total nitrogen of the applied water, and the total nitrogen in the effluent was 75 per cent. of the total nitrogen applied in the water.

By reference to the diagram of results with city water and Tank No. 8, which accompanies the tables of daily observations, we get a general review of the nitrification within this tank.

In the first four months, December, 1887, to March, 1888, we find that the nitrates of the effluent are less than the nitrates of the applied water.

With April, and a temperature above 39° Fah., we find the nitrates of the effluent greater than those of the water; and these continually increase, until, on June 5, they are more than five times those of the water. They soon decrease, and in the latter part of August become equal; and, through September and October and a part of November, they are a little less than those of the applied water. During the five months, April to August, 1888, when the nitrates of the effluent were higher than those of the water, they contained 47 per cent. more nitrogen than was in the nitrates of the applied water; and from the beginning of the application of water to the end of August, the nitrates of the effluent had contained 19 per cent. more nitrogen than the nitrates of the applied water.

In these five months in which the nitrates of the effluent were higher than those of the water, the total nitrogen of the effluent amounted to 92 per cent. of the total nitrogen applied; and, from the beginning of the application of water to the end of August, the total nitrogen contained in the effluent had been 72 per cent. of the total nitrogen that had been applied in the water.

In those filter tanks whose sand has been examined from time to time, to determine the amount of organic matter stored therein, we have found that, wherever the effluent contained from 50 per cent. to 75 per cent. of the nitrogen applied to the filter, there was no nitrogen being stored in the material. The difference between these percentages and the full amount of nitrogen applied escaped, — probably into the air; from which we may conclude that in this tank, at the end of August, all stored nitrogenous matter had been burned up; and, there being so little applied in the water at this time, there was for a time none to burn. Hence nitrification ceased through the following three months; after which, some nitrogenous matter having accumulated in the tank, it again began in the latter part of November, and continued constantly throughout the second year, being most complete in the months of April, May and June, when the nitrogen in the nitrates of the effluent averaged 89 per cent. of the total nitrogen of the applied water.

In the twelve months of the year 1889, the nitrates of the effluent averaged 43 per cent. more than the nitrates of the applied water, and were 64 per cent. of the total nitrogen in the applied water. The total nitrogen of the effluent in the second year amounted to 87 per cent. of the total nitrogen of the applied water; and it is very probable, if not quite certain, that there was no more nitrogenous matter stored in the tank at the end of the year than there was at the beginning; and that this tank, having been used constantly for the filtration of city water for two years, without any disturbance of material or cleansing of the surface, except that of the cleansing process of nitrification, is in better condition for the filtration of water than it was at the beginning, and shows no indication that the filtration of the same quantity of water that has been applied during the past year may not be continued indefinitely.

Without knowing all of the conditions that are essential to nitrification, we find, in several of the tanks, — notably No. 12, No. 13, No. 14, and the one now under consideration, — what appear to be striking parallels to the conditions that would exist if the organic material were burned by fire. There must first be an accumulation of combustible material. When started, the rapidity and completeness of combustion is greatest where most material has been accumulated (see No. 12, 13 and 14). In No. 8, the greatest rapidity of burning was in May and June, 1888, after four months of accumulation with no nitrification. This was followed by two months of slow burning, growing more feeble, until extinguished in September. Some accumulation of material occurred in the next three months, and the burning again started in December, and continued feebly through the cold months, and, becoming more active in April and May, burned with greatest intensity in June, — though with less intensity and shorter duration than in the previous year, apparently for the reason that there was less to burn; until, the stored material being nearly exhausted, it burned feebly but continuously the organic matter daily supplied through the following months.

The quantity of water filtered through Tank No. 8 was, on December, 1887, 453 gallons per day, or the equivalent of 90,600 gallons per acre per day. In the next six months, January to June, 1888, it averaged 217 gallons, or the equivalent of 43,400 gallons per acre per day.

On July 12, 1888, the quantity applied was increased to 1,000 gallons a day for six days in the week, and this quantity was continued to November 14; after which, for the following fourteen months, to the end of the year 1889, 1,500 gallons were applied,— except occasionally, in very rainy weather, the tank would not dispose of so much; hence, in the last eighteen months, the quantity applied on six days in the week was, for four months, the equivalent of 200,000 gallons per acre per day, and for about fourteen months the equivalent of 300,000 gallons per acre per day. The actual amount of effluent from the tank for every day of the year 1889 averaged 1,275 gallons, or the equivalent of 255,000 gallons per acre per day.

When the small quantities of water were applied in the first seven months, the sum of ammonias of the effluent averaged 32 per cent. of the sum of ammonias of the applied water. During the four months, August to November, when 200,000 gallons per acre per day were applied, the sum of the ammonias of the effluent averaged 26 per cent. of those of the applied water; and in the remaining thirteen months, up to December, 1889, the sum of the ammonias of the effluent averaged 40 per cent. of those of the applied water. The percentages varied in the several months from 32 per cent. to 47 per cent.

In the first four months, December, 1887, to March, 1888, the free ammonia of the effluent averaged 0.0008 parts, which was 27 per cent. of the free ammonia of the applied water. The albuminoid ammonia in the effluent in the same time averaged 0.0029 parts, which was 24 per cent. of the albuminoid ammonia of the applied water.

In April, with the first increase in the nitrates, the ammonias also increased, the free ammonia being for the month 0.0020 parts, or 87 per cent. of that of the applied water, and the albuminoid ammonia being 0.0036 parts, or 32 per cent. of that of the applied water; but, with the continued increase in the nitrates, the free ammonia decreased to 0.0009 parts, which was the average through May, June and July, and is higher than it has ever been since. In these three months the free ammonia of the effluent was 69 per cent. of that of the applied water, and the albuminoid ammonia, which averaged 0.0036 parts, was 36 per cent. of that of the applied water.

During the following four months of no nitrification, — August to November, 1888, — the free ammonia of the effluent averaged 0.0003 parts, or 29 per cent. of that of the applied water; and the albuminoid ammonia averaged 0.0030 parts, which was 25 per cent. of that of the applied water. In the following thirteen months, when the quantity was the equivalent of 300,000 gallons per acre per day for six days in the week, the free ammonia of the effluent varied from 0.0002 parts to 0.0008 parts, and averaged 0.0004 parts, which is 40 per cent. of that of the applied water. The albuminoid ammonia of the effluent during these thirteen months has averaged 0.0047 parts, which is 40 per cent. of the albuminoid ammonia of the applied water; the percentage during the last six months being slightly less than that in the first half of the year.

The means of the analyses of the applied water and of the effluent for the year 1889 are as follows, in parts per 100,000: —

	Applied Water.	Filtered Effluent.		Applied Water.	Filtered Effluent.
Loss on ignition,	1.29	0.83	Sum of ammonias,	0.0130	0.0053
Fixed residue,	2.84	2.56	Chlorine,	0.20	0.20
Free ammonia,	0.0009	0.0004	Nitrates,	0.0171	0.0244
Albuminoid ammonia,	0.0121	0.0049	Nitrites,	0.0000	0.0000

This filtered water compares favorably, in chemical composition, with excellent unpolluted ground water supplies.

From the beginning the effluent has been colorless. During the past year the color of the applied water has averaged 0.25 on the scale of color adopted by our chemists. It is about two-thirds as deep as the ordinary color of Cochituate water in Boston. This color has been entirely removed by the filter, and the effluent has been throughout the year a clear, bright, colorless water.

The Microscopic Organisms in the Effluent of Tank No. 8.

The microscopic organisms found in the effluent of this tank have been very few. In the five months, August to December, 1888, the number found in five gallons of the city water applied, and in five gallons of the effluent were recorded generally once a week. The names of those found in the city water more than once are given in the following table, together with the number of days when found, and the average number upon those days. In appended columns are given the number of days when found, and the number found of the same organisms in the filtered effluent. All appear to have been filtered out, except Leptothrix and Monas, a few of which were found in the effluent.

Number of Microscopic Organisms found, on Twenty different Days, in five gallons of the City Water, and in five gallons of the Effluent from Tank No. 8 in the six months, July to December, 1888, omitting those that were found in City Water but once.

Name of Organism.	Number of Days when found in City Water.	Average Number when found in City Water.	Number of Days when found in Effluent of No. 8.	Average Number when found in Effluent of No. 8.
Anabæna,	2	35	-	-
Asterionella,	18	591	-	-
Chlorococcus,	16	35,046	-	-
Clathrocystis,	3	35	-	-
Encyonema,	2	20	-	-
Leptothrix,	2	70	1	40
Melosira,	14	1,162	-	-
Navicula,	6	43	-	-
Nitzchia,	3	73	-	-
Ophiocytium,	2	30	-	-
Pediastrum,	8	34	-	-
Pinnularia,	2	45	-	-
Raphidium,	5	56	-	-
Scenedesmus,	9	94	-	-
Staurastrum,	7	42	-	-
Staurogenia,	11	434	-	-
Stephanodiscus,	8	71	-	-
Synedra,	19	269	-	-
Tabellaria,	18	218	-	-
Tetraspora,	2	150	-	-
Anurea,	2	15	-	-
Dinobryon,	15	394	-	-
Entomostracon,	2	4	-	-
Monas,	2	35	2	15
Trachelomonas,	7	136	-	-

On only four of the twenty days of this half-year were any organisms found which were in the city water, and these were Leptothrix, Monas and Rotifera.

These all live in places like the underdrains and gravel at the bottom of the tank; and it is not probable that any of them came through the filter.

After making twelve examinations in the latter part of 1888, and finding no organisms, except on one occasion, when Leptothrix and Monas were found, no examinations were made until Aug. 17, 1889, when no organisms were found. After this, occasional examinations were made, but no organisms were found on more than one occasion, or in numbers greater than one in 200 cubic centimeters, except Leptothrix, which was found on two occasions.

We can then safely conclude that the microsopic organisms of the city water are entirely removed by this filter, when filtering at the rate of 300,000 gallons per acre per day.

Bacteria in the Effluent from Tank No. 8.

This tank was filled on Oct. 27, 1887, by throwing the material, scattering, into water which had been drawn from the canal. The material remained saturated until November 15; and on November 18, after about 2,000 gallons of water had drained out of the tank, 15,111 bacteria were found in a cubic centimeter of the effluent. On November 22 the number counted was 1,015; and on November 29 — the first count after city water had begun to flow through the tank — the number was 128. It decreased in the next week to 51; and the average number for December, 1887, was 55, while the average number found in the city water was 70.

In the following two years the average number of bacteria found in the effluent from this tank was 21, which was one-fifth of the number found in the city water applied to the tank. The number found in the effluent has varied but little, but has been in general somewhat smaller in the second year than in the first. From December, 1887, to March, 1888, the average number found in the effluent was 40, which was 24 per cent. of the number in the city water. In the next four months, during which there was nitrification in the tank, the average number found in the effluent was 15, which was 19 per cent. of the number found in the water. From August to November, 1888, when little or no nitrification took place, the average number was 24, which was 16 per cent. of the number found in the applied water; and in the second year the average number found was 15, or 21 per cent. of the number found in the applied water. In eleven months of this time the average number was but 8 per cubic centimeter.

With these small numbers found in the effluent, averaging, as has been said, one-fifth of the number applied in the water, we can see that the conditions for their passage through the filter, or for their growth in the underdrains, are unfavorable. Up to the present time we have been unable to determine, with certainty, whether any of those found in the effluent came down through the filtering material. It is hoped that careful study of the species found, and comparison of the applied water and the effluent in the coming year, may give more definite information on this point.

That there is a growth in the underdrains and outlet pipe, where air enters from below, was shown by wiping out the pipe with a sterilized sponge in January, 1890. During this month the average number counted in the effluent was six per cubic centimeter. Upon wiping out the pipe, one foot in length at a time, and then expressing the water from the saturated sponge, the number of bacteria found in a cubic centimeter of the expressed water varied from 212 from the first foot near the outlet to 5,880 from the sixth foot; averaging for each foot in length 1,570. Again in May, when the number in the effluent averaged seven, the number sponged out of the outlet pipe averaged 568 per cubic centimeter for each foot.

These numbers, probably growing mostly on the damp surface of the pipe, just above the surface of the stream usually flowing, may reasonably be regarded as indicating a growth in this pipe and in the underdrains sufficient to supply the small number found in the effluent.

The details of the one hundred and sixty counts of bacteria made upon the city water, and one hundred and fifty counts made upon the effluent of Tank No. 8, are given in the following tables; and the monthly averages may be found in the table of monthly averages of daily results with this tank, previously given.

Table of the Number of Bacteria found in a Cubic Centimeter of City Water.

Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.
1887.		**1888** — Con.		**1888** — Con.		**1889** — Con.	
Nov. 29,	36	March 15,	385	Sept. 27,	137	Feb. 27,	33
Dec. 1,	69	17,	64	Oct. 6,	70	March 5,	39
3,	57	20,	107	9,	120	12,	63
6,	46	22,	68	11,	160	19,	71
8,	106	24,	206	13,	142	26,	19
10,	151	27,	99	16,	99	April 2,	26
13,	115	29,	141	23,	53	9,	35
15,	44	31,	184	25,	154	16,	23
17,	40	April 3,	98	27,	127	24,	27
20,	30	28,	24	30,	58	30,	26
22,	43	May 8,	40	Nov. 1,	18	May 7,	16
24,	102	10,	33	3,	32	14,	44
1888.		12,	128	6,	64	21,	38
Jan. 3,	67	19,	26	8,	50	28,	30
5,	45	22,	19	10,	27	June 4,	7
7,	263	26,	31	13,	69	11,	55
10,	16	29,	15	16,	136	18,	152
14,	163	31,	10	19,	129	26,	53
17,	897	June 7,	39	21,	156	July 2,	61
21,	115	9,	38	23,	114	16,	195
24,	69	12,	58	26,	71	23,	44
26,	228	14,	76	28,	141	30,	41
28,	218	16,	77	30,	122	Aug. 6,	12
31,	68	21,	81	Dec. 5,	54	12,	27
Feb. 2,	76	26,	73	7,	33	19,	16
4,	90	July 3,	50	10,	22	27,	56
7,	49	7,	75	12,	30	Sept. 2,	42
9,	79	13,	126	14,	27	10,	109
11,	209	17,	92	17,	39	16,	113
14,	59	21,	80	21,	101	24,	99
16,	69	26,	62	26,	65	Oct. 2,	128
18,	80	Aug. 4,	105	**1889.**		10,	170
21,	135	14,	88	Jan. 2,	48	16,	46
23,	255	18,	97	8,	168	25,	152
25,	461	23,	167	15,	45	Nov. 5,	43
28,	290	Sept. 11,	127	22,	146	16,	91
March 1,	156	15,	351	29,	27	21,	375
3,	624	18,	594	Feb. 6,	42	Dec. 4,	82
6,	179	20,	369	12,	36	10,	21
8,	259	22,	247	19,	36	17,	95
10,	81	25,	157				

Table of the Number of Bacteria found in a Cubic Centimeter of Effluent from Tank No. 8.

Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date	Number of Bacteria.
1887.		**1888**—Con.		**1888**—Con.		**1889**—Con.	
Nov. 18, .	15,111	Feb. 25, .	15	Aug. 21, .	19	April 2, .	5
22, .	1,015	28, .	90	Sept. 11, .	28	9, .	14
29, .	128	March 1, .	58	15, .	29	16, .	17
Dec. 1, .	114	3, .	32	20, .	14	24, .	1
3, .	69	6, .	36	25, .	10	30, .	10
6, .	51	8, .	35	29, .	9	May 7, .	6
8, .	82	10, .	30	Oct. 2, .	6	14, .	5
10, .	80	15, .	116	6, .	8	21, .	13
13, .	54	17, .	49	11, .	0	28, .	4
15, .	30	20, .	92	16, .	8	June 4, .	17
17, .	45	22, .	32	20, .	5	11, .	8
20, .	19	24, .	25	25, .	26	18, .	7
22, .	5	27, .	8	30, .	23	26, .	3
24, .	40	April 19, .	26	Nov. 3, .	62	July 2, .	5
30, .	74	25, .	12	8, .	85	9, .	0
1888.		28, .	20	13, .	58	16, .	40
Jan. 3, .	23	May 8, .	21	19, .	59	23, .	0
5, .	20	10, .	20	23, .	20	30, .	8
7, .	141	12, .	50	28, .	25	Aug. 6, .	1
10, .	20	19, .	11	Dec. 5, .	15	12, .	3
12, .	22	22, .	6	10, .	3	19, .	348
14, .	34	26, .	7	14, .	7	27, .	1
17, .	24	29, .	4	21, .	337	Sept. 2, .	12
19, .	67	31, .	9	26, .	11	10, .	3
21, .	75	June 5, .	6	**1889.**		16, .	5
24, .	6	9, .	5	Jan. 2, .	7	24, .	5
26, .	11	14, .	16	8, .	16	Oct. 2, .	4
28, .	19	21, .	19	15, .	9	10, .	4
31, .	54	26, .	13	22, .	20	16, .	5
Feb. 2, .	5	July 3, .	9	29, .	9	25, .	12
4, .	26	7, .	9	Feb. 6, .	22	Nov. 5, .	5
7, .	12	13, .	23	12, .	4	16, .	23
9, .	13	17, .	13	19, .	1	21, .	6
11, .	7	21, .	8	27, .	1	Dec. 4, .	10
14, .	16	26, .	11	March 5, .	2	10, .	3
16, .	3	Aug. 2, .	29	12, .	10	17, .	13
18, .	11	7, .	14	19, .	8	28, .	4
21, .	15	11, .	10	26, .	4		
23, .	14	16, .	6				

TABLES OF CHEMICAL ANALYSES OF CITY WATER

AND OF THE

Effluent from Tank No. 8.

CITY WATER.

Date.	Color.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as	
		Loss on Ignition.	Fixed.	Free.	Albu-minoid.	Sum of.		Nitrates.	Nitrites.
1887.									
Nov. 17,	–	1.15	3.25	.0034	.0144	.0178	.30	.0200	.0000
26,	–	1.35	2.95	.0016	.0104	.0120	.28	.0180	.0000
29,	–	1.65	2.90	.0004	.0146	.0150	.30	.0200	.0000
30,	–	1.30	2.90	.0022	.0164	.0186	.32	.0180	.0000
Dec. 2,	–	1.30	3.00	.0014	.0134	.0148	.30	.0180	.0000
3,	–	1.20	3.10	.0042	.0144	.0186	.28	.0180	.0000
5,	–	1.45	2.65	.0014	.0106	.0120	.32	.0200	.0000
6,	–	1.45	2.85	.0026	.0130	.0156	.34	.0150	.0000
7,	–	.35	3.95	.0026	.0148	.0174	.32	.0180	.0000
8,	–	.75	3.55	.0026	.0122	.0148	.38	.0200	.0000
9,	–	1.10	3.25	.0032	.0134	.0166	.32	.0220	.0000
10,	–	2.10	2.85	.0020	.0128	.0148	.30	.0200	.0000
12,	–	1.80	3.30	.0018	.0134	.0152	.34	.0200	.0000
13,	–	1.45	3.00	.0018	.0122	.0140	.29	.0200	.0000
14,	–	1.15	2.90	.0026	.0132	.0158	.26	.0180	.0000
15,	–	1.35	2.30	.0026	.0134	.0160	.24	.0180	–
1[illegible],	–	1.35	2.90	.0040	.0158	.0198	.27	.0200	–
16,	–	1.25	2.95	.0020	.0124	.0144	.30	.0180	.0000
20,	–	1.10	2.60	.0038	.0138	.0176	.22	.0150	.0000
21,	–	1.25	2.75	.0018	.0106	.0124	.20	.0120	.0000
26,	–	.90	2.90	.0034	.0132	.0166	.19	.0150	.0000
28,	–	1.20	3.10	.0030	.0138	.0168	.20	.0070	.0000
30,	–	1.10	3.05	.0036	.0158	.0194	.20	.0070	.0000
1888.									
Jan. 2,	–	1.40	3.00	.0034	.0152	.0186	.17	.0050	.0000
4,	–	1.30	2.80	.0030	.0132	.0162	.19	.0070	.0000
6,	–	1.30	2.70	.0016	.0140	.0156	.21	.0100	.0000
9,	–	1.20	2.65	.0040	.0130	.0170	.16	.0250	.0000

City Water — Continued.

Date.	Color.	Residue on Evaporation. Loss on Ignition.	Fixed.	Ammonia. Free.	Albuminoid.	Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrites.
1888 — Con.									
Jan. 11,	–	1.30	2.60	.0036	.0130	.0166	.13	.0250	.0000
15,	–	1.10	2.70	.0022	.0110	.0132	.19	.0250	.0000
19,	–	1.30	2.65	.0016	.0092	.0108	.12	.0100	.0001
23,	–	1.30	2.75	.0030	.0132	.0162	.17	.0090	.0000
26,	–	1.40	2.80	.0022	.0122	.0144	.20	.0200	.0000
30,	–	1.20	3.15	.0026	.0114	.0140	.15	.0100	.0005
Feb. 2,	–	1.45	2.75	.0034	.0112	.0146	.18	.0250	.0000
6,	–	.95	3.30	.0036	.0120	.0156	.27	.0150	.0000
9,	.15	1.40	2.80	.0036	.0112	.0148	.20	.0180	.0000
13,	.20	.50	3.55	.0030	.0118	.0148	.26	.0100	.0000
16,	.20	.85	2.90	.0032	.0116	.0148	.26	.0050	.0000
23,	.20	1.35	2.70	.0038	.0116	.0154	.22	.0100	.0000
Mar. 1,	.35	1.20	3.00	.0044	.0098	.0142	.20	.0200	Present.
8,	–	1.20	2.30	.0032	.0114	.0146	.19	.0250	.0000
15,	.30	1.70	3.20	.0028	.0082	.0110	.18	.0200	.0000
22,	.30	1.00	2.75	.0032	.0130	.0162	.23	.0200	Present.
29,	.35	1.05	2.75	.0032	.0114	.0146	.21	.0180	.0002
Apr. 5,	.30	.95	2.20	.0018	.0102	.0120	.25	.0100	Present.
12,	.20	.70	2.35	.0016	.0124	.0140	.16	.0100	.0002
19,	.20	.75	2.35	.0026	.0108	.0134	.18	.0180	.0002
26,	.30	.90	3.15	.0014	.0102	.0116	.15	.0250	.0002
May 10,	.10	1.00	2.40	.0008	.0082	.0090	.12	.0180	.0001
17,	.10	1.30	2.20	.0002	.0112	.0114	.12	.0180	.0003
24,	.30	1.50	2.15	.0008	.0094	.0102	.12	.0150	.0003
June 5,	.30	.80	3.10	.0008	.0092	.0100	.13	.0150	.0001
12,	.30	1.44	1.96	.0004	.0090	.0094	.18	.0120	.0000
19,	.20	1.00	2.24	.0008	.0094	.0102	.21	.0120	.0000
26,	.20	1.12	2.56	.0006	.0104	.0110	.19	.0180	.0000
July 3,	–	.96	3.04	.0024	.0100	.0124	.24	.0200	.0000
10,	.10	.80	3.20	.0064	.0126	.0190	.22	.0150	.0006
17,	.10	1.08	3.00	.0004	.0114	.0118	.26	.0230	.0000
24,	.25	.76	2.96	.0006	.0100	.0106	.36	.0300	.0000
31,	.10	1.04	2.80	.0012	.0120	.0132	.23	.0220	.0000
Aug. 7,	.10	2.40	2.20	.0000	.0120	.0120	.33	.0230	.0000
14,	.10	1.16	2.88	.0010	.0096	.0106	.29	.0250	.0000
21,	.05	2.64	1.80	.0010	.0116	.0126	.29	.0200	.0000
28,	.10	1.56	2.60	.0008	.0116	.0124	.24	.0220	.0000
Sept. 4,	.05	2.32	2.76	.0002	.0100	.0102	.25	.0220	.0000
6,	.15	–	–	.0026	.0144	.0170	.25	.0230	.0000
11,	.10	1.40	2.84	.0012	.0116	.0128	.26	.0220	.0000
18,	.05	1.44	3.04	.0006	.0112	.0118	.24	.0240	.0000
25,	.10	1.04	3.24	.0016	.0118	.0134	.24	.0230	.0000

After August 1, residue on evaporation was obtained with sodium carbonate.

City Water — Continued.

Date.	Color.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
1888 — Con.									
Oct. 2,	.40	1.44	2.60	.0014	.0124	.0138	.22	.0220	.0000
9,	.30	1.68	2.60	.0006	.0180	.0186	.20	.0240	.0000
16,	.40	1.60	2.52	.0006	.0134	.0140	.22	.0220	.0000
23,	.50	1.22	2.56	.0022	.0144	.0166	.24	.0220	.0000
30,	.60	1.32	2.20	.0012	.0140	.0152	.20	.0200	.0000
Nov. 6,	.50	1.16	3.16	.0006	.0118	.0124	.24	.0240	.0000
13,	.40	1.08	3.12	.0008	.0134	.0142	.23	.0240	.0000
20,	.40	1.36	2.48	.0004	.0100	.0104	.24	.0210	.0000
27,	.40	1.56	2.56	.0004	.0102	.0106	.26	.0200	.0000
Dec. 4,	.30	1.12	2.92	.0004	.0086	.0090	.26	.0220	.0000
11,	.20	1.20	2.68	.0006	.0098	.0104	.24	.0250	.0000
18,	.25	1.04	2.78	.0010	.0076	.0086	.21	.0330	.0000
24,	.25	.88	3.00	.0014	.0108	.0122	.20	.0240	.0000
1889.									
Jan. 1,	.30	.96	2.68	.0004	.0124	.0128	.23	.0300	.0000
8,	.30	1.00	3.25	.0006	.0078	.0084	.25	.0320	.0000
15,	.25	1.08	2.56	.0000	.0096	.0096	.21	.0220	.0000
22,	.30	1.28	2.48	.0002	.0094	.0096	.21	.0230	.0000
29,	.20	.90	2.60	.0002	.0102	.0104	.26	.0230	.0000
Feb. 5,	.20	1.24	2.64	.0014	.0072	.0086	.21	.0270	.0000
12,	.20	.72	2.96	.0004	.0094	.0098	.25	.0230	.0000
19,	.15	.92	2.68	.0006	.0082	.0088	.25	.0180	.0000
26,	.20	1.16	2.36	.0006	.0086	.0092	.24	.0250	.0002
Mar. 5,	.15	.84	2.96	.0006	.0098	.0104	.24	.0250	.0000
12,	.15	.64	3.04	.0022	.0100	.0122	.24	.0200	.0000
19,	.20	.48	2.88	.0018	.0078	.0096	.21	.0220	.0000
26,	.20	.64	2.52	.0004	.0080	.0084	.23	.0230	.0000
April 2,	.20	.72	2.64	.0012	.0094	.0106	.17	.0230	.0000
9,	.13	.48	2.52	.0008	.0088	.0096	.17	.0180	.0000
16,	.20	.80	2.60	.0010	.0120	.0130	.17	.0140	.0001
23,	.15	1.12	2.68	.0006	.0088	.0094	.16	.0150	.0000
30,	.25	1.24	2.08	.0006	.0086	.0092	.14	.0160	.0001
May 7,	.20	1.00	2.32	.0004	.0100	.0104	.13	.0120	.0000
14,	.20	.84	2.44	.0004	.0094	.0098	.14	.0100	.0000
21,	.20	1.32	2.64	.0000	.0112	.0112	.15	.0120	.0001
28,	.30	1.20	2.32	.0008	.0118	.0126	.16	.0170	.0000
June 4,	.20	1.20	2.32	.0006	.0100	.0106	.17	.0150	.0001
11,	.20	1.60	2.48	.0010	.0120	.0130	.14	.0200	.0001
18,	.20	1.92	2.88	.0010	.0152	.0162	.16	.0170	.0000
25,	.25	1.52	2.44	.0002	.0154	.0156	.16	.0150	.0000

During the year 1888, from March 1 to April 5, the water was slightly turbid, with a slight brown flocculent sediment. From April 12 to May 24 it was distinctly turbid, with more or less sediment. During the rest of the year it was generally very slightly turbid, and with very slight or no sediment.

City Water — Concluded.

Date.	Color.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as	
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.
1889 — Con.									
July 2,	–	1.40	2.68	.0020	.0154	.0174	.17	.0150	.0000
9,	.00	1.24	2.72	.0008	.0142	.0150	.18	.0200	.0000
16,	.30	1.12	2.68	.0014	.0150	.0164	.18	.0150	.0000
23,	.20	1.08	2.88	.0006	.0110	.0116	.21	.0150	.0000
30,	.20	1.52	3.08	.0006	.0112	.0118	.20	.0150	.0000
Aug. 6,	.20	1.48	2.72	.0006	.0120	.0126	.20	.0200	.0000
13,	.50	2.24	6.12	.0012	.0260	.0272	.18	.0150	.0000
20,	.20	2.20	3.35	.0002	.0114	.0116	.20	.0200	.0000
27,	.30	–	–	.0006	.0140	.0146	.19	.0220	.0000
Sept. 3,	.30	1.52	3.52	.0016	.0142	.0158	.23	.0190	.0000
10,	.20	1.88	3.40	.0018	.0128	.0146	.25	.0180	.0002
17,	.40	1.30	3.30	.0008	.0138	.0146	.26	.0200	.0000
24,	.20	1.00	3.10	.0016	.0148	.0164	.25	.0150	.0000
30,	.30	.80	3.80	.0016	.0152	.0168	.23	.0100	.0000
Oct. 7,	.30	1.40	3.10	.0012	.0148	.0160	.22	.0160	.0001
14,	.30	2.10	2.40	.0015	.0150	.0165	.20	.0100	.0000
21,	.30	2.10	2.60	.0022	.0150	.0172	.21	.0080	.0000
28,	.30	2.10	2.80	.0010	.0154	.0164	.21	.0100	.0000
Nov. 4,	.30	–	–	.0008	.0156	.0164	.22	.0140	.0000
11,	.40	1.20	2.80	.0014	.0136	.0150	.21	.0060	.0000
18,	.30	1.70	2.20	.0010	.0144	.0154	.21	.0100	.0000
25,	.30	1.20	2.90	.0010	.0140	.0150	.22	.0090	.0000
Dec. 2,	.30	1.50	2.60	.0010	.0126	.0136	.20	.0100	.0000
9,	.30	2.30	2.30	.0016	.0138	.0154	.18	.0160	.0000
16,	–	1.30	2.40	.0008	.0114	.0122	.18	.0110	.0000
23,	.40	–	–	.0010	.0124	.0134	.17	.0170	.0000
30,	.30	1.20	3.10	.0020	.0134	.0154	.18	.0080	.0000

August 13. — Water turned into pipe after gates had been shut the previous week to clean old reservoir.

During the year 1889 the water was generally very slightly turbid, and with very slight sediment for the first seven months and generally clear and free from sediment the rest of the year.

FILTER TANK No. 8.

November, 1887.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Water on Surface in the morning. Inches.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
15, .	-	1,417	1.55	3.35	.0008	.0074	.0082	.30	.0000	-	-	-	-
16, .	-	160	-	-	-	-	-	-	-	-	-	-	-
17, .	408	448	-	-	-	-	-	-	-	-	-	47°	-
18, .	408	458	.90	2.45	.0010	.0080	.0090	.43	.0000	None.	-	46°	43°
19, .	408	375	-	-	-	-	-	-	-	-	-	45°	-
20, .	408	432	-	-	-	-	-	-	-	-	-	46°	-
21, .	408	383	-	-	-	-	-	-	-	-	0	-	-
22, .	408	376	1.00	4.05	.0012	.0082	.0094	.76	.0030	None.	-	-	-
23, .	408	403	-	-	-	-	-	-	-	-	-	-	-
24, .	408	426	-	-	-	-	-	-	-	-	-	45°	-
25, .	408	409	-	-	-	-	-	-	-	-	-	45°	-
26, .	408	456	.55	3.75	.0002	.0018	.0020	.38	.0000	None.	-	44°	-
27, .	-	166	-	-	-	-	-	-	-	-	-	-	-
28, .	544	264	-	-	-	-	-	-	-	-	-	44°	-
29, .	544	510	-	-	-	-	-	-	-	-	5/8	-	-
30, .	544	477	.30	3.10	.0006	.0044	.0050	.31	.0000	None.	5/8	-	-

Nov. 20. — Surface partly covered with water in the morning. 26. — One and three-sixteenths inches of water on surface at 9.00 P.M. 28. — Two and three-sixteenths inches. 30. — Two and one-fourth inches. 30. — Seven-sixteenths inch of ice on surface at 8.25 A.M.

Total effluent to end of month, 7,160 gallons.

Filter Tank No. 8 — Continued.

December, 1887.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Water on Surface in the morning. Inches.	Temperature. Water.	Temperature. Effluent.
1, .	484	338	-	-	-	-	-	-	-	-	0	-	-
2, .	293	296	-	-	-	-	-	-	-	-	-	-	-
3, .	405	403	.90	2.95	.0012	.0034	.0046	.35	.0010	None.	0	-	-
4, .	407	390	-	-	-	-	-	-	-	-	0	-	-
5, .	490	474	.50	2.90	.0004	.0026	.0030	.32	.0020	None.	0	-	-
6, .	500	488	-	-	-	-	-	-	-	-	1⅛	-	-
7, .	544	510	-	-	-	-	-	-	-	-	½	-	-
8, .	590	516	-	-	.0000	.0024	.0024	.32	.0030	None.	⅝	-	39°
9, .	550	555	-	-	-	-	-	-	-	-	1	-	-
10, .	545	603	.30	2.55	.0002	.0032	.0034	.24	.0060	None.	¾	46°	-
11, .	510	568	-	-	-	-	-	-	-	-	1¼	-	-
12, .	514	637	.40	2.45	.0002	.0028	.0030	.23	.0080	None.	1⅛	-	-
13, .	664	578	-	-	-	-	-	-	-	-	-	42°	-
14, .	600	566	.40	2.55	.0000	.0016	.0016	.24	.0050	None.	⅝	-	-
15, .	520	567	-	-	-	-	-	-	-	-	¾	-	-
16, .	552	286	.40	2.55	.0004	.0028	.0032	.25	.0020	None.	⅞	-	-
17, .	518	513	-	-	-	-	-	-	-	-	½	-	-
18, .	547	409	-	-	-	-	-	-	-	-	-	43°	-
19, .	545	415	.50	2.65	.0014	.0044	.0058	.31	.0050	None.	½	44°	-
20, .	498	502	-	-	-	-	-	-	-	-	⅞	-	-
21, .	530	493	.35	2.55	.0004	.0022	.0026	.25	.0040	None.	1¼	46°	-
22, .	520	495	-	-	-	-	-	-	-	-	1	41°	-
23, .	518	473	.25	2.65	.0002	.0024	.0026	.22	.0050	Present.	-	-	-
24, .	465	533	.40	2.45	.0000	.0036	.0036	.20	.0030	None.	0	-	-
25, .	470	437	-	-	-	-	-	-	-	-	0	-	-
26, .	454	440	-	-	-	-	-	-	-	-	0	41°	-
27, .	338	336	.30	2.75	.0004	.0040	.0044	.22	.0040	Present.	0	-	-
28, .	258	301	-	-	-	-	-	-	-	-	0	-	-
29, .	294	330	.30	2.60	.0006	.0046	.0052	.22	.0050	None.	0	-	-
30, .	440	263	-	-	-	-	-	-	-	-	-	-	-
31, .	202	217	.30	2.35	.0004	.0028	.0032	.21	.0080	None.	-	-	-

Dec. 1 to 5. — From 1 inch to 2 inches of ice on surface. 6. — Five-eighths inch. 7. — Seven-sixteenths inch. 9 and 10. — One-sixteenth inch. 14. — Three-sixteenths inch. 17. — Eleven-sixteenths inch. 18. — One and seven-eighths inches of ice and water. 19. — Seven-eighths inch of ice. 20. — Three-eighths inch. 22. — One-fourth inch. 23 to 27. — From 1 inch to 2¼ inches. 28 to 31. — From 2¼ inches to 4 inches. 2. — No water on surface at 1.04 P.M. and 2⅝ inches at 8.45 P.M. 4. — Two and five-eighths inches at 8.48. P.M. 16. — From 2⅝ inches to 2 3-16 inches, from 11.50 A.M. to 3.08 P.M. 30 and 31. — Surface covered in the morning. 16 and 17. — Outlet closed a part of the time. 19. — Some effluent lost.

Total effluent to end of month, 21,216 gallons.

Filter Tank No. 8 — Continued.

January, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Water on Surface in the morning. Inches.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1, .	132	158	-	-	-	-	-	-	-	-	-	39°	-
2, .	210	151	-	-	-	-	-	-	-	-	-	42°	-
3, .	218	195	.35	2.70	.0010	.0038	.0048	.24	.0080	Present.	2	38	-
4, .	238	205	-	-	-	-	-	-	-	-	1	39°	-
5, .	160	203	.40	2.45	.0014	.0024	.0038	.25	.0080	Present.	-	41	-
6, .	205	159	.75	2.95	.0000	.0044	.0044	.24	.0080	None.	-	38°	-
7, .	240	190	-	-	-	-	-	-	-	-	-	45°	-
8, .	200	210	-	-	-	-	-	-	-	-	-	43°	-
9, .	225	226	.35	2.65	.0006	.0022	.0028	.26	.0080	None.	-	42°	-
10, .	222	189	-	-	-	-	-	-	-	-	-	42°	-
11, .	198	170	.50	2.15	.0012	.0024	.0036	.37	.0120	Present.	-	40°	-
12, .	-	155	-	-	-	-	-	-	-	-	-	-	-
13, .	-	110	-	-	-	-	-	-	-	-	-	-	-
14, .	-	217	-	-	-	-	-	-	-	-	-	-	-
15, .	-	201	-	-	-	-	-	-	-	-	-	-	-
16, .	-	362	-	-	-	-	-	-	-	-	-	-	-
17, .	-	397	.20	2.70	.0006	.0028	.0034	.23	.0100	Present.	-	-	-
18, .	-	397	-	-	-	-	-	-	-	-	-	-	-
19, .	-	404	.45	2.30	.0012	.0014	.0026	.24	.0150	Present.	-	-	35°
20, .	-	412	-	-	-	-	-	-	-	-	-	-	-
21, .	-	349	-	-	-	-	-	-	-	-	-	-	-
22, .	-	316	-	-	-	-	-	-	-	-	-	-	-
23, .	-	193	.60	2.45	.0014	.0022	.0036	.24	.0180	Present.	-	-	-
24, .	-	113	-	-	-	-	-	-	-	-	-	-	-
25, .	-	83	-	-	-	-	-	-	-	-	-	-	-
26, .	-	86	.40	2.60	.0016	.0026	.0042	.24	.0180	Present	-	-	-
27, .	-	173	-	-	-	-	-	-	-	-	-	35°	-
28, .	-	228	-	-	-	-	-	-	-	-	-	-	-
29, .	-	198	-	-	-	-	-	-	-	-	-	-	-
30, .	-	213	.50	2.40	.0010	.0022	.0032	.20	.0150	Present.	-	-	-
31, .	-	203	-	-	-	-	-	-	-	-	-	-	34°

Jan. 1. — Four inches of ice and water on surface. 2. — Four inches of ice and 4 inches of frost. 3. — Four inches of ice. 4. — Three inches. 5. — Three and a half inches of ice and water. 6. — Three and a half inches of ice. 7 to 11. — Four inches of ice and water. 27. — Seven and a half inches of ice and 15 inches of frost. Holes cut through it. 12 to 31. — Tank filled at each flooding.

Total effluent to end of month, 28,082 gallons.

Filter Tank No. 8 — Continued.

February, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.
1, ...	-	200	-	-	-	-	-	-	-	-	-	-
2, ...	-	174	.50	2.35	.0004	.0030	.0034	.19	.0200	None.	-	-
3, ...	-	156	-	-	-	-	-	-	-	-	-	-
4, ...	-	180	-	-	-	-	-	-	-	-	-	34°
5, ...	-	146	-	-	-	-	-	-	-	-	-	-
6, ...	-	163	.35	2.45	.0006	.0030	.0036	.23	.0180	None.	-	35°
7, ...	-	123	-	-	-	-	-	-	-	-	-	35°
8, ...	-	119	-	-	-	-	-	-	-	-	-	-
9, ...	-	126	.50	2.50	.0006	.0022	.0028	.25	.0000	None.	-	-
10, ...	-	121	-	-	-	-	-	-	-	-	-	-
11, ...	-	97	-	-	-	-	-	-	-	-	-	35°
12, ...	-	96	-	-	-	-	-	-	-	-	-	-
13, ...	-	96	.30	2.80	.0006	.0040	.0046	.26	.0020	None.	-	-
14, ...	-	105	-	-	-	-	-	-	-	-	-	36°
15, ...	-	108	-	-	-	-	-	-	-	-	-	35°
16, ...	-	90	.50	2.60	.0004	.0028	.0032	.21	.0100	Present.	-	35°
17, ...	-	79	-	-	-	-	-	-	-	-	-	-
18, ...	-	60	-	-	-	-	-	-	-	-	35°	-
19, ...	0	69	-	-	-	-	-	-	-	-	-	-
20, ...	0	75	-	-	-	-	-	-	-	-	-	-
21, ...	0	79	-	-	-	-	-	-	-	-	-	37°
22, ...	0	92	-	-	-	-	-	-	-	-	-	-
23, ...	-	120	.65	2.55	.0004	.0026	.0030	.20	.0070	Present.	35°	36°
24, ...	-	341	-	-	-	-	-	-	-	-	-	-
25, ...	-	467	-	-	-	-	-	-	-	-	36°	35°
26, ...	-	418	-	-	-	-	-	-	-	-	-	-
27, ...	-	469	-	-	-	-	-	-	-	-	-	-
28, ...	-	613	-	-	-	-	-	-	-	-	-	34°
29, ...	-	460	-	-	-	-	-	-	-	-	-	34°

Feb. 1 to 18, and 23 to 29. — Tank filled at each flooding. 18. — Trench cut through ice and 2 inches of sand. 25 and 26. — Air came up in one or two holes in surface.

Total effluent to end of month, 33,524 gallons.

Filter Tank No. 8 — Continued.

March, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Water remained on Surface.	Temperature. Water.	Temperature. Effluent.
1, .	-	387	.80	2.10	.0012	.0032	.0044	.23	.0180	None.	-	-	34°
2, .	-	386	-	-	-	-	-	-	-	-	-	-	-
3, .	-	527	-	-	-	-	-	-	-	-	-	-	34°
4, .	-	343	-	-	-	-	-	-	-	-	-	36°	34°
5, .	-	373	-	-	-	-	-	-	-	-	-	35°	34°
6, .	-	386	-	-	-	-	-	-	-	-	-	-	34°
7, .	-	334	-	-	-	-	-	-	-	-	-	35°	34°
8, .	-	385	-	-	-	-	-	-	-	-	-	-	36°
9, .	-	366	-	-	-	-	-	-	-	-	-	-	35°
10, .	-	433	-	-	-	-	-	-	-	-	-	-	35°
11, .	-	359	-	-	-	-	-	-	-	-	-	-	35°
12, .	-	405	-	-	-	-	-	-	-	-	-		35°
13, .	-	363	-	-	-	-	-	-	-	-	-	-	-
14, .	-	409	-	-	-	-	-	-	-	-	-	-	35°
15, .	-	467	1.00	2.40	.0014	.0010	.0024	.21	.0250	None.	-	-	-
16, .	-	423	-	-	-	-	-	-	-	-	-	-	35°
17, .	-	331	-	-	-	-	-	-	-	-	-	-	35°
18, .	-	353	-	-	-	-	-	-	-	-	-	-	36°
19, .	-	503	-	-	-	-	-	-	-	-	-	36°	36°
20, .	-	405	-	-	-	-	-	-	-	-	-	36°	37°
21, .	-	484	-	-	-	-	-	-	-	-	-	37°	38°
22, .	-	1,259	.35	2.55	.0010	.0050	.0060	.22	.0180	None.	-	-	38°
23, .	150	191	-	-	-	-	-	-	-	-	38 m.	37°	39°
24, .	150	144	-	-	-	-	-	-	-	-	-	36°	38°
25, .	150	126	-	-	-	-	-	-	-	-	40 m.	36°	39°
26, .	150	152	-	-	-	-	-	-	-	-	-	-	38°
27, .	150	324	-	-	-	-	-	-	-	-	-	-	38°
28, .	150	223	-	-	-	-	-	-	-	-	-	36°	38°
29, .	150	176	.80	2.75	.0020	.0026	.0046	.20	.0150	None.	56 m.	37°	38°
30, .	150	124	-	-	-	-	-	-	-	-	20 m.	36°	39°
31, .	150	21	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, clear or nearly so, and generally free from sediment. March 1 to 22.—Tank filled at each flooding. 22.—Water siphoned from surface. 31.—Outlet closed at 10.14 A.M. River high.

Total effluent to end of month, 44,736 gallons.

Filter Tank No. 8 — Continued.

April, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Water remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1, .	150	-	-	-	-	-	-	-	-	-	-	-	-
2, .	150	330	-	-	-	-	-	-	-	-	-	-	38°
3, .	150	-	-	-	-	-	-	-	-	-	-	36°	-
4, .	150	539	-	-	-	-	-	-	-	-	28 m.	36°	39°
5, .	150	125	.35	2.90	.0028	.0034	.0062	.21	.0120	None.	-	37°	40°
6, .	150	223	-	-	-	-	-	-	-	-	37 m.	37°	39°
7, .	-	-	-	-	-	-	-	-	-	-	-	-	-
8, .	-	-	-	-	-	-	-	-	-	-	-	-	-
9, .	-	-	-	-	-	-	-	-	-	-	-	-	-
10, .	150	145	-	-	-	-	-	-	-	-	-	37°	40°
11, .	150	238	-	-	-	-	-	-	-	-	-	37°	39°
12, .	150	104	.45	2.75	.0020	.0046	.0066	.21	.0180	Present.	-	37°	41°
13, .	150	160	-	-	-	-	-	-	-	-	33 m.	37°	41°
14, .	150	137	-	-	-	-	-	-	-	-	-	38°	41°
15, .	150	153	-	-	-	-	-	-	-	-	-	38°	41°
16, .	150	142	-	-	-	-	-	-	-	-	35 m.	38°	41°
17, .	150	137	-	-	-	-	-	-	-	-	37 m.	38°	42°
18, .	150	156	-	-	-	-	-	-	-	-	-	38°	41°
19, .	150	132	.35	2.60	.0020	.0052	.0072	.11	.0200	None.	-	38°	42°
20, .	150	132	-	-	-	-	-	-	-	-	36 m.	38°	41°
21, .	300	298	-	-	-	-	-	-	-	-	-	39°	41°
22, .	-	81	-	-	-	-	-	-	-	-	-	-	-
23, .	150	72	-	-	-	-	-	-	-	-	-	41°	42°
24, .	150	132	-	-	-	-	-	-	-	-	-	40°	42°
25, .	150	145	-	-	-	-	-	-	-	-	-	42°	42°
26, .	150	135	.80	2.40	.0012	.0012	.0024	.18	.0300	None.	-	42°	43°
27, .	150	146	-	-	-	-	-	-	-	-	-	41°	42°
28, .	300	254	-	-	-	-	-	-	-	-	-	43°	43°
29, .	-	49	-	-	-	-	-	-	-	-	-	-	-

Effluent colorless, from distinctly turbid to clear, and with little or no sediment. April 2. — Outlet open from 2.01 P.M. to 4.08 P.M. 4. — Outlet opened at 7.09 A.M. 7, 5.21 A.M., to 10, 8.13 A.M. — Outlet closed. River high. 21. — Second 150 gallons applied disappeared in thirty-five minutes. 29. — Outlet closed at 6.43 P.M. River high.

Total effluent to end of month, 48,901 gallons.

Filter Tank No. 8 — Continued.

May, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	-	-	-	-	-	-	-	-	-	-	-	-
2, ...	-	-	-	-	-	-	-	-	-	-	-	-
3, ...	-	-	-	-	-	-	-	-	-	-	-	-
4, ...	150	142	-	-	-	-	-	-	-	-	44°	46°
5, ...	420	400	-	-	-	-	-	-	-	-	45°	46°
6, ...	-	69	-	-	-	-	-	-	-	-	-	-
7, ...	150	71	-	-	-	-	-	-	-	-	44°	-
8, ...	150	129	-	-	-	-	-	-	-	-	44°	48°
9, ...	150	223	-	-	-	-	-	-	-	-	46°	46°
10, ...	150	168	.50	2.50	.0014	.0024	.0038	.17	.0400	Present.	46°	48°
11, ...	150	139	-	-	-	-	-	-	-	-	51°	48°
12, ...	300	358	-	-	-	-	-	-	-	-	46°	48°
13, ...	-	-	-	-	-	-	-	-	-	-	-	-
14, ...	-	-	-	-	-	-	-	-	-	-	-	-
15, ...	-	-	-	-	-	-	-	-	-	-	-	-
16, ...	-	-	-	-	-	-	-	-	-	-	-	-
17, ...	150	386	2.20	1.50	.0000	.0040	.0040	.17	.0450	None.	47°	49°
18, ...	150	136	-	-	-	-	-	-	-	-	47°	50°
19, ...	300	321	-	-	-	-	-	-	-	-	48°	49°
20, ...	-	70	-	-	-	-	-	-	-	-	-	-
21, ...	150	70	1.80	1.80	.0012	.0026	.0038	.18	.0500	Present.	49°	49°
22, ...	150	139	-	-	-	-	-	-	-	-	48°	49°
23, ...	150	139	-	-	-	-	-	-	-	-	48°	50°
24, ...	150	141	1.35	3.20	.0008	.0018	.0026	.20	.0650	None.	51°	51°
25, ...	150	130	-	-	-	-	-	-	-	-	49°	52°
26, ...	300	263	-	-	-	-	-	-	-	-	52°	52°
27, ...	-	62	-	-	-	-	-	-	-	-	-	-
28, ...	150	84	.75	3.45	.0010	.0060	.0070	.17	.0750	None.	51°	50°
29, ...	150	255	-	-	-	-	-	-	-	-	51°	53°
30, ...	150	144	-	-	-	-	-	-	-	-	53°	54°
31, ...	150	130	-	-	-	-	-	-	-	-	53°	54°

Effluent colorless, clear or nearly so, and very nearly free from sediment. May 4. — Outlet opened at 10.32 A.M. 12, 8.55 P.M., to 17, 7.46 A.M. — Outlet closed. River high.

Total effluent to end of month, 53,070 gallons.

Filter Tank No. 8 — Continued.

June, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.
1, ...	240	250	-	-	-	-	-	-	-	-	55°	54°
2, ...	300	261	-	-	-	-	-	-	-	-	55°	55°
3, ...	-	60	-	-	-	-	-	-	-	-	-	-
4, ...	150	82	-	-	-	-	-	-	-	-	56°	56°
5, ...	150	136	.60	3.20	.0004	.0028	.0032	.14	.0800	.0001	54°	58°
6, ...	150	124	-	-	-	-	-	-	-	-	56°	58°
7, ...	150	152	-	-	-	-	-	-	-	-	-	58°
8, ...	150	137	-	-	-	-	-	-	-	-	56°	58°
9, ...	300	260	-	-	-	-	-	-	-	-	61°	60°
10, ...	-	63	-	-	-	-	-	-	-	-	-	-
11, ...	150	70	-	-	-	-	-	-	-	-	58°	61°
12, ...	150	131	1.00	2.72	.0000	.0030	.0030	.21	.0700	.0000	57°	60°
13, ...	150	127	-	-	-	-	-	-	-	-	61°	61°
14, ...	150	203	-	-	-	-	-	-	-	-	61°	60°
15, ...	150	194	-	-	-	-	-	-	-	-	62°	61°
16, ...	300	289	-	-	-	-	-	-	-	-	62°	63°
17, ...	-	65	-	-	-	-	-	-	-	-	-	-
18, ...	150	66	-	-	-	-	-	-	-	-	62°	66°
19, ...	150	128	.96	3.32	.0016	.0034	.0050	.25	.0570	.0000	64°	63°
20, ...	150	97	-	-	-	-	-	-	-	-	67°	63°
21, ...	150	140	-	-	-	-	-	-	-	-	64°	63°
22, ...	150	149	-	-	-	-	-	-	-	-	65°	65°
23, ...	300	272	-	-	-	-	-	-	-	-	65°	67°
24, ...	-	76	-	-	-	-	-	-	-	-	-	-
25, ...	150	117	-	-	-	-	-	-	-	-	65°	65°
26, ...	300	354	.76	3.20	.0018	.0054	.0072	.20	.0400	.0001	65°	66°
27, ...	300	327	-	-	-	-	-	-	-	-	65°	66°
28, ...	300	266	-	-	-	-	-	-	-	-	63°	65°
29, ...	300	302	-	-	-	-	-	-	-	-	63°	65°
30, ...	600	579	-	-	-	-	-	-	-	-	63°	67°

Effluent colorless, clear or very nearly so, and with very little or no sediment.
Total effluent to end of month, 58,547 gallons.

Filter Tank No. 8 — Continued.

July, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		500 Gallons applied remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1, .	–	60	–	–	–	–	–	–	–	–	–	–	–
2, .	300	236	–	–	–	–	–	–	–	–	–	65°	66°
3, .	300	275	.56	3.16	.0020	.0050	.0070	.22	.0250	.0000	–	64°	66°
4, .	300	288	–	–	–	–	–	–	–	–	–	66°	66°
5, .	300	284	–	–	–	–	–	–	–	–	–	66°	67°
6, .	300	286	–	–	–	–	–	–	–	–	–	65°	66°
7, .	600	561	–	–	–	–	–	–	–	–	–	67°	68°
8, .	–	60	–	–	–	–	–	–	–	–	–	–	–
9, .	300	236	–	–	–	–	–	–	–	–	–	66°	67°
10, .	300	278	.52	2.84	.0004	.0048	.0052	.22	.0260	.0000	–	67°	68°
11, .	300	261	–	–	–	–	–	–	–	–	–	66°	70°
12, .	1,000	1,076	–	–	–	–	–	–	–	–	2 h. 5 m.	67°	66°
13, .	1,000	970	–	–	–	–	–	–	–	–	2 h. 8 m.	68°	69°
14, .	1,000	983	–	–	–	–	–	–	–	–	–	68°	71°
15, .	–	75	–	–	–	–	–	–	–	–	–	–	–
16, .	1,000	914	–	–	–	–	–	–	–	–	2 h. 1 m.	67°	69°
17, .	1,000	996	.56	2.72	.0014	.0040	.0054	.69	.0230	.0000	1 h. 50 m.	67°	70°
18, .	1,000	999	–	–	–	–	–	–	–	–	1 h. 57 m.	68°	71°
19, .	1,000	1,132	–	–	–	–	–	–	–	–	2 h. 16 m.	67°	71°
20, .	1,000	1,049	–	–	–	–	–	–	–	–	2 h. 13 m.	68°	71°
21, .	1,000	1,004	–	–	–	–	–	–	–	–	–	68°	71°
22, .	–	70	–	–	–	–	–	–	–	–	–	–	–
23, .	1,000	991	–	–	–	–	–	–	–	–	2 h. 8 m.	68°	71°
24, .	1,000	984	.28	2.40	.0008	.0018	.0026	.37	.0350	.0000	2 h. 12 m.	68°	71°
25, .	1,000	985	–	–	–	–	–	–	–	–	–	68°	72°
26, .	1,000	1,032	–	–	–	–	–	–	–	–	1 h. 44 m.	69°	73°
27, .	1,000	1,025	–	–	–	–	–	–	–	–	–	69°	72°
28, .	1,000	1,015	–	–	–	–	–	–	–	–	–	68°	71°
29, .	–	71	–	–	–	–	–	–	–	–	–	–	–
30, .	1,000	917	–	–	–	–	–	–	–	–	–	68°	69°
31, .	1,000	1,009	.36	2.36	.0000	.0028	.0028	.25	.0290	.0000	–	69°	71°

Effluent clear and colorless, and with very little or no sediment.
Total effluent to end of month, 78,669 gallons.

Filter Tank No. 8 — Continued.

August, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		500 Gallons applied remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1,	1,000	1,027	-	-	-	-	-	-	-	-	2h. 22m.	69°	72°
2,	1,000	1,010	-	-	-	-	-	-	-	-	-	69°	72°
3,	1,000	1,044	-	-	-	-	-	-	-	-	-	70°	73°
4,	1,000	1,014	-	-	-	-	-	-	-	-	-	70°	73°
5,	-	69	-	-	-	-	-	-	-	-	-	-	-
6,	1,000	1,037	-	-	-	-	-	-	-	-	-	69°	73°
7,	1,000	1,062	1.36	2.16	.0000	.0032	.0032	.27	.0250	.0000	-	69°	72°
8,	1,000	1,016	-	-	-	-	-	-	-	-	-	69°	71°
9,	1,000	1,032	-	-	-	-	-	-	-	-	-	70°	70°
10,	1,000	991	-	-	-	-	-	-	-	-	2h. 19m.	69°	72°
11,	1,000	1,025	-	-	-	-	-	-	-	-	-	69°	71°
12,	-	70	-	-	-	-	-	-	-	-	-	-	-
13,	1,000	1,092	-	-	-	-	-	-	-	-	3h. 25m.	69°	69°
14,	1,000	978	.48	2.64	.0002	.0028	.0030	.42	.0240	.0000	2h. 32m.	69°	69°
15,	1,000	985	-	-	-	-	-	-	-	-	2h. 33m.	69°	70°
16,	1,000	1,016	-	-	-	-	-	-	-	-	2h. 30m.	69°	72°
17,	1,000	1,139	-	-	-	-	-	-	-	-	2h. 49m.	69°	70°
18,	1,000	1,014	-	-	-	-	-	-	-	-	-	69°	71°
19,	-	49	-	-	-	-	-	-	-	-	-	-	-
20,	1,000	900	-	-	-	-	-	-	-	-	2h. 1m.	69°	73°
21,	1,000	1,029	1.48	1.92	.0020	.0054	.0074	.26	.0250	.0000	2h. 20m.	69°	73°
22,	1,000	1,179	-	-	-	-	-	-	-	-	2h. 38m.	69°	72°
23,	1,000	1,025	-	-	-	-	-	-	-	-	2h. 36m.	69°	71°
24,	1,000	1,021	-	-	-	-	-	-	-	-	2h. 41m.	69°	72°
25,	1,000	1,033	-	-	-	-	-	-	-	-	2h. 36m.	69°	72°
26,	-	72	-	-	-	-	-	-	-	-	-	-	-
27,	1,000	925	-	-	-	-	-	-	-	-	2h. 21m.	68°	72°
28,	1,000	1,005	1.16	1.68	.0002	.0040	.0042	.31	.0200	.0000	2h. 45m.	68°	71°
29,	1,000	1,002	-	-	-	-	-	-	-	-	2h. 46m.	68°	71°
30,	1,000	971	-	-	-	-	-	-	-	-	2h. 39m.	69°	71°
31,	1,000	979	-	-	-	-	-	-	-	-	2h. 46m.	68°	71°

Effluent colorless, clear or nearly so, and very nearly free from sediment. After August 1, residue on evaporation was obtained with sodium carbonate.

Total effluent to end of month, 106,480 gallons.

Filter Tank No. 8—Continued.

September, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		500 Gallons applied remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1, .	1,000	1,076	–	–	–	–	–	–	–	–	–	68°	71°
2, .	–	70	–	–	–	–	–	–	–	–	–	–	–
3, .	1,000	880	–	–	–	–	–	–	–	–	2 h. 21 m	68°	71°
4, .	1,000	1,016	.44	2.40	.0000	.0028	.0028	.26	.0230	.0000	2 h. 46 m.	69°	71°
5, .	1,000	1,002	–	–	–	–	–	–	–	–	2 h. 43 m.	69°	71°
6, .	1,000	979	–	–	–	–	–	–	–	–	2 h. 53 m.	68°	71°
7, .	1,000	981	–	–	–	–	–	–	–	–	2 h. 53 m.	67°	70°
8, .	1,000	1,247	–	–	–	–	–	–	–	–	–	67°	70°
9, .	–	91	–	–	–	–	–	–	–	–	–	–	–
10, .	1,000	943	–	–	–	–	–	–	–	–	2 h. 43 m.	67°	68°
11, .	1,000	907	.32	2.56	.0000	.0024	.0024	.27	.0200	.0000	3 h. 8 m.	67°	70°
12, .	1,000	1,080	–	–	–	–	–	–	–	–	3 h. 29 m.	67°	69°
13, .	1,000	992	–	–	–	–	–	–	–	–	2 h. 42 m.	67°	70°
14, .	1,000	1,016	–	–	–	–	–	–	–	–	3 h. 8 m.	67°	70°
15, .	1,000	991	–	–	–	–	–	–	–	–	2 h.	66°	69°
16, .	–	79	–	–	–	–	–	–	–	–	–	–	–
17, .	1,000	946	–	–	–	–	–	–	–	–	2 h. 59 m.	67°	69°
18, .	1,000	1,226	.16	3.80	.0004	.0030	.0034	.25	.0220	.0000	3 h. 51 m.	66°	68°
19, .	1,000	1,018	–	–	–	–	–	–	–	–	3 h. 12 m.	66°	67°
20, .	1,000	1,028	–	–	–	–	–	–	–	–	–	66°	67°
21, .	1,000	1,212	–	–	–	–	–	–	–	–	–	65°	65°
22, .	1,000	1,076	–	–	–	–	–	–	–	–	–	65°	65°
23, .	–	85	–	–	–	–	–	–	–	–	–	–	–
24, .	1,000	894	–	–	–	–	–	–	–	–	3 h. 19 m.	65°	63°
25, .	1,000	1,072	.32	3.32	.0010	.0026	.0036	.25	.0220	.0000	3 h. 54 m.	64°	64°
26, .	1,000	1,288	–	–	–	–	–	–	–	–	–	63°	63°
27, .	1,000	1,039	–	–	–	–	–	–	–	–	4 h. 5 m.	63°	63°
28, .	1,000	1,013	–	–	–	–	–	–	–	–	–	62°	61°
29, .	1,000	959	–	–	–	–	–	–	–	–	3 h. 59 m.	62°	61°
30, .	–	89	–	–	–	–	–	–	–	–	–	–	–

Effluent colorless, free from sediment, and generally clear.
Total effluent to end of month, 132,775 gallons.

Filter Tank No. 8 — Continued.

October, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	500 Gallons applied remained on Surface.	Temperature. Water.	Temperature. Effluent.
1, .	1,000	932	-	-	-	-	-	-	-	-	-	61°	62°
2, .	1,000	1,132	.32	2.52	.0002	.0028	.0030	.22	.0210	.0000	-	62°	60°
3, .	1,000	1,030	-	-	-	-	-	-	-	-	-	60°	59°
4, .	1,000	1,044	-	-	-	-	-	-	-	-	-	59°	58°
5, .	1,000	1,109	-	-	-	-	-	-	-	-	-	59°	57°
6, .	1,000	1,166	-	-	-	-	-	-	-	-	-	58°	58°
7, .	-	251	-	-	-	-	-	-	-	-	-	-	-
8, .	1,000	949	-	-	-	-	-	-	-	-	-	57°	57°
9, .	1,000	1,003	.56	2.56	.0002	.0036	.0038	.23	.0220	.0000	-	57°	57°
10, .	1,000	996	-	-	-	-	-	-	-	-	4 h. 50 m.	57°	57°
11, .	1,000	1,040	-	-	-	-	-	-	-	-	-	56°	56°
12, .	1,000	1,011	-	-	-	-	-	-	-	-	-	58°	54°
13, .	1,000	1,045	-	-	-	-	-	-	-	-	-	55°	53°
14, .	-	91	-	-	-	-	-	-	-	-	-	-	-
15, .	1,000	908	-	-	-	-	-	-	-	-	-	56°	53°
16, .	1,000	1,041	.64	2.44	.0000	.0022	.0022	.26	.0220	.0000	-	55°	54°
17, .	1,000	1,114	-	-	-	-	-	-	-	-	5 h.	54°	52°
18, .	1,000	1,006	-	-	-	-	-	-	-	-	-	55°	52°
19, .	1,000	1,003	-	-	-	-	-	-	-	-	-	55°	53°
20, .	1,000	1,040	-	-	-	-	-	-	-	-	-	54°	52°
21, .	-	96	-	-	-	-	-	-	-	-	-	-	-
22, .	1,000	882	-	-	-	-	-	-	-	-	3 h. 40 m.	53°	53°
23, .	1,000	1,010	.48	2.24	.0004	.0036	.0040	.20	.0230	.0000	-	52°	51°
24, .	1,000	1,129	-	-	-	-	-	-	-	-	-	52°	50°
25, .	1,000	983	-	-	-	-	-	-	-	-	-	52°	50°
26, .	1,000	1,021	-	-	-	-	-	-	-	-	4 h. 38 m.	52°	-
27, .	1,000	1,007	-	-	-	-	-	-	-	-	-	51°	50°
28, .	-	138	-	-	-	-	-	-	-	-	-	-	-
29, .	1,000	900	-	-	-	-	-	-	-	-	-	51°	52°
30, .	1,000	979	.60	2.08	.0000	.0016	.0016	.20	.0200	.0000	-	51°	52°
31, .	1,000	987	-	-	-	-	-	-	-	-	-	51°	52°

Effluent colorless, free from sediment, and generally clear.
Total effluent to end of month, 160,818 gallons.

Filter Tank No. 8 — Continued.

November, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		750 Gallons applied remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1,	1,000	1,009	–	–	–	–	–	–	–	–	–	51°	52°
2,	1,000	985	–	–	–	–	–	–	–	–	–	52°	52°
3,	1,000	993	–	–	–	–	–	–	–	–	–	52°	52°
4,	–	98	–	–	–	–	–	–	–	–	–	–	–
5,	1,000	851	–	–	–	–	–	–	–	–	–	51°	54°
6,	1,000	1,017	.44	2.20	.0000	.0022	.0022	.23	.0240	.0000	–	53°	53°
7,	1,000	986	–	–	–	–	–	–	–	–	–	52°	53°
8,	1,000	997	–	–	–	–	–	–	–	–	–	52°	54°
9,	1,000	1,085	–	–	–	–	–	–	–	–	–	51°	53°
10,	1,000	1,123	–	–	–	–	–	–	–	–	–	52°	53°
11,	–	116	–	–	–	–	–	–	–	–	–	–	–
12,	1,000	847	–	–	–	–	–	–	–	–	–	52°	52°
13,	1,000	998	.58	2.06	.0000	.0030	.0030	.23	.0250	.0000	–	52°	50°
14,	1,000	991	–	–	–	–	–	–	–	–	–	53°	50°
15,	1,500	1,521	–	–	–	–	–	–	–	–	7 h. 30 m.	54°	48°
16,	1,500	1,477	–	–	–	–	–	–	–	–	6 h. 28 m.	48°	48°
17,	1,500	1,456	–	–	–	–	–	–	–	–	–	48°	49°
18,	–	113	–	–	–	–	–	–	–	–	–	–	–
19,	1,500	1,367	–	–	–	–	–	–	–	–	6 h. 24 m.	48°	48°
20,	1,500	1,418	.40	1.96	.0000	.0036	.0036	.21	.0200	.0000	–	47°	47°
21,	1,500	1,455	–	–	–	–	–	–	–	–	–	46°	45°
22,	1,500	1,409	–	–	–	–	–	–	–	–	–	46°	43°
23,	1,500	1,328	–	–	–	–	–	–	–	–	–	45°	42°
24,	1,500	1,483	–	–	–	–	–	–	–	–	–	44°	43°
25,	–	119	–	–	–	–	–	–	–	–	–	–	–
26,	1,500	1,521	–	–	–	–	–	–	–	–	–	44°	42°
27,	1,500	1,666	.60	2.00	.0000	.0032	.0032	.26	.0220	.0000	–	44°	41°
28,	1,500	1,246	–	–	–	–	–	–	–	–	–	43°	42°
29,	–	–	–	–	–	–	–	–	–	–	–	–	–
30,	–	–	–	–	–	–	–	–	–	–	–	–	–

Effluent clear and colorless, and generally free from sediment.

Nov. 3.— Five hundred gallons of water applied disappeared in 5 h. 48 m. 6.— In 4 h. 44 m. 7.— In 5 h. 8.— In 4 h. 10.— In 6 h. 23 m. 22.— One-eighth inch of ice on surface. 23.— One-fourth inch. 28.— Outlet closed at 8.42 P.M. River high.

Total effluent to end of month, 190,493 gallons.

Filter Tank No. 8 — Continued.

December, 1888.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	750 Gallons applied remained on Surface.	Temperature. Water.	Temperature. Effluent.
1, .	1,500	1,638	-	-	-	-	-	-	-	-	-	43°	43°
2, .	-	118	-	-	-	-	-	-	-	-	-	-	-
3, .	1,500	1,299	-	-	-	-	-	-	-	-	-	42°	43°
4, .	1,500	1,437	.70	1.95	.0002	.0034	.0036	.24	.0200	.0000	-	43°	40°
5, .	1,500	1,452	-	-	-	-	-	-	-	-	-	42°	41°
6, .	1,500	1,389	-	-	-	-	-	-	-	-	-	42°	41°
7, .	1,500	1,520	-	-	-	-	-	-	-	-	-	42°	40°
8, .	1,500	1,486	-	-	-	-	-	-	-	-	-	42°	41°
9, .	-	137	-	-	-	-	-	-	-	-	-	-	-
10, .	1,500	1,339	-	-	-	-	-	-	-	-	-	41°	41°
11, .	1,500	1,436	.72	2.13	.0004	.0042	.0046	.23	.0260	.0000	-	41°	40°
12, .	1,500	1,426	-	-	-	-	-	-	-	-	-	40°	40°
13, .	1,500	1,431	.68	2.56	.0000	.0022	.0022	.22	.0360	.0000	-	40°	39°
14, .	1,500	1,265	-	-	-	-	-	-	-	-	-	39°	38°
15, .	1,500	1,450	-	-	-	-	-	-	-	-	-	39°	36°
16, .	-	128	-	-	-	-	-	-	-	-	-	-	-
17, .	1,500	1,897	-	-	-	-	-	-	-	-	-	40°	37°
18, .	1,500	862	.56	2.36	.0000	.0028	.0028	.19	.0290	.0000	-	39°	39°
19, .	-	-	-	-	-	-	-	-	-	-	-	-	-
20, .	-	-	-	-	-	-	-	-	-	-	-	-	-
21, .	-	261	-	-	-	-	-	-	-	-	-	-	-
22, .	1,500	1,167	-	-	-	-	-	-	-	-	-	37°	39°
23, .	-	120	-	-	-	-	-	-	-	-	-	-	-
24, .	1,500	1,475	.70	2.55	.0008	.0044	.0052	.20	.0300	.0000	-	38°	37°
25, .	1,500	1,532	-	-	-	-	-	-	-	-	-	38°	39°
26, .	1,500	1,451	-	-	-	-	-	-	-	-	-	39°	38°
27, .	1,500	1,567	-	-	-	-	-	-	-	-	6h. 18m.	40°	38°
28, .	1,500	1,419	-	-	-	-	-	-	-	-	-	39°	40°
29, .	1,500	1,426	-	-	-	-	-	-	-	-	-	38°	40°
30, .	-	106	-	-	-	-	-	-	-	-	-	-	-
31, .	1,500	1,399	-	-	-	-	-	-	-	-	-	38°	40°

Effluent colorless, free from sediment and generally clear.

Dec. 1. — Outlet opened at 5.20 A.M. 14. — Five-eighths inch of ice on surface. 16. — Ice melting. 19. — Three-eighths inch of ice and one-half inch of frost on surface. 21. — Surface covered with ice; 1¾ inches of frost. 18, 4.35 P.M., to 21, 7.51 A.M. — Outlet closed. River high.

Total effluent to end of month, 224,126 gallons.

Filter Tank No. 8 — Continued.

January, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	750 Gallons applied remained on Surface.	Temperature. Water.	Temperature. Effluent.
1, .	1,500	1,450	.40	2.40	.0004	.0042	.0046	.21	.0300	.0000	-	38°	39°
2, .	1,500	1,539	-	-	-	-	-	-	-	-	-	39°	39°
3, .	1,500	1,563	-	-	-	-	-	-	-	-	-	39°	39°
4, .	1,500	1,568	-	-	-	-	-	-	-	-	-	39°	39°
5, .	1,500	1,602	-	-	-	-	-	-	-	-	-	39°	38°
6, .	-	249	-	-	-	-	-	-	-	-	-	-	-
7, .	1,500	1,597	-	-	-	-	-	-	-	-	7 h.	39°	38°
8, .	1,500	1,547	.36	2.60	.0002	.0042	.0044	.25	.0300	.0000	8 h. 25 m.	38°	38°
9, .	1,500	1,614	-	-	-	-	-	-	-	-	-	38°	39°
10, .	1,500	1,550	-	-	-	-	-	-	-	-	-	38°	39°
11, .	1,500	1,580	-	-	-	-	-	-	-	-	-	38°	40°
12, .	1,500	1,580	-	-	-	-	-	-	-	-	-	38°	39°
13, .	-	122	-	-	-	-	-	-	-	-	-	-	-
14, .	1,500	1,396	-	-	-	-	-	-	-	-	-	38°	38°
15, .	1,500	1,522	.72	2.32	.0000	.0040	.0040	.21	.0250	.0000	-	38°	38°
16, .	1,500	1,561	-	-	-	-	-	-	-	-	-	38°	38°
17, .	1,500	1,714	-	-	-	-	-	-	-	-	-	39°	38°
18, .	1,500	1,548	-	-	-	-	-	-	-	-	-	39°	40°
19, .	1,500	1,526	-	-	-	-	-	-	-	-	-	38°	40°
20, .	-	128	-	-	-	-	-	-	-	-	-	-	-
21, .	1,500	1,402	-	-	-	-	-	-	-	-	7 h. 35 m.	38°	39°
22, .	1,500	1,527	.80	1.80	.0002	.0062	.0064	.20	.0250	.0000	7 h. 35 m.	37°	37°
23, .	1,500	1,509	-	-	-	-	-	-	-	-	-	37°	36°
24, .	1,500	1,637	-	-	-	-	-	-	-	-	-	38°	36°
25, .	1,500	1,532	-	-	-	-	-	-	-	-	-	37°	36°
26, .	1,500	1,678	-	-	-	-	-	-	-	-	-	37°	36°
27, .	-	147	-	-	-	-	-	-	-	-	-	-	-
28, .	1,500	1,504	-	-	-	-	-	-	-	-	-	38°	37°
29, .	1,500	1,486	.32	2.24	.0002	.0038	.0040	.22	.0250	.0000	-	37°	37°
30, .	1,500	1,526	-	-	-	-	-	-	-	-	-	37°	37°
31, .	1,500	1,555	-	-	-	-	-	-	-	-	-	37°	37°

Effluent colorless, free from sediment and generally clear.

Jan. 21. — The second 750 gallons applied filled the tank. 22. — No frost in tank, but considerable ice and snow on surface. 26 and 29. — No frost in tank.

Total effluent to end of month, 266,585 gallons.

Filter Tank No 8 — Continued.

February, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		750 Gallons applied remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1, .	1,500	1,621	-	-	-	-	-	-	-	-	-	38°	37°
2, .	1,500	1,592	-	-	-	-	-	-	-	-	-	37°	35°
3, .	-	169	-	-	-	-	-	-	-	-	-	-	-
4, .	1,500	1,381	-	-	-	-	-	-	-	-	-	36°	36°
5, .	1,500	1,626	.64	2.12	.0002	.0024	.0026	.23	.0250	.0000	-	37°	36°
6, .	1,500	1,495	-	-	-	-	-	-	-	-	8 h. 18 m.	37°	36°
7, .	1,500	1,461	-	-	-	-	-	-	-	-	-	36°	36°
8, .	1,500	1,411	-	-	-	-	-	-	-	-	-	36°	36°
9, .	1,500	1,599	-	-	-	-	-	-	-	-	-	36°	35°
10, .	-	138	-	-	-	-	-	-	-	-	-	-	-
11, .	1,450	1,301	-	-	-	-	-	-	-	-	-	36°	36°
12, .	1,450	1,475	.55	2.85	.0002	.0030	.0032	.22	.0250	.0000	-	36°	35°
13, .	1,500	1,422	-	-	-	-	-	-	-	-	-	36°	-
14, .	1,500	1,515	-	-	-	-	-	-	-	-	-	37°	35°
15, .	1,500	1,528	-	-	-	-	-	-	-	-	-	36°	34°
16, .	1,500	1,706	-	-	-	-	-	-	-	-	-	36°	35°
17, .	-	240	-	-	-	-	-	-	-	-	-	-	-
18, .	1,500	1,420	-	-	-	-	-	-	-	-	-	36°	35°
19, .	1,500	1,542	.35	2.15	.0004	.0040	.0044	.23	.0200	.0000	-	36°	35°
20, .	1,500	1,482	-	-	-	-	-	-	-	-	-	36°	35°
21, .	1,500	1,489	-	-	-	-	-	-	-	-	-	36°	35°
22, .	1,500	1,550	-	-	-	-	-	-	-	-	-	37°	36°
23, .	1,500	1,459	-	-	-	-	-	-	-	-	-	36°	36°
24, .	-	156	-	-	-	-	-	-	-	-	-	-	-
25, .	1,500	1,293	-	-	-	-	-	-	-	-	-	36°	36°
26, .	1,500	1,488	.70	2.00	.0004	.0046	.0050	.22	.0270	.0001	-	35°	35°
27, .	1,500	1,438	-	-	-	-	-	-	-	-	-	36°	35°
28, .	1,500	1,589	-	-	-	-	-	-	-	-	-	36°	35°

Effluent clear and colorless, and generally free from sediment.

Feb. 3 and 17.—Ice melting on surface. 5 and 7.—No frost in tank. 11 and 12.—The quantity applied filled the tank.

Total effluent to end of month, 303,171 gallons.

Filter Tank No. 8 — Continued.

March, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Water on Surface in the morning. Inches.	Temperature. Water.	Temperature. Effluent.
1, .	1,500	1,626	-	-	-	-	-	-	-	-	-	36°	36°
2, .	1,500	1,601	-	-	-	-	-	-	-	-	-	36°	37°
3, .	-	159	-	-	-	-	-	-	-	-	-	-	-
4, .	1,500	1,360	-	-	-	-	-	-	-	-	-	36°	39°
5, .	1,500	1,549	.30	2.85	.0002	.0032	.0034	.21	.0300	.0000	-	36°	39°
6, .	1,500	1,573	-	-	-	-	-	-	-	-	-	36°	39°
7, .	1,500	1,651	-	-	-	-	-	-	-	-	-	36°	39°
8, .	1,500	1,594	-	-	-	-	-	-	-	-	-	36°	38°
9, .	1,500	1,617	-	-	-	-	-	-	-	-	-	36°	38°
10, .	-	229	-	-	-	-	-	-	-	-	-	-	-
11, .	1,500	1,367	-	-	-	-	-	-	-	-	-	36°	37°
12, .	1,500	1,511	.30	2.55	.0002	.0038	.0040	.22	.0230	.0000	-	37°	38°
13, .	1,500	1,568	-	-	-	-	-	-	-	-	-	37°	38°
14, .	1,500	1,584	-	-	-	-	-	-	-	-	-	37°	39°
15, .	1,500	1,501	-	-	-	-	-	-	-	-	-	37°	40°
16, .	1,500	1,550	-	-	-	-	-	-	-	-	-	37°	40°
17, .	-	309	-	-	-	-	-	-	-	-	-	-	-
18, .	1,500	1,317	-	-	-	-	-	-	-	-	-	37°	39°
19, .	1,500	1,384	.44	2.26	.0002	.0022	.0024	.22	.0230	.0000	-	37°	39°
20, .	1,500	1,422	-	-	-	-	-	-	-	-	0	37°	39°
21, .	1,500	1,462	-	-	-	-	-	-	-	-	1	37°	39°
22, .	1,500	1,718	-	-	-	-	-	-	-	-	1½	37°	39°
23, .	1,500	1,692	-	-	-	-	-	-	-	-	0	37°	40°
24, .	-	272	-	-	-	-	-	-	-	-	0	-	-
25, .	1,500	1,311	-	-	-	-	-	-	-	-	-	38°	42°
26, .	1,500	1,384	.44	2.52	.0002	.0028	.0030	.20	.0250	.0000	-	38°	43°
27, .	1,500	1,469	-	-	-	-	-	-	-	-	1½	38°	43°
28, .	1,500	1,472	-	-	-	-	-	-	-	-	½	38°	43°
29, .	1,450	1,624	-	-	-	-	-	-	-	-	1	39°	43°
30, .	1,500	1,685	-	-	-	-	-	-	-	-	1	39°	43°
31, .	-	284	-	-	-	-	-	-	-	-	0	-	-

Effluent colorless, and generally clear and free from sediment.

March 2. — First 500 gallons of water applied disappeared in 6 h. 10 m. 6. — Third 500 gallons in 12 h. 40 m. 29. — Quantity applied filled tank.

Total effluent to end of month, 344,016 gallons.

Filter Tank No. 8 — Continued.

April, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Water on Surface in the morning. Inches.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1, .	1,500	1,262	-	-	-	-	-	-	-	-	-	39°	43°
2, .	1,500	1,736	.80	2.05	.0004	.0038	.0042	.17	.0250	.0000	-	39°	41°
3, .	1,500	1,410	-	-	-	-	-	-	-	-	0	39°	41°
4, .	1,500	1,496	-	-	-	-	-	-	-	-	¼	39°	41°
5, .	1,500	1,588	-	-	-	-	-	-	-	-	-	39°	41°
6, .	1,500	1,701	-	-	-	-	-	-	-	-	½	39°	42°
7, .	-	280	-	-	-	-	-	-	-	-	0	-	-
8, .	1,500	1,236	-	-	-	-	-	-	-	-	-	40°	43°
9, .	1,500	1,374	.35	2.45	.0004	.0042	.0046	.17	.0200	.0000	0	40°	44°
10, .	1,500	1,509	-	-	-	-	-	-	-	-	-	41°	45°
11, .	1,500	1,515	-	-	-	-	-	-	-	-	-	41°	47°
12, .	1,500	1,526	-	-	-	-	-	-	-	-	0	41°	48°
13, .	700	1,076	-	-	-	-	-	-	-	-	0	41°	49°
14, .	-	85	-	-	-	-	-	-	-	-	0	-	-
15, .	1,500	1,271	-	-	-	-	-	-	-	-	-	42°	49°
16, .	1,500	1,367	.30	2.70	.0004	.0064	.0068	.16	.0290	.0001	0	42°	50°
17, .	1,500	1,379	-	-	-	-	-	-	-	-	0	42°	50°
18, .	1,450	1,512	-	-	-	-	-	-	-	-	1	43°	50°
19, .	1,500	1,819	-	-	-	-	-	-	-	-	1	45°	50°
20, .	1,500	1,673	-	-	-	-	-	-	-	-	0	46°	52°
21, .	-	169	-	-	-	-	-	-	-	-	0	-	-
22, .	1,500	1,226	-	-	-	-	-	-	-	-	-	47°	54°
23, .	1,500	1,408	.96	2.74	.0002	.0048	.0050	.15	.0300	.0001	0	46°	55°
24, .	1,500	1,522	-	-	-	-	-	-	-	-	0	46°	54°
25, .	1,500	1,658	-	-	-	-	-	-	-	-	0	47°	54°
26, .	1,500	1,691	-	-	-	-	-	-	-	-	0	48°	54°
27, .	1,500	1,701	-	-	-	-	-	-	-	-	0	49°	56°
28, .	-	249	-	-	-	-	-	-	-	-	0	-	-
29, .	1,250	1,121	-	-	-	-	-	-	-	-	-	49°	54°
30, .	1,000	1,398	.60	2.30	.0004	.0038	.0042	.15	.0270	.0001	0	50°	55°

Effluent colorless, and generally clear and free from sediment.

April 10 and 11. — A little water on surface in the morning. 15. — First 500 gallons applied disappeared in 5 h. 30. 22. — In 4 h. 55 m.

Total effluent to end of month, 382,974 gallons.

Filter Tank No. 8 — Continued.

May, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Water on Surface in the morning. Inches.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1, .	1,500	1,446	–	–	–	–	–	–	–	–	0	50°	56°
2, .	1,500	1,524	–	–	–	–	–	–	–	–	0	50°	56°
3, .	1,500	1,501	–	–	–	–	–	–	–	–	0	50°	56°
4, .	1,500	1,796	–	–	–	–	–	–	–	–	0	51°	56°
5, .	–	402	–	–	–	–	–	–	–	–	0	–	–
6, .	1,500	1,310	–	–	–	–	–	–	–	–	–	51°	55°
7, .	1,500	1,408	.65	2.35	.0000	.0032	.0032	.13	.0270	.0000	0	51°	57°
8, .	1,500	1,493	–	–	–	–	–	–	–	–	0	51°	58°
9, .	1,500	1,534	–	–	–	–	–	–	–	–	0	52°	59°
10, .	1,500	1,525	–	–	–	–	–	–	–	–	0	53°	63°
11, .	1,500	1,448	–	–	–	–	–	–	–	–	0	54°	63°
12, .	–	158	–	–	–	–	–	–	–	–	–	–	–
13, .	1,500	1,311	–	–	–	–	–	–	–	–	–	54°	63°
14, .	1,500	1,477	.65	2.90	.0000	.0036	.0036	.14	.0250	.0000	0	54°	63°
15, .	1,500	1,531	–	–	–	–	–	–	–	–	0	55°	63°
16, .	1,500	1,460	–	–	–	–	–	–	–	–	0	55°	63°
17, .	1,500	1,495	–	–	–	–	–	–	–	–	0	56°	64°
18, .	1,500	1,526	–	–	–	–	–	–	–	–	0	57°	65°
19, .	–	121	–	–	–	–	–	–	–	–	0	–	–
20, .	1,500	1,460	–	–	–	–	–	–	–	–	–	58°	66°
21, .	1,500	1,665	.70	2.40	.0004	.0052	.0056	.15	.0300	.0001	0	59°	67°
22, .	1,500	1,520	–	–	–	–	–	–	–	–	–	59°	66°
23, .	1,500	1,440	–	–	–	–	–	–	–	–	–	59°	66°
24, .	1,500	1,467	–	–	–	–	–	–	–	–	–	60°	65°
25, .	1,500	1,518	–	–	–	–	–	–	–	–	–	60°	64°
26, .	–	147	–	–	–	–	–	–	–	–	–	–	–
27, .	1,500	1,298	–	–	–	–	–	–	–	–	–	60°	64°
28, .	1,500	1,499	.28	2.92	.0020	.0056	.0076	.16	.0220	.0001	–	61°	62°
29, .	1,500	1,461	–	–	–	–	–	–	–	–	–	60°	62°
30, .	1,500	1,437	–	–	–	–	–	–	–	–	–	60°	63°
31, .	1,500	1,537	–	–	–	–	–	–	–	–	–	60°	63°

Effluent colorless, and generally clear and free from sediment.
May 10. — First 500 gallons of water applied disappeared in 6 h. 8 m.
Total effluent to end of month, 423,889 gallons.

Filter Tank No. 8 — Continued.

June, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	1,500	1,470	–	–	–	–	–	–	–	–	60°	64°
2, ...	–	302	–	–	–	–	–	–	–	–	–	–
3, ...	1,500	1,343	–	–	–	–	–	–	–	–	60°	65°
4, ...	1,500	1,483	.75	2.90	.0000	.0040	.0040	.17	.0350	.0001	60°	66°
5, ...	1,500	1,478	–	–	–	–	–	–	–	–	60°	66°
6, ...	1,500	1,430	–	–	–	–	–	–	–	–	61°	65°
7, ...	1,500	1,353	–	–	–	–	–	–	–	–	61°	66°
8, ...	1,500	1,477	–	–	–	–	–	–	–	–	61°	67°
9, ...	–	155	–	–	–	–	–	–	–	–	–	–
10, ...	1,500	1,255	–	–	–	–	–	–	–	–	62°	66°
11, ...	1,500	1,472	.60	2.05	.0010	.0046	.0056	.15	.0320	.0000	63°	67°
12, ...	1,500	1,455	–	–	–	–	–	–	–	–	62°	69°
13, ...	1,500	1,470	–	–	–	–	–	–	–	–	63°	70°
14, ...	1,500	1,482	–	–	–	–	–	–	–	–	63°	70°
15, ...	1,500	1,546	–	–	–	–	–	–	–	–	64°	71°
16, ...	–	130	–	–	–	–	–	–	–	–	–	–
17, ...	1,500	1,346	–	–	–	–	–	–	–	–	64°	71°
18, ...	1,500	1,452	.72	2.60	.0004	.0050	.0054	.16	.0380	.0000	63°	72°
19, ...	1,500	1,420	–	–	–	–	–	–	–	–	64°	71°
20, ...	1,500	1,527	–	–	–	–	–	–	–	–	64°	70°
21, ...	1,500	1,463	–	–	–	–	–	–	–	–	66°	70°
22, ...	1,500	1,489	–	–	–	–	–	–	–	–	65°	71°
23, ...	–	123	–	–	–	–	–	–	–	–	–	–
24, ...	1,500	1,245	–	–	–	–	–	–	–	–	65°	72°
25, ...	1,500	1,404	.56	2.56	.0002	.0060	.0062	.17	.0600	.0000	66°	72°
26, ...	1,500	1,540	–	–	–	–	–	–	–	–	67°	71°
27, ...	1,500	1,491	–	–	–	–	–	–	–	–	67°	71°
28, ...	1,500	1,495	–	–	–	–	–	–	–	–	68°	71°
29, ...	1,500	1,538	–	–	–	–	–	–	–	–	68°	73°
30, ...	–	100	–	–	–	–	–	–	–	–	–	–

Effluent clear and colorless, and free from sediment.
June 1. — First 500 gallons of water applied disappeared in 5 h. 45 m.
Total effluent to end of month, 460,823 gallons.

Filter Tank No. 8 — Continued.

July, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		500 Gallons applied remained on Surface.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1, .	1,500	1,280	-	-	-	-	-	-	-	-	-	69°	74°
2, .	1,500	1,347	.80	2.60	.0006	.0054	.0060	.18	.0300	.0000	-	69°	75°
3, .	1,500	1,448	-	-	-	-	-	-	-	-	-	69°	75°
4, .	1,500	1,584	-	-	-	-	-	-	-	-	-	69°	-
5, .	1,500	1,489	-	-	-	-	-	-	-	-	-	69°	74°
6, .	1,500	1,546	-	-	-	-	-	-	-	-	-	70°	74°
7, .	-	180	-	-	-	-	-	-	-	-	-	-	-
8, .	1,500	1,320	-	-	-	-	-	-	-	-	-	69°	74°
9, .	1,500	1,465	.52	2.68	.0008	.0064	.0072	.18	.0300	.0000	-	69°	74°
10, .	1,500	1,410	-	-	-	-	-	-	-	-	-	69°	73°
11, .	1,500	1,543	-	-	-	-	-	-	-	-	-	69°	72°
12, .	1,500	1,533	-	-	-	-	-	-	-	-	-	70°	70°
13, .	1,500	1,551	-	-	-	-	-	-	-	-	-	71°	71°
14, .	-	120	-	-	-	-	-	-	-	-	-	-	-
15, .	1,500	1,427	-	-	-	-	-	-	-	-	-	70°	70°
16, .	1,500	1,466	.72	2.24	.0008	.0062	.0070	.18	.0250	.0000	-	70°	70°
17, .	1,500	1,701	-	-	-	-	-	-	-	-	-	70°	70°
18, .	1,500	1,585	-	-	-	-	-	-	-	-	-	70°	70°
19, .	1,500	1,480	-	-	-	-	-	-	-	-	-	70°	71°
20, .	1,500	1,812	-	-	-	-	-	-	-	-	-	70°	71°
21, .	-	150	-	-	-	-	-	-	-	-	-	-	-
22, .	1,500	1,274	-	-	-	-	-	-	-	-	4h. 55m.	70°	71°
23, .	1,500	1,536	.60	2.40	.0008	.0042	.0050	.20	.0220	.0000	-	70°	72°
24, .	1,500	1,473	-	-	-	-	-	-	-	-	-	70°	74°
25, .	1,500	1,430	-	-	-	-	-	-	-	-	-	70°	74°
26, .	1,500	1,458	-	-	-	-	-	-	-	-	-	70°	73°
27, .	1,500	1,580	-	-	-	-	-	-	-	-	-	69°	73°
28, .	-	210	-	-	-	-	-	-	-	-	-	-	-
29, .	1,500	1,303	-	-	-	-	-	-	-	-	-	70°	72°
30, .	1,500	1,513	.84	2.66	.0010	.0042	.0052	.16	.0200	.0000	-	70°	72°
31, .	1,500	1,547	-	-	-	-	-	-	-	-	-	70°	73°

Effluent clear and colorless, and free from sediment.
Total effluent to end of month, 501,584 gallons.

Filter Tank No. 8 — Continued.

August, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.
1, ...	1,500	1,565	-	-	-	-	-	-	-	-	69°	72°
2, ...	1,500	1,474	-	-	-	-	-	-	-	-	69°	73°
3, ...	1,500	1,452	-	-	-	-	-	-	-	-	69°	73°
4, ...	-	140	-	-	-	-	-	-	-	-	-	-
5, ...	1,500	1,327	-	-	-	-	-	-	-	-	69°	73°
6, ...	1,500	1,452	1.12	2.44	.0006	.0048	.0054	.20	.0250	.0000	69°	72°
7, ...	1,500	1,409	-	-	-	-	-	-	-	-	69°	72°
8, ...	1,500	1,421	-	-	-	-	-	-	-	-	69°	72°
9, ...	1,500	1,401	-	-	-	-	-	-	-	-	69°	72°
10, ...	1,500	1,449	-	-	-	-	-	-	-	-	69°	72°
11, ...	-	140	-	-	-	-	-	-	-	-	-	-
12, ...	1,500	1,239	-	-	-	-	-	-	-	-	68°	71°
13, ...	1,500	1,381	1.45	2.90	.0002	.0060	.0062	.18	.0250	.0000	68°	71°
14, ...	1,500	1,648	-	-	-	-	-	-	-	-	68°	70°
15, ...	1,500	1,503	-	-	-	-	-	-	-	-	68°	69°
16, ...	1,500	1,488	-	-	-	-	-	-	-	-	68°	68°
17, ...	1,500	1,503	-	-	-	-	-	-	-	-	68°	68°
18, ...	-	130	-	-	-	-	-	-	-	-	-	-
19, ...	1,500	1,304	-	-	-	-	-	-	-	-	67°	69°
20, ...	1,500	1,473	2.12	2.88	.0002	.0052	.0054	.20	.0200	.0000	68°	68°
21, ...	1,500	1,427	-	-	-	-	-	-	-	-	68°	68°
22, ...	1,500	1,489	-	-	-	-	-	-	-	-	68°	70°
23, ...	1,500	1,390	-	-	-	-	-	-	-	-	67°	70°
24, ...	1,500	1,536	-	-	-	-	-	-	-	-	67°	71°
25, ...	-	145	-	-	-	-	-	-	-	-	-	-
26, ...	1,500	1,283	-	-	-	-	-	-	-	-	68°	70°
27, ...	1,500	1,442	-	-	.0002	.0038	.0040	.20	.0250	.0000	68°	70°
28, ...	1,500	1,476	-	-	-	-	-	-	-	-	68°	70°
29, ...	1,500	1,490	-	-	-	-	-	-	-	-	68°	70°
30, ...	1,500	1,521	-	-	-	-	-	-	-	-	68°	71°
31, ...	1,500	1,493	-	-	-	-	-	-	-	-	68°	71°

Effluent clear and colorless, and free from sediment.
Total effluent to end of month, 541,175 gallons.

Filter Tank No. 8 — Continued.

September, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.
1, ...	-	145	-	-	-	-	-	-	-	-	-	-
2, ...	1,500	1,284	-	-	-	-	-	-	-	-	68°	71°
3, ...	1,500	1,444	.80	3.00	.0000	.0040	.0040	.22	.0270	.0000	68°	72°
4, ...	1,500	1,494	-	-	-	-	-	-	-	-	68°	71°
5, ...	1,500	1,476	-	-	-	-	-	-	-	-	68°	71°
6, ...	1,500	1,399	-	-	-	-	-	-	-	-	69°	71°
7, ...	1,500	1,450	-	-	-	-	-	-	-	-	69°	72°
8, ...	-	140	-	-	-	-	-	-	-	-	-	-
9, ...	1,500	1,220	-	-	-	-	-	-	-	-	68°	68°
10, ...	1,500	1,431	1.16	3.12	.0004	.0058	.0062	.25	.0280	.0000	68°	70°
11, ...	1,500	1,492	-	-	-	-	-	-	-	-	68°	69°
12, ...	1,500	1,462	-	-	-	-	-	-	-	-	67°	68°
13, ...	1,500	1,439	-	-	-	-	-	-	-	-	67°	67°
14, ...	1,500	1,640	-	-	-	-	-	-	-	-	67°	68°
15, ...	-	154	-	-	-	-	-	-	-	-	-	-
16, ...	1,500	1,314	-	-	-	-	-	-	-	-	67°	69°
17, ...	1,500	1,434	.80	3.30	.0012	.0060	.0072	.25	.0320	.0000	68°	70°
18, ...	1,500	1,393	-	-	-	-	-	-	-	-	67°	70°
19, ...	1,500	1,517	-	-	-	-	-	-	-	-	66°	69°
20, ...	1,500	1,463	-	-	-	-	-	-	-	-	66°	67°
21, ...	1,500	1,516	-	-	-	-	-	-	-	-	66°	65°
22, ...	-	162	-	-	-	-	-	-	-	-	-	-
23, ...	1,500	1,251	-	-	-	-	-	-	-	-	65°	62°
24, ...	1,500	1,423	.90	2.50	.0002	.0054	.0056	.25	.0200	.0000	65°	64°
25, ...	1,500	1,470	-	-	-	-	-	-	-	-	64°	63°
26, ...	1,500	1,507	-	-	-	-	-	-	-	-	63°	64°
27, ...	1,500	1,480	-	-	-	-	-	-	-	-	63°	64°
28, ...	1,500	1,488	-	-	-	-	-	-	-	-	62°	63°
29, ...	-	207	-	-	-	-	-	-	-	-	-	-
30, ...	1,500	1,233	.70	3.50	.0002	.0044	.0046	.23	.0170	.0000	62°	63°

Effluent clear and colorless, and free from sediment.
Total effluent to end of month, 577,703 gallons.

Filter Tank No. 8 — Continued.

October, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	1,500	1,367	-	-	-	-	-	-	-	-	62°	62°
2, ...	1,500	1,408	-	-	-	-	-	-	-	-	61°	62°
3, ...	1,500	1,411	-	-	-	-	-	-	-	-	61°	61°
4, ...	1,500	1,528	-	-	-	-	-	-	-	-	61°	61°
5, ...	1,500	1,470	-	-	-	-	-	-	-	-	60°	60°
6, ...	-	242	-	-	-	-	-	-	-	-	-	-
7, ...	1,500	1,269	1.20	2.50	.0000	.0040	.0040	.23	.0180	.0000	60°	60°
8, ...	1,500	1,405	-	-	-	-	-	-	-	-	59°	58°
9, ...	1,500	1,482	-	-	-	-	-	-	-	-	58°	58°
10, ...	1,500	1,469	-	-	-	-	-	-	-	-	59°	56°
11, ...	1,500	1,461	-	-	-	-	-	-	-	-	58°	56°
12, ...	1,500	1,606	-	-	-	-	-	-	-	-	57°	55°
13, ...	-	298	-	-	-	-	-	-	-	-	-	-
14, ...	1,500	996	1.50	2.40	.0002	.0074	.0076	.21	.0160	.0000	56°	54°
15, ...	1,500	1,424	-	-	-	-	-	-	-	-	55°	54°
16, ...	1,500	1,515	-	-	-	-	-	-	-	-	55°	53°
17, ...	1,500	1,324	-	-	-	-	-	-	-	-	55°	53°
18, ...	1,500	1,515	-	-	-	-	-	-	-	-	54°	54°
19, ...	1,500	1,587	-	-	-	-	-	-	-	-	53°	53°
20, ...	-	270	-	-	-	-	-	-	-	-	-	-
21, ...	1,500	1,060	1.90	2.50	.0002	.0062	.0064	.21	.0140	.0000	53°	53°
22, ...	1,500	1,522	-	-	-	-	-	-	-	-	53°	52°
23, ...	1,500	1,447	-	-	-	-	-	-	-	-	52°	52°
24, ...	1,500	1,479	-	-	-	-	-	-	-	-	52°	51°
25, ...	1,500	1,546	-	-	-	-	-	-	-	-	52°	49°
26, ...	1,500	1,507	-	-	-	-	-	-	-	-	-	50°
27, ...	-	240	-	-	-	-	-	-	-	-	-	-
28, ...	1,500	1,159	1.60	2.30	.0008	.0066	.0074	.21	.0160	.0000	51°	52°
29, ...	1,500	1,465	-	-	-	-	-	-	-	-	51°	51°
30, ...	1,500	1,493	-	-	-	-	-	-	-	-	51°	51°
31, ...	1,500	1,523	-	-	-	-	-	-	-	-	51°	51°

Effluent clear and colorless, and free from sediment.
Oct. 15. — Surface half covered with water in the morning. 22, 29 and 30. — All covered.
Total effluent to end of month, 617,191 gallons.

Filter Tank No. 8 — Continued.

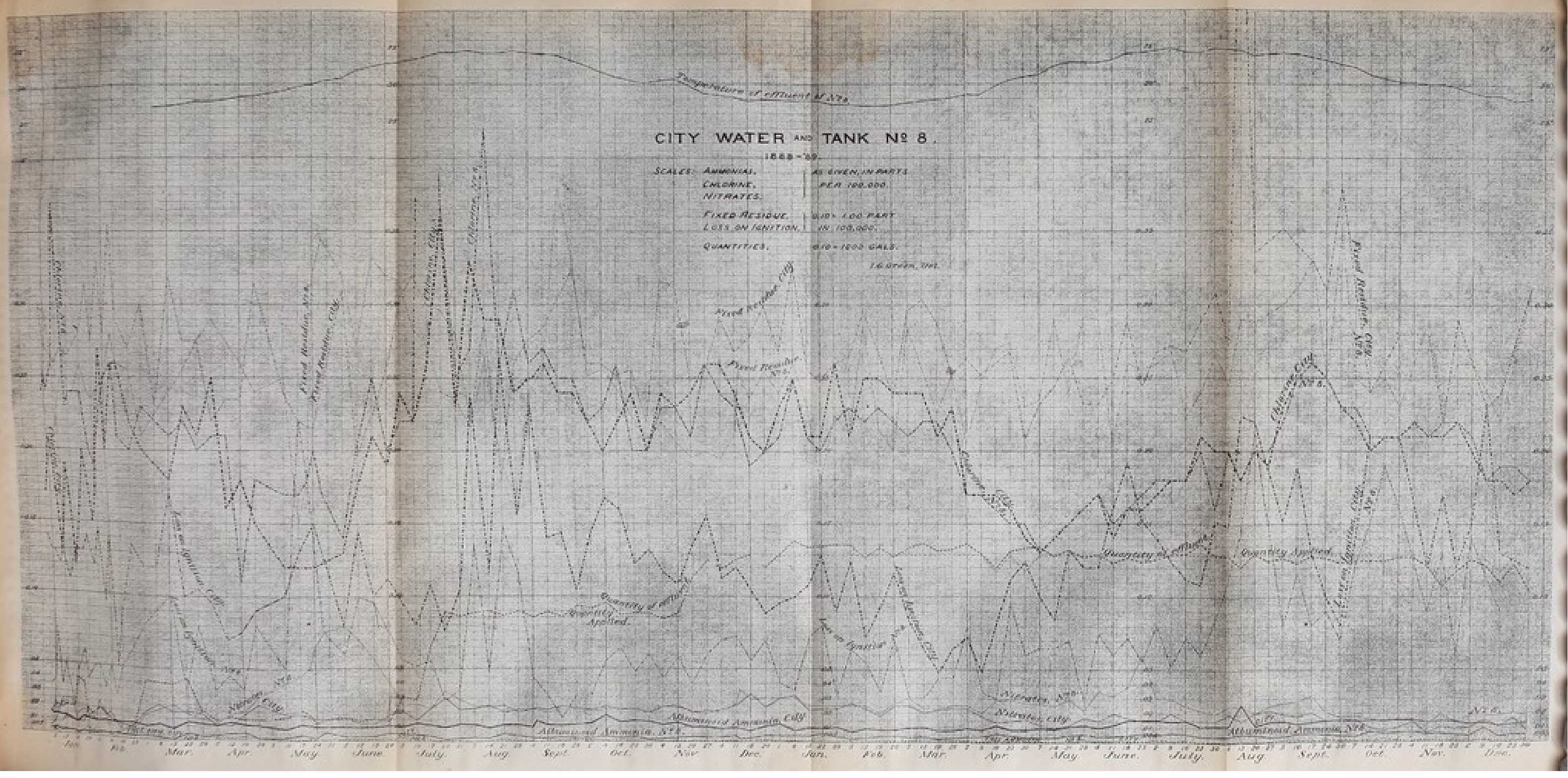
November, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Water on Surface in the morning. Inches.	Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		Water.	Effluent.
1,	1,500	1,419	-	-	-	-	-	-	-	-	-	51°	51°
2,	1,500	1,658	-	-	-	-	-	-	-	-	-	52°	51°
3,	-	330	-	-	-	-	-	-	-	-	-	-	-
4,	1,500	999	-	-	.0008	.0072	.0080	.21	.0140	.0000	-	51°	52°
5,	1,500	1,268	-	-	-	-	-	-	-	-	-	51°	50°
6,	1,500	1,531	-	-	-	-	-	-	-	-	-	51°	51°
7,	1,500	1,649	-	-	-	-	-	-	-	-	-	51°	49°
8,	1,500	1,230	-	-	-	-	-	-	-	-	-	50°	49°
9,	1,450	1,517	-	-	-	-	-	-	-	-	-	51°	49°
10,	-	437	-	-	-	-	-	-	-	-	-	-	-
11,	1,500	846	.90	2.90	.0002	.0058	.0060	.21	.0110	.0000	-	50°	50°
12,	1,300	1,288	-	-	-	-	-	-	-	-	2	50°	50°
13,	1,350	1,162	-	-	-	-	-	-	-	-	-	51°	54°
14,	1,500	1,857	-	-	-	-	-	-	-	-	-	50°	51°
15,	1,000	913	-	-	-	-	-	-	-	-	-	49°	50°
16,	1,000	959	-	-	-	-	-	-	-	-	-	49°	50°
17,	-	192	-	-	-	-	-	-	-	-	-	-	-
18,	1,500	1,161	1.30	2.30	.0002	.0058	.0060	.22	.0190	.0000	-	48°	47°
19,	1,500	1,272	-	-	-	-	-	-	-	-	-	48°	47°
20,	1,500	1,425	-	-	-	-	-	-	-	-	-	49°	47°
21,	1,500	1,432	-	-	-	-	-	-	-	-	-	48°	48°
22,	1,450	1,405	-	-	-	-	-	-	-	-	-	47°	48°
23,	1,500	1,478	-	-	-	-	-	-	-	-	-	46°	49°
24,	-	397	-	-	-	-	-	-	-	-	-	-	-
25,	1,500	816	.60	2.60	.0002	.0050	.0052	.22	.0140	.0000	-	47°	48°
26,	1,500	1,419	-	-	-	-	-	-	-	-	-	47°	47°
27,	1,500	1,766	-	-	-	-	-	-	-	-	-	46°	45°
28,	1,400	1,518	-	-	-	-	-	-	-	-	0	47°	44°
29,	1,500	1,523	-	-	-	-	-	-	-	-	-	46°	44°
30,	1,500	1,304	-	-	-	-	-	-	-	-	-	45°	44°

Effluent clear and colorless, and free from sediment.

Nov. 5, 7, 9, 13, 20 to 23, 26 and 27. — Surface covered with water in the morning. 10. — Partly covered.

Total effluent to end of month, 653,362 gallons.



CITY WATER AND TANK No 8.
1888-'89.
SCALES: AMMONIAS, CHLORINE, NITRATES. AS GIVEN, IN PARTS PER 100,000.
FIXED RESIDUE, LOSS ON IGNITION. 0.10 = 1.00 PART IN 100,000.
QUANTITIES. 0.10 = 1000 GALS.
Temperature of effluent of No 8.
Fixed Residue, City
Fixed Residue, No 8.
Chlorine, City
Chlorine, No 8.
Quantity of effluent
Quantity Applied.
Albuminoid Ammonia, City
Albuminoid Ammonia, No 8.
Nitrates, City
Nitrates, No 8.
Jan. Feb. Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec.
Jan. Feb. Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec.

Filter Tank No. 8 — Concluded.

December, 1889.

Date.	Quantity applied. Gallons.	Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.
1, ...	-	325	-	-	-	-	-	-	-	-	-	-
2, ...	1,500	924	1.40	2.60	.0002	.0050	.0052	.21	.0180	.0000	45°	44°
3, ...	1,450	1,291	-	-	-	-	-	-	-	-	45°	43°
4, ...	1,350	1,317	-	-	-	-	-	-	-	-	43°	43°
5, ...	1,500	1,594	-	-	-	-	-	-	-	-	43°	42°
6, ...	1,500	1,354	-	-	-	-	-	-	-	-	44°	41°
7, ...	1,500	1,547	-	-	-	-	-	-	-	-	43°	41°
8, ...	-	247	-	-	-	-	-	-	-	-	-	-
9, ...	1,500	1,151	-	-	.0012	.0100	.0112	.18	.0180	.0000	43°	43°
10, ...	1,500	1,302	-	-	-	-	-	-	-	-	42°	43°
11, ...	1,350	1,281	-	-	-	-	-	-	-	-	43°	43°
12, ...	1,400	1,252	-	-	-	-	-	-	-	-	42°	43°
13, ...	1,300	1,272	-	-	-	-	-	-	-	-	43°	42°
14, ...	1,250	1,232	-	-	-	-	-	-	-	-	42°	42°
15, ...	-	288	-	-	-	-	-	-	-	-	-	-
16, ...	1,400	1,079	.90	2.20	.0000	.0044	.0044	.19	.0190	.0000	42°	42°
17, ...	1,450	1,400	-	-	-	-	-	-	-	-	42°	39°
18, ...	1,450	1,456	-	-	-	-	-	-	-	-	42°	39°
19, ...	1,500	1,574	-	-	-	-	-	-	-	-	43°	37°
20, ...	1,500	1,369	-	-	-	-	-	-	-	-	42°	38°
21, ...	1,500	1,453	-	-	-	-	-	-	-	-	42°	40°
22, ...	-	347	-	-	-	-	-	-	-	-	-	-
23, ...	1,500	970	-	-	.0005	.0055	.0060	.19	.0200	.0000	41°	41°
24, ...	1,300	1,137	-	-	-	-	-	-	-	-	41°	40°
25, ...	1,200	1,268	-	-	-	-	-	-	-	-	41°	-
26, ...	1,250	1,148	-	-	-	-	-	-	-	-	42°	41°
27, ...	1,250	1,113	-	-	-	-	-	-	-	-	41°	41°
28, ...	1,200	1,230	-	-	-	-	-	-	-	-	42°	41°
29, ...	-	430	-	-	-	-	-	-	-	-	-	-
30, ...	1,500	965	.90	3.10	.0006	.0054	.0060	.18	.0190	.0000	41°	40°
31, ...	1,350	1,229	-	-	-	-	-	-	-	-	42°	40°

Effluent clear and colorless, and free from sediment.

Dec. 3. — Surface covered with water in the morning. 4. — Water on surface frozen to a depth of half inch.

Total effluent to end of month, 687,909 gallons.

FILTER TANK No. 20.

Filter Tank No. 20 was one of the galvanized iron tanks in the building, having an area of one twenty-thousandth of an acre. The bottom was covered with a layer of stones which were about one inch by two inches; these were covered with coarse gravel, and this by finer gravel, making a depth of stones and gravel of three and a half inches. Above this the tank was filled, a depth of five feet and three inches, with clean, coarse mortar sand, like that of Tank No. 1. The top of the sand was then ten and a half inches from the top of the tank.

Immediately after this tank was filled, water passed through it, when kept six inches deep upon the surface, at the rate of 300,000,000 gallons per acre per day. A month later, with water kept from one to two inches deep upon the surface, it flowed through at the rate of 50,000,000 gallons per acre per day.

From July 27, 1888, to November 7, the quantity of water applied to this filter averaged 224 gallons per day, or the equivalent of 4,480,000 gallons per acre per day. About 17 gallons were applied in each hour, from six in the morning till nine at night, omitting three hours when the men were at their meals.

This quantity generally disappeared from the surface within ten minutes of the time of application. In the following seven months one-half of the above quantity was applied in a similar manner, averaging 2,200,000 gallons per acre per day.

Tables of analyses and observations upon this filter are given at the end of this section, and the same results, together with those upon the applied water, are graphically presented in a diagram following the tables.

The monthly averages of results of analysis of the applied water and of the effluent, together with the number of bacteria found in a cubic centimeter of each, are given in the following table: —

Monthly Averages of Daily Results with Tank No. 20.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1888.												
July 27-31, .	City water,	–	1.04	2.80	.0012	.0120	.0132	.23	.0220	.0000	69°	62
July 27-31, .	Effluent, .	216	0.82	2.74	.0008	.0085	.0093	.27	.0235	.0000	71°	223
	Per cent., .	–	79	98	67	71	70	–	–	–	–	–
August, . .	City water,	–	1.94	2.37	.0007	.0112	.0119	.29	.0225	.0000	69°	114
	Effluent, .	231	1.44	2.42	.0008	.0098	.0106	.29	.0225	.0000	73°	150
	Per cent., .	–	74	102	114	87	89	–	–	–	–	–
September, .	City water,	–	1.55	2.97	.0012	.0118	.0130	.25	.0228	.0000	67°	283
	Effluent, .	213	0.86	3.28	.0003	.0083	.0086	.25	.0225	.0000	70°	46
	Per cent., .	–	55	110	25	70	66	–	–	–	–	–
October, . .	City water,	–	1.45	2.50	.0012	.0144	.0156	.22	.0220	.0000	57°	109
	Effluent, .	228	1.28	2.66	.0006	.0131	.0137	.22	.0220	.0000	58°	36
	Per cent., .	–	88	106	50	91	88	–	–	–	–	–
November, .	City water,	–	1.29	2.83	.0005	.0114	.0119	.24	.0222	.0000	50°	87
	Effluent, .	146	1.21	2.75	.0005	.0098	.0103	.24	.0267	.0000	53°	38
	Per cent., .	–	94	97	100	86	87	–	–	–	–	–
December, .	City water,	–	1.06	2.85	.0008	.0092	.0100	.23	.0260	.0000	41°	46
	Effluent, .	102	1.16	2.61	.0009	.0083	.0092	.23	.0287	.0000	44°	20
	Per cent., .	–	109	92	112	90	92	–	–	–	–	–
1889.												
January, . .	City water,	–	1.04	2.71	.0003	.0099	.0102	.23	.0260	.0000	38°	87
	Effluent, .	108	1.03	2.62	.0004	.0072	.0076	.23	.0254	.0000	46°	22
	Per cent., .	–	99	97	133	73	75	–	–	–	–	–
February, . .	City water,	–	1.01	2.66	.0007	.0084	.0091	.24	.0232	.0000	37°	37
	Effluent, .	110	0.91	2.67	.0002	.0064	.0066	.22	.0240	.0000	44°	11
	Per cent., .	–	90	100	29	76	73	–	–	–	–	–
March, . .	City water,	–	.65	2.85	.0012	.0089	.0101	.23	.0225	.0000	37°	49
	Effluent, .	107	.59	2.77	.0003	.0064	.0067	.22	.0227	.0000	45°	75
	Per cent., .	–	91	97	25	72	66	–	–	–	–	–
April, . .	City water,	–	.87	2.50	.0008	.0095	.0103	.16	.0172	.0000	43°	25
	Effluent, .	107	.83	2.56	.0005	.0070	.0075	.16	.0178	.0000	53°	11
	Per cent., .	–	65	102	62	74	73	–	–	–	–	–
May, . . .	City water,	–	1.09	2.43	.0004	.0106	.0110	.14	.0127	.0000	54°	32
	Effluent, .	124	1.06	3.14	.0007	.0095	.0102	.14	.0126	.0000	64°	3,421
	Per cent., .	–	97	129	175	90	93	–	–	–	–	–
June 1-11, .	City water,	–	1.40	2.40	.0008	.0110	.0118	.15	.0175	.0001	61°	31
	Effluent, .	110	1.30	5.46	.0029	.0110	.0139	.15	.0160	.0002	70°	1,087
	Per cent., .	–	93	227	362	100	118	–	–	–	–	–

For a little more than two months, or until Oct. 1, 1888, the filtered water from this tank came through colorless. The free ammonia of the effluent was 60 per cent. of that of the applied water, the albuminoid ammonia was 78 per cent. and the sum of the ammonias averaged 76 per cent. In this time there was no nitrification, the nitrates in the effluent being the same as in the applied water.

In the following month, October, the color of the filtered water was about three-quarters as deep as that of the applied water. The free ammonia was 50 per cent. of that of the applied water, the albuminoid ammonia 91 per cent., and the sum of the ammonias 88 per cent. of the sum of ammonias of the applied water; and there was no nitrification.

During the three months in which this large quantity of more than 4,000,000 gallons per acre per day was being filtered, the analyses indicate no nitrification, and this was the condition of the water generally flowing through the tank; but subsequent analyses, made of samples taken early in the morning when little water had been drained from the filter during the night, and especially on Monday morning, after no water had been applied on Sunday, show that in the nights and on Sunday there was some nitrification.

The means of the analyses, in parts per 100,000, for these three months, of the applied water and of the effluent, are as follows: —

	Applied Water.	Filtered Water.		Applied Water.	Filtered Water.
Free ammonia, ...	.0010	.0006	Sum of ammonias, . . .	.0135	.0110
Albuminoid ammonia, . .	.0125	.0104	Nitrates, ...	.0225	.0223

During the first three months' use of this filter, when filtering at the rate of 4,480,000 gallons per acre per day, the sum of ammonias were reduced from 0.0135 parts in the applied water to 0.0110 parts in the effluent; but there was no nitrification, except at night and on Sunday.

During this period much of the water applied passed through the tank within half an hour, and the remainder within an hour; except a part of the last charge in the evening, which remained till the next morning.

The quantity of water applied at once, covering the surface to the depth of one foot, and disappearing within seven minutes, must have driven the air before it, and completely saturated the sand for a depth of nearly four feet, so that the lower part of this body of water would spread out in films over the particles, and come in contact with air only in the lower foot of the filter, where time would be wanting to allow the chemical change of nitrification to take place.

On Monday morning, November 5, while the first charge of water was passing through, the nitrates of the effluent amounted to 0.0580 parts, while those of the applied water were about 0.0220 parts. This nitrification was evidently due to the slow motion of the contained water through the sand during the previous thirty hours, when no water was applied. During the ordinary flow of the day, between applications of one foot in depth over the surface each hour, the conditions for nitrification did not exist.

In the following seven months, when half as much water, or a little more than 2,000,000 gallons per acre per day, was applied in the same manner, there was no appreciable nitrification.

In this time the quantity applied each hour was a little less than the amount held in the sand; hence the water was generally a little more than an hour in passing through the filter. Most of the water applied passed through one-third of the depth of the filter in a body, and was spread out in films over the particles of sand only in the lower portion of the filter, and thus exposed to the air for a time, which was less than an hour. This time and these circumstances appear to be insufficient to produce nitrification.

These results indicate that six inches in depth of water per hour is too rapid application for effectual intermittent filtration through this coarse sand. The rest of eight hours during the night is probably of no advantage to the process of nitrification during the day, when the time of passage is only about one hour.

Although satisfactory purification did not follow in the remaining seven months in which this material was used, the details of its action and the methods of use are given, for such information as they may contain.

In the three months, November and December, 1888, and January, 1889, the color of the effluent continued to be about three-quarters as deep as that of the applied water. The slight increase in nitrates observed was due to action on Sunday, when no water was applied.

The free ammonia of the effluent was about the same as that of the applied water. The albuminoid ammonia of the effluent averaged 0.0084 parts, while that of the applied water averaged 0.0102 parts. The sum of the ammonias of the effluent averaged 0.0090 parts, and were 84 per cent. of those of the applied water.

On January 23 and 24, at each application of water, there was added 1.14 grammes of clay. After February 2, through February and March, very small quantities of precipitated alumina were added with the water. These quantities were increased at intervals of about a week, from one pound in 538,000 gallons to eight pounds in 538,000 gallons of water. This was the same amount of alumina that would have been applied if alum had been used at rates varying from one-half a pound to four pounds in 25,000 gallons of water. The whole amount of alumina applied to the tank in these two months was but little more than one ounce; and, as none of it was found to be in the effluent, this amount of alumina was added to the filtering material. Its effect upon the color of the water was small.

In February the color of the effluent was nine-tenths as deep as that of the applied water; in March it was two-thirds as deep; and in the first half of April it was about three-quarters as deep. From the middle to the last of April more alumina was added in much larger quantities, making the total amount of alumina that had been added to the filter 1.5 ounces; and, on the last two days of the month, when the alumina applied was at the rate of 50 pounds in 538,000 gallons, the color of the water was entirely removed.

This quantity of 1.5 ounces of alumina added to about 1,000 pounds of sand, appears to be insufficient to permanently reduce the color of the effluent; but subsequent experiments, now in progress upon another tank, with about six times as much alumina, indicate long-continued reduction of the color of the effluent.

On April 13 some deposited material was washed out of the tank by forcing water up from the bottom, by attaching the hose to the outlet faucet. This operation did not improve the condition of the filter, because the water came up more freely in some parts than in others, and washed out of those parts portions of the fine material, so that, when water was then applied to the surface, it would follow down more freely through those parts from which the fine material had been removed.

Through the three months, February, March and April, 1889, the nitrates of the effluent were generally the same, but average very slightly in excess of those of the applied water; being 0.0217 parts, while those of the water were 0.0207 parts, — a difference which may be entirely due to errors of observation. The free ammonia was very small, averaging 0.0003 parts, which was one-third of that of the applied water. The albuminoid ammonia averaged 0.0066 parts, or three-fourths of that of the applied water The sum of the ammonias was 70 per cent. of those of the applied water.

From May 1 to 6, 400 cubic centimeters of lime water were added with each application of 10 gallons to the filter; and from May 6 to June 10, 800 cubic centimeters of lime water were added with each application of water. The result was not in any wise satisfactory, as there was no nitrification, and the ammonias averaged a little greater than those of the applied water.

MICROSCOPIC ORGANISMS FOUND IN THE EFFLUENT OF TANK NO. 20.

In the five months, August to December, 1888, when the amount of water daily filtered averaged at the rate of 3,680,000 gallons per acre, observations were made, on twenty different days, upon the organisms seen by the microscope upon a very fine cloth through which five gallons of city water had been strained, and upon another cloth through which five gallons of effluent from Tank No. 20 had been strained.

The names and numbers of the organisms are given in the following table : —

Number of microscopic organisms found on twenty different days, in five gallons of the city water, and in five gallons of the effluent from Tank No. 20 in the five months, August to December, 1888, omitting those that were found in city water but once.

NAME OF ORGANISM.	Number of Days when found in City Water.	Average Number when found in City Water.	Number of Days when found in Effluent of No. 20.	Average Number when found in Effluent of No. 20.
Anabæna,	2	35	-	-
Asterionella,	18	591	5	59
Chlorococcus,	16	35,046	18	15,187
Clathrocystis,	3	35	-	-
Encyonema,	2	20	-	-
Leptothrix,	2	70	-	-
Melosira,	14	1,162	2	50
Navicula,	6	43	-	-
Nitzchia,	3	73	-	-
Ophiocytium,	2	30	-	-
Pediastrum,	8	34	7	53
Pinnularia,	2	45	-	-
Raphidium,	5	56	-	-
Scenedesmus,	9	94	8	145
Staurastrum,	7	42	-	-
Staurogenia,	11	434	10	740
Stephanodiscus,	8	71	-	-
Synedra,	19	269	5	19
Tabellaria,	18	218	7	68
Tetraspora,	2	150	-	-
Anurea,	2	15	-	-
Dinobryon,	15	394	3	48
Entomostraca,	2	4	-	-
Monas,	2	35	-	-
Trachelomonas,	7	136	10	143

Of the twenty vegetable microscopic organisms found in the city water, eight were found in the effluent. Of these, Chlorococcus, Scenedesmus, Pediastrum and Staurogenia came through with but little reduction. Asterionella, Melosira, Synedra and Tabellaria were much reduced in number.

Of the five animal forms found in the city water, two came through; viz., Trachelomonas in full number, and Dinobryon reduced to three per cent.

Number of Bacteria in the Effluent of Tank No. 20.

During the three months in which water was filtering at the rate of about 4,000,000 gallons per acre per day, the number of bacteria in the effluent averaged 76 per cubic centimeter, or one-half the number found in the applied water.

In the following six months, when filtering at the rate of about 2,000,000 gallons per acre per day, the number counted in the effluent averaged 25 per cubic centimeter, or 43 per cent. of the number in the applied water.

In May and June, 1889, when lime was applied with the water, the number in the solution was not determined; but the number in the effluent was greater than when water was applied.

The average numbers of bacteria found monthly are given on page 649. The numbers observed on forty-eight different days are given in the following table: —

Number of Bacteria per Cubic Centimeter found in the Effluent of Tank No. 20.

Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.
1888.		**1888** — Con.		**1889.**		**1889** — Con.	
July 24, .	199	Oct. 23, .	46	Jan. 2, .	18	April 2, .	5
28, .	223	27, .	29	8, .	6	9, .	5
Aug. 4, .	204	Nov. 1, .	23	15, .	31	16, .	26
14, .	180	6, .	12	22, .	35	24, .	9
18, .	100	10, .	28	Feb. 6, .	8	30, .	8
23, .	114	16, .	22	12, .	13	May 7, .	62
Sept. 13, .	53	21, .	34	19, .	14	14, .	13,020
18, .	44	26, .	110	27, .	9	21, .	492
22, .	65	Dec. 7, .	13	March 5, .	209	28, .	112
27, .	21	12, .	12	12, .	41	June 4, .	2,016
Oct. 4, .	26	17, .	5	19, .	38	11, .	158
9, .	45	26, .	48	26, .	13		
13, .	34						

TABLES

OF

CHEMICAL ANALYSES AND OBSERVATIONS

Upon Filter Tank No. 20.

FILTER TANK No. 20.

July – November, 1888.

Total Effluent to end of Month. Gallons.	Date.	Daily Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.
	1888.											
–	July 23, .	–	0.68	3.00	.0172	.0070	.0242	0.23	.0400	.0005	68°	–
–	24, .	50	.32	2.28	.0056	.0054	.0110	.36	.0220	.0002	68°	–
–	27, .	259	.88	2.76	.0010	.0064	.0074	.29	.0250	.0001	69°	–
1,956	31, .	204	.76	2.72	.0006	.0106	.0112	.25	.0220	.0000	68°	71°
–	Aug. 7, .	226	1.76	2.48	.0010	.0110	.0120	.31	.0220	.0000	69°	73°
–	14, .	223	0.84	2.96	.0002	.0084	.0086	.34	.0260	.0000	69°	71°
–	21, .	223	1.72	1.56	.0012	.0084	.0096	.26	.0200	.0000	69°	74°
9,117	28, .	238	1.44	2.68	.0008	.0116	.0124	.27	.0220	.0000	69°	74°
–	Sept. 4, .	227	1.16	3.12	.0002	.0072	.0074	.25	.0220	.0000	68°	72°
–	11, .	226	1.00	2.92	.0004	.0084	.0088	.26	.0200	.0000	68°	70°
–	18, .	226	0.68	3.60	.0002	.0066	.0068	.24	.0240	.0000	67°	70°
15,513	25, .	200	.60	3.48	.0004	.0112	.0116	.24	.0240	.0000	65°	65°
–	Oct. 2, .	222	1.12	2.64	.0008	.0122	.0130	.23	.0200	.0000	62°	62°
–	9, .	222	1.36	2.92	.0002	.0150	.0152	.21	.0240	.0000	60°	60°
–	16, .	224	1.24	2.64	.0006	.0106	.0112	.23	.0240	.0000	57°	57°
–	23, .	224	1.38	2.68	.0012	.0146	.0158	.22	.0220	.0000	54°	55°
22,591	30, .	228	1.32	2.40	.0004	.0132	.0136	.20	.0200	.0000	52°	53°
–	Nov. 5, .	223	1.32	3.18	.0008	.0108	.0116	.23	.0580	.0000	52°	57°
–	6, .	267	1.16	2.96	.0004	.0110	.0114	.21	.0240	.0000	51°	55°
–	13, .	176	1.04	2.64	.0006	.0106	.0112	.23	.0260	.0000	52°	55°
–	16, .	132	1.28	2.68	.0004	.0104	.0108	.24	.0200	.0000	53°	56°
–	20, .	96	1.08	2.56	.0002	.0076	.0078	.24	.0200	.0000	48°	52°
–	23, .	130	1.40	2.60	.0006	.0092	.0098	.28	.0170	.0000	46°	47°
26,672	27, .	97	1.16	2.66	.0004	.0094	.0098	.26	.0220	.0000	44°	46°

July to September inclusive. — Effluent was colorless, generally clear or but slightly turbid, and free or nearly free from sediment. October and November. — Nearly clear, with very little or no sediment, and with an average color of 0.34 and 0.30 for the two months respectively.

July 24. — Twenty-two gallons of water applied disappeared in 6.7 minutes. July 25. — In 7.3 minutes. Air mingled with water flowing from faucet.

After August 1. — Residue on evaporation obtained with sodium carbonate. August 8. — Nineteen gallons of water applied disappeared in 5.5 minutes. August 11. — In 7.5 minutes. August 16. — In 7.2 minutes. Air mingled with water flowing from faucet.

September 15. — Nineteen gallons of water applied disappeared in 8.8 minutes. September 20. — In 8.75 minutes. September 25. — Hole drilled midway in side of tank.

October 3. — Nineteen gallons of water applied disappeared in 9 minutes. October 9. — Water applied disappeared more slowly than usual, and air came up between sand and sides of tank. October 10. — Faucets put in side of tank one-fourth, one-half, three-fourths and seven-eighths way down. October 16. — Eighteen gallons of water applied disappeared in 16.25 minutes. October 30. — Nineteen gallons in 11.4 minutes.

November 7. — Eighteen gallons of water applied disappeared in 11.75 minutes. November 9. — Twelve gallons in 6.1 minutes. October 19. — Nine gallons in 5.8 minutes. October 28, 4 P.M., to December 1, 8.50 A.M. — Outlet closed. River high.

Filter Tank No. 20 — Continued.

December, 1888 — February, 1889.

Total Effluent to end of Month. Gallons.	Date.	Daily Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.
	1888.											
–	Dec. 4, .	65	1.16	2.60	.0002	.0088	.0090	.23	.0220	.0000	43°	47°
–	7, .	130	1.36	2.40	.0008	.0090	.0098	.26	.0300	.0000	42°	45°
–	11, .	97	1.20	2.40	.0020	.0082	.0102	.24	.0260	.0000	42°	45°
–	14, .	128	1.28	2.76	.0006	.0082	.0088	.25	.0350	.0000	40°	42°
–	18, .	94	1.08	2.56	.0006	.0070	.0076	.22	.0350	.0000	39°	46°
29,318	24, .	25	0.88	2.92	.0010	.0088	.0098	.21	.0240	.0000	38°	36°
	1889.											
–	Jan. 1, .	91	0.68	2.76	.0006	.0066	.0072	.23	.0300	.0000	39°	48°
–	4, .	127	1.12	3.00	.0010	.0114	.0124	.20	.0300	.0000	39°	45°
–	8, .	96	0.88	3.00	.0004	.0070	.0074	.24	.0280	.0000	39°	43°
–	11, .	124	1.16	2.52	.0004	.0072	.0076	.24	.0240	.0000	38°	47°
–	15, .	96	1.12	2.52	.0000	.0078	.0078	.24	.0200	.0000	38°	45°
–	18, .	107	1.04	2.32	.0002	.0062	.0064	.24	.0240	.0000	38°	45°
–	22, .	93	1.28	2.40	.0000	.0066	.0066	.20	.0230	.0000	38°	46°
–	24, .	120	1.16	2.72	.0004	.0072	.0076	.26	.0250	.0000	37°	45°
32,652	29, .	102	0.80	2.32	.0002	.0046	.0048	.27	.0250	.0000	37°	46°
–	Feb. 1, .	124	1.08	2.40	.0002	.0066	.0068	.23	.0250	.0000	37°	44°
–	5, .	95	1.04	2.36	.0004	.0056	.0060	.20	.0270	.0000	37°	43°
–	8, .	129	0.92	2.68	.0004	.0060	.0064	.21	.0220	.0000	37°	45°
–	12, .	97	0.72	2.88	.0002	.0060	.0062	.24	.0250	.0000	36°	42°
–	15, .	132	1.00	2.80	.0002	.0072	.0074	.21	.0250	.0000	36°	44°
–	19, .	95	0.92	2.64	.0000	.0060	.0060	.23	.0200	.0000	36°	45°
–	22, .	130	0.68	3.04	.0000	.0068	.0068	.22	.0230	.0000	36°	43°
35,737	26, .	96	0.92	2.60	.0004	.0066	.0070	.23	.0250	.0000	36°	43°

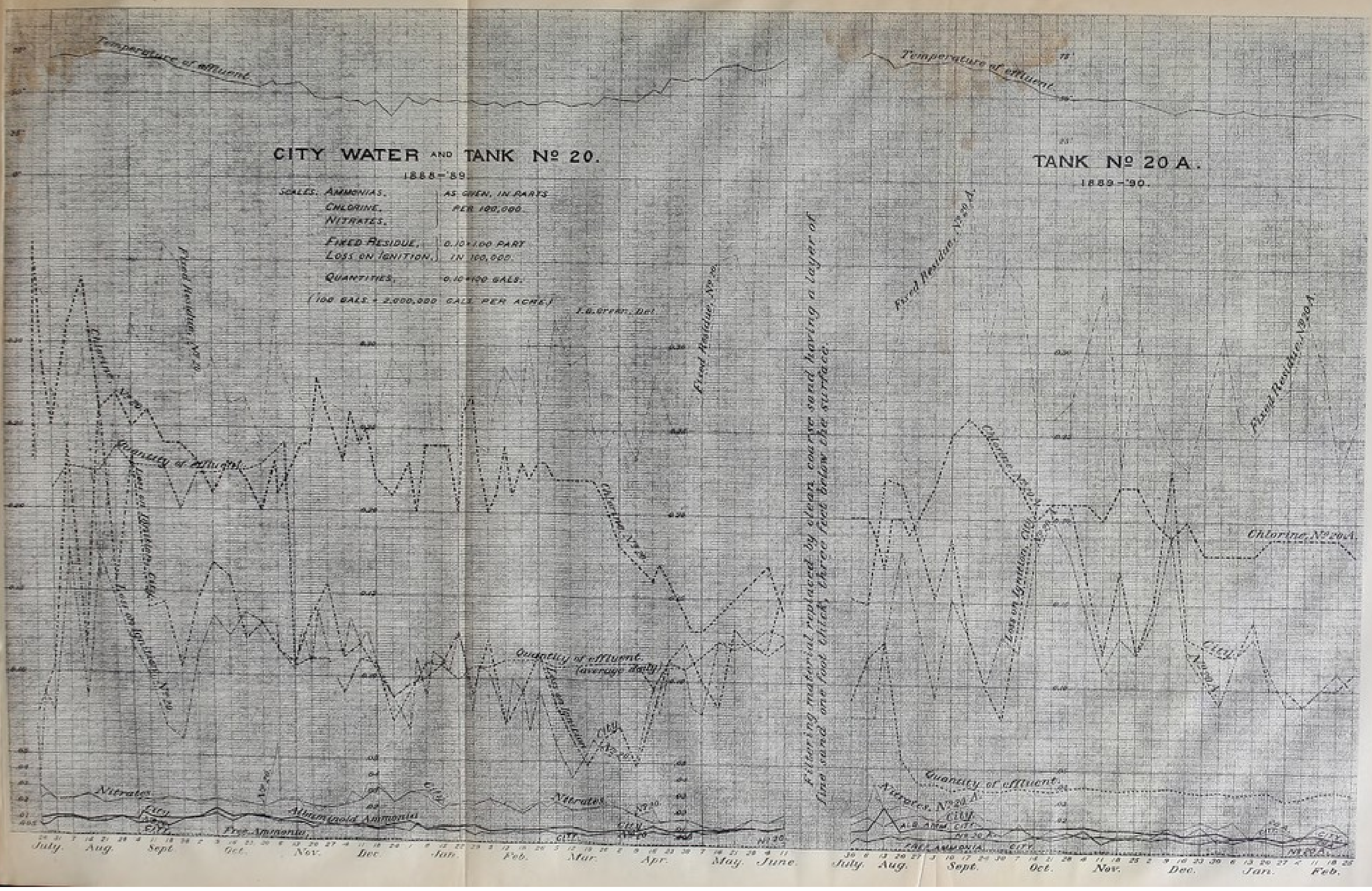
December to February inclusive. — Effluent generally nearly clear and with very little or no sediment, and with color averaging 0.20, 0.16 and 0.16 for the three months respectively.

Dec. 5. — Ten gallons of water applied disappeared in 7 m. 14. — Ice on surface, and faucet frozen up in the morning. 18, 3 P.M., to 22, 11.43 A.M. — Outlet closed. River high. 24, 9.10 P.M., to 26, 11.02 A.M. — Outlet closed on account of leak in measuring basin. 26. — Ten gallons of water applied disappeared in 7.5 m.

Jan. 8. — Nine gallons of water applied disappeared in 7.9 m. 17. — Usual quantity of water not applied, owing to special experiments on tank. 23, 11 A.M., to 25, 6 A.M. — One and fourteen-hundredths grams of clay were added to each 9 gallons of water applied.

Feb. 2 to 9. — One grain of precipitated alumina was added to every 77 gallons of water applied. 10 to 18. — Two grains. 19 to March 4. — Three grains. One grain of precipitated alumina in 77 gallons of water is equivalent to 1 pound of alum in 50,000 gallons.

Feb. 14. — Nine gallons of water applied disappeared in 8.75 m. 28. — In 9.25 m.



CITY WATER AND TANK No. 20.
1888–'89.
SCALES. AMMONIAS. CHLORINE. NITRATES. AS GIVEN, IN PARTS PER 100,000.
FIXED RESIDUE. LOSS ON IGNITION. 0.10 = 1.00 PART IN 100,000.
QUANTITIES. 0.10 = 100 GALS.
(100 GALS. = 2,000,000 GALS. PER ACRE.)
Temperature of effluent.
Fixed Residue, No. 20.
Chlorine, No. 20.
Quantity of effluent.
Loss on Ignition, City.
Loss on Ignition, No. 20.
Quantity of effluent (average daily).
Nitrates.
Albuminoid Ammonia.
Free Ammonia.
City.
July. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May. June.
Filtering material replaced by clean coarse sand having a layer of fine sand one foot thick, three feet below the surface.
TANK No. 20 A.
1889–'90.
Temperature of effluent.
Fixed Residue, No. 20 A.
Chlorine, No. 20 A.
Loss on Ignition, City.
Quantity of effluent.
Nitrates, No. 20 A.
Free Ammonia.
July. Aug. Sept. Oct. Nov. Dec. Jan. Feb.

Filter Tank No. 20 — Concluded.

March to June, 1889.

Total Effluent to end of Month. Gallons.	Date.	Daily Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.
	1889.											
-	March 1,	127	0.80	2.76	.0004	.0078	.0082	.23	.0220	.0000	36°	45°
-	5,	92	0.60	3.16	.0002	.0060	.0062	.22	.0250	.0000	36°	46°
-	12,	108	0.40	2.88	.0000	.0066	.0066	.22	.0200	.0000	36°	43°
-	19,	109	0.56	2.96	.0004	.0050	.0054	.22	.0220	.0000	37°	45°
-	22,	128	0.64	2.52	.0002	.0060	.0062	.22	.0220	.0000	37°	43°
39,043	26,	95	0.56	2.36	.0004	.0068	.0072	.21	.0250	.0000	37°	48°
-	April 2,	110	0.52	2.56	.0014	.0070	.0084	.18	.0230	.0000	38°	47°
-	9,	110	0.52	2.32	.0006	.0064	.0070	.17	.0180	.0000	39°	46°
-	16,	95	0.96	2.76	.0004	.0088	.0092	.16	.0220	.0001	41°	55°
-	19,	131	0.80	2.76	.0002	.0078	.0080	.17	.0140	.0000	43°	51°
-	23,	98	1.08	2.57	.0004	.0074	.0078	.16	.0150	.0000	46°	60°
42,263	30,	107	1.08	2.40	.0002	.0044	.0046	.14	.0150	.0001	47°	58°
-	May 3,	131	0.84	2.76	.0000	.0090	.0090	.13	.0120	.0000	50°	60°
-	7,	103	0.80	2.64	.0002	.0076	.0078	.13	.0120	.0000	50°	59°
-	14,	124	1.24	3.52	.0014	.0084	.0098	.14	.0120	.0000	53°	67°
-	21,	123	1.20	3.56	.0018	.0104	.0122	.15	.0100	.0001	56°	68°
46,112	28,	124	1.24	3.24	.0002	.0120	.0122	.16	.0170	.0000	59°	65°
-	June 4,	116	1.32	5.28	.0022	.0098	.0120	.17	.0150	.0002	60°	67°
47,320	11,	124	1.28	5.64	.0036	.0122	.0158	.14	.0170	.0002	61°	72°

March to June, inclusive. — Effluent nearly clear, with very slight or no sediment, and with color averaging 0.12, 0.10, 0.19 and 0.15 for the four months respectively.

March 5 to 10. — Four grains of precipitated alumina were added to every 77 gallons of water applied. 11 to 17. — Six grains. 18 to 29. — Eight grains. 30 to April 14. — None. April 15 to 28. — Ten grains. 29 to 30. — Fifty grains. Total alumina added from February 2 to April 30, 1.52 ounces. April 13. — Sand in tank thoroughly washed, by forcing water in through the outlet.

May 1 to 6. — Four hundred cubic centimeters of lime water added to every 10 gallons of water applied. May 7 to June 11. — 800 cubic centimeters.

FILTER TANK No. 20 A.

In the latter part of June, 1889, the filtering material of Tank No. 20, which had been used since July, 1888, was removed from the tank, and the tank was again filled in the following manner. There were three inches and a half in depth of coarse and fine gravel and very coarse sand put upon the bottom of the tank, above which was one foot of coarse mortar sand like that of Tank No. 1. Above this was one foot in depth of fine sand like that of Tank No. 2, and above this, three feet in depth of coarse sand like that of Tank No. 1. It was found that 28 gallons of water saturated this sand, and, upon draining for six days, 17 gallons flowed out, leaving 11 gallons of water and 17 gallons of air in the sand. This filter will hereafter be called Tank No. 20 A.

Water was first applied for filtration on July 25, 1889; and from this time until August 14, the quantity of water averaged 116 gallons a day, or the equivalent of 2,320,000 gallons per acre per day; but after August 14 the quantity applied averaged 38 gallons per day, or 760,000 gallons per acre per day. This has been applied hourly through the day as before, about 3 gallons at a time being applied in fifteen seconds. This rate was continued through the remaining part of the year 1889. In the first half of 1890, the rate was 714,000 gallons per acre per day.

The effluent was colorless for about two months, till October 10. Through the rest of the month of October there was a slight color in the effluent, which was about one-third of the depth of the color of the applied water. The color of the effluent increased a little in November, and, through this month and the month of December, was about three-eighths of the depth of color of the applied water. In the latter part of the winter it increased to two-thirds of that of the city water; but, with increased nitrification of April and May, it decreased, and for the four months, April to July, 1890, it averaged 0.12, or 45 per cent. of the color of the city water.

The results of chemical analysis and daily observations upon this tank for the year, from August, 1889, to July, 1890, are given at the end of this section.

At page 656 may be found a diagram giving the chemical results obtained with city water and with effluent from this tank, from August, 1889, to July, 1890.

The monthly averages of results for the year are contained in the following table: —

Monthly Averages of Results with Filter Tank No. 20 A.

Date.		Quantity of Effluent. Gallons.	Color.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.	Number of Bacteria per Cubic Centimeter.
				Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1889.													
August, .	City water,	–	.30	1.97	4.06	.0007	.0158	.0165	.19	.0192	.0000	69°	28
	Effluent, .	75	.05	1.10	2.82	.0002	.0074	.0076	.19	.0270	.0000	72°	23
	Per cent., .	–	–	56	69	29	47	46	–	141	–	–	–
September,	City water,	–	.28	1.30	3.42	.0015	.0141	.0156	.24	.0164	.0000	67°	91
	Effluent, .	37	.00	1.21	3.50	.0008	.0079	.0087	.24	.0218	.0000	67°	18
	Per cent., .	–	–	93	102	53	56	56	–	133	–	–	–
October, .	City water,	–	.30	1.92	2.72	.0015	.0150	.0165	.21	.0110	.0000	57°	124
	Effluent, .	39	.10	1.70	2.82	.0005	.0099	.0104	.21	.0125	.0000	54°	6
	Per cent., .	–	–	89	104	33	66	63	–	114	–	–	–
November,	City water,	–	.32	1.37	2.63	.0010	.0144	.0154	.21	.0097	.0000	50°	170
	Effluent, .	39	.12	1.20	2.93	.0005	.0099	.0104	.21	.0102	.0000	50°	13
	Per cent., .	–	–	88	111	50	69	68	–	105	–	–	–
December,	City water,	–	.32	1.57	2.60	.0013	.0127	.0140	.18	.0124	.0000	43°	66
	Effluent, .	37	.12	1.35	2.60	.0008	.0089	.0097	.19	.0164	.0000	43°	7
	Per cent., .	–	–	86	100	62	70	69	–	132	–	–	–
1890.													
January, .	City water,	–	.35	1.15	2.55	.0011	.0105	.0116	.18	.0120	.0000	39°	53
	Effluent, .	37	.20	1.12	2.65	.0011	.0086	.0097	.18	.0165	.0000	42°	25
	Per cent., .	–	–	97	104	100	82	84	–	137	–	–	–
February, .	City water,	–	.30	1.00	2.47	.0015	.0108	.0123	.19	.0150	.0000	39°	175
	Effluent, .	37	.20	1.00	2.75	.0014	.0076	.0090	.19	.0150	.0000	42°	19
	Per cent., .	–	–	100	111	93	70	73	–	100	–	–	–
March, .	City water,	–	.30	0.95	2.32	.0029	.0125	.0154	.18	.0140	.0000	38°	148
	Effluent, .	36	.20	0.95	2.40	.0015	.0093	.0108	.18	.0152	.0000	44°	34
	Per cent., .	–	–	100	103	52	74	70	–	109	–	–	–
April, .	City water,	–	.35	1.28	2.54	.0017	.0128	.0145	.16	.0144	.0000	41°	–
	Effluent, .	37	.17	1.22	2.56	.0012	.0086	.0098	.15	.0184	.0000	48°	–
	Per cent., .	–	–	95	100	71	67	68	–	128	–	–	–
May, . .	City water,	–	.22	1.03	2.20	.0013	.0118	.0131	.13	.0175	.0000	50°	–
	Effluent, .	36	.10	1.00	2.30	.0011	.0092	.0103	.13	.0242	.0000	60°	–
	Per cent., .	–	–	97	105	85	79	79	–	138	–	–	–
June, . .	City water,	–	.22	–	–	.0018	.0140	.0158	.13	.0160	.0000	56°	33
	Effluent, .	34	.10	–	–	.0015	.0098	.0113	.13	.0187	.0000	65°	16
	Per cent., .	–	–	–	–	83	70	72	–	117	–	–	–
July, . .	City water,	–	.25	–	–	.0020	.0132	.0152	.20	.0264	.0000	–	106
	Effluent, .	31	.10	–	–	.0012	.0075	.0087	.19	.0255	.0000	74°	13
	Per cent., .	–	–	–	–	60	57	57	–	96	–	–	–

The chemical analyses show that nitrification was taking place in all months except February and July. In the first six months the average increase in nitrates was 29 per cent., and in the last six months was 13 per cent.; being 38 per cent. at the highest in the month of May.

The sum of ammonias of the filtered water for the first six months was 63 per cent. of those of the unfiltered water, and, in the last six months, was 69 per cent. of those of the unfiltered water.

The free ammonia of the filtered water has for the year averaged 0.0010 parts per 100,000, or two-thirds of that of the unfiltered; and the albuminoid ammonia has averaged 0.0086 parts, which is also two-thirds of that of the unfiltered water.

The quantity of water filtered by this tank in the year has been about 15,000 gallons, or the equivalent of 300,000,000 gallons upon an acre; and it appears as if it would continue, with the same treatment, removing about one-half of the color and about one-third of the ammonias, as it has done during the past six months.

There was, however, a seriously objectionable condition in the foregoing treatment. The water was applied hourly, — except when the men were away at their meals, — from 5 A.M. to 9 P.M., and before noon the water accumulated in the coarse sand, above the layer of fine sand, and remained constantly on the surface until some time in the night. By tapping the side of the tank and applying a glass tube, it was found that the fine sand not only remained saturated, but that it held water over Sunday, when none was applied, to the depth of a foot or more in the coarse sand above it. By taking series of samples of the effluent through the day, it was found that the nitrates were the highest — by about 36 per cent. over those of the morning — about 4 o'clock P.M.; when the water which drained down during the night from the upper part of the coarse sand, — where it was in contact with air, — reached the outlet.

These results indicated that the absorbed oxygen in the applied water was not sufficient to carry on the desired nitrification, and that the best results were not to be obtained by occasional intermissions, while the principal part of the water passed through in a body without exposure to air. These intermissions, during a part of the night and on Sunday, have served to remove the organic matter from the sand sufficiently to allow the passage of nearly three-quarters of a million of gallons daily per acre; but have not presented the conditions in which the principal part of the water passing through could be most completely purified by nitrification.

To test the effect of exposing the water to more air while passing through the sand, the quantity of water was decreased to one-half a million gallons per acre, applied on six days in the week. This quantity was continued for a month, from July 23 to August 22, 1890, with the following results: —

Free Ammonia	Albuminoid Ammonia	Chlorine	Nitrates	Nitrites	Bacteria
0.0010	0.0064	0.22	0.0283	0.0000	33.

The purification was much more complete. The color was reduced to one-third; the free ammonia to 30 per cent., and the albuminoid ammonia to 44 per cent., of that of the applied water. The nitrates were 22 per cent. more than those of the applied water.

During this time the surface did not remain covered with water from one hourly application to the next, and there was some air in the upper layers of the coarse sand, with which each charge of water came in contact. The result was the removal of about twice as much of the impurity of the applied water as in the former condition, and giving an effluent of a quality but little below that of an excellent unpolluted ground water.

This tank, No. 20 A, filtered the equivalent of 88,000,000 gallons per acre, giving a colorless effluent. Tank No. 20, of coarse sand like No. 1, filtered in three months the equivalent of 300,000,000 gallons per acre before any color appeared in the effluent; and Tank No. 8 has, in three years, filtered the equivalent of 200,000,000 gallons per acre, and no color has yet appeared in the effluent.

The largest quantity that passed through colorless was through the filter of coarse sand in which the water was most completely exposed to air, although it remained in the sand the shortest time.

The quantity that has already passed, colorless, through No. 8, is so much greater than that through No. 20 A that their specific differences will be stated. Each has a layer of fine material. In No. 8, this is a layer of loam eight inches deep, the top of which is six inches below the surface. In No. 20 A, this is a layer of fine sand one foot deep, the top of which is three feet below the surface. If the sand above the fine layer in No. 8 be kept saturated, the loam will be saturated; but there will be about four feet in depth of sand

and gravel below the loam, in which the water will be exposed to air entering the outlet pipe; while in No. 20 A, if the fine layer and the sand above be saturated, there will be but little more than one foot in depth of coarse sand below, in which water may be exposed to air entering the outlet.

When the upper layers of neither tank are kept saturated, we must look for the difference in the character of fine material of the fine layers.

The sizes of the finer grains in each of the fine layers, and in the coarse sand of No. 20 A, are given in the following table: —

Diameter of Grains. (Inches.)	Loam in Tank No. 8. Per cent.	Fine Sand in Tank No. 20 A. Per cent.	Coarse Sand in Tank No. 20 A. Per cent.	Diameter of Grains. (Inches.)	Loam in Tank No. 8. Per cent.	Fine Sand in Tank No. 20 A. Per cent.	Coarse Sand in Tank No. 20 A. Per cent.
0.020 to 0.048	17	2	43.0	0.004 to 0.006	4	29	0.1
0.012 to 0.020	8	3	4.5	0.002 to 0.004	10	30	0.07
0.008 to 0.012	3	5	0.8	0.0008 to 0.002	14	9	0.03
0.006 to 0.008	4	21	0.5	0.0000 to 0.0008	1	1	0.005

The amounts of material whose particles were less than 0.004 inch in diameter, were, in the loam of No. 8, 25 per cent.; in the coarse sand of No. 20 A, 0.11 of one per cent.; and in the fine sand of No. 20 A, 40 per cent. Upon heating to redness, the 40 per cent., the equivalent of 0.3 of one per cent. of the whole, passed off; while, upon so heating the 25 per cent. from the loam, there passed off 1.3 per cent. of the whole.

These results indicate approximately the amount of organic matter contained in these finer parts of each sand, which, in the fine sand of No. 20 A, is exceedingly small. The fine parts of this sand are nearly white, and appear to be pulverized quartz; while those from the loam of No. 8 are brown, and of such a nature that, when thoroughly dry, they absorb moisture from the air and form a soft mass.

The percentages above given are by weight when dry; and, as this fine material of the loam has less specific gravity than that of the sand, and swells when moist, it would occupy much more of the space in the interstices of the coarser grains.

The amount of alumina in the loam, in form to be of use in decolorizing water, is probably two or three times as much as in the fine sand of No. 20 A.

We have spoken particularly of the ability to remove color by these filters, because this is, to a considerable extent, indicative of the purification of the water; but color may be removed completely by a filter without efficient purification; in fact, the purification by No. 20, in the fall of 1888, when all color was removed, was unaccompanied by nitrification, and was not as complete as in the following February and March, when its color was two-thirds of that of the applied water; and in August, 1890, No. 20 A, after filtering the equivalent of 300,000,000 gallons upon an acre, and then filtering at the rate of half a million gallons daily, on an acre, gave an effluent almost identical, in chemical composition, with that of No. 8, which had filtered the equivalent of 180,000,000 gallons, while the former retained one-third of the color and the latter was colorless.

Bacteria in the Effluent of No. 20 A.

The number of bacteria found in a cubic centimeter of the effluent from this tank, at different dates, is given in the following table; and the monthly averages, together with those of the applied water, may be found in the table previously given.

The average number for the year found in the city water was 99, and in the filtered effluent was 17, per cubic centimeter.

Number of Bacteria per Cubic Centimeter found in the Effluent of Tank No. 20 A.

Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.	Date.	Number of Bacteria.
1889.		**1889** — Con.		**1890** — Con.		**1890** — Con.	
July 30, .	16	Nov. 16, .	15	Feb. 14, .	72	May 20, .	25
Aug. 6, .	5	21, .	19	18, .	6	27, .	33
8, .	4	Dec. 4, .	7	25, .	6	31, .	20
12, .	12	10, .	5	March 11, .	6	June 3, .	23
19, .	31	17, .	8	18, .	89	6, .	24
27, .	63	**1890.**		25, .	8	10, .	11
Sept. 2, .	14	Jan. 1, .	14	April 1, .	31	17, .	13
10, .	18	7, .	5	8, .	28	24, .	7
16, .	21	14, .	82	15, .	18	July 1, .	30
Oct. 2, .	8	21, .	4	22, .	9	8, .	21
10, .	5	28, .	20	29, .	12	15, .	8
16, .	6	Feb. 4, .	4	May 6, .	5	22, .	1
25, .	5	8, .	13	13, .	17	29, .	7
Nov. 5, .	6	11, .	14				

TABLES OF CHEMICAL ANALYSES

AND

DAILY OBSERVATIONS OF EFFLUENT

FROM

Filter Tank No. 20A.

FILTER TANK No. 20A.

July to December, 1889.

Total Effluent to end of Month. Gallons.	Date.	Daily Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature. Water.	Temperature. Effluent.	Color.
	1889.												
726	July 30, .	90	.80	2.52	.0004	.0042	.0046	.20	.0200	.0000	70°	-	0
-	Aug. 2, .	137	.80	2.72	.0002	.0072	.0074	.20	.0220	.0000	70°	73°	0
-	6, .	101	.80	2.72	.0002	.0052	.0054	.20	.0250	.0000	69°	76°	0
-	9, .	136	.80	2.64	.0000	.0066	.0066	.19	.0400	.0000	69°	74°	0
-	13, .	119	1.28	2.76	.0002	.0076	.0078	.17	.0250	.0000	69°	72°	.1
-	16, .	76	-	-	.0000	.0092	.0092	.20	.0250	.0000	68°	67°	.1
-	20, .	39	1.80	3.25	.0002	.0070	.0072	.20	.0280	.0000	68°	69°	0
-	23, .	49	-	-	.0004	.0084	.0088	.19	.0270	.0000	68°	71°	0
3,064	27, .	36	-	-	.0008	.0076	.0084	.20	.0240	.0000	67°	70°	0
-	Sept. 3, .	41	.92	3.48	.0008	.0076	.0084	.22	.0170	.0000	68°	70°	0
-	10, .	37	1.52	3.60	.0008	.0086	.0094	.25	.0260	.0001	68°	71°	0
-	17, .	39	1.30	3.90	.0006	.0080	.0086	.26	.0280	.0000	67°	67°	0
-	24, .	37	1.00	3.00	.0012	.0084	.0096	.25	.0200	.0000	66°	67°	0
4,164	30, .	37	1.30	3.50	.0008	.0070	.0078	.23	.0180	.0000	63°	61°	0
-	Oct. 7, .	39	1.20	3.40	.0002	.0072	.0074	.22	.0180	.0000	61°	60°	.1
-	14, .	38	1.80	2.60	.0002	.0100	.0102	.20	.0080	.0000	59°	54°	.1
-	21, .	37	2.00	2.60	.0012	.0100	.0112	.21	.0140	.0000	55°	51°	.1
5,377	28, .	39	1.80	2.70	.0006	.0124	.0130	.21	.0100	.0000	52°	49°	.1
-	Nov. 4, .	40	-	-	.0004	.0098	.0102	.21	.0130	.0000	51°	50°	.2
-	11, .	39	1.10	3.40	.0006	.0108	.0114	.20	.0060	.0000	51°	49°	.1
-	18, .	38	1.30	2.30	.0002	.0090	.0092	.22	.0110	.0000	50°	50°	.1
6,558	25, .	39	1.20	3.10	.0006	.0102	.0108	.22	.0110	.0000	48°	48°	.1
-	Dec. 2, .	39	1.40	2.60	.0006	.0086	.0092	.20	.0140	.0000	46°	45°	.1
-	9, .	40	1.90	2.40	.0016	.0108	.0124	.19	.0160	.0000	44°	41°	.1
-	16, .	38	1.20	2.30	.0004	.0080	.0084	.20	.0160	.0000	43°	45°	-
-	23, .	37	-	-	.0002	.0070	.0072	.18	.0200	.0000	42°	44°	.1
7,703	30, .	38	.90	3.10	.0014	.0098	.0112	.18	.0160	.0000	41°	42°	.2

July to December inclusive, effluent clear and free from sediment. August and September, generally no color. October 1 to December 23, color, 0.1, and 0.2 thereafter.

June 28. — Sand removed from tank. July 1. — Tank filled with fresh sand. 17. — Outlet closed, and water applied till level with top of sand. 19. — Outlet opened, and tank allowed to drain. Beginning July 25, water was applied forty-five seconds each hour for fourteen hours daily, except Sunday. First 8 gallons applied disappeared in 6.25 minutes.

August 13. — Water on surface before the regular hourly application at 4 P.M., seventy-five hundredths inch. Beginning August 14, water was applied only fifteen seconds each hour for fourteen hours daily, except Sunday.

October 9 to 18. — Water applied disappeared less readily in the afternoon, and generally the surface was continually covered from 3 P.M. to 5 P.M. October 19 to November 15. — Surface generally covered from 1 P.M. to 7 P.M. November 16 to December 5, from 12 M. to 9 P.M. December 6 to 31, from 12 M. to 7 P.M.

Filter Tank No. 20 A. — Concluded.

January to July, 1890.

Total Effluent to end of Month Gallons.	Date.	Daily Quantity of Effluent. Gallons.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Temperature.		Color.
			Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	Water.	Effluent.	
-	Jan. 6, .	36	1.20	2.60	.0008	.0078	.0086	.18	.0200	.0000	41°	44°	.2
-	13, .	37	1.30	2.50	.0020	.0108	.0128	.18	.0100	.0000	40°	41°	.2
-	20, .	38	1.10	2.70	.0008	.0090	.0098	.19	.0200	.0000	39°	42°	.2
8,843	27, .	33	.90	2.80	.0010	.0070	.0080	.19	.0160	.0000	38°	41°	.2
-	Feb. 4, .	35	.90	3.20	.0016	.0082	.0098	.19	.0100	.0000	38°	41°	.2
-	11, .	38	1.00	2.90	.0018	.0084	.0102	.19	.0200	.0000	37°	43°	.2
-	18, .	39	1.10	2.30	.0016	.0052	.0068	.19	.0160	.0000	37°	43°	.2
9,887	25, .	37	1.00	2.60	.0008	.0086	.0094	.18	.0140	.0000	37°	40°	.2
-	Mar. 4, .	34	.80	2.40	.0016	.0100	.0116	.19	.0110	.0000	36°	45°	.2
-	11, .	36	1.10	2.30	.0020	.0102	.0122	.17	.0200	.0000	36°	42°	.2
-	18, .	37	.60	2.80	.0020	.0096	.0116	.18	.0180	.0000	36°	46°	.2
11,004	25, .	38	1.30	2.10	.0006	.0074	.0080	.16	.0120	.0000	36°	43°	.2
-	April 1, .	38	1.10	2.70	.0008	.0088	.0096	.15	.0200	.0000	37°	44°	.2
-	8, .	37	1.00	2.30	.0012	.0080	.0092	.15	.0220	.0000	39°	47°	.1
-	15, .	37	1.00	3.10	.0016	.0088	.0104	.16	.0220	.0000	40°	48°	.2
-	22, .	36	1.60	2.60	.0012	.0098	.0110	.14	.0200	.0000	42°	49°	.2
12,114	29, .	36	1.40	2.10	.0014	.0076	.0090	.15	.0080	.0000	45°	51°	-
-	May 6, .	36	.90	2.20	.0008	.0100	.0108	.14	.0250	.0000	48°	57°	.1
-	13, .	36	-	-	.0004	.0074	.0078	.13	.0200	.0000	49°	58°	.1
-	20, .	36	1.40	2.10	.0012	.0086	.0098	.12	.0280	.0000	52°	63°	.1
13,267	27, .	36	.70	2.60	.0020	.0110	.0130	.12	.0240	.0000	54°	63°	.1
-	June 3, .	35	-	-	.0018	.0102	.0120	.12	.0070	.0000	55°	62°	.1
-	10, .	36	-	-	.0018	.0112	.0130	.13	.0220	.0000	56°	62°	.1
-	17, .	37	-	-	.0018	.0112	.0130	.12	.0240	.0000	57°	64°	.1
14,302	24, .	34	-	-	.0006	.0066	.0072	.15	.0220	.0000	60°	71°	.1
-	July 1, .	36	-	-	.0014	.0086	.0100	.16	.0300	.0000	-	73°	.1
-	8, .	35	-	-	.0014	.0066	.0080	.18	.0300	.0000	-	74°	.1
-	15, .	38	-	-	.0012	.0080	.0092	.20	.0220	.0000	-	73°	.1
15,252	22, .	38	-	-	.0010	.0070	.0080	.22	.0200	.0000	-	73°	.1

January to July inclusive, effluent clear and free from sediment, with color 0.2 till May 6, and 0.1 thereafter.

January 1 to 25. Surface generally covered from 12 M. or 1 P.M. to 7 or 9 P.M. January 26 to February 18, from 11 A.M. to 9 P.M. February 10 to 28, from 12 M. to 7 P.M. March 1 to 27, from 12 M. or 1 P.M. to 7 or 9 P.M. March 28 to April 6, from 1 P.M to 7 P.M. April 7 to 21, from 12 M. to 7 P.M. April 22 to May 25, from 12 M. or 1 P.M. to 7 or 9 P.M. May 26 to July 23, from 11 A.M. or 12 M. to 7 or 9 P.M.

PURIFICATION OF SEWAGE BY CHEMICAL PRECIPITATION.

Very complete series of experiments upon purification of sewage by chemical precipitation have been made at the experiment station of the Board at Lawrence, by Mr. Hazen, the chemist in charge, and his results are fully presented in his report, appended.

Lime, copperas, alum and sulphate of iron were used as precipitants, either alone or in combination; and the experiments were so conducted as to determine the quantity of each, when used alone, that would give the best result; and the best proportions in which any of them could be used together; and the resulting cost.

The most satisfactory results were those obtained with sulphate of iron. The second in order were with copperas and lime; the third were with lime; and the least satisfactory were with alum.

The results are not given in form to compare with those obtained by filtration through sand by the sum of ammonias, but we can compare the relative purification of the two methods by the resulting albuminoid ammonias. While our filters removed 99.5 per cent. of the organic impurities of the sewage, as determined by the relation of the sum of ammonias of the effluent to that of the sewage, at the same time they removed 98 per cent. of the albuminoid ammonia. We can then compare the completeness of purification of sewage by chemical precipitation with that by intermittent filtration, by comparing the percentage of the albuminoid ammonias remaining in the sewage after precipitation with two per cent., which is the average amount of albuminoid ammonia remaining in the filtered effluent.

The experiments on precipitation show that there is a definite quantity of lime that will give the best results with any given sewage. This quantity depends upon the character of the sewage, and is the quantity that is necessary to neutralize the carbonic acid. This quantity is the most economical to use, as a larger quantity would produce no better result, and a smaller quantity would produce a result poorer in proportion to its cost. With the ordinary sewage at Lawrence this quantity of lime is found to be about 1,800 pounds for 1,000,000 gallons of sewage; and, at the wholesale price there of $9 a ton, the annual cost of lime per inhabitant, upon the assumption that there are 100 gallons of sewage daily for each, would be 30 cents.

With the other precipitants used, viz., alum, copperas and lime, and ferric sulphate, the purification, with the same cost of precipitants, was not quite so good with alum as with lime, and was a little better with copperas and lime, and with ferric sulphate.

At greater cost, these other precipitants caused more impurities to be removed; but the increased amount so removed was not proportionately so great as the increased cost.

To make as definite a comparison as practicable, on two occasions portions of sewage well mixed from the same tank were treated with each of the precipitants, in quantities that would, at present, cost 30 cents per year for treating 100 gallons of sewage daily. The average results are placed in the following table, together with results obtained by allowing the same sewage to settle one hour without any precipitant, and those obtained in the laboratory by filtering the same sewage through filter paper, and the general results obtained by intermittent filtration through four or five feet of sand: —

Conditions of Treatment.	Percentage of the Albuminoid Ammonia of the Sewage that was removed.
Settled one hour, —	
With 1,800 pounds of lime per 1,000,000 gallons,	52
With 650 pounds of alum per 1,000,000 gallons,	51
With 1,000 pounds of copperas and 700 pounds of lime per 1,000,000 gallons,	57
With 276 pounds of ferric oxide in the form of ferric sulphate per 1,000,000 gallons,	59
With no precipitant,	21
Filtered through paper,	39
Filtered intermittently through four or five feet of sand,	98

When the amounts of alum and of ferric oxide were increased one-third, making their yearly cost 40 cents for 100 gallons daily, the amount of albuminoid ammonia removed was increased nearly 10 per cent., being, for alum, 56 per cent., and for ferric sulphate, 64 per cent.

An average of all of the experiments shows that, with a cost of 30 cents as above, copperas and lime mixed in the proportions above given, and ferric sulphate, remove about 58 per cent. of the albuminoid ammonia; that lime removes about 55 per cent., and alum removes about 51 per cent.

At higher costs, copperas with lime, and ferric sulphate, remove increasing quantities up to about 66 per cent., — when the cost is 45 cents, — with indications that there would be little if any increase above this percentage at still higher costs. Alum removes increasing percentages at costs above 30 cents, but the results are five or six per cent. below those with ferric sulphate.

The general result with these precipitants is, that from one-half to two-thirds of the organic impurities of the sewage, as indicated by the albuminoid ammonia, may be removed by chemical precipitation, while 98 per cent. may be removed by intermittent filtration; or, there remains in the effluent, after chemical precipitation, from sixteen to twenty-four times as much, or an average of twenty times as much organic impurity as in the effluent from intermittent filtration.

The number of bacteria remaining in the effluent, after chemical precipitation, averages, from these experiments, about five per cent. of those in the sewage; while the number found in the effluent from two of the filters we have been considering averages five one-hundredths of one per cent. of those in the sewage, and the number found in the effluent from three of the filters averages but two-thousandths of one per cent. of the number in the sewage, and none of these are believed to come from the sewage.

The best results that we have obtained by chemical precipitation, — and we know of no others that are so good, — leave as much as one-third of the nitrogenous organic matter of the sewage in the effluent; this is an abundant food supply for the unlimited growth of the large number of bacteria that remain. The number is called large, because five per cent. of 700,000, or 35,000, in a thimbleful, is a large number; and, if any of these are disease-producing germs, there would be no safety in turning such a liquid into a drinking-water stream; and, whether it would be admissible to turn a liquid containing from one-third to one-half as much nitrogenous organic matter as sewage, with abundant bacteria, into any other stream, would depend upon nearly the same conditions that would attend discharging a less amount of sewage into the same stream. There would, however, be this difference, and it is an important one,— the objectionable appearance would have been removed, and would not come again, unless, collecting in pools or in eddies or on flats, or rising to the surface on a liquid having greater specific gravity, putrefaction of the remaining organic matter should follow.

The remaining organic matter would probably not putrefy as readily as the original sewage diluted to the same extent; but that it is not so stable a compound that it will not readily decompose under favorable conditions, is shown by the fact that five-sixths of it may be nitrified while moving slowly for one day over gravel stones in intermittent filtration.

Such an effluent as may be obtained from chemical precipitation of sewage, turned into a large and rapidly flowing stream, or into a tidal current that would soon take it to sea, would be disposed of without making a nuisance, when crude sewage might be very objectionable. Under such circumstances, and there may be others where the conditions for intermittent filtration are unfavorable, the partial purification of sewage by chemical precipitation may be the best practicable way to avoid a nuisance. But the incompleteness of the purification and the cost of 30 cents per inhabitant yearly for chemicals, together with the additional expense of manipulation and disposing of the sludge, will be likely to confine the application of chemical precipitation in the purification of sewage to narrow limits.

SUMMARY OF THE ADDITIONAL RESULTS

OF

FILTRATION OF SEWAGE AND OF WATER,

OBTAINED IN 1890.

The experiments upon the purification of sewage and of water, by intermittent filtration, have been continued through 1890, partly with new materials, but principally with increasing quantities of sewage or of water, upon materials that had been in use as filters during the previous two years.

Among the most interesting results obtained, upon the intermittent filtration of sewage, were those in which the filtering material was entirely of gravelstones as large as beans. The sand had not only been screened out, but all of the stones had been washed, so that no sand adhered to them, before they were put into the tank. They formed a bed five feet in depth; and for nine months sewage pumped directly from the city sewer was applied nine times a day, for six days in the week, in quantity equivalent to 81,400 gallons per acre per day. The quality of the effluent varied somewhat; but during the last two months, June and July, after the above quantity had been applied daily for more than seven months, we obtained the following average results: —

Date.		Quantity in Gallons.	Ammonia.			Chlorine.	Nitrogen as		Bacteria per Cubic Centimeter.
			Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	
1889.									
May 23-June 22,	Sewage, .	–	1.9919	0.6031	2.5950	5.16	0.0000	0.0000	–
	Effluent, .	3.5	0.0031	0.0375	0.0406	6.00	2.0700	0.0002	10,305
	Per cent.,	–	0.2of1	6.	1.5	–	–	–	–
June 23-July 22,	Sewage, .	–	2.2500	0.7255	2.9755	7.46	0.0000	0.0000	1,813,500
	Effluent, .	3.5	0.0050	0.0354	0.0404	9.01	2.2500	0.0004	13,523
	Per cent.,	–	0.2of1	5.	1.3	–	–	–	0.7 of 1

Here we find that 98.6 per cent. of the organic matter of the sewage, shown by the sum of ammonias, is removed by being burned and converted into nitrates, and more than 99 per cent. of the bacteria that were in the sewage were killed. We must regard this as a remarkably good result, with an effluent averaging 70,000 gallons an acre for every day in the year.

The foregoing results were so satisfactory that the quantity was increased by applying the same amount hourly for fourteen hours, instead of for nine hours. The quantity applied was then the equivalent of 126,600 gallons per acre per day, for six days in the week. This quantity was continued for three months, until Oct. 24, 1890, with very little change from the result previously obtained.

The average results for the last month were as follows: —

Date.		Quantity in Gallons.	Ammonia.			Chlorine.	Nitrogen as		Bacteria per Cubic Centimeter.
			Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	
Sept. 24-Oct. 24,	Sewage, .	–	2.0559	0.6453	2.7012	5.55	0.0000	0.0000	3,034,000
	Effluent, .	5.0	0.0068	0.0325	0.0393	6.42	1.5700	0.0003	11,592
	Per cent.,	–	0.3of1	5.	1.5	–	–	–	0.4 of 1

We still find 98.5 per cent. of the organic matter of the sewage is removed, and its nitrogen is in the mineral form of nitrates; and more than 99.6 per cent. of the bacteria are killed. This result was so satisfactory that the quantity was still further increased in November.

These results show more definitely than any others the essential character of intermittent filtration. We see that it is not a straining process. By the application of small quantities of sewage over the whole surface of the tank each hour, each stone in the tank was kept covered with a thin film of liquid, very slowly moving from stone to stone, from the top towards the bottom, and continually in contact with air in the spaces between the stones. The liquid, starting at the top as sewage, reached the bottom within twenty-four hours, with the organic matter nearly all burned out. The removal of this organic matter is in no sense a mechanical one of holding back material between the stones, for they are as clean as they were a year ago; but it is a chemical change, aided by bacteria, by which the organic substances are burned, forming products of mineral matter, which pass off daily in the purified liquid.

The liquid flowing out at the bottom is a clear, bright water, comparing favorably, in every respect that can be shown by chemical or biological examination, with water from some of the wells on the streets of our cities that are used for refreshing draughts by the public during the summer.

Filter Tank No. 1.

This is composed of very coarse mortar sand. From Oct. 11 to Dec. 3, 1889, a trap was upon the outlet, excluding air, and the purification was not so satisfactory as previously. In accordance with the conclusions reached in the previous year, the surface of this tank was spaded under to a depth of about four inches on November 27; and, for the purpose of washing out the salt that was in the tank from sewage, city water was applied, 500 gallons three days in the week, from November 28 to December 7. This was done for the purpose of determining, upon again applying sewage, by the increase of chlorine, how rapidly the foremost particles of sewage flow through this sand, when it is applied in considerable quantity. While city water was being applied, the average analysis of the effluent was as follows, in parts per 100,000:—

Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Nitrates.	Nitrites.
0.0018	0.0119	1.05	0.7418	0.0011

On the last day the chlorine was reduced to 0.46 parts. Sewage began to flow on to the sand at 10.53 on December 9, and 500 gallons continued to flow on till 11.44. There was no increase in flow at the outlet at 11.29, but at 11.32 the flow out had increased from one-fortieth of a gallon per minute to one-tenth of a gallon, and in the next three minutes the rate of flow increased to nine-tenths of a gallon per minute, and thereafter continued increasing until 12 o'clock, when the rate was fifteen gallons per minute.

At 11.32 the number of bacteria in a cubic centimeter of the effluent was 70, a little higher than it had been through the morning; but at 11.35 the number had increased to 2,190 per cubic centimeter, and three minutes later the number was 1,886. The increase to 2.190 at 11.35 indicates that as much as two-thirds of one per cent. of the effluent was then of the sewage, which contained 300,000 bacteria per cubic centimeter. At this time not more than six gallons of liquid had flowed out after the first sewage was put on the surface, a period of forty-two minutes; but it was not more than six minutes after the application of sewage began to increase the flow at the outlet.

The indication of the arrival of the most advanced particles of sewage at the outlet, by the increase in chlorine, comes a little later than that by the increase in bacteria. One reason may be that the chlorine at the outlet was decreasing while sewage was coming down through the sand, and perhaps it would have decreased faster if some forward particles of sewage had not added some chlorine.

At 11.35 the chlorine of the effluent was 0.60 parts; at 11.36, 0.52 parts; at 11.38, 0.46 parts; and at 11.41 it had stopped decreasing, being still 0.46 parts, and after this it steadily increased. This indicates that the forward particles of sewage reached the outlet when fourteen gallons of effluent had been pressed out by sewage applied at the surface. This was at 11.39, or four minutes later, and after eight more gallons had passed out, than when the increase in the number of bacteria indicated the arrival of sewage.

From this we learn that the 1,000 gallons of liquid held in the smaller interstices of this coarse sand, after it has been draining for a day or more, are to a very small extent pushed down by the forward particles of the incoming sewage; but that some of these particles move rapidly down through the larger interstices, pushing before them but little of the contained water, and reach the outlet within three-quarters of an hour after being applied at the surface, having pushed before them not more than one per cent. of the contained water.

We have the following series of analyses of sewage and of effluent during the day, Dec. 9, 1889:—

	Time of Collection.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Rate of Flow. Cubic Centimeters per Minute.	Number of Bacteria per Cubic Centimeter.
		Loss on Ignition.	Fixed.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
Sewage,	-	-	-	.8000	.4800	1.2800	2.86	-	-	-	304,200
Effluent,	8.34	1.2	9.3	.0022	.0082	.0104	.70	.5700	.0001	80	24
"	10.32	-	-	-	-	-	-	-	-	73	29
"	10.44	2.0	8.1	.0022	.0100	.0122	.75	.6500	.0001	78	-
"	10.53	-	-	-	-	-	.72	-	-	76	15
"	11.11	-	-	-	-	-	.72	-	-	75	10
"	11.14	-	-	-	-	-	.72	-	-	77	19
"	11.23	-	-	-	-	-	.72	-	-	77	12
"	11.29	-	-	-	-	-	.72	-	-	76	Broken.
"	11.32	-	-	-	-	-	.62	-	-	273	70
"	11.35	-	-	-	-	-	.60	-	-	2,680	2,190
"	11.36	2.2	7.0	.0010	.0176	.0186	.52	.4400	.0001	4,000	-
"	11.38	-	-	-	-	-	.46	-	-	7,320	1,886
"	11.41	-	-	-	-	-	.46	-	-	10,680	10,080
"	11.44	2.5	4.7	.0030	.0360	.0390	.56	.2200	.0006	12,000	3,828
"	11.47	-	-	-	-	-	.67	-	-	14,800	9,744
"	11.50	-	-	-	-	-	.79	-	-	17,300	4,850
"	11.53	-	-	-	-	-	.82	-	-	19,100	Liquefied.
"	11.56	3.6	6.8	.0146	.0450	.0596	.94	.2600	.0008	22,000	14,580
"	12.02	-	-	-	-	-	.94	-	-	46,200	9,108
"	12.05	5.5	6.9	.0236	.0470	.0706	1.00	.2700	.0010	30,150	8,580
"	12.11	-	-	-	-	-	1.04	-	-	14,800	10,824
"	12.17	5.0	5.5	.0220	.0514	.0734	1.06	.2800	.0010	13,920	7,740
"	4.32	2.4	7.8	.0194	.0338	.0532	1.37	.3700	.0004	920	8,360

Five hundred gallons of sewage applied from 10 h. 53 m. to 11 h. 44 m.

These observations show that when the chlorine began to increase, the free and albuminoid ammonia also increased; and, soon after, the nitrates increased.

To determine whether the ammonias and nitrates pass through in quantities proportioned to the chlorine, or whether they undergo important changes in the quick passage of the more advanced particles, we have computed the different forms of nitrogen, as if they came through without change, in proportion to the amount of chlorine. The assumption is made, in accordance with the condition of the effluent on the previous days, that thirty-three per cent. of liquid like that of the effluent in the morning before sewage was applied, formed one portion of the effluent continually, and this, together with such amounts of city water from the upper part of the tank, and of applied sewage, as will give the existing chlorine at any hour, make up the existing effluent.

The actual analyses of the effluent at different times, in the forty minutes after sewage appeared at the outlet, are given in the following table, followed by the computed analyses :—

Time.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Nitrates.	Nitrites.	No. of Bacteria.	Per cent. of Sewage.
11.44, ...	0.0030	0.0360	0.56	0.2200	.0006	3,828	-
Computed, ...	0.0577	0.0376	0.55	0.2000	.0001	21,000	7
11.56, ...	0.0146	0.0450	0.94	0.2600	.0008	14,580	-
Computed, ...	0.1775	0.1145	0.93	0.2000	.0001	66,000	22
12.05, ...	0.0236	0.0470	1.00	0.2700	.0010	8,580	-
Computed, ...	0.2015	0.1285	1.01	0.2000	.0001	75,000	25
12.17, ...	0.0220	0.0514	1.06	0.2800	.0010	7,740	-
Computed, ...	0.2500	0.1560	1.07	0.2000	.0001	93,000	31

These results, though approximate only, give assurance of a marked chemical change within a few minutes, so that sewage which is ten minutes longer on the passage through the sand comes out with free and albuminoid ammonia and the number of bacteria much more reduced than that having a shorter passage. The nitrates also indicate an increase, with a short increase in the time of passage, which is confirmed by other experiments; but the amount of this increase and the change in the nitrites are the least certain points in the computation.

The short time in which sewage—applied in large quantity after an intermission—passes through five feet of very coarse sand, before nitrification can become complete and before all of the bacteria can be killed, indicates the advantage, with such material, of more frequent applications of small quantities.

The longer time required by a fine sand for the first application of sewage to pass through is shown by an experiment on Tank No. 2, when, under similar circumstances, it required a week for the most forward particles to reach the outlet.

Upon resuming the application of sewage, it was found that, while the nitrates were high, the ammonias were also higher than in the previous year. This condition continued for about two months, or until the middle of February, 1890. The average result was as follows: —

Free ammonia, . . 0.1048, or 7 per cent. of that of the sewage.
Albuminoid ammonia, 0 0330, or 5 per cent. of that of the sewage.
Sum of ammonias, . 0.1378, or 7 per cent. of that of the sewage.
Chlorine, . . . 4.55.
Nitrates, . . . 1 0677.
Nitrites, . . . 0.0010.
Quantity per acre daily, 52,000 gallons.
Bacteria per cubic centimeter, 2,705.

After this the nitrates increased for three months from 1.3 parts to 3.0 parts per 100,000, and the sum of ammonias decreased until the middle of May, after which, for a month, while filtering at the rate of 50,000 gallons per acre per day, the resulting analyses were as follows: —

Free ammonia, . . 0.0028, or 0.1 of 1 per cent. of that of the sewage.
Albuminoid ammonia, 0.0202, or 3 per cent. of that of the sewage.
Sum of ammonias, . 0.0230, or 1 per cent. of that of the sewage.
Chlorine, . . . 5.09.
Nitrates, . . . 2.3583.
Nitrites, . . . 0 0002.
Bacteria per cubic centimeter, 3,296.

After the middle of June the quantity filtered was increased to 77,000 gallons per acre per day, with the following average result for three months: —

Free ammonia, . .	0.0152, or 0.7 of 1 per cent. of that of the sewage.
Albuminoid ammonia,	0.0406, or 5 per cent. of that of the sewage.
Sum of ammonias, .	0.0558, or 1.8 per cent. of that of the sewage.
Chlorine, . . .	8.46.
Nitrates, . . .	1.5100.
Nitrites, . . .	0.0022.
Bacteria per cubic centimeter,	21,038.

The quantity filtered was again increased. The average quantity for the next two months was 102,000 gallons per acre per day, and we have the following very satisfactory average analysis: —

Free ammonia, . .	0.0143, or 0.7 of 1 per cent. of that of the sewage.
Albuminoid ammonia,	0.0223, or 4 per cent. of that of the sewage.
Sum of ammonias, .	0.0366, or 1.3 per cent. of that of the sewage.
Chlorine, . . .	6.24.
Nitrates, . . .	1.0562.
Nitrites, . . .	0.0003.
Bacteria per cubic centimeter,	12,334.

This sand is, at the end of its third year of use, filtering about double the quantity filtered at the end of the second year, with a rather purer effluent. The better result is attributed to raking over the surface, to the depth of one inch, once a week.

Filter Tank No. 2.

This filter of very fine sand was allowed to stand through a part of November, 1889, without receiving sewage, and on November 26 the surface was spaded under to the depth of four inches. From November 29 to December 13 city water was applied to the tank instead of sewage, till the chlorine of the effluent was reduced to 0.19 parts per 100,000,— nearly the same as in city water. The application of sewage was resumed December 14, and it was found that the increase in chlorine indicated that sewage began to reach the bottom in small amount on December 20, after 1,780 gallons had passed through; that is, that these forward particles had passed by about 500 gallons of water held in the smaller interstices. A slight increase in the number of bacteria when about 40 gallons less had passed through appears to have been a somewhat more delicate test of the presence at the outlet of the most forward particles of the sewage. The effluent had the full strength of the chlorine of the sewage when 2,800 gallons had passed out, after the first sewage was applied at the surface. But, before this, when the chlorine of the effluent was but one-half that of the sewage, the nitrates of the effluent increased in one day from 0.2300 parts to 1.3500 parts per 100,000; indicating that, although nitrification had been reduced by the passing of city water through the filter, — for the reason that there was little organic matter to be nitrified, — the conditions for nitrification had not been lessened; so that, as soon as organic matter was presented, it oxidized very rapidly, and increased the nitrates to a larger percentage of the total nitrogen than usual.

The nitrates continued high through the winter, averaging 1.072 parts for the next two months, and then increased through March and April and to the middle of May, when they were 2.750 parts. In the first three months, January to March, with the usual quantity of 42,000 gallons per acre filtering daily, the ammonias were higher than usual; the free ammonia averaged 0.0205 parts, and the albuminoid ammonia 0.0119 parts, making the sum of ammonias 0.0324 parts per 100,000, or 1.5 per cent. of those of the sewage.

From April 9 to June 28, while the same quantity was filtering, the sum of ammonias was only 0.0130 parts, or 0.6 of one per cent. of those of the sewage; the free ammonia averaged 0.0016 parts, and the albuminoid ammonia 0.0114 parts. The nitrates decreased steadily from the middle of May to the last of June, from 2.750 parts to 1.000 part. Then the surface of the tank was raked over to the depth of one inch, and the nitrates, in one week, rose to 2.500 parts, and continued between this amount and 1.530 parts for the following three months. These higher nitrates were undoubtedly due to raking over the surface of the filter once a week.

With the first of July, the quantity of sewage applied was increased to 700 gallons, applied three days in a week, or an average rate of 60,000 gallons per acre per day. The sum of ammonias increased slightly for the first month, but afterwards steadily decreased, as follows: July, 0.0142 parts; August, 0.0130 parts; September, 0.0113 parts; and October, 0.0083 parts. In the last month they formed but 0.3 of one per cent. of those of the sewage.

The average analysis of the effluent for the last month was as follows: —

Free ammonia, . .	0.0004, or 0.02 of 1 per cent. of that of the sewage.
Albuminoid ammonia,	0.0079, or 1.2 per cent. of that of the sewage.
Sum of ammonias, .	0.0083, or 0.3 of one per cent. of that of the sewage.
Chlorine, . . .	5.37.
Nitrates, . . .	1.4140, or 51 per cent. of the total nitrogen of the sewage.
Nitrites, . . .	0.0000.
Bacteria per cubic centimeter, 17.	

This is a very satisfactory result for this material. Two years before, we found it necessary to reduce the quantity of sewage to 200 gallons, applied three times a week, before we could obtain such purification. A year ago we obtained nearly as good an effluent with this filter when six-tenths as much sewage was filtering. The ability to filter the increased quantity at this time is believed to be entirely due to raking over the surface of the filter to the depth of an inch once a week, which has been done since the latter part of June, 1890.

Filter Tank No. 3A.

The peat which filled Tank No. 3 for two years was removed on Nov. 14, 1889, and on November 20 the tank was filled, above the gravel and sand around the underdrains, with a depth of 2.5 feet of fine sand like that in Tank No. 2, above which was 2.5 feet of coarse sand like that of Tank No. 1. The name was changed to Tank No. 3A. Five hundred gallons of water were applied to this tank daily for about a month, and on Jan. 6, 1890, the first sewage was applied. The quantity of sewage applied was 150 gallons a day, except Sundays, until June 30; then 300 gallons a day until September 7; then 350 gallons a day until October 20, when the quantity was increased to 500 gallons a day.

The nitrates of the effluent continued from 0.010 parts to 0.020 parts until March 20; when, the temperature of the effluent being at 38° Fah., the nitrates increased to 0.040 parts, after which they increased, slowly at first and then more rapidly, until the middle of May, when they were 3,750 parts. They then decreased, and in the latter part of June were 2,000 parts. From this time to September 7 they averaged 1.870 parts, and from September 7 to October 20 the average was 1.490 parts per 100,000.

Previous to the beginning of nitrification the free ammonias of the effluent increased to 0.6000 parts per 100,000, and the albuminoid ammonias to 0.0500 parts. The sum of ammonias were then 40 per cent. of those of the sewage; but the albuminoid ammonia was but 12 per cent. of that of the sewage.

While the nitrates were the highest, in the middle part of May, the total nitrogen coming from the tank was 40 per cent. more than was being applied. The ammonias were rapidly decreasing, and on June 19 their sum was less than one per cent. of the sum of ammonias in the sewage. The quantity of sewage applied was doubled after June 30, and the surface was raked over to the depth of one inch once a week. The ammonias, at first higher, gradually decreased through the month of July; and from August 1 to September 7 there was a steady and very complete purification.

The average analysis was as follows: —

Free ammonia, . .	0.0037, or 0.2 of 1 per cent. of that of the sewage.
Albuminoid ammonia,	0.0092, or 1.4 per cent. of that of the sewage.
Sum of ammonias, .	0.0129, or 0.5 of 1 per cent. of that of the sewage.
Chlorine, . . .	7.17.
Nitrates, . . .	1.9200.
Nitrites, . . .	0.0004.
Bacteria per cubic centimeter,	1,642.

With the increase in quantity of sewage applied after September 7 to 60,000 gallons per acre per day, the free ammonia increased until it became 0.0322 parts; but in the following three weeks it steadily decreased, until the analysis on October 16 was as follows: —

Free ammonia, . . 0.0026, or 0.1 of 1 per cent. of that of the sewage.
Albuminoid ammonia, 0.0082, or 1 per cent. of that of the sewage.
Sum of ammonias, . 0.0108, or 0.4 of 1 per cent. of that of the sewage.
Chlorine, . . . 4.94.
Nitrates, . . . 1.1000.
Nitrites, . . . 0.0000.
Bacteria per cubic centimeter, 3,960.

After this the daily quantity applied was increased to 100,000 gallons per acre, for six days in the week, which will be continued through the winter.

Filter Tank No. 4.

This filter, of extremely fine sand, has, since June, 1889, received sewage through a trench of coarse sand. The excellent results obtained in October, 1889, have continued. The equivalent of 26,000 gallons of sewage a day upon an acre has been continued through August, 1890; and the quality of the effluent has been very nearly constant through winter and summer; the principal variation being in the nitrates, which were as usual higher in April, May and June.

The average analysis for the ten months, November, 1889, to August, 1890, was as follows: —

Free ammonia, . . 0.0017, or 0.1 of 1 per cent. of that of the sewage.
Albuminoid ammonia, 0.0120, or 1.8 per cent. of that of the sewage.
Sum of ammonias, . 0.0137, or 0.6 of 1 per cent. of that of the sewage.
Chlorine, . . . 5.36.
Nitrates, . . . 1.3337.
Nitrites, . . . 0.0001.
Bacteria per cubic centimeter, 184.

This result was so satisfactory that the daily quantity of sewage was, on September 8, increased to 34,200 gallons per acre, and the average analysis for the following three months was as follows: —

Free ammonia, . . 0.0011, or 0.05 of 1 per cent. of that of the sewage.
Albuminoid ammonia, 0.0118, or 1.7 per cent. of that of the sewage.
Sum of ammonias, . 0.0129, or 0.5 of 1 per cent. of that of the sewage.
Chlorine, . . . 5.98.
Nitrates, . . . 1.0854.
Nitrites, . . . 0.0000.

When sewage was applied to the surface of this material, we were unable to obtain as good results as the above; and it was not till the quantity filtered was reduced to 12,000 gallons per acre per day that purification became nearly as complete as the results now obtained by applying to the coarse sand in the trench 34,200 gallons per acre per day.

Filter Tank No. 5.

This tank of garden soil, five feet deep, had a trench dug two and a half feet deep and one and a half feet wide, its outer edge being one and a half feet inside of the periphery. This trench was filled with coarse sand like that of Tank No. 1, and sewage has since been applied to this sand. The quantity applied has been 100 gallons, three times a week, from November, 1889, to September, 1890, or the equivalent of 8,600 gallons per acre per day. The quantity of effluent was a little greater, owing to the rain, in the first eight months; but during the last three months was less, on account of greater evaporation.

No nitrates were found in the effluent except for a short time in April, 1890, and again a few times in August and September. The sum of ammonias of the effluent was greater than that of the sewage, from November to January; but from February till near the end of August the sum of ammonias was nearly the same in each.

During the eleven months the free ammonia has averaged 2.8273, which is 68 per cent. more than the free ammonia of the applied sewage. But the albuminoid ammonia has averaged only 0.1869 parts, and has been very constantly 29 per cent. of that of the sewage.

While there has been little or no nitrification, there has been a marked reduction in the organic nitrogen, so that there remains but 29 per cent. of the amount in the sewage. This is only about one-third as much organic nitrogen as remained in the effluent when the sewage was applied directly to the surface of the filter, before the sewage was applied to the trench filled with coarse sand. This is a step in purification, but a very incomplete one, compared with the result in all of the sand filters.

After October 3 the quantity of sewage applied was reduced to 50 gallons, applied three times a week, or the equivalent of 4,300 gallons per acre per day, which is but little more than the rainfall upon the same area.

Filter Tank No. 6.

This tank, of coarse and fine sand and fine gravel, four feet deep, continued to receive 42,600 gallons daily per acre from June, 1889, to Sept. 8, 1890. In 1890 nitrification was continually active. It was most complete in April, May and August, when the nitrates exceeded 2.0 parts per 100,000. In December, 1889, the free ammonia increased for a time up to 0.0650 parts, but soon fell to 0.0068 parts.

The average analysis from January to August, 1890, was as follows: —

Free ammonia, . .	0.0028, or 0.16 of 1 per cent. of that of the sewage.
Albuminoid ammonia,	0.0181, or 2.7 per cent. of that of the sewage.
Sum of ammonias, .	0.0209, or 0.9 of 1 per cent. of that of the sewage.
Chlorine, . . .	5.54.
Nitrates, . . .	1.4125.
Nitrites, . . .	0.0002.

Bacteria per cubic centimeter, 7,144.

After Sept. 8, 1890, the quantity of sewage applied daily was increased to the equivalent of 60,000 gallons per acre, and the resulting analysis for the following three months was as follows: —

Free ammonia, . .	0.0030, or 0.15 of 1 per cent. of that of the sewage.
Albuminoid ammonia,	0.0164, or 2 4 per cent. of that of the sewage.
Sum of ammonias, .	0.0194, or 0.7 of 1 per cent. of that of the sewage.
Chlorine, . . .	5.50.
Nitrates, . . .	1.2627.
Nitrites, . . .	0.0001.

Bacteria per cubic centimeter, 10,044.

The surface of this filter has not been worked over or in any way disturbed for nearly three years. There is very little sediment upon the surface, but experience with other filters indicates that better results will be obtained if the surface be raked over once a week; and, although the results with this filter, having but four feet in depth of filtering material, have been remarkably good, in making a further increase of quantity the surface will be periodically disturbed.

Filter Tank No. 7.

This filter has a covering of soil and of loam, but the sewage has, since October, 1889, been applied in an open-jointed drain pipe beneath the loam. The drain pipe is surrounded with coarse gravel, which extends one foot and a half below it, and for a width of two feet.

From September, 1889, to August, 1890, 150 gallons of sewage were applied daily on six days in the week, or 25,700 gallons per day per acre.

For the ten months, November, 1889, to August, 1890, nitrification has been active. The nitrates have not been as high as with the sand filters, but have averaged 1.1544 parts per 100,000. The ammonias have been nearly constant.

The average analysis for the ten months was as follows: —

Free ammonia,	0.0024, or 0.1 of 1 per cent. of that of the sewage.
Albuminoid ammonia,	0,0111, or 1.7 per cent. of that of the sewage.
Sum of ammonias,	0.0135, or 0.6 of 1 per cent. of that of the sewage.
Chlorine,	5.49.
Nitrates,	1.1544.
Nitrites,	0.0001.
Bacteria per cubic centimeter,	501.

After Sept. 7, 1890, the quantity of sewage applied was increased to 200 gallons per day, for six days in the week, or the equivalent of 34,280 gallons per acre per day.

This quantity, for a time, was too much for the filter to purify, and, at the end of October, the free ammonia had increased to 0.1920 parts; the albuminoid ammonia was 0.0200 parts; the nitrates had been reduced to 0.4500 parts, but had again risen to 0.9000 parts; and the nitrites were 0.0110 parts.

From this time the effluent steadily improved, and on December 11 the analysis was as follows: —

Free ammonia,	0.0082
Albuminoid ammonia,	0.0084
Sum of ammonias,	0.0166
Chlorine,	4.34
Nitrates,	0.8900
Nitrites,	0.0009

Filter Tank No. 14.

During the summer of 1889 this tank of coarse sand, like that of No. 1, had sewage applied at the rate of 60,000 gallons per acre for six days in the week. The tight cover was kept on all of the time, and air was admitted at first for fifteen minutes a day, then for five minutes, then for three minutes, and finally for one minute. The air was kept in motion through the tank by means of an aspirator. Nitrification was nearly complete, and during the last month of October, 1889, when air was admitted in small quantity only, for one minute a day, the average analysis was as follows :—

Free ammonia,	0.0011
Albuminoid ammonia,	0.0129
Chlorine,	4.87
Nitrates,	1.4133
Nitrites,	0.0034

For the next month no air was admitted, but the aspirator continued running, causing the air within the tank to circulate through the sand. The nitrification was as complete, and the removal of organic matter nearly as great, as in the previous month. It was evident that oxygen must have been supplied from some source ; and it was concluded that it came, in very small amount, from the absorbed oxygen of the water of the aspirator, which continually came in contact with the air which it was causing to circulate.

On December 7 the aspirator was removed. Nitrification rapidly decreased ; and through January and the most of February the nitrates and nitrites were zero. The free ammonia rose to 1.4, and the albuminoid ammonia to 0.13, parts.

On March 10, 1890, the cover was removed, and on March 21 the nitrates had risen to 2.6 parts. The ammonias rapidly decreased, and at the end of April there was a well-established purification. For the next month and a half the analyses averaged as follows: free ammonia, 0.0033 ; albuminoid ammonia, 0.0153 ; chlorine, 4.84 ; nitrates, 2.6643 ; nitrites, 0.0011.

After the middle of June, the quantity of sewage was increased to the equivalent of 100,000 gallons per acre, for six days in the week. The free ammonias rose for a few days, and then fell to their former amount. The albuminoid ammonias increased permanently. The average analysis for the three months July, August and September, 1890, was as follows:—

Free ammonia, . .	0.0043, or 0.2 of 1 per cent. of that of the sewage.
Albuminoid ammonia,	0.0240, or 4 per cent. of that of the sewage.
Sum of ammonias, .	0.0283, or 1 per cent. of that of the sewage.
Chlorine, . . .	6.63.
Nitrates, . . .	2.3425.
Nitrites, . . .	0.0008.

This was a very good result when filtering so large a quantity.

In October a little sewage remained on the surface in spots, in the first half of the month, and the ammonias increased; but, upon raking over the surface — which had not been disturbed for six months — to the depth of one inch, once a week, the nitrates again increased, and for the month of November the ammonias were the same as in the analysis just given, with no indication that this quantity may not be as well purified for an indefinite period.

On Dec. 4, 1890, the daily quantity of sewage was increased to 120,000 gallons per acre, for six days in the week.

Filter Tank No. 15A.

This tank, of coarse gravelstones, has been treated with the equivalent of 20,000 gallons per acre, for six days in the week, of sewage having an excess of acid, made so by adding to ordinary sewage varying amounts of sulphuric acid.

From Nov. 4, 1889, to May 8, 1890, the amount of sulphuric acid added was 22 54 parts per 100,000. From May 9 to July 30 the amount was 45 parts per 100,000; and from July 31 to October 26 the amount added was 90 parts per 100,000. The object was to see the effect of intermittent filtration of sewage having an excess of sulphuric acid. It will be seen that, while purification was much less than with alkaline sewage, there was at all times some nitrification, and the organic nitrogen was very much reduced.

The average analysis of the effluent in the first four months of the year, while the smaller quantity was added, was as follows : —

Free ammonia, .	. 1.4881, or 102 per cent. of that of the sewage.
Albuminoid ammonia,	0.0884, or 13 per cent. of that of the sewage.
Sum of ammonias,	. 1.5765, or 73 per cent. of that of the sewage.
Chlorine, . .	. 4.93.
Nitrates, . .	. 0.0930.
Nitrites, . .	. 0.0016.

In the second period, when 45 parts per 100,000 of sulphuric acid were added to the sewage, the average analysis for three months was as follows : —

Free ammonia, .	. 2.8425, or 142 per cent. of that of the sewage.
Albuminoid ammonia,	0.1468, or 22 per cent. of that of the sewage.
Sum of ammonias,	. 2.9893, or 113 per cent. of that of the sewage.
Chlorine, . .	. 7.45.
Nitrates, . .	. 0.0932.
Nitrites, . .	. 0.0009.

In the third period, from July 31 to Oct. 26, 1890, when 90 parts per 100,000 of sulphuric acid were added, we have the following average analysis : —

Free ammonia, .	. 2.3983, or 114 per cent. of that of the sewage.
Albuminoid ammonia,	0.1532, or 24 per cent. of that of the sewage.
Sum of ammonias,	. 2.5515, or 93 per cent. of that of the sewage.
Chlorine, . .	. 8.17.
Nitrates, . .	. 0.0311.
Nitrites, . .	. 0.0004.

While there has been a small amount of nitrification through the year, which has decreased with the great excess of acid of the last three months, there has been a continued removal of more than three-quarters of the organic nitrogen, as shown by the albuminoid ammonia.

Filter Tanks No. 17A and No. 19.

These two iron tanks, in the building, were, on Jan. 25, 1890, filled with sand intermediate in fineness between that of No. 1 and that of No. 2. The sand of each was taken from the same pit, and is presumed to be of like quality; but, in filling No. 17A, marble dust was added in layers containing ten pounds, or having a depth of a little more than one-half inch, at distances of one, three and four feet, and of four feet and nine inches from the top of the layer of coarse sand on the gravel at the bottom. The upper layer of marble dust was covered with three inches of sand.

These two filters were treated alike for nine months, to see if there was any advantage, when filtering an ordinary alkaline sewage, in having layers of an alkaline earth in the filter.

Sewage was applied to each on Jan. 28, 1890, the quantity being 1.5 gallons on week days, until February 18, after which it was 3 gallons, or at the rate of 60,000 gallons per acre.

The nitrates were a little higher in No. 19 during the first month, and they rose rapidly in this tank fifteen days earlier than in Tank No. 17A. Perhaps this was due to more freedom of motion of air through the tank which contained no marble dust.

The nitrates were high in both filters after May 1; but were a little higher in the tank without the marble dust.

The average analysis in each for the following six months was as follows: —

	Tank No. 17A.	Tank No. 19.
Free ammonia,	0.0026	0.0055
Albuminoid ammonia,	0.0130	0.0110
Sum of ammonias,	0.0156	0.0165
Chlorine,	5.84	5.73
Nitrates,	2.0219	2.2492
Nitrites,	0.0009	0.0029
Bacteria per cubic centimeter,	25.	35.

No advantage appears in favor of the addition of marble dust in this trial of nine months with ordinary alkaline sewage. After Oct. 26, 1890, Tank No. 17A was treated with sewage to which a definite amount of sulphuric acid was added, and the quantity of sewage applied to Tank No.

19 was increased to the equivalent of 120,000 gallons per acre, on six days in the week.

Filter Tank No. 25.

This iron tank, 20 inches in diameter and 12.2 feet high, had the usual gravel and coarse sand put in at the bottom for a depth of six inches, above which was five feet of sand and loam from a cemetery. Water was filtered through this sand and loam for three months, when the resulting effluent gave the following analysis: free ammonia, 0.0014; albuminoid ammonia, 0.0024; chlorine, 0.23; nitrates, 0.0250; and nitrites, 0.0002 parts per 100,000.

On Dec. 18, 1889, the carcass of a dog, weighing eleven and a half pounds, was put on the surface, and this was covered with six feet of sand and loam similar to that below.

From Jan. 1, 1890, to November 21, one and a half gallons of water were poured upon the surface each week. This is a little more than the average weekly rainfall upon such a surface. The changes that occurred in the effluent from month to month are presented in the following table of monthly averages of analyses of the effluent: —

Date.	Ammonia.			Chlorine.	Nitrogen as		Bacteria per Cubic Centimeter.
	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.	
1889.							
October 30,	.0014	.0024	.0038	.23	.0250	.0002	–
December,	.0100	.0161	.0261	3.11	.0280	.0004	–
1890.							
January,	.0065	.0044	.0109	6.26	.0275	.0001	–
February,	.0033	.0043	.0076	7.30	.0225	.0010	–
March,	.0031	.0082	.0113	8.21	.0125	.0000	–
April,	.0037	.0114	.0151	9.21	.0050	.0002	–
May,	.0034	.0153	.0187	7.47	.0200	.0000	–
June,	.0033	.0214	.0247	4.67	.0350	.0000	–
July,	.0878	.0178	.1056	3.23	.1700	.0050	–
August,	1.6990	.0394	1.7384	2.52	.8500	.1850	–
September,	6.5350	.0461	6.5811	1.85	.7750	.0617	4,319
October,	11.4250	.6850	12.1100	1.76	.1475	.0271	18,360
November,	26.6250	2.8000	29.4250	1.49	.0925	.0082	4,796

The chlorine increased in four months from 0.23 parts — which was that of the water going through the lower five feet before the carcass was buried — to 9.21 parts; and then gradually decreased in seven months to 1.49 parts per 100,000 of the water coming through.

The nitrates were no higher than the water applied, for six months; that is, in this time there was no nitrification, but in the next two months the nitrates increased to 0.8500 parts, and then gradually fell in three months to 0.0925 parts. It may be that this small amount of nitrification took place in the lower layers of the tank where air was received from the outlet. In future the outlet will be trapped so that no air can enter there, to determine whether air permeates this material from the surface to sufficient depth to produce nitrification of organic matter six feet below the surface.

The nitrites increased with the nitrates to 0.1850 parts, and decreased to 0.0082 parts in November.

The free ammonia was low and nearly constant, at about 0.0034 parts, for six months, and then increased at a very rapid rate in the remaining five months to 26.6250 parts, in November.

The albuminoid ammonia increased but little for seven months, and then slowly for two months; after which it increased very rapidly, and for November averaged 2.8000 parts per 100,000.

The odor of the effluent grew very strong and offensive through April, May and June, and was the most nauseating the first week in July, since which it has decreased much, but is still strong.

Filter Tanks No. 26 to No. 31.

These six tin tanks are smaller than the iron tanks, being but 2.95 feet deep and 1.41 feet in diameter. Each is filled with filtering material to the depth of 2.5 feet, which, with the 0.25 foot of gravel at the bottom, makes a total depth of 2.75 feet.

Tanks No. 26 and No. 29 were filled with washed gravelstones that would not go through a sieve having meshes five-eighths of an inch square.

Tanks Nos. 27 and 30 were filled 2.5 feet deep with sand like that of Tank No. 1, and Tanks Nos. 28 and 31 were filled to the same depth with a finer sand like that of Tank No. 19.

The first named in each of these couples was first treated with sewage on April 1, 1890, when nitrification was active in all of the old tanks; and the second of each couple was first treated with sewage on May 27, after each of the first set had been rapidly nitrifying for two weeks. The object was to determine upon what the beginning of nitrification depended, — whether temperature, season of the year, or quantity of stored nitrogen.

When the first series was started, April 1, Tank No. 3A, which was started in January, had been increasing in nitrates for two weeks, having begun when its temperature was at 38° Fah. This is within two degrees of the temperature when all of our tanks, started in the winter, have begun to nitrify. The temperature of the effluent of this series was 46° at the start, but the nitrates did not increase until three or four weeks later, when the temperature was 53°.

This delay in nitrification was not, then, on account of the low temperature, nor was it entirely due to the season of the year; for No. 3A, beginning to nitrify in March, had nitrates 1.0 part in 100,000 ten days to two weeks before this series; and Tanks Nos. 2, 3, 4, 6 and 7 were increasing rapidly in nitrates before this series commenced.

There appears to be required at this very favorable season of the year for nitrification, with temperatures of effluent of about 53°, the accumulation of nitrogenous matter in the filter, or, it may be, an accumulation of nitrifying bacteria throughout the filter, before nitrification begins to increase.

In both series nitrification began a little earlier in the filter of No. 1 sand than in that of the finer sand, and in this a very little earlier than with the gravel. The latter had in each case been washed, and possibly the conditions within the material modified thereby.

Comparing the results obtained with the two series, the latter member of each couple starting eight weeks after the former, we have the following data in each, up to the time when nitrates began to increase rapidly :—

	Number of days after the first Sewage was applied.	Amount of Nitrogen applied in the Sewage. Pounds.	Amount of Nitrogen which came off in the Effluent. Pounds.	Difference, or Amount of Nitrogen stored in the Filter. Pounds.	Temperature of Effluent. Fah.
No. 26, ...	26	0.0023	0.0005	0.0018	54°
No. 29, ...	11	0.0010	0.0001	0.0009	66°
No. 27, ...	22	0.0078	0.0016	0.0062	52°
No. 30, ...	8	0.0030	0.0004	0.0026	61°
No. 28, ...	26	0.0090	0.0020	0.0070	54°
No. 31, ...	8	0.0030	0.0003	0.0027	61°

We see that in the latter series, with the temperature of the effluent at 63°, the number of days after sewage was first applied was between one-half and one-third as many, and the amount of nitrogen stored was between one-half and one-third as much, as in the former series, when the temperature was 53°.

In both cases, and in all other cases, we have found that some stored nitrogen is necessary, before nitrification begins to be active; and that the amount required is less in warm weather than in cold. It may be that the warmer season is also more favorable for the accumulation of nitrifying bacteria. When the conditions for high nitrification are established, we have found the nitrification continues as complete through the cold season as at other times in the year, except in the months when vegetation grows most rapidly, and nitrification is exceptionally high.

After nitrification was well established in these two sets of tanks, — which in the first set was in the middle of May, and in the second the middle of June, — some time was required for the removal of organic matter before they reached an established condition of purification.

In the tanks filled with gravel, the sum of ammonias in the effluent of No. 26 in June was 2 per cent. of those in the sewage, and in July the sum of ammonias of both No. 26 and No. 29 were but one and one-quarter per cent. of those of the sewage. Up to this time the amount of sewage filtered daily was at the rate of 10,000 gallons per acre.

After July 24, the quantity filtered was 20,000 gallons per acre per day, applied in nine hourly portions.

The average results in the month of August were as follows: —

	Free Ammonia.	Albuminoid Ammonia.	Sum of Ammonias.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.
Sewage, ...	2.4228	0.7786	3.2014	9.64	0.0000	0.0000	1,931,000
Effluent No. 26, . . .	0.0075	0.0260	0.0385	9.01	1.4250	0.0008	18,316
Per cent., ...	0.3 of 1	3.	1.	–	–	–	1.
Effluent No. 29, . . .	0.0049	0.0169	0.0218	8.82	1.6625	0.0013	9,923
Per cent., ...	0.2 of 1	2.	0.7 of 1	–	–	–	0.5 of 1

This quality of effluent continued nearly the same through September, with the exception of an increase in albuminoid ammonia of No. 26. In October and November the results were not so good; but, with a continuance of 20,000 gallons of sewage per acre per day, these filters of gravel-stones only two feet and nine inches deep, without having the surface disturbed for eight and seven months, gave effluents containing only four and three per cent. of the organic matter of the sewage, as shown by the sum of ammonias.

Tanks No. 27 and No. 30, of sand like No. 1, 2.5 feet deep, came into a condition of reasonable purification in two weeks and one week respectively, after reaching the most active nitrification. Then their effluents contained about two and one per cent. of the organic matter of the sewage, as shown by the sum of ammonias. But this condition was not permanent, while the equivalent of 40,000 gallons per acre was applied at once on each of six days in the week; and in the third week in July the sum of ammonias of the effluent amounted to near thirty per cent. of those of the sewage; but, by changing the method of application of the sewage to the equivalent of 10,000 gallons four times a day, — on July 24, — the quality of the effluent was immediately improved, and through August and September we have the following excellent results: —

	Free Ammonia.	Albuminoid Ammonia.	Sum of Ammonias.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.
Sewage, ...	2.1764	0.6583	2.8347	7.21	0.0000	0.0000	1,249,000
Effluent No. 27, ...	0.0046	0.0197	0.0243	8.12	1.9125	0.0002	5,705
Per cent., ...	0.2 of 1	3.	0.9 of 1	–	–	–	0.5 of 1
Effluent No. 30, ...	0.0049	0.0112	0.0161	8.78	1.9687	0.0005	582
Per cent., ...	0.2 of 1	1.7	0.6 of 1	–	–	–	0.05 of 1

This was a remarkably good result for 40,000 gallons a day filtering through a depth of 2.5 feet of coarse sand. More than 99 per cent. of the organic matter, and a still larger fraction of the bacteria, were removed by the process of nitrification.

In October the result was not quite so good, as some sewage remained on the surface; but, upon raking over the surface once a week, the effluents again improved to the condition of August and September.

Tanks No. 28 and No. 31, of finer sand, 2.5 feet deep, filtering at the rate of 40,000 gallons per acre per day for six days in the week, purified in July to the extent of removing 99.3 per cent. of the sum of ammonias of the sewage; and, after changing the method of application to four charges daily,—on July 24,—we have the following average results for August:—

	Free Ammonia.	Albuminoid Ammonia.	Sum of Ammonias.	Chlorine.	Nitrates.	Nitrites.	Number of Bacteria per Cubic Centimeter.
Sewage, ...	2.4228	0.7786	3.2014	9.64	0.0000	0.0000	1,931,000
Effluent No. 28, ...	0.0042	0.0168	0.0210	11.84	2.0625	0.0000	70
Per cent., ...	0.2 of 1	2.	0.7 of 1	–	–	–	0.004 of 1
Effluent No. 31, ...	0.0089	0.0150	0.0239	9.41	2.3125	0.0026	62
Per cent., ...	0.4 of 1	2.	0.7 of 1	–	–	–	0.003 of 1

For a short time in October the surface of Tank No. 31 was continually covered with sewage, but after the middle of the month both tanks had their surface raked over once a week, and a condition similar to that of August continues.

It is evident that shallow filters, 2.5 feet deep, require more attention to the condition of the surface than those of greater depth; but the very complete nitrification and removal of organic matter of the past six months show that, with proper care, they may serve a very useful purpose.

INTERMITTENT FILTRATION OF WATER.

The experiments upon the intermittent filtration of water have been continued another year, with interesting results.

With filters of coarse sand, we have filtered intermittently the equivalent of from 200,000,000 to 300,000,000 gallons on an acre, giving an entirely colorless and satisfactory effluent. After these amounts were filtered, the effluent continued to be much improved, but the color was not entirely removed, and gradually increased. Upon reducing the quantity daily filtered, and allowing more air to enter the sand, the color was reduced, as well as the organic nitrogen; and we are seeking the best method of treatment by which the active life of such a filter may be lengthened.

With filters of coarse sand, having a layer of loam, or fine sand, we find the quantity that will pass through is limited; but, with 300,000 gallons a day per acre continued for three years, we have entirely satisfactory results.

Filter Tank No. 8.

This large tank in the field, filled with fine gravel and coarse and fine sand, with a layer of loam eight inches deep, having its upper surface six inches below the top of the filter, has continued, through the year, to filter 1,500 gallons of city water applied daily on six days of the week. This is the equivalent of 300,000 gallons daily per acre for six days in the week.

This filter has been filtering city water constantly for three years, giving an entirely colorless effluent. The total quantity filtered is the equivalent of 206,000,000 gallons on an acre.

The average analysis of the effluent for the year 1890, to the end of November, is as follows: —

Free ammonia, . .	0.0007, or 41 per cent. of that of applied water.
Albuminoid ammonia,	0.0056, or 45 per cent. of that of applied water.
Sum of ammonias, .	0.0063, or 44 per cent. of that of applied water.
Chlorine, . . .	0.17.
Nitrates, . . .	0.0239, or 134 per cent. of that of applied water.
Nitrites, . . .	0.0000.

Number of bacteria per cubic centimeter, 56, or 47 per cent. of the number found in the applied water.

The average analyses for each month, of both city water and effluent, are given in the following table: —

Monthly Averages of Results with Filter Tank No. 8, for 1890.

Date.		Quantity of Effluent. Gallons.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid.	Ammonia. Sum of.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Temperature.	Number of Bacteria per Cubic Centimeter.
1890.												
Dec. 31, '88-Jan. 30, '89, . .	City water,	–	1.15	2.55	.0011	.0105	.0116	.19	.0120	.0000	39°	53
January, . .	Effluent, .	899	.90	2.42	.0004	.0059	.0063	.19	.0230	.0000	39°	6
	Per cent., .	–	78	95	40	56	54	–	192	–	–	–
Jan. 31-Feb. 27,	City water,	–	1.00	2.47	.0015	.0108	.0123	.18	.0150	.0000	36°	175
February, . .	Effluent, .	1,072	.92	2.55	.0009	.0055	.0064	.18	.0205	.0000	36°	17
	Per cent., .	–	92	103	60	51	52	–	137	–	–	–
Feb. 28-Mar. 30,	City water,	–	.95	2.32	.0029	.0125	.0154	.17	.0140	.0000	40°	148
March, . . .	Effluent, .	273	.82	2.60	.0008	.0071	.0079	.17	.0210	.0000	39°	4
	Per cent., .	–	86	112	28	57	51	–	150	–	–	–
Mar. 31-Apr. 29,	City water,	–	1.28	2.54	.0017	.0128	.0145	.16	.0144	.0000	42°	–
April, . . .	Effluent, .	761	.96	2.70	.0010	.0067	.0077	.15	.0286	.0000	45°	9
	Per cent., .	–	75	106	60	52	53	–	129	–	–	–
Apr. 30-May 30,	City water,	–	1.03	2.20	.0013	.0118	.0131	.13	.0175	.0000	51°	–
May, . . .	Effluent, .	971	.80	2.60	.0010	.0059	.0069	.13	.0335	.0000	56°	7
	Per cent., .	–	77	118	77	50	53	–	191	–	–	–
May 31-June 29,	City water,	–	–	–	.0019	.0140	.0159	.13	.0160	.0000	58°	33
June, . . .	Effluent, .	1,129	–	–	.0010	.0066	.0076	.13	.0240	.0000	64°	3
	Per cent., .	–	–	–	53	47	48	–	150	–	–	–
June 30-July 30,	City water,	–	–	–	.0020	.0132	.0152	.20	.0264	.0000	67°	106
July, . . .	Effluent, .	1,267	–	–	.0005	.0044	.0049	.20	.0260	.0000	71°	5
	Per cent., .	–	–	–	25	33	32	–	100	–	–	–
July 31-Aug. 30,	City water,	–	–	–	.0032	.0152	.0184	.22	.0232	.0000	70°	97
August, . .	Effluent, .	1,213	–	–	.0010	.0058	.0068	.22	.0232	.0000	73°	572
	Per cent., .	–	–	–	31	38	37	–	100	–	–	–
Aug. 31-Sept. 29,	City water,	–		–	.0017	.0128	.0145	.18	.0230	.0000	66°	148
September, .	Effluent, .	1,195	–	–	.0005	.0050	.0055	.18	.0218	.0000	68°	3
	Per cent., .	–	–	–	30	39	38	–	95	–	–	–
Sept. 30-Oct. 30,	City water,	–	–	–	.0007	.0127	.0134	.17	.0146	.0000	58°	181
October, . .	Effluent, .	1,036	–	–	.0003	.0036	.0039	.18	.0187	.0000	57°	7
	Per cent., .	–	–	–	43	28	29	–	128	–	–	–
Oct. 31-Nov. 29,	City water,	–	–	–	.0007	.0114	.0121	.16	.0212	.0000	49°	119
November, .	Effluent, .	825	–	–	.0005	.0048	.0053	.18	.0225	.0000	46°	3
	Per cent., .	–	–	–	71	42	44	–	106	–	–	–

The removal of organic nitrogen in the last three months is more complete than in the first three months, and is the same as in the corresponding three months of last year.

The number of bacteria in the effluent, in all but one month, has averaged six per cubic centimeter; and it is probable that none came down through the filter.

The effluent has been, as in the previous years, a clear, bright, colorless spring water.

Filter Tank No. 18^A.

Filter Tank No. 18^A is the iron tank formerly No. 18, which, in July, 1889, was refilled with coarse and fine gravel-stones to the depth of three inches, above which was a depth of five feet of coarse sand like that of Tank No. 1.

From August 13 to September 17, this sand was treated with one gallon or one-half a gallon of water, containing aluminum sulphate on one day, and sodium carbonate the next, by which about nine ounces of alumina was precipitated within the sand and remained there.

After Oct. 5, 1889, no water was applied until Jan. 29, 1890; but from this time the equivalent of 1,000,000 gallons of city water a day, for six days in the week, was applied until the end of October, 1890. The water was applied at hourly intervals, in a little less than one minute, fourteen times a day. It disappeared from the surface immediately.

The color of the applied water was entirely removed until the last of September.

The monthly averages of analyses of the applied city water, and of the effluent, are contained in the following table: —

Monthly Averages of Results with Filter Tank No. 18A.

DATE.		Quantity of Effluent. Gallons.	Color.	RESIDUE ON EVAPORATION.		AMMONIA.			Chlorine.	NITROGEN AS		Temperature.	Number of Bacteria per Cubic Centimeter.
				Fixed.	Loss on Ignition.	Free.	Albuminoid.	Sum of.		Nitrates.	Nitrites.		
1890.													
February, .	City water,	-	.30	1.00	2.47	.0015	.0108	.0123	.18	.0150	.0000	36°	175
February, .	Effluent, .	45	.00	.90	3.08	.0022	.0028	.0050	.18	.0198	Present.	43°	22
	Per cent., .	-	-	90	125	147	26	41	-	132	-	-	-
March, .	City water,	-	.30	.95	2.32	.0029	.0125	.0154	.17	.0140	.0000	40°	148
March, .	Effluent, .	44	.00	.52	2.32	.0022	.0057	.0079	.17	.0177	.0000	44°	246
	Per cent., .	-	-	55	100	76	46	51	-	126	-	-	-
April, .	City water,	-	.35	1.28	2.54	.0017	.0128	.0145	.16	.0144	.0000	42°	-
April, .	Effluent, .	43	.00	.74	2.14	.0014	.0053	.0067	.15	.0204	.0000	49°	139
	Per cent., .	-	-	58	84	82	41	46	-	142	-	-	-
May, . .	City water,	-	.23	1.03	2.20	.0013	.0118	.0131	.13	.0175	.0000	51°	-
May, . .	Effluent, .	44	.00	.70	2.27	.0005	.0067	.0072	.13	.0200	.0000	60°	270
	Per cent., .	-	-	68	103	38	57	55	-	114	-	-	-
June, .	City water,	-	.23	-	-	.0019	.0140	.0159	.13	.0160	.0000	58°	33
June, .	Effluent, .	42	.00	-	-	.0012	.0080	.0092	.13	.0235	.0000	67°	114
	Per cent., .	-	-	-	-	63	57	58	-	147	-	-	-
July, . .	City water,	-	.24	-	-	.0020	.0132	.0152	.20	.0264	.0000	67°	106
July, . .	Effluent, .	44	.00	-	-	.0011	.0068	.0079	.20	.0236	.0012	73°	26
	Per cent., .	-	-	-	-	55	52	52	-	88	-	-	-
August, .	City water,	-	.25	-	-	.0032	.0152	.0184	.22	.0232	.0000	70°	97
August, .	Effluent, .	42	.00	-	-	.0014	.0076	.0090	.23	.0190	.0008	73°	75
	Per cent., .	-	-	-	-	44	50	49	-	82	-	-	-
September,	City water,	-	.28	-	-	.0016	.0134	.0150	.17	.0208	.0000	66°	148
September,	Effluent, .	43	.02	-	-	.0008	.0081	.0089	.18	.0230	Present.	67°	35
	Per cent., .	-	7.1	-	-	50	60	59	-	111	-	-	-
October, .	City water,	-	.28	-	-	.0006	.0120	.0126	.17	.0152	.0000	58°	181
October, .	Effluent, .	41	.08	-	-	.0005	.0086	.0091	.18	.0193	.0000	56°	41
	Per cent., .	-	28	-	-	83	72	72	-	127	-	-	-
Average, .	City water,	-	.27	-	-	.0019	.0129	.0148	.17	.0181	.0000	54°	127
	Effluent, .	43	.01	-	-	.0013	.0066	.0079	.17	.0207	.0000	59°	107
	Per cent., .	-	-	-	-	68	51	53	-	114	-	-	-

During the nine months we see that the nitrates of the effluent have averaged higher than of the applied water by 14 per cent., although there were two months, July and August, when they were lower. The most of the water was, during the day, about three hours in passing through the sand, and this time has been sufficient for satisfactory nitrification to take place, although not so complete nitrification as with Tank No. 8. The free ammonia of the effluent has been 68 per cent. of that of the applied water, and the albuminoid ammonia has been reduced to 51 per cent. of that of the applied water.

The great reduction in the organic nitrogen, as shown by the albuminoid ammonia, and the conversion of this into nitrates, is the important step in purification, and this was much more completely accomplished in the first three months than in those that follow. In the first three months the albuminoid ammonia of the water was reduced from 0.0120 parts to 0.0046 parts, or to 38 per cent., while in the last three months it was reduced from 0.0135 parts to 0.0078 parts, or to 58 per cent. It was evident that, although this filter of very coarse sand, in which had been precipitated a small amount of alumina, had very satisfactorily filtered the equivalent of 234,000,000 gallons of water upon an acre in nine months, it was at that time deteriorating; and the sand will now be subjected to the precipitation, throughout its mass, of another small amount of alumina, to determine whether this is the element which enabled it to give so good results for so long a time.

The Laboratory Work.

The laboratory work at the Lawrence Experiment Station, during the past year, has consisted mainly of the examination of about two thousand samples of sewage, water and sand. A new laboratory building, completed in July, gives greatly improved facilities for work, and includes a well-equipped biological department.

During the year a few changes have been made in the methods of analysis, the most important of which are a greatly improved method of determining nitrates, and a more delicate method of measuring colors. The systematic determination of loss on ignition has been discontinued, and the determination of oxygen consumed from potassium permanganate has been adopted, a long series of experiments, given in the report now being published, having shown that the loss on ignition gives much too high results for organic matter, in presence of the high nitrates of our effluents, even when made with the use of sodium carbonate, and making deduction of the amount that the salts present would lose if quite free from organic matter. This additional loss is due to the fact that, in burning, the organic matter takes a portion of the oxygen, necessary for its combustion, from the nitrates present, reducing them to nitrites and carbonates. The loss in weight thus includes, with the organic matter, the weight of a large portion of the oxygen required for its combustion.

The oxygen consumed shows the relative quantities of oxidizable organic matter, but not its total amount. The comparative results are most satisfactory, being far more regular than the loss on ignition, and in general unaffected by the presence of large quantities of mineral matter.

By the aid of the new nitrate process, it has been found that there is no loss of nitrogen by the nitrification of an ammonia solution applied to sand; and very little, if any, loss in the presence of a large amount of common salt. In the presence of sugar, however, there is a considerable percentage of nitrogen unaccounted for, probably given off as free nitrogen; and it seems probable that the presence of carbonaceous substances, more or less similar to sugar, causes the loss of nitrogen which has been observed in sewage filtration.

The Biological Work.

The biological work of the Lawrence Experiment Station has been steadily continued throughout the year. A systematic and extended examination of the ice supplies of the Commonwealth was concluded early in the year, and forms a portion of a special report to the last Legislature.

During the summer of 1890 an investigation of the public wells of Massachusetts was undertaken, and many important facts were brought to light; but, for the full understanding and final sanitary interpretation of the results already obtained, it will be necessary to continue the work for at least another year.

Special studies of the micro-organisms of sewage have been made during the year, and, in part, brought to a successful conclusion. As a result, a number of important but hitherto obscure organisms have been fully studied, classified and photographed. Our knowledge of the true nature of sewage has thus been advanced, and a step taken which is important and necessary in making much-desired investigations upon the relations of disease germs to sewage.

The necessary preliminary steps have also been taken for a thorough examination of the behavior of the germ of typhoid fever in sewage and in drinking waters; and it is hoped that during the coming year highly important practical conclusions may be arrived at in this very important subject.

By the work of the past year new light has been thrown, also, upon the question of sewage purification, and the disposal of organic waste materials by soils and waters, in an elaborate series of experiments continued since the autumn of 1888 by the biologists and chemists of the Board. It has long been known that micro-organisms are the indispensable agents of this process of nitrification; but it is only within the year that a more intimate and specific knowledge of these organisms and the conditions of their activity have been obtained. During 1890, however, a single worker in France and two in England have announced great advances in this direction. Almost simultaneously the experts of the Board arrived at confirmatory results, the first of the kind obtained, as yet, in America. These results are presented in an appended report by Mr. Jordan.

RAINFALL AND EVAPORATION.

Rainfall and Evaporation.

During the three years in which the experiments upon filtration have been in progress, one of the large tanks in the field has been used to measure the rainfall and the evaporation. This tank is 17 feet 4 inches in diameter at the top, and nearly 6 feet deep. The surface of the water has been kept within 1.25 feet from the top, and has generally been within 0.5 foot from the top.

In winter the ice which formed was cut around the edge sufficiently to free the mass of ice from the sides of the tank, and allow it to float, so that observations upon the height of water would give the true change in quantity. These observations were made with a hook gauge resting upon a bolt in the top of one of the staves of the tank. This gauge, divided to feet and thousandths, was read daily, morning and afternoon. The ice cut around the edge was thrown upon the surface of the mass of ice.

By comparison with the rain gauge kept at the station, and another kept a mile away, the rise in the tank, which indicated the fall of rain or snow, was found on a few occasions in winter to be increased by snow being blown into it. Deduction has been made for this in the following table. The blowing in of snow between storms probably decreased the apparent evaporation slightly; and some particles of ice flying out of the tank, when the ice was cut around the edge every cold morning, probably increased the apparent evaporation to a small extent. These errors would tend to counterbalance one another, and their resulting amount would, as appeared evident at the time, have very little effect upon the total evaporation.

The enlargement of the area of surface of ice exposed to the air, caused by piling the ice chips from the edge upon the mass of ice, may have increased appreciably the evaporation from the ice during the cold months.

The results for each month are given in the following table: —

Rainfall and Evaporation in 1888-89 and 1890.

Date.	Rainfall in Inches.	Evaporation in Inches.	Evaporation in percentage of Rainfall.	Average daily Evaporation in Inches.	Maximum daily Evaporation in Inches.	Average daily Evaporation on days when there was no Rainfall. Inches.	Maximum weekly Evaporation. Inches.
1888.							
January,	4.44	2.45	55	.08	.17	.11	.78
February,	3.83	2.16	56	.07	.22	.09	.94
March,	5.17	3.11	60	.10	.20	.12	.90
April,	3 28	3.23	99	.11	.25	.13	.90
May,	4.14	3.00	72	.10	.18	.13	1.01
June,	2.08	4.94	238	.16	.26	.18	1.55
July,	2.36	5.20	220	.17	.26	.18	1 49
August,	4.55	3.88	85	.12	.19	.14	1.16
September,	7.88	2.52	32	.08	.19	.11	.94
October,	5.86	1.75	30	.06	.16	.08	.62
November,	6.74	1.26	19	.04	.12	.06	.46
December,	4.78	1.09	23	.03	.10	.05	.36
Year,	55.11	34.59	63	.09	–	.12	–
1889.							
January,	5.21	.97	19	.03	.07	.04	.34
February,	1.70	1.74	102	.06	.25	.08	.62
March,	2.68	1.69	63	.05	.10	.06	.58
April,	3.82	2.33	61	.08	.17	.11	.86
May,	4.10	3.58	87	.12	.19	.12	.96
June,	3.13	3.71	118	.12	.26	.19	1.46
July,	7.48	3.49	47	.11	.23	.15	1.03
August,	2.71	3.49	129	.11	.20	.13	1.01
September,	2.78	2.51	90	.08	.17	.11	.71
October,	4.13	1.99	48	.06	.11	.08	.58
November,	6.58	1.07	16	.03	.08	.06	.41
December,	3.32	.90	27	.03	.06	.03	.29
Year,	47.64	27.47	58	.08	–	.10	–
1890.							
January,	3.02	.80	26	.03	.20	.05	.46
February,	3.74	.90	24	.03	.10	.08	.25
March,	6.64	.62	9	.02	.08	.06	.25
April,	1.68	2.26	135	.08	.17	.11	.90
May,	4.78	2.27	48	.07	.19	.13	.86
June,	3.82	4.20	110	.14	.24	.19	1.20
July,	2.15	4.56	212	.15	.30	.21	1 51
August,	5.50	3.62	66	.12	.22	.20	1.20
September,	5.82	2.48	43	.08	.17	.15	.90
October,	8.26	1.40	17	.05	.20	.11	.60
November,	1.63	.96	59	.03	.08	.04	.26
December,	5.39	1.34	25	.04	.18	.06	.49
Year,	52.43	25.41	48	.07	–	.12	–
Mean for three years,	51.73	29.16	56	.08	–	.11	–

The rainfall in each of the three years was above the average, which for twenty-four years was 44.21 inches. That of 1888, of 55.11 inches, was the highest that has ever been observed here; 47.64 inches in 1889 was 3.43 inches above the average, and 52.43 inches in 1890 was 8.22 inches above the average. Although the rainfall in 1888 was 7.5 inches more than in 1889, the evaporation was also 7.1 inches more; but in 1890, with the very heavy rainfall, the evaporation was 2.06 inches less than in 1889. The mean yearly evaporation for the three years was 29.16 inches, and that of the four cold months, January, February, March and December, was 5.98 inches, or six-tenths as much as the average four months of the year.

The maximum daily evaporation was, in June and July, 1888, and in June, 1889, 0.26 inch, and was a little greater, 0.30 inch in July, 1890. The average daily evaporation on days when there was no rainfall was highest in the same months, and amounted to 0.18 inch in 1888, 0.19 inch in 1889, and 0.21 inch in 1890.

In the same months the maximum weekly evaporation amounted to 1.5 inches. The greatest evaporation in one month was 5.2 inches, in July, 1888, and the least was 0.62 inch, in March, 1890.

The average daily evaporation for the three years was 0.08 inch, and the average daily evaporation on days when there was no rainfall was 0.11 inch.

The average daily evaporation in the four months — May, June, July and August — was 0.12 inch, or 50 per cent. more than the average per year.

The care and skill with which the results of experiments have been tabulated and represented by diagrams during the first two years by Mr. Irving G. Green, and during the last year by Mr. Frank L. Fales, are worthy of cordial commendation.

A REPORT

OF THE

CHEMICAL WORK OF THE LAWRENCE EXPERIMENT STATION,

INCLUDING

METHODS OF ANALYSIS,

AND

SOME INVESTIGATIONS OF THE PROCESS OF NITRIFICATION.

By THOMAS M. DROWN AND ALLEN HAZEN.

A REPORT OF THE CHEMICAL WORK OF THE LAWRENCE EXPERIMENT STATION.

The chemical work of the Lawrence Experiment Station has consisted mainly in systematic analyses of the sewage and of the various effluents resulting from the filtration of the sewage through the different media. These results will be found tabulated in the preceding pages.

In connection with the regular routine work, there have been made, from time to time, analyses both chemical and mechanical of the various filtering materials, analyses of the gaseous contents of the tanks, and many other determinations of an allied character which throw light on the nature and efficiency of the intermittent filtration of sewage. Similar work has also been done, but on a much more limited scale, in connection with the filtration of water.

The experiments on the purification of sewage by chemical precipitation were carried out as a special investigation. The record of these experiments will be found in the report of Mr. Hazen on the "Chemical Precipitation of Sewage."

Character of the Sewage.

The study of the changes which sewage undergoes in any process of purification centres itself, from a chemical stand-point, in the determination of the amount and character of the organic matter which the sewage contains in solution and suspension. Sewage may be said in a general way to be water carrying with it less than one per cent. of foreign matters of mineral and organic origin.

The organic matters which give sewage its distinctive character are seldom present in the sewage of cities, with abundant water supply, to the amount of one-tenth of one per cent. Yet it is this small amount of organic matter which, by reason of the putrefactive changes which it is capable of undergoing, makes the sewage repellent to the senses, and gives it, either directly or indirectly, its power of producing disease.*

* The character of the sewage of Lawrence used in these experiments is shown in the table of analyses, on pages 35 and 36, and also on pages 88 to 121.

The organic matter of sewage is of various origin: household wastes, animal and vegetable refuse, human excrement, etc., all in a somewhat advanced state of decomposition. The extent of this decomposition in ordinary sewage is limited by the amount of oxygen in the water which carries it. Sewage as it issues from city sewers contains no dissolved oxygen and no oxidized nitrogen. The available oxygen of the water has all been consumed in the oxidation of a portion of the carbon of the organic matter, and has not sufficed for the oxidation of the nitrogen also. In this condition it is not the excessively repulsive fluid it is popularly supposed to be. Further and complete decomposition can only go on by access of an additional supply of oxygen, which the sewage may take up from the air or from the waters into which it flows.

The Products of Oxidation of Organic Matter.

In the decomposition of nitrogenous organic matter on exposure to oxygen the carbon is first oxidized; this leaves the nitrogen in the form of ammonia, which, under favorable conditions, is still further oxidized into water and nitric acid. It is not intended to be asserted that all the carbon must be oxidized before nitrification can begin; without doubt the two actions often go on co-incidently. But, in general, this order of oxidation is observed, not only where there is a smaller amount of oxygen present than would suffice for the complete decomposition of nitrogenous matter, but also where the oxygen is in excess of that needed for complete decomposition.

Sewage affords a good instance of the decomposition of organic matter arrested in its first stage, with the carbon partially oxidized. The nitrogen of the organic matter is converted into ammonia in direct proportion as the carbon is converted into carbonic acid. In general, therefore, it may be said that ammonium carbonate is characteristic of sewage; or, as expressed in the ordinary method of recording the results of water analyses, "free ammonia" is seen to be the principal ingredient of organic origin in sewage.

When sewage flows into the waters of a stream or lake, there is often an immediate development of nitrites and nitrates which is rendered possible by the presence of oxygen in the waters. But it is when sewage percolates through porous earth that the most favorable conditions for the complete oxidation of the organic matter are found, and it is to the study of the changes which sewage undergoes under such conditions that the chemical work has been mainly directed.

The process of the decay of organic matter, whereby it is converted into inorganic matter through the action of oxygen, is one with which we are all familiar in a general way from personal observation. The two extremes, living organized matter on the one hand and inert mineral matter on the other, are sharply distinguished from each other. A minute study of this process shows it to be one of considerable intricacy, differing in character under different conditions, and involving the formation of a great number of intermediate products. Further, it is well known that these changes are not the result of direct chemical action, but are in some way dependent on the life of micro-organisms. The fact that we often speak of these changes in language inherited from the older chemical notions of direct oxidation, does not imply that this action of the bacteria is overlooked or ignored.

Oxidation of organic matter, such as we have under consideration, does not go on in nature without the presence of these minute organisms, even though the supply of oxygen is unlimited. By chemical means, as in the use of oxidizing agents, such as nitric acid, potassium permanganate and the like, we can break up organic matter and accomplish its partial oxidation. The effect of these oxidizing agents, is, however, limited to the carbon, hydrogen and sulphur of the organic compounds, and does not extend to the nitrogen. Ammonia is invariably formed when nitrogenous organic matter is thus treated. Except when we have the action of nascent oxygen, as in the galvanic decomposition of water, we may say that the oxidation of organic nitrogen requires the presence and vital activity of bacteria.

Chemical analysis as directed to the investigation of the purification of sewage is mainly concerned in the determination of the condition of the nitrogen, as an index of the state and progress of the oxidation of the organic matter. Four forms of nitrogen compounds lend themselves readily to accurate determinations; namely, organic nitrogen (or albuminoid ammonia), ammonia, nitrous acid and nitric acid, this order being that of progressive change from organized to mineral matter. In addition to these substances there have also been determined in the sewage and effluents the turbidity, sediment, color, odor, total solids, loss on ignition and chlorine; occasionally, also, the oxygen consumed from potassium permanganate, the mineral constituent, etc.

Following is a description of the processes employed in these determinations: —

METHODS OF ANALYSIS.*

DETERMINATION OF THE FREE AND ALBUMINOID AMMONIA.

The usual determination of free and albuminoid ammonia is carried out by distilling off from 500 cubic centimeters of the water 150 cubic centimeters in three portions for the free ammonia; then adding 40 cubic centimeters of alkaline permanganate, and distilling off 250 cubic centimeters into 50 cubic centimeter tubes. The condensing pipes are of block tin, three-eighths of an inch internal diameter, which descend vertically through eighteen inches of flowing water in a copper tank. The condensing apparatus, which is fitted with six of these tin tubes, is in general arrangement the same as that described by Prof. S. W. Johnson in the Bulletin No. 10 of the United States Department of Agriculture, Division of Chemistry.†

The condensation of the ammonia in this apparatus is complete. For some time an apparent loss of ammonia was noticed, which seemed to confirm Dr. Smart's statement that from 5 to 15 per cent. of the ammonia might be lost from imperfect condensation. But it was subsequently found in the course of experiments carried on at the station, that the temperature of the water when nesslerized is an important factor in the depth of color produced, cold solutions producing much less intensity of color than warmer solutions with the same contents of ammonia.‡

The equalization of temperature after nesslerization does not bring about the same depth of color. When a distillate is nesslerized directly after condensation with water of much lower temperature than that of the room, the color will be much lighter than that produced from the same amount of ammonia in the standard solution. When care is observed to have the temperature of the distillate the same as that of the standard, it will be found that the ammonia obtained by distillation from water to which a known amount of ammonium chloride has been added is quantitatively accurate.

* The methods employed at the Lawrence Experiment Station are essentially the same as those used in the analyses of natural waters, and given in the first volume of this report. Some modifications of these methods have, however, come into use in the Lawrence laboratory as better adapted to the analysis of sewage and the effluents therefrom.

† Also Jour. Analytical Chem., Vol. IV., p. 179.

‡ See paper "On the Effect of Temperature upon the Determination of Ammonia by Nesslerization," by Allen Hazen and Harry W. Clark, in the Am. Chem. Journal, Vol. 12, p. 425.

In the determination of the free and albuminoid ammonia in the sands of the filtering tanks, and in sewage, it has been found most convenient to place the sand or sewage in a small, long-necked flask, and to pass through it, by means of a glass tube, extending nearly to the bottom of the flask, steam from ammonia free water which is boiled in a flask of a suitable size.* When the ammonia is all driven off, which is always the case in the first distillate of 50 cubic centimeters, alkaline permanganate is added to the small flask, and the distillation continued. The albuminoid ammonia is given off under these conditions much more promptly than when the sewage is diluted as in the ordinary process of water analysis, and bumping is avoided.

Determination of the Organic Nitrogen.

The determination of the total organic nitrogen in the sewage and effluent by the Frankland process has not been attempted, owing to the difficult and tedious nature of the process, and the uncertainty that attaches to the results. The Kjeldahl nitrogen process has been used for this purpose with success, and a large number of determinations have been made, with the object of obtaining, if possible, a factor by which the albuminoid ammonia might be multiplied to convert it into organic nitrogen.† It was not to be expected that, in all the varieties and conditions of the nitrogenous matter which are found in the sewage and sands and effluents, the relation of the albuminoid ammonia to the organic nitrogen would be the same. As the result of many hundred comparative determinations of the albuminoid ammonia and organic nitrogen in natural waters, in sewage and in the effluents, it may be said that the organic nitrogen, calculated as ammonia, is about twice as great as the albuminoid ammonia. This is in general agreement with the yield of nitrogen as ammonia which Wanklyn obtained by his process from albumen.

Determination of the Nitrogen as Nitrates.

The phenolsulphonic acid process of Grandval and Lajoux ‡ has been used for the determination of the nitrates in waters and the effluents

* See paper "On An Apparatus for the Determination of Ammonias in Sand and Sewage," by Allen Hazen, Am. Chem. Journal, Vol. 12, p. 427.

† See Vol. I. of this Report, page 526, also a paper "On the Determination of Organic Nitrogen in Natural Waters by the Kjedahl Method," by T. M. Drown and Henry Martin, Tech. Quarterly, February, 1889; Chemical News, Vol. 59, p. 82.

‡ Comptes Rendus, July 6, 1885.

from the sewage filtration. It consists in treating the residue of evaporation of a measured portion of water with phenolsulphonic acid, and, after dilution with water, adding an excess of alkali. The yellow color produced when nitric acid is present is compared with that obtained by a like treatment of a known amount of potassium nitrate.

Certain precautions must be observed in carrying out this process to ensure good results. The residue of evaporation must not contain organic matter, or iron in sufficient amount to affect the yellow color. The coloring matters of brown surface waters must be removed by treating the water with a very little precipitated and washed aluminum hydrate, or by warming with a little alum and sodium carbonate. Iron salts are also removed by sodium carbonate.

The water is evaporated in a small porcelain dish. The addition of a little sodium carbonate is necessary, otherwise a considerable loss of nitric acid may take place on evaporation.

The amount of phenol dissolved in the sulphuric acid is usually about 5 per cent., but the presence of a larger or smaller amount does not seem to affect the result. It is necessary that the phenol be quite pure. The sulphuric acid must not contain more than 10 per cent. of water, or the results will be too low.

The phenolsulphonic acid is added directly to the residue of evaporation in the porcelain dish. Enough should be added to cover easily and promptly the entire residue. The reaction is complete at once and without warming. Water is added to the dish to dilute the acid, and then an excess of alkali, when if nitrates were present in the water, the yellow color will appear. Either ammonia or fixed caustic alkali can be used for this purpose. Ammonia is of course inadmissible when the operation is performed in a room in which ammonia determinations are made.

Standards for the comparison of the depth of color produced may be made in several ways: Measured quantities of a solution of potassium nitrate may be evaporated under the same conditions as the water to be tested, or, a solution may be prepared by treating a considerable quantity of potassium nitrate with an excess of phenolsulphonic acid, and then diluting largely with water. The use of a solution thus prepared, having a known content of nitrogen, obviates the necessity of evaporation to dryness, the yellow color being produced by the direct addition of alkali.

This yellow color is permanent, and standards protected from dust have been in daily use for months without deterioration. When permanent standards are used, it is desirable to verify them from time to time by the evaporation of measured volumes of potassium nitrate solution as in the first method mentioned. Comparison of color should of course be made in the same bulk. Tubes holding 50 cubic centimeters such as are used for nesslerization of ammonia, have been used.

It is generally stated that the compound formed in this process is picric acid, or trinitro-phenol. This is not the case. The principal product is para-mononitro-phenol with more or less ortho, and possibly a small amount of di- and trinitro-phenols. This is shown to be the case by some experiments with solutions of the different compounds, which there was reason to suppose might be formed in this process, made of such strength that each contained one part per 100,000 of nitrogen. A standard solution was also made of the same strength by treating potassium nitrate with phenolsulphonic acid. The volume of these different solutions required to give equal colors with excess of alkali when compared in 50 cubic centimeters, Nessler tubes, is shown in the following table: —

Comparison of Solutions of Nitro-Phenols.

Standard.	Ortho-mononitro-phenol.	Para-mononitro-phenol.	Dinitro-phenol.	Trinitro-phenol.	Standard.	Ortho-mononitro-phenol.	Para-mononitro-phenol.	Dinitro-phenol.	Trinitro-phenol.
.10	.11	.07	.20	.30	1.0	.80	1.8	3.00	7.00
.20	.20	.13	.40	.70	2.0	1.1	9.0	7.00	15.0
.30	.30	.22	.60	1.10	3.0	1.5	35.0	15.0	30.0
.40	.38	.32	.90	1.60	5.0	1.9	[60.+]	30.0	45.0
.50	.45	.40	1.15	2.10	7 0	2.3	-	45.0	-
.60	.55	.60	1.55	3.00	20.0	5.0	-	-	-
.70	.62	.80	1.90	4.00	50.0	10.0	-	-	-

The standards do not agree with any of the solutions, least of all with the trinitro-phenol solution. They are more deeply colored than either the di- or the trinitro-phenol at any point. The lower standards agree with the ortho-mononitro-phenol, and are lower than the para, while the higher standards are much more deeply colored than the para, but lighter than the ortho compound.

Attempts have been made to so mix these different solutions that the mixture would have the color of the standard solution in all degrees of dilution. These attempts have not been entirely successful. It is very easy to make a mixture which will agree with the standard at any particular point or at a number of points, but there is difficulty in so adjusting it that it will agree at every point. A mixture of 15 per cent. ortho with 60 to 80 per cent. para and the rest di- and trinitro-phenols will not be very far from the standard at any point. It is concluded from this that the yellow color produced is not that of a single compound, but of a mixture of several. It is clear, therefore, that different methods of procedure in this process may give widely differing results, owing to variations in the proportions of the nitro-phenols formed. It is on this account of the highest importance that absolute identity of treatment of the waters and of the standards should be observed. It is also desirable that the amount of water evaporated for this test should contain between .003 to .006 milligrams of nitrogen. Irregularities arising from differences of color are much less within these limits than when larger quantities are used.

Another disturbing element in this process is chlorine, which causes a loss of nitric acid when the residue of evaporation is treated with the phenolsulphonic acid. As a result of an extensive series of experiments on the effluents of the sewage filtration and on solutions containing known amounts of nitrates, it has been satisfactorily settled that the determinations of nitrogen as nitrates in these effluents have been about ten per cent. too low, owing to the presence of 5 to 6 parts of chlorine per 100,000, which was originally contained in the sewage.

This process has now been given up at the laboratory of the experiment station, and replaced by the aluminum process, which gives much more accurate results in our effluents containing much chlorine and comparatively little organic matter.

The process is carried out as follows: A 50 cubic centimeter tube is filled with the water, and an excess (about 2 grams) of aluminum wire is added, with 2 cubic centimeters of a very strong solution of caustic soda, free from nitrogen. It is then allowed to stand over night in a warm place, and a measured portion, usually from 2 to 10 cubic centimeters, removed and made up with distilled water of the same temperature as the ammonia standards to 50 cubic centimeters, and nesslerized. The blank is so small that it can be neglected when 10 cubic centimeters or less is nesslerized. The ammonia carried off by the evolved hydrogen has frequently been caught in a trap, and determined. With 2 cubic centimeters of caustic soda and at temperatures below 30°, the loss will not exceed 2 per cent. in any case. Using too little caustic soda or keeping the tubes at too low a temperature, the nitrate is not all reduced, while with opposite conditions an appreciable amount of ammonia is carried away by the hydrogen. Taking due care as to these conditions, we have obtained very satisfactory results. In calculating the nitrate, deduction is made for the free ammonia and nitrite, but when the ammonia amounts to a considerable fraction of the total nitrogen, it is first removed by boiling with the caustic soda and thoroughly cooled before adding the aluminum. When waters do not give good colors by direct nesslerization it is necessary to distill. This can be most conveniently done indirectly by a current of steam.

Determination of the Nitrogen as Nitrites.

The nitrogen in the form of nitrites is determined by the Griess method essentially as described in the first volume of this report. The practice at the station has been as follows: One cubic centimeter each of an acid-saturated solution of sulphanilic acid and of a saturated solution of napthylamine hydrochlorate are added to 50 cubic centimeters of water, and comparison made of the pink color produced when nitrites are present, with solutions of known amounts of nitrites in pure water. The comparison is made after one hour's standing. A marked pink color is produced by as little as .0001 part of nitrogen as nitrite in 100,000 parts of water.

The Determination of the Residue of Evaporation, and the Loss on Ignition.

The residue of the evaporation of a water to dryness in a platinum dish on a water bath, and drying in an oven at 100° or 110° C. is known as the "total solids" of the water. It includes both mineral and organic matter, and may contain the water of hydration of some salts. When the residue is heated to redness, the organic matter is burned off, and this "loss on ignition" was, before the introduction of modern methods of water analysis, supposed to express the amount of organic matter in the water. It is now known that this loss on ignition as ordinarily obtained is a meaningless determination, although it is still often included in the record of water analyses.

We have endeavored to carry out this ignition of the solid residue of evaporation under carefully controlled conditions, so that it shall express closely the total organic matter in the water, and become a determination of value.

In order to have a reasonably constant temperature of ignition, sufficiently high to burn off all the organic matter and yet not high enough to decompose calcium carbonate, sodium and potassium nitrates, or volatilize the alkaline chlorides, we heat the platinum dish containing the residue, in a radiator, which is another platinum dish enough larger to allow an air space of about half an inch between the dishes. Over the inner dish is suspended a disk of platinum foil, to radiate back the heat into the dish. The larger platinum dish is heated to bright redness by an argand gas burner.*

This procedure answers well with ordinary soft surface waters, but waters with high and varied mineral contents may suffer loss on evaporation (especially when magnesium salts are present), and also in the subsequent heating in the radiator.

To avoid this loss, a known amount of sodium carbonate is added to the solution before evaporation. The lime and magnesia are then precipitated as carbonates, and the acid radicals are all provided with an alkaline base. The solid residue obtained under these conditions does not contain water of crystallization, and the total solids, after deducting the amount of sodium carbonate added, may for this reason be less than would be obtained by the simple evaporation of the water without the addition of the alkali.

The fixed residue obtained represents exactly the anhydrous mineral matter present, for the weight of the sodium carbonate used, and the anhydrous calcium or magnesium salt, is just equal to that of the calcium or magnesium carbonate and sodium salt formed.

This addition of sodium carbonate to the water before evaporation is not new, but the precise effect of its use upon the loss on ignition, in the presence of different mineral compounds, has not been before fully studied.

The following experiments on solutions of various salts (in most cases free from all organic matter) show how far the composition of the mineral salts may affect the determination of the organic matter by the loss on ignition: —

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* See paper on the "Loss on Ignition in Water Analysis," by T. M. Drown, Tech. Quarterly, Dec., 1888, Chem. News, vol. 59, p. 272.

Table showing the Loss on Ignition on Heating the Residue of Evaporation of Various Salts, with and without Sodium Carbonate.

Salts Taken.	Amount Taken. Grams.	Total Solids.	Loss on Ignition.	Fixed Residue.
Distilled water,	100	.0001	.0000	.0001
Distilled water, another sample,	100	.0007	.0002	.0005
Distilled water with sodium carbonate, after deducting the amount added,	100	.0004	.0000	.0004
Sodium carbonate,	.0027	.0032	.0000	.0032
Sodium carbonate,	.0053	.0063	.0002	.0061
Sodium carbonate,	.0133	.0137	.0001	.0136
Sodium carbonate,	.0133	.0135	.0002	.0133
Sodium carbonate,	.0133	.0138	.0001	.0137
Sodium carbonate,	.0250	.0240	.0002	.0238
Sodium carbonate,	.0250	.0262	.0000	.0262
Sodium carbonate,	.0250	.0259	.0002	.0257
Sodium carbonate,	.0265	.0272	.0000	.0272
Sodium carbonate,	.0265	.0270	.0000	.0270
Sodium carbonate,	.0476	.0492	.0002	.0490
Sodium chloride,	.0050	.0058	.0000	.0058
Sodium chloride,	.0250	.0248	.0000	.0248
Sodium chloride,	.0500	.0504	.0003	.0501
Sodium nitrate,	.0212	.0220	.0001	.0219
Sodium nitrate,	.0425	.0430	.0001	.0429
Sodium nitrate with sodium carbonate,	.0212	.0217	.0001	.0216
Potassium sulphate,	.0100	.0102	.0000	.0102
Potassium sulphate,	.0250	.0250	.0000	.0250
Potassium sulphate, with sodium carbonate,	.0100	.0118	.0010	.0108
Potassium sulphate, with sodium carbonate,	.0250	.0266	.0006	.0260
Potassium nitrate,	.0072	.0076	.0000	.0076
Potassium nitrate,	.0144	.0146	.0001	.0145
Potassium nitrate,	.0200	.0204	.0003	.0201
Potassium nitrate,	.0200	.0200	.0002	.0198
Potassium nitrate,	.0361	.0366	.0000	.0366
Potassium nitrate,	.0721	.0719	.0001	.0718
Potassium nitrate with sodium carbonate,	.0072	.0071	.0003	.0068
Potassium nitrate with sodium carbonate,	.0200	.0214	.0009	.0205
Potassium nitrate with sodium carbonate,	.0200	.0209	.0005	.0204
Calcium chloride,	.0101	.0134	-	.0146
Calcium chloride with sodium carbonate,	.0101	.0103	.0000	.0103
Calcium chloride with sodium carbonate,	.0338	.0347	.0003	.0344
Calcium chloride with sodium carbonate,	.0338	.0340	.0003	.0337
Calcium carbonate dissolved in CO_2 water,	.0480	.0492	.0003	.0489
Magnesium chloride,	.0200	.0390	.0290	.0100
Magnesium chloride,	.0200	.0362	.0262	.0100
Magnesium chloride,	.0400	.0742	.0540	.0202

Table showing the Loss on Ignition on Heating the Residue of Evaporation of Various Salts, with and without Sodium Carbonate — Concluded.

SALTS TAKEN.	Amount Taken. Grams.	Total Solids.	Loss on Ignition.	Fixed Residue.
Magnesium chloride with sodium carbonate, . .	.0200	.0211	.0058	.0153
Magnesium chloride with sodium carbonate, . .	.0200	.0209	.0036	.0173
Magnesium chloride with sodium carbonate, . .	.0400	.0392	.0066	.0326
Magnesium chloride with sodium carbonate, . .	.0400	.0435	.0053	.0382
Magnesium carbonate in CO_2 water, ...	.0019	.0030	.0012	.0018
Magnesium carbonate in CO_2 water, ...	.0037	.0062	.0025	.0037
Magnesium carbonate in CO_2 water, ...	.0113	.0136	.0052	.0084
Magnesium carbonate in CO_2 water, ...	.0188	.0219	.0058	.0161
Magnesium carbonate in CO_2 water, ...	.0281	.0352	.0154	.0198
Magnesium carbonate in CO_2 water, ...	.0376	.0427	.0156	.0271
Magnesium carbonate in CO_2 water, ...	.1879	.2485	.0711	.1774
Magnesium carbonate in CO_2 water, ...	.3759	.4670	.1072	.3598
Magnesium carbonate with sodium carbonate, . .	.0188	.0220	.0059	.0161
Sugar, ...	.0050	.0065	.0050	.0015
Sugar with sodium carbonate, ...	.0050	.0067	.0049	.0018
Sugar with .0212 gr., sodium nitrate, ...	.0050	.0267	.0070	.0197
Sugar with .0212 gr. nitrate, and sodium carbonate, .	.0050	.0286	.0092	.0196

It will be seen that with most of the salts there is a slight loss on ignition, ranging from nothing to .0003 gram. Within these limits are included the blank (distilled water) sodium carbonate, sodium chloride, sodium nitrate, potassium nitrate, potassium sulphate, calcium chloride (with soda) and calcium carbonate. With these salts the loss seems to be independent of the nature of the salt and of the amount used. The loss, averaging only .00012 gram for thirty-two determinations, depends rather upon the manipulation than upon any change in the salts.

With potassium nitrate and potassium sulphate with sodium carbonate, the loss is greater. This may be due to the production of potassium carbonate, which is deliquescent. The quantity taken for the last two experiments contained eight or ten times as much potassium as is usually present in 100 cubic centimeters of Lawrence effluent. The loss on ignition found was .0005 and .0009 gram. Taking the average of these two determinations, the probable loss on ignition due to potassium in effluents is .00008 gram.

By far the greatest loss is due to magnesium salts. Without sodium carbonate the loss on ignition is so large that neither the total solids nor fixed residue is an approximation to the weight of the anhydrous salt. With sodium carbonate the loss is very much reduced, but still is much greater than with the other salts. This is owing principally to the loss of carbonic acid, and probably also of combined water from magnesium carbonate. The loss is to some extent proportional to the amount of the magnesia, but is less in presence of sodium carbonate than with magnesium carbonate alone. Since in the determinations of solids there is always an excess of sodium carbonate present, the results obtained with its use need only be considered. These were 69, 43, 40, 32, and 66 per cent. (average 50 per cent.) of the weight of the magnesia present. Nine analyses of Lawrence sewage and effluents have shown from .51 to 1.06 parts magnesia, averaging .74 parts, or in 100 cubic centimeters, .00074 gram. Taking the average loss on ignition due to magnesia as one-half of this, we have .00037 gram.

If we now attempt to apply a correction for the loss on ignition in the Lawrence sewage and effluents based on the above data we have: —

Loss due to manipulation, ...	0.00012 gram.
Loss of water from potassium carbonate, ...	0.00008 "
Loss of carbonic acid from magnesium carbonate, .	0.00037 "
Total, ...	0.00057 "

in 100 cubic centimeters; or 0.57 parts per 100,000.

It is probable that the magnesia is lower in winter than in summer, as the chlorine and other salts are known to be, and so the average winter blank would be smaller, and the summer blank greater than this estimate.

Aside from this, the winter results are more accurate, for the dry air of the laboratory during cold weather is more favorable for accurate weighing.

In water containing organic matter, together with high nitrates, as in the case with our effluents, the organic matter, in burning, takes a portion of the oxygen necessary for its combustion from the nitrates, reducing them to nitrites and carbonates. This loss is shown by the experiments with sugar in the preceding table. The additional loss must be less than the weight of oxygen required to burn completely the organic matter, and so it will probably never exceed the weight of the organic matter, and the total loss corrected for the loss due to the salts themselves will not exceed twice the weight of the organic matter present.

The loss in weight on ignition in the case of sewage and of surface waters which blacken on ignition, may under these conditions be regarded as a close approximation to the organic matter present, both animal and vegetable. In the Lawrence effluents the loss corrected for the average blank gives a maximum limit for the organic matter, and one-half of the corrected loss, as above indicated, may be taken as a minimum limit, keeping in mind, always, the possible error in single determinations.

Determination of the Chlorine.

The determination of chlorine is made by titration with silver nitrate solution, using potassium chromate as indicator. The titrations are made in a porcelain dish, with another dish alongside containing the chromate solution for comparison. A careful study of this process has shown that the results vary with the volume of solution in which the titration is made, the amount of chromate used, and the amount of precipitated silver chloride present.* Within limits, it may be said that the greater the amount of potassium chromate used as indicator, the smaller will be the required excess of silver solution. One milligram per cubic centimeter of liquid titrated — a much larger amount than is generally recommended — has been found advantageous. A correction for volume may be made by applying the formula $X = .003v + .02$ where v is the volume of the liquid at the end of the titration in cubic centimeters, with a silver solution, 1 cubic centimeter of which equals half a milligram of chlorine. Thus, with a volume of 3 cubic centimeters the correction is 0.03 cubic centimers; with a volume of 50 cubic centimeters the correction is 0.17 cubic centimeters. The required excess of silver solution, in addition to the correction for volume, increases regularly with the amount of precipitated silver chloride, and is nearly proportional to the amount of silver solution used.

The correction is about one per cent. of the volume of the silver solution. If the silver solution is standardized against sodium chloride making the correction for volume, it will be of this strength, and no correction will be required for the amount of precipitate. If the amount of chlorine in the solution is very small, the results are

* See paper on the "Determination of Chlorine in Water," by Allen Hazen, Am. Chem. Journal, Vol. XI., p. 409.

somewhat irregular, so that, if less than 1 cubic centimeter of silver solution is required per 50 cubic centimeters of water, it is best to run in 1 cubic centimeter of salt solution, and deduct the equivalent of silver solution from the result. Or, a considerable quantity of the water may be concentrated to a small bulk before titration. In this evaporation, loss of hydrochloric acid can be avoided by the addition of a little sodium carbonate. Commonly, 0.0200 gram or less is sufficient, and this quantity does not interfere with the titration. If too much has been used, calcium nitrate may be added before titration. Chlorine is also frequently determined by using the solid residue of evaporation after ignition. As already described under the determination of solids and loss on ignition, the fixed solid residue is obtained by evaporation of the water, sewage or effluent, with the addition of sodium carbonate, and ignition in a radiator. Under these conditions there is no loss of chlorine, and the residue in the platinum dish treated with hot water and transferred to a porcelain dish gives results which agree perfectly with those obtained from the waters directly, or after evaporation to small bulk.

It has sometimes been necessary to determine chlorine in waters too alkaline for titration in the ordinary way. If phenolphthalein is added, and the pink just discharged with sulphuric acid, the liquid will then contain alkali only as bicarbonate, which does not interfere with the titration.

Acid water must be made neutral by sodium carbonate before titration.

Determination of the Oxygen Consumed.

During the time covered by this report there have been made a large number of determinations of the oxygen consumed on treating the sewage and effluents with a solution of potassium permanganate. The results obtained were in general accordance with the determinations of the nitrogen compounds and the loss on ignition; that is to say, an effluent showing a good purification, as indicated by low free and albuminoid ammonia, low nitrites and loss on ignition and high nitrates, would give a low absorption of oxygen from permanganate.

The oxygen given up by the permanganate combines with the carbon of the organic matter, perhaps, also to some extent with the hydrogen, but not with the nitrogen. Its amount bears some relation, therefore, to the amount of the organic carbon present in the water.

There is a great difference in organic compounds as to their susceptibility to oxidation under these conditions, and caution must be exercised in drawing conclusions as to the quality and amount of organic matter in a water from the amount of the oxygen absorption. Thus, the brown coloring matter of swampy waters, which has very little tendency to undergo decomposition under natural conditions, reduces permanganate largely even in the cold; while, on the other hand, some highly nitrogenous compounds, which decompose readily in solution, are almost without effect on permanganate under similar conditions. The process has its greatest value when used to compare waters or effluents of the same general character and having the same origin.

There are many modifications of the process in general use, the most prominent being the Tidy process, in which the permanganate is used cold, and the Kubel, in which it is used at a boiling temperature. That the results should have comparative value, it is absolutely necessary that the process should always be carried out in the same way, even to the minutest detail of quantity, time and temperature. This is of far more importance than the selection of any one of the many proposed modifications. The present practice at the station is to add the permanganate to the boiling water, with sulphuric acid, and continue the boiling for precisely two minutes, and then add oxalic acid, and finish the titration with permanganate

Determination of the Dissolved Oxygen.

The process of L. W. Winkler * has been used with most satisfactory results. As we have used it, the process is as follows: —

When water is taken from a faucet, a glass-stoppered bottle of known capacity, holding from 50 to 250 cubic centimeters, is filled by means of a tube which passes to the bottom of the bottle. A considerable amount of water is allowed to pass through the bottle and overflow at the top. In taking samples from streams or ponds, a stopper with two holes is used. A tube passing through one of these holes is sunk in the water to the desired depth, and the other is connected with a larger bottle of at least four times the capacity of the smaller one, and fitted in the same way. From the larger bottle the air is exhausted by the lungs or by an air pump until it is nearly filled with water. Unless the determination is to be made

* Berichte, Vol. 21, p. 2843.

at once, the rubber stopper is quickly replaced by the glass stopper in the smaller bottle, so that no air is left in the bottle.

In making the determinations, a small amount of a saturated solution of manganous sulphate is added with a pipette having a long capillary point reaching below the surface of the water, and in the same way a concentrated solution of potassium iodide and hydrate. The glass stopper is now inserted, leaving no bubble of air, and the contents well mixed. Sulphuric acid is then added, preferably after most of the precipitate has settled to the bottom of the bottle. The contents of the bottle are now poured into a flask or other convenient vessel, and the liberated iodine (in amount proportional to the amount of dissolved oxygen in the water) is titrated with thiosulphate.

In calculating the amount of oxygen, allowance must be made for the volume of the reagents used, which should not be more than 1 per cent. of the total volume. If the precipitate had settled, no allowance should be made for the acid used, for the water it displaces contains no oxygen or iodine.

Some determinations of dissolved oxygen in water, saturated by drawing a continuous stream of air through it until a constant result was obtained, agree well with those of Roscoe and Lunt.*

If water is collected in the ordinary way and transferred to the apparatus by pouring, there will inevitably be an absorption of oxygen, unless the water is already saturated. Thus a process which gives excellent results when the water is nearly or quite saturated may fail entirely to give accurate results when the dissolved oxygen is low or absent.†

Winkler's mode of collecting samples by a tube passing to the bottom of the bottle in which the determination is to be made, and allowing several times as much water as the bottle holds to overflow at the top, is the most satisfactory. If this or some similar precaution is not taken, the results will certainly be too high, except in cases where the water is saturated with oxygen.

We have found it advantageous to make dissolved oxygen determinations on the spot. The very simple apparatus required for the Winkler process can be packed in small space, and the entire determination requires only a few minutes. The absorption

* Journal Chem. Soc., 1889, p. 552.

† See paper "On the Determination of Carbonic Acid in Waters," by Allen Hazen, Tech. Quarterly, Vol. III., No. 2.

of the oxygen by the manganous hydrate is complete almost at once, and it is unnecessary to allow it to settle for a long time before adding acid. The titration can be made with a small burette or pipette, with accurate results.

Determination of the Alkalinity.

The determination of the alkalinity of the sewage and effluents is made by titration with twentieth normal sulphuric acid in a porcelain dish, using methyl orange as an indicator; a second dish containing some of the indicator is placed alongside for comparison.

The result is expressed as the number of cubic centimeters of normal acid required to neutralize the alkali in 100 cubic centimeters of water. This is a most convenient notation, for, when multiplied by the equivalent weight * of any substance, it gives directly the parts per 100,000 of that substance equivalent to the number. Thus alkalinity of .090 is produced by $.090 \times 50 = 4.5$ parts calcium carbonate, 50 being the equivalent weight of that substance.

If the water is acid, the same notation is used, but with a negative sign. In this case it is, of course, the amount of normal alkali required to neutralize 100 cubic centimeters of water.

Experiments Designed to Explain the Loss of Nitrogen in the Filtration of Sewage.

In the early part of this volume (see pages 43 and 257) attention was drawn to the fact that all of the nitrogen of the sewage was not accounted for by the nitrogen compounds in the effluent and those remaining in the sand.

In making calculations of this character, it is obvious that the analytical data may be more or less at fault. Inaccuracies may arise first from errors of sampling, and second from errors of analysis. Errors of measurement of sewage and effluent could never have been sufficiently great to deserve consideration.

First. Errors of Sampling. — There is some difficulty in filling a bottle from a tank of sewage so that it shall truly represent the contents of the tank. Some of the suspended matter settles rapidly, and only by very great care in stirring can an average sample be obtained. This source of error is doubtless much reduced where the average of hundreds of samples is taken. Four or five samples

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* Sutton Volumetric Analysis, 5 ed., p. 22.

of sewage have been taken each week, and there seems to be no good reason to doubt that the analysis of these five hundred or more samples represent fairly the average composition of the sewage during the twenty-three months covered by this report.

There is also difficulty in taking a sample of an effluent which shall fairly represent its average composition between samples. There may be considerable variation in the composition of effluents at different parts of the flow. These changes have been studied on numerous series of samples at different times on the same day. It is noticed that the total nitrogen in these samples is much less subjected to change than the individual ingredients, such as ammonia or nitrates; for, in general, as the ammonias increase the nitrates decrease. Only when nitrification is very incomplete is there much variation in the total nitrogen at different periods of the flow. Then the decrease in nitrates is greater than the increase in ammonia. When nitrification is almost complete, as it has been for the greater part of the time, the ammonia when it is highest is quite insignificant on a balance sheet, and there is no appreciable hourly variation in the nitrates.

In the examination of the sand there is difficulty in getting average samples, especially of the upper layers, which contain most of the organic nitrogen. Here, as elsewhere, we depend not upon a few analyses, but upon the average of a large number of samples and the analyses of mixed samples taken from a considerable area.

Second. Errors of Analysis. — The total nitrogen is calculated from four determinations, — free and albuminoid ammonia, nitrates and nitrites. The determination of free ammonia is quite accurate, the usual error is small (not more than 5 per cent.), and about evenly divided above and below the truth.

Nitrites are never present in considerable quantities, and the determination is reasonably exact. The nitrate determinations are a little low, owing to the presence of chlorine. The error from this cause is about 10 per cent. By far the largest single source of error is the determination of organic nitrogen. To make the balance sheet, it is assumed that one-half of the organic nitrogen is obtained as albuminoid ammonia. This factor, as previously stated, is based upon many comparative determinations of albuminoid ammonia and organic nitrogen in the same samples of water and sewage.

It does not seem probable that the loss of nitrogen can be accounted for by any of these sources of error. The error from sampling cannot be, on the whole, very large. The error in the nitrate determinations reduces the apparent loss by 10 per cent. If the albuminoid ammonia should contain two-thirds or even all of the organic nitrogen, there would yet remain a considerable loss. In the hope of obtaining some clue to the cause of this loss of nitrogen in the filters, the following experiments on the nitrification of substances of known composition were tried; namely, ammonium chloride, peptone, and egg albumen.

The ammonium chloride was used on Tank 13, which was filled with coarse sand, and had been for some time in use as a sewage filter. It was in good nitrifying condition, but did not contain a large amount of stored nitrogen. The ammonium salt, together with a suitable amount of alkali, was dissolved in city water. The experiment, the details of which are given on pages 198 to 212, was continued for several months, with the result that the effluent contained in the form of nitrates practically all the nitrogen applied in the form of ammonia. The determination of the nitrates by the phenolsulphonic test, which gives results 10 per cent. too low, indicated about 90 per cent. of the applied nitrogen. In this case errors of sampling and measuring were eliminated, since both the amount and composition of the charge applied were known with great accuracy, and the small amount of organic nitrogen in the city water was quite insignificant. That no loss occurs in the nitrification of ammonium salts under these conditions seems therefore to be proved.

The experiment with the peptone was designed to ascertain if loss of nitrogen might not take place during the first stage of oxidation of organic matter; namely, when ammonia is formed as the result of the oxidation of the carbon. Tank 11 was used for this experiment, which was filled with finer sand than No. 13. The nitrogen in the peptone was carefully determined by the Kjeldahl process. It was applied each day in city water, the solution being made immediately before application. The analyses of the effluent will be found on pages 519–522. In this case, as in that of the ammonia, about 90 per cent. of the nitrogen, as determined by the phenolsulphonic test, was for three months found in the effluent.

It does not follow, from this experiment with a simple soluble substance like peptone, containing its nitrogen mostly in the amido form, that other and more complex organic substances would behave in the same way. Still, it is interesting to know that loss of nitrogen is not a necessary consequence of the nitrification of all organic nitrogenous matter.

The experiment with egg albumen, which was baked and pulverized, and added to the tank in solid form in suspension in city water, was not conclusive. Several accidents happened to the filter in the course of the experiment, which vitiated the results; but there were indications that there was not at least any considerable loss of nitrogen.

Further experiment is necessary to learn the conditions which cause a loss of nitrogen in the sands treated with sewage.

Some Experiments in Nitrification.

A number of experiments have been made from time to time, to determine the influence of various substances in the process of nitrification. An account of some of these experiments is found in the following pages.

The Capacity of Sand to Nitrify Ammonia.

For nearly a year Tank No. 13 had been filtering sewage at the rate of 60,000 gallons per acre daily. Commencing Jan. 14, 1889, at which time it was giving a perfectly nitrified effluent, a solution of ammonium chloride in city water containing 1 part ammonia per 100,000 was substituted for the sewage. With this solution there was mixed just enough sodium carbonate to combine with the chlorine of the ammonium chloride, and also with the nitric acid equivalent to the ammonia ($NH_4 Cl + Na_2 CO_3 + 4O = NaCl + NaNO_3 + 2\, H_2O + CO_2$). From the first, nitrification was complete, the effluent being almost free from ammonia, and containing nearly all of the nitrogen applied as nitrates.

On January 28 the strength of the solution applied was increased to two parts ammonia, and subsequently it was increased from time to time, until on April 22 it contained 34 parts ammonia. The details of the experiment, together with the chemical analyses (and bacterial examinations), are tabulated on pages 198 to 212.

It was always found that, after increasing the dose, complete nitrification was not at once obtained, but the effluent contained ammonia and nitrites for a time. The ammonia first disappears from the effluent, and the nitrites soon follow, with increased development of nitrates. On July 10, the dose, which had been applied in three gallons of water, was applied in one and a half gallons, so that it contained 68 parts ammonia. While applying this strong solution containing many times as much ammonia as is found in the strongest sewage, a nearly complete nitrification was obtained.

Effect of an Excess and Deficiency of Alkali on Nitrification.

An excess of sodium carbonate was added with the dose of No. 13, from July 2 to Aug. 5, 1889. The proportion added was 4 of ammonium chloride to 5 of sodium carbonate. This amount of alkali did not in the least interfere with the nitrification. The excess of sodium carbonate passed through without change, and increased the alkalinity of the effluent.

Commencing October 8, an insufficient quantity of sodium carbonate was added with the ammonium chloride. The proportion added was 4 of ammonium chloride to 3 of sodium carbonate. The first result of this reduction was to cause an almost total stoppage of nitrification. After a little time, however, nitrification began again, but did not become complete, as, indeed, it could not without the presence of free nitric acid in the effluent. This was not the case, for the effluent was always alkaline.

An unexpected result of this treatment was the production of an enormous quantity of nitrites. At times more than one-half of the total nitrogen was in this form. It is not easy to see how lack of base could produce this result, for nitrogen as nitrous acid requires as much alkali for its neutralization as nitrogen as nitric acid.

Effect of Acid upon Nitrification.

Tank 15*A* is a small tank filled with very coarse gravel. In October, 1889, it was in good nitrifying condition, receiving sewage at the rate of 20,000 gallons per acre per day. Commencing October 22, sulphuric acid equal to an alkalinity of 0.46 was added to the sewage. As sewage has an alkalinity of about 0.30, there was an excess of 0.16 of acid. The total amount of acid used was 22.5 parts per 100,000, or 1870 pounds per million gallons. The result of making the sewage acid was a great increase of free ammonia, and a decrease of nitrates in the effluent. The nitrates and nitrites have not, however, completely disappeared even after several months, although the entire mass of the gravel of the tank must be acid. (See table, page 557.)

The actual degree of acidity of the effluent agrees closely with the amount calulated from the quantity of acid added to the sewage.

The amount of nitrates is about one-tenth as much as would probably be formed if no acid was added to the sewage. Nitrites are also present in the effluent. While there is here very incomplete nitrification, the organic matter is reduced in amount, so that there is not very much more in the effluent than there was before the addition of acid.

Effect of Common Salt upon Nitrification.

Tank No. 11 is a small tank filled with sand like that in Tank No. 6. It had been used for sewage filtration, and for the experiments with peptone. Commencing July 2, a solution of ammonium chloride with a suitable amount of sodium carbonate in city water was added. After a month the tank was in good order, and the effluent contained about as much nitrogen as the charge.

On August 8, common salt was added to the charge in such quantity that it contained some 1,200 parts of chlorine per 100,000. It was thus about two-thirds as salt as sea water. Nitrification was checked, and the solution came through almost unchanged.

On August 27, the addition of salt was suspended. During the time that the salt water was being washed out of the tank, large amounts of nitrites were formed.

On September 9, nitrification was again complete. Salt was then again added to the charge, but in much smaller quantity than before. The amount added remained constant until September 25, when a little more was added, and on each succeeding day the amount was slightly increased, until in January, 1890, the solution was nearly saturated. The amount of salt used at any time can be seen from the chlorine of the effluent. (See tables, page 524.) Sea water contains about 1,800 parts chlorine.

The dose of salt at first added did not very seriously interfere with nitrification; and it is quite possible that, if the strength of the dose had been increased more slowly, a better result would have been obtained, with larger amounts of salt. This is indicated by the fact that, with a gradually increasing dose, nitrification continued with more salt than was sufficient to stop it when applied at once, August 8.

It has been noticed that, with incomplete nitrification in presence of salt, large amounts of nitrites are produced.

Effect of Sugar upon Nitrification.

Tank No. 12 is a small tank of coarse sand the same as that used in Tank No. 1, and had been used for the filtration of sewage, egg-albumen and city water. Commencing Oct. 23, 1889, there was applied to it a solution of granulated sugar in city water containing 100 parts per 100,000. The effect of this was to stop nitrification. From the first the greater part of the sugar came through apparently unchanged, and after six weeks the effluent contained three-fourths of the applied sugar.

On December 9, three gallons of sewage were applied daily without any sugar. Nitrification was resumed at once, and became nearly complete; i.e., the effluent contained very little ammonia and 0.8 part nitrogen as nitrate. (See table, page 179.)

Commencing January 1, 10 parts of granulated sugar were dissolved in the sewage, and on the 13th the amount was increased to 20 parts. The effect of this was to reduce slowly the amount of nitrates in the effluent to .08 parts on January 31, without any increase of ammonias. The effluent then contained a very small percentage of the nitrogen of the applied sewage. From this time the nitrates rapidly increased to 1.1 parts on February 28. The effluent contained no sugar, or at least less than 1 per cent. of the amount applied, while in November and December from one-half to three-fourths of all applied came through. It will be noticed that in the first case the sugar was added in solution in the city water supply, in the latter it was dissolved in sewage.

This experiment is not yet carried far enough to determine whether the presence of sugar or similar organic matter has the tendency to cause the loss of nitrogen.

Effect of the Amount of Free Oxygen upon Nitrification.

All the experiments thus far described have been made with filters of such open material that there is an abundance of oxygen in every part. We had found that with continuous filtration there is no nitrification, and there is reason to believe that this is due to the lack of oxygen. Still, the movement of the liquid through the sand is different in continuous and intermittent filtration, and it was thought desirable to make an experiment in which the conditions of descent of sewage should be exactly like those of intermittent filtration, but from which all oxygen should be excluded. It was also desired to find what was the minimum amount of oxygen which would support nitrification. For these experiments Tank No. 14 was used, a small tank filled with sand like that of Tank 1, which had been used for sewage filtration in the ordinary way for about a year.

The bottom of the tank was trapped, and a cover put on the top. The cover was attached to the tank by a mercury seal, which made it air tight, and a pressure gauge was connected with a small faucet. Sewage was put in through a large funnel with a stop cock, so that no air was admitted. A perforated plate distributed it over the surface.

The effluent was free to pass the trap at the bottom, but no air could get back into the tank with any ordinary pressure. The cover was in place February 21, but it was a week before all the small leaks were stopped. During this time 9 gallons of sewage were applied daily, and there must have been a good supply of air from the leaks. When the sewage was put on there was heavy pressure, driving air out, and later, as it drained from the bottom, there was a suction, bringing in fresh air, and nitrification was nearly complete. (See table of analyses, pages 224 to 236.)

On March 1 the tank was shown by the pressure gauge to be perfectly tight, and no new supply of air could get into it. In a week nitrification had stopped, and the effluent was little better than sewage; and this condition continued until March 16, when the cock for admitting sewage was left open, thus ventilating the top of the tank. This proved inadequate. The condition of the effluent did not improve, and on March 27 the cover was taken off. Even this did not afford sufficient air, for the tank was clogged by the organic matter which had not been oxidized during the time that the air was excluded, and two days after removing the cover the air from the middle of the tank contained less than 1 per cent. of oxygen. On April 1 the effluent was no better, and on April 2 half an inch of the accumulated slime was removed from the surface; and, in order to get the tank in good working order as soon as possible, an aspirator was attached to one of the side faucets near the bottom. This drew a gallon of air every four minutes, thus supplying ample oxygen to every part of the tank. With this treatment the effluent rapidly improved, and in two weeks nitrification was again nearly complete. During this time the air of the tank, as shown by two analyses, contained almost as much oxygen as outside air (20.7 and 19.7, instead of 20.9 per cent).

On April 17 the cover was again put on and the aspirator stopped. The oxygen of the air of the tank was rapidly used up, analysis showing on the following days 19.7, 14.3 and 7.4 per cent. oxygen, and on April 25 there was only 0.6 per cent. As soon as the oxygen was exhausted nitrification stopped. The sample collected on the 22d had been one or two days in the tank, and so had been in the sand while some oxygen still remained. But before the next sample was collected, on April 25, nitrification had practically ceased. The small amount of nitrate found was probably formed previously, and was now washed from the tank, for different charges of sewage mix with each other to a very considerable extent.

On April 27 the cock at the top was opened, and the aspirator attached to the faucet near the bottom as before, thus introducing a free supply of fresh air. The amount of sewage applied was reduced to 3 gallons. Nine gallons had proved too large a quantity for these experiments, for the changes were too rapid to be followed easily and accurately. The effluent of April 29 had been collected before the fresh air was brought in, and so represents the previous condition, although collected after the aspirator was started. As before, the tank very quickly recovered itself with fresh air, and nitrification became very high fed by the material stored when the supply of oxygen was cut off. On May 6 the aspirator was removed, and the tank again made air tight. Nitrification continued until all the oxygen was exhausted, and indeed for a short time after that. This suggested that the oxygen in different parts of the tank might not be used up at the same time. Thus, the oxygen at the top of the tank might be first exhausted, and later that toward the bottom. The gas samples were taken from the middle of the tank, and it is possible that, after the oxygen had disappeared from this point, there might yet be a day's supply near the bottom of the tank.

To overcome this difficulty, the aspirator was so arranged that air was drawn from the bottom of the tank and then the same air returned to the top. In this way all the air in the tank was kept thoroughly mixed, while no new air was (theoretically at least) admitted. This arrangement was completed on May 20. It will be seen that, if there is any leakage in the aspirator and its connections, the air of the tank will not be returned, but instead fresh air introduced, and that the entire air of the tank will be changed in a few hours. It will then require a week or more to use up the air. This was what happened several times from May 20 to June 5, when the connections were so securely fastened that for months not a leak occurred. The oxygen was then reduced to 1.7 per cent., and two days later to .8 per cent. It was not our desire to stop nitrification, but to see how little oxygen was capable of supporting it. Fresh air was introduced each day, commencing June 15, by breaking the connection of the aspirator with the bottom of the tank for fifteen minutes. During that time new air was forced into the tank, while its volume of old air came out at the bottom. On June 20 the air coming from the bottom of the tank had 6.5 per cent. oxygen. This was thought to be a larger amount than was necessary for nitrification, and so air was admitted only five minutes daily. This arrangement was continued until August 15. During this time nitrification was nearly complete. No air analysis was made until August 1, when the air coming from the tank had 1.9 per cent. oxygen. On the 8th there was 3.5 per cent., and on the 14th 4.1 per cent. After that air was admitted only three minutes daily, until October 7. Purification continued to be satisfactory. Three air analyses gave, September 4, 1 per cent. oxygen; September 5, 3.3 per cent.; October 7, 1.5 per cent.

From October 7 to November 4, air was admitted only one minute daily. A single air analysis on October 10 gave 1.8 per cent. oxygen. Commencing November 4, no air was admitted, but the aspirator was still run to keep the air mixed. Nitrification continued to be nearly complete, and the air of the tank contained oxygen. On November 15, there was 3.1 per cent., and on November 27, 9.9 per cent. This oxygen must have come from the city water supply running through the aspirator. When gas containing little oxygen (as the gas in the tank) is brought in contact with water saturated or nearly saturated with oxygen, it will take a portion of the oxygen from the water.

In the summer the dissolved oxygen in the city water was low, but in the fall it rapidly increased, until during the last weeks of this experiment it was fully saturated. The air of the tank was brought in intimate contact with city water eight or ten times a day, and obtained from it enough oxygen to completely oxidize the three gallons of sewage. This makes it clear why the amount of oxygen in the air of the tank did not decrease as less fresh air was admitted. It was getting more oxygen every day from the city water as that became more nearly saturated. On December 7 the aspirator was taken off, and soon after nitrification was checked and ultimately stopped.

Résumé.

By intermittent filtration, a solution of ammonia with its equivalent of sodium carbonate is converted into sodium nitrate without appreciable loss of nitrogen. This change will take place with solutions containing many times as much ammonia as sewage. A slightly increased amount of soda does not affect the result, but with an insufficient quantity of alkali nitrification is incomplete, and the effluent contains ammonia and nitrites, the latter often in large quantity. When sewage is made slightly acid, nitrification is almost stopped; still, a small amount of both nitrates and nitrites are formed. Oxidation of the organic matters is not stopped by acid, although it may be checked to some extent.

Common salt interferes with nitrification only when present in large quantity. By gradually increasing its amount, nitrification takes place in presence of as much salt as would prevent nitrification if it were applied at once to a filter which had not previously had salt.

Sugar interferes with nitrification, but it is not yet clear whether there is a loss of nitrogen during nitrification in presence of sugar.

No nitrification (or purification of sewage) can take place by filtration if the air in the pores of the filter contains no oxygen. A small amount of oxygen (1 to 3 per cent.) in the air of the filter is as effective, or very nearly so, as a larger quantity, provided the air is changed so often that some oxygen is always present at every point.

REPORT OF EXPERIMENTS

UPON THE

CHEMICAL PRECIPITATION OF SEWAGE

MADE AT THE

LAWRENCE EXPERIMENT STATION

During 1889.

By ALLEN HAZEN,
Chemist in charge at the Station.

THE CHEMICAL PRECIPITATION OF SEWAGE.

Sewage, as it is found in our city sewers, contains a great variety of substances. Among its principal ingredients are urine and fæces, together with wasted food and wash water. This is diluted with a large amount of water, and in rainy weather, there is in addition a large amount of street washings, which consist of sand from pavements, and organic refuse of various kinds. With the separate system of sewerage, the street washings and rain water would be excluded, so that all the sewage would be like that which is now found in dry weather.

Of this mixed sewage, a portion, the inorganic matter, consisting of sand and various salts, is, from a sanitary point of view, quite harmless. Another portion, the organic matter, furnishes abundant food for bacteria, always present in great numbers. To remove this organic portion is the great problem in purification.

If sewage is allowed to stand for a few hours, a portion of the organic matter will settle out; but the greater part is either too finely divided to separate in a moderate length of time, or is in solution. By adding certain chemicals to the sewage, an inorganic precipitate is formed, which settles rapidly, and carries with it nearly all of the suspended matter, and also a portion of the dissolved matter. This is the *chemical precipitation of sewage*. Nothing definite is known of the chemistry of the process which makes insoluble a portion of the dissolved organic matter, but it is probably similar to the use of mordants in dyeing for fixing soluble colors.

Substances Commonly Used for Chemical Precipitation.

The substances best adapted and most commonly used for chemical precipitation are lime, and the salts of aluminum and iron.

Lime, containing 70 per cent. available calcium oxide, can be bought for $9 a ton. Ferrous sulphate or copperas, containing

26 per cent. of ferrous oxide, costs $10 a ton. Aluminum sulphate or crude alum, containing 14 per cent. of alumina, costs $25 a ton. A ferric salt can be made by oxidizing copperas with chlorine, or with sulphuric acid and nitrate of soda.

The approximate cost of these oxides in solution is as follows: —

Aluminum oxide, ...	9 cents per pound.
Ferric oxide, ...	3 cents per pound.
Ferrous oxide, ...	2 cents per pound.
Calcium oxide, ...	$\frac{3}{8}$ of a cent per pound.

Using these figures, the cost of chemicals has been calculated for the different experiments. One hundred gallons of sewage daily for each inhabitant is assumed in calculating the annual cost.

It seems altogether probable, considering the cheapness of the materials from which they are prepared, that the cost of both crude alum and ferric sulphate, or the corresponding chlorides, might be materially decreased from the prices given, in case there should be a considerable demand for them. Lime and copperas have already a large sale, and could not probably be obtained at lower prices by an increased consumption.

I have endeavored, in the following-described experiments, to determine, first, the best method of using each chemical substance, and to establish, if possible, some relation between the composition of the sewage and the amount of precipitant which will give the best result, or as good a result as a larger quantity; and, second, to compare the effect of equal values of the different precipitants upon the same sewage, after finding, by the first experiments, how to use each with the greatest advantage. The experiments also give an idea of the amount of matter which can be removed by chemical precipitation under favorable circumstances. The observations have been confined to the composition of the sewage and of the effluent, neglecting the sludge altogether.

Experiments Made in Large Tank.

The first experiments were made in a tank 45 feet long, 30 inches wide, and 10 to 12 inches deep, holding about 700 gallons. As the sewage came by gravity through a trough, chemicals in solution were allowed to run in, and to become thoroughly mixed with it. The sewage then ran from the trough to the tank, where it was allowed to settle. A portion of the sewage was diverted into a smaller tank before mixing with chemicals, and allowed to settle for the same length of time. In one experiment, on June 1, when the tank was full, it was allowed to overflow at the other end from that at which the sewage entered, the sewage with the chemicals flowing in continuously. In this way the average length of time for the sewage to settle in passing through the tank was 90 minutes. In the other experiments, the inflow of sewage was stopped when the tank was filled, and the time of settling reckoned from the time when the tank was full. The results of these experiments are as follows: —

Results of Experiments in Large Tank.

[Parts per 100,000.]

	Settled, Hours.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Bacteria per Cubic Centimeter.
Original sewage, May 1, 1889,	–	54.0	26.4	27.6	2.20	.93	4.58	liquefied.
Filtered through paper,	–	38.0	15.2	22.8	2.20	.37	–	–
Lime water used,	–	150.0	4.4	145.6	1.80	.19	3.83	5
Effluent with lime water equal to 1,000 pounds of lime per 1,000,000 gallons,	20	56.8	18.0	38.8	1.60	.35	4.58	11,328
Original sewage, May 3,	–	42.8	17.4	25.4	2.59	.56	5.14	1,185,600
Filtered through paper,	–	34.6	12.4	22.2	2.60	.29	–	–
Sewage after settling,	22	35.6	9.8	25.8	2.29	.33	5.68	1,518,000
Lime water used,	–	214.0	23.0	191.0	2.10	.29	5.35	7
Effluent with lime water equal to 2,000 pounds of lime per 1,000,000 gallons,	3	48.2	12.6	35.6	2.12	.34	4.84	6,026
	4½	49.2	12.2	37.0	2.19	.43	4.98	5,820
	22	46.4	11.2	35.2	1.75	.19	4.97	10,404
Original sewage, May 7,	–	58.1	34.2	23.9	3.15	.63	4.09	7,854
Filtered through paper,	–	31.2	10.2	21.0	2.82	.33	–	–
Sewage after settling,	4	44.8	23.0	21.8	1.90	.32	4.04	–
Sewage after settling,	22	43.2	17.8	25.4	2.63	.32	3.98	–
Effluent with 2,000 pounds of lime per 1,000,000 gallons,	4	50.2	15.2	35.0	1.84	.30	4.90	7,301
	22	48.6	15.6	33.0	1.78	.34	4.49	8,720
Original sewage, May 9,	–	55.2	26.2	29.0	2.37	.59	5.48	–
Filtered through paper,	–	43.6	16.8	26.8	2.38	.34	–	–
Sewage after settling,	4	45.6	15.0	30.6	2.47	.23	8.31	–
Sewage after settling,	22	41.0	13.8	27.2	2.40	.36	8.23	–
Effluent with 2,000 pounds of lime per 1,000,000 gallons,	4	46.0	11.2	34.8	2.02	.34	4.55	24,486
	22	49.6	14.4	35.2	1.88	.26	4.97	51,874
Original sewage, May 14,	–	50.0	26.0	24.0	2.52	.54	4.45	–
Filtered through paper,	–	36.2	12.8	23.4	2.44	.28	–	–
Sewage after settling,	27	40.4	14.8	25.6	1.96	.37	4.30	–
Effluent with 1,600 pounds of lime per 1,000,000 gallons,	27	51.0	15.4	35.6	2.40	.41	5.00	12,410,0[illegible]

Results of Experiments in Large Tank—Concluded.

	Settled, Hours.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Bacteria per Cubic Centimeter.
Original sewage, May 16,	-	43.8	21.0	22.8	1.84	.44	4.12	390,600
Filtered through paper,	-	40.0	16.4	23.6	1.80	.22	-	-
Sewage after settling,	20	35.8	14.4	21.4	1.92	.22	4.30	511,500
Lime water used,	-	225.8	15.0	210.8	1.76	.25	5.06	3
Effluent with 2,100 pounds of lime per 1,000,000 gallons,	20	61.8	17.2	44.6	1.88	.30	5.30	2,898
Original sewage, 11.45 A.M., June 1,	-	45.2	18.8	26.4	2.36	.60	6.81	-
Filtered through paper,	-	42.8	16.8	26.0	2.40	.27	-	-
Effluent with 5,000 pounds alum per 1,000,000 gallons,	1½	43.0	16.4	26.0	2.00	.39	6.77	-
Original sewage, 2 P.M., June 1,	-	55.6	22.2	33.4	1.72	.55	11.70	-
Filtered through paper,	-	50.4	15.8	34.6	1.80	.29	-	-
Effluent with 500 pounds of alum and 800 pounds of lime per 1,000,000 gallons,	1½	51.2	12.6	38.6	1.60	.34	6.72	-
Original sewage, June 14,	-	53.6	23.2	30.4	2.00	.40	4.85	-
Filtered through paper,	-	42.6	17.2	25.4	2.04	.09	-	-
Sewage after settling,	1	34.4	11.6	22.8	2.48	.38	5.61	-
Effluent with 500 pounds copperas and 600 pounds of lime per 1,000,000 gallons,	1	39.2	9.2	30.0	2.52	.31	4.30	-
Original sewage, June 18,	-	58.2	28.8	29.4	2.28	.51	7.70	-
Filtered through paper,	-	46.4	20.8	25.6	2.36	.35	-	-
Sewage after settling,	1	51.2	21.6	29.6	2.44	.46	7.03	-
Effluent with 500 pounds of alum and 700 pounds of lime per 1,000,000 gallons,	1	62.6	23.0	39.6	2.24	.38	6.26	-

Summary of Results in the Large Tank.

Date.	Chemicals per 1,000,000 gallons.	Settled, Hours.	Organic Matter removed, Per Cent.	
			Loss on Ignition.	Albuminoid Ammonia.
May 1,	1,000 pounds of lime,	20	32	62
May 3,	2,000 pounds of lime,	3	38	39
May 7,	2,000 pounds of lime,	4	56	52
May 9,	2,000 pounds of lime,	4	57	43
May 14,	1,600 pounds of lime,	27	41	25
May 16,	2,100 pounds of lime,	20	18	32
Average,	1,800,	-	40	42
June 1,	500 pounds of alum,	1½	13	35
June 1,	500 pounds of alum and 800 pounds of lime,	1½	43	38
June 18,	500 pounds of alum and 800 pounds of lime,	1	20	26
June 14,	500 pounds of copperas and 600 pounds of lime,	1	60	22

Experiments in Barrels.

While this method of precipitation in a large tank approaches in many ways more closely than any other to a sewage plant on a large scale, it did not prove satisfactory for the end that we had in view, i. e., comparative results with the same sample of sewage. Since the composition of the sewage is constantly changing, there was not only a great difference between the sewage of different days, but also between the different portions of sewage required to fill the same tank. It was thus impossible to compare strictly the effluent with the original sewage; for the chlorine shows that in almost every case the sample of sewage taken for analysis does not represent exactly the same sewage that the effluent does. Moreover, it is evidently unfair to compare the effect of different chemicals upon different sewages, unless, indeed, the average of a large number of experiments upon similar sewage, by each process, is taken. To work out in this way the problems which it was hoped to solve, seemed almost impossible.

It was decided that the only way to get entirely satisfactory results was to make several parallel experiments on the same sample of sewage. To accomplish this, barrels were set so that they could be filled from one of the sewage tanks. The tank was filled with sewage and thoroughly mixed, and, while it was still being stirred, the barrels were filled from it and chemicals added as desired. One barrel was left to settle without chemicals, for comparison. It is possible, in this way, to get several comparable results. The barrels were 30 inches high, and held about 50 gallons each. As the capacity of each was accurately known, it was easy to compute the amount of precipitant for each barrel, at any desired amount per 1,000,000 gallons.

The sewage in each barrel was thoroughly mixed with the chemicals, and allowed to settle. A sample of the effluent above the sludge was then drawn from a tap about 10 inches from the bottom, first letting it run freely for a minute, so that the sample fairly represented the contents of the barrel, above the very thin layer of sludge.

The results obtained in this way, during May and June, and also one series Sept. 25, and one Oct. 1, 1889, are as follows:—

Results of Experiments in Barrels (May 21–Oct. 1, 1889).

[Parts per 100,000.]

	Settled, Hours.	Turbidity.*	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Bacteria per Cubic Centimeter.
Original sewage, May 21,	–	.80	58.6	22.0	36.6	1.16	.38	3.40	706,800
Filtered through paper,	–	–	33.2	12.0	21.2	1.04	.14	–	–
Sewage after settling,	1	.60	49.6	16.4	33.2	1.16	.25	3.40	553,800
Effluent with 8,000 pounds of lime per 1,000,000 gallons sewage,	1	.05	248.0	13.4	234.6	1.16	.25	4.22	3
Effluent with 500 pounds of copperas,	1	.60	49.6	14.0	35.6	1.00	.30	3.47	79,000
Effluent with 500 pounds copperas and 500 pounds lime,	1	.11	41.4	11.4	30.0	1.12	.11	3.57	8,487
Original sewage, May 23,	–	.50	54.8	23.6	31.2	1.80	.45	4.12	
Filtered through paper,	–	–	35.8	12.8	23.0	1.76	.16	–	–
Effluent with 500 pounds of alum,	2	.30	39.8	13.4	26.4	1.72	.31	4.30	–
Effluent with 500 pounds of lime,	2	.25	46.4	15.2	31.2	1.56	.26	4.24	–
Effluent with 500 pounds of alum and 500 pounds of lime,	2	.14	44.6	14.0	30.6	1.80	.22	4.20	–
Original sewage, May 24,	–	.67	57.2	25.6	31.6	1.92	.71	7.50	–
Filtered through paper,	–	–	44.2	16.0	28.2	1.96	.34	–	–
Sewage after settling,	1	.40	48.2	19.8	28.4	1.84	.59	7.42	–
Effluent with 500 pounds of alum and 500 pounds of lime per 1,000,000 gallons sewage,	1	.11	52.0	13.6	38.4	1.92	.29	7.35	–
	2	.08	51.2	13.2	38.0	1.52	.41	7.36	–
Effluent with 500 pounds of copperas and 500 pounds of lime,	1	.17	54.8	16.0	38.8	1.52	.36	7.32	–
	2	.15	51.4	13.0	38.4	1.56	.35	7.34	–
Original sewage, May 31,	–	.33	50.4	21.6	28.8	2.60	.64	8.08	1,125,600
Filtered through paper,	–	–	43.0	15.8	27.2	2.60	.27	–	
Sewage after settling,	1	.26	43.4	15.0	28.4	2.80	.35	8.07	5,632,000
Effluent with 500 pounds of alum,	1	.15	57.2	19.4	37.8	2.60	.32	8.07	890,400
	2	.13	45.4	15.2	30.2	2.52	.30	8.04	453,900
Effluent with 500 pounds of alum and 500 pounds of lime,	1	.17	57.6	18.0	39.6	2.52	.42	8.08	2,702,200
Original sewage, June 6,	–	.60	77.2	35.6	41.6	2.12	.76	6.12	–
Filtered through paper,	–	–	42.4	15.6	26.8	2.00	.30	–	–
Sewage after settling,	1	.30	49.4	21.8	27.6	2.08	.43	6.12	–
Effluent with 120 pounds of ferric oxide as ferric sulphate,	1	.19	40.4	13.2	27.2	2.00	.34	6.24	–
Effluent with 120 pounds of ferric oxide and 700 pounds of lime,	1	.16	51.0	12.0	39.0	1.92	.28	6.46	–
Original sewage, June 7,	–	.50	56.4	23.2	33.2	2.12	.73	6.21	–
Filtered through paper,	–	–	40.8	13.2	27.6	2.18	.23	–	–
Effluent with 500 pounds of copperas and 700 pounds lime,	1	.11	53.0	13.2	39.8	1.96	.33	6.21	–
Effluent with 500 pounds of alum and 700 pounds of lime,	1	.12	58.4	16.0	42.4	2.00	.36	6.24	–
Effluent with 120 pounds of ferric oxide and 700 pounds of lime,	1	.12	53.6	13.2	40.4	2.00	.34	6.34	–

* One divided by the number of inches of material through which a small platinum wire can be seen.

Results of Experiments in Barrels (May 21–Oct. 1, 1889) — Concluded.

[Parts per 100,000.]

	Settled, Hours.	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Bacteria per Cubic Centimeter.
Original sewage, June 12,	–	.67	80.4	40.2	40.2	2.28	.64	7.52	–
Filtered through paper,	–	–	44.4	17.6	26.8	2.08	.28	–	–
Sewage after settling,	1	.40	50.2	20.2	30.0	2.60	.45	7.59	–
Effluent with 700 pounds of lime,	1	.23	53.2	15.0	38.2	2.40	.39	7.40	–
Effluent with 500 pounds of copperas and 700 pounds of lime,	1	.18	52.6	11.4	41.2	1.88	.39	7.71	–
Original sewage, June 13,	–	.67	52.0	25.8	26.2	1.84	.50	5.96	–
Filtered through paper,	–	–	42.0	18.0	24.0	1.88	.21	–	–
Sewage after settling,	1	.28	46.4	18.2	28.2	1.88	.32	5.96	–
Effluent with 120 pounds of ferric oxide and 700 pounds of lime,	1	.18	45.8	9.8	36.0	1.92	.33	6.00	–
Effluent with 120 pounds of ferric oxide precipitated with 100 pounds of lime before adding to the sewage,	1	.28	41.0	11.8	29.2	2.00	.38	6.01	–
Original sewage, June 17,	–	.67	58.2	32.4	25.8	2.48	.69	5.38	–
Filtered through paper,	–	–	42.6	19.4	23.2	2.48	.31	–	–
Sewage after settling,	1	.50	52.6	26.6	26.0	2.00	.62	5.40	–
	2	–	50.0	23.6	26.4	2.56	.64	5.40	–
Effluent with 500 pounds of copperas and 700 pounds of lime,	1	.17	54.4	17.2	37.2	2.24	.45	5.38	–
	2	–	54.2	16.6	37.6	2.24	.35	5.41	–
Original sewage, June 21,	–	.50	67.0	44.4	22.6	2.90	.68	5.30	–
Filtered through paper,	–	–	39.2	18.8	20.4	2.80	.38	–	–
Sewage after settling,	1	.33	53.2	29.8	23.4	2.92	.51	5.37	–
Effluent with 670 pounds of lime,	1	.12	50.0	26.8	23.2	2.36	.35	5.21	–
Effluent with 120 pounds of ferric oxide,	1	.25	39.6	15.2	24.4	2.88	.61	5.31	–
Original sewage, Sept. 25,	–	.40	47.2	24.4	22.8	2.00	.64	4.80	–
Filtered through paper,	–	–	34.4	12.4	22.0	2.00	.46	–	–
Sewage after settling,	1	.30	40.8	16.4	24.4	2.00	.60	4.77	–
Effluent with 650 pounds of lime,	1	.20	47.2	16.0	31.2	1.94	.62	4.77	–
Effluent with 1,300 pounds of lime,	1	.10	52.4	14.4	38.0	1.94	.32	4.76	–
Effluent with 2,000 pounds of lime,	1	.10	57.2	18.4	38.8	2.00	.38	4.82	–
Effluent with 650 pounds of lime and 250 pounds of alum,	1	.17	51.2	17.2	34.0	2.00	.34	4.77	–
Effluent with 650 pounds of lime and 500 pounds of alum,	1	.14	45.6	12.0	33.6	1.94	.36	4.73	–
Effluent with 650 pounds of lime and 1,000 pounds of alum,	1	.07	41.6	9.6	32.0	1.94	.34	4.87	–
Original sewage, Oct. 1,	–	.55	52.2	20.2	32.0	1.70	.51	8.72	–
Filtered through paper,	–	–	45.4	14.0	31.4	1.70	.28	–	–
Sewage after settling,	1	.38	48.8	16.4	32.4	1.75	.43	8.65	–
Effluent with 650 pounds of lime,	1	.28	55.6	16.0	39.6	1.75	.34	8.50	–
Effluent with 2,000 pounds of lime,	1	.10	54.4	10.8	43.6	1.60	.27	8.22	–
Effluent with 500 pounds of copperas,	1	.35	51.6	18.4	33.2	1.70	.45	8.66	–
Effluent with 250 pounds of copperas and 650 pounds of lime,	1	.22	46.8	13.6	33.2	1.70	.35	8.42	–
Effluent with 500 pounds of copperas and 750 pounds of lime,	1	.16	51.0	12.0	39.0	1.80	.25	8.29	–
Effluent with 1000 pounds of copperas and 800 pounds of lime,	1	.12	51.4	10.4	41.0	1.70	.23	8.32	–

Per Cent. of Organic Matter Removed after Settling for one Hour with,—

Date.	Without Chemicals.		700 Pounds Lime.		500 Pounds Alum.		500 Pounds Alum and 700 Pounds Lime.		500 Pounds Copperas		500 Pounds Copperas and 700 Pounds Lime.		120 Pounds Ferric Oxide as Ferric Sulphate.		120 Pounds Ferric Oxide and 700 Pounds Lime.	
	Loss on Ignition.	Albuminoid Ammonia.	Loss on Ignition.	Albuminoid Ammonia.	Loss on Ignition.	Albuminoid Ammonia.	Loss on Ignition.	Albuminoid Ammonia.	Loss on Ignition.	Albuminoid Ammonia.	Loss on Ignition.	Albuminoid Ammonia.	Loss on Ignition.	Albuminoid Ammonia.	Loss on Ignition.	Albuminoid Ammonia.
May 21, .	26	34	-	-	-	-	-	-	36	21	48	71	-	-	-	-
23, .	-	-	36	42	43	31	40	51	-	-	-	-	-	-	-	-
24, .	23	17	-	-	-	-	47	59	-	-	38	49	-	-	-	-
31, .	30	45	-	-	10	50	17	34	-	-	-	-	-	-	-	-
June 6, .	39	43	-	-	-	-	-	-	-	-	-	-	63	55	66	65
7, .	-	-	-	-	-	-	31	51	-	-	43	55	-	-	43	54
12, .	50	30	64	39	-	-	-	-	-	-	71	39	-	-	-	-
13, .	30	36	-	-	-	-	-	-	-	-	-	-	-	-	62	34
17, .	18	10	-	-	-	-	-	-	-	-	47	35	-	-	-	-
21, .	33	25	40	49	-	-	-	-	-	-	-	-	66	11	-	-
Sept. 25, .	33	7	35	3	-	-	51	44	-	-	-	-	-	-	-	-
Oct. 1, .	19	16	21	34	-	-	-	-	-	-	40	51	-	-	-	-
Average,	30	26	39	33	27	40	37	48	36	21	48	50	64	33	57	51

Summary of Results of Barrel Experiments to Oct. 1, 1889.

	Cost for Chemicals per Inhabitant Annually.	Number of Experiments.	Per cent. Loss on Ignition Removed.	Per cent. Albuminoid Ammonia Removed.
Sewage after settling, ...	$0.00	10	30	26
Effluent with 700 pounds of lime, ...	.11	5	39	33
Effluent with 500 pounds of alum, ...	.23	2	27	40
Effluent with 500 pounds of alum and 700 pounds of lime, .	.34	5	37	48
Effluent with 500 pounds of copperas, ...	.09	1	36	21
Effluent with 500 pounds of copperas and 700 pounds of lime,	.20	6	48	50
Effluent with 120 pounds of ferric oxide, ...	.13	2	64	33
Effluent with 120 pounds of ferric oxide and 700 pounds of lime, ...	.24	3	57	51

These results, while agreeing in the main with those that follow, cannot be regarded with the same confidence as the others which are more fully discussed. Owing to limited opportunities for analytical work during May and June, only two or three experiments were made on one day, and the analyses were not usually made until the following day. There was thus a very considerable source of error, for sewage decomposes with great rapidity on standing.

Experiments to Determine the Efficiency of the Different Chemicals.

Commencing Oct. 2, 1889, a series of experiments was made, to determine more definitely the most suitable proportion of the various chemicals, and their respective merits. These experiments were made in barrels, as has already been described, and the determinations of those substances which were liable to change were made in every case within two or three hours after the collection of the samples.

The time of settling has been uniformly one hour. A slightly better result would be obtained by waiting longer before taking the samples; but a few experiments have indicated that the difference between one and four hours' settling is very slight, and, in comparative experiments, the advantage of making the experiments and completing the chemical analysis on the same day (thus avoiding change by putrefaction) is very great. It is also thought that an hour's settling in a tank thirty inches deep may be equivalent to two or three hours' settling in a tank six feet deep.

As the methods of analysis used for these experiments differ somewhat in detail from those used for waters, it may be well to mention here the processes employed.

The organic matter of sewage is in a state of rapid change, and very different results for loss on ignition and albuminoid ammonia will be obtained from the same sample, if it be examined at different intervals of time after collection. The addition of the chemicals used for precipitation removes in many cases a large portion of the bacteria, and in these cases the decomposition goes on much more slowly than in the untreated sewage. In order to ascertain the amount of organic matter removed, it is necessary in all cases to determine the ammonias and to evaporate for the solids immediately after taking the sample. In all the following experiments these determinations have been so made.

The ammonia determinations have been made by the indirect process in a current of steam, described elsewhere, using 10 cubic centimeters of sewage, and, for the albuminoid ammonia, 20 cubic centimeters of alkaline permanganate solution. One portion of free ammonia (50 cubic centimeters) is taken off and diluted before nesslerizing. Two portions of albuminoid ammonia are distilled. In the third and following portions the amount of ammonia is very small, and has been neglected. It comes probably in part, at least, from urea. This method gives much more satisfactory results than can be obtained by dilution with ammonia-free water, and distillation in the ordinary way. It also requires much less time.

The solids have been determined in the usual way, using 50 cubic centimeters with sodium carbonate, and the solid residues have been titrated for chlorine.

Nitrates and nitrites have not always been looked for, but they are almost invariably absent, and, if present in small quantities, they would have no significance.

Turbidity has been determined by noting the depth in the barrel at which a small platinum wire can be seen. The number given is one divided by the depth in inches. Thus, when the wire can be seen four inches, the turbidity is 0.25. The result depends to some extent upon the light, and the experience of the observer, but the comparative results are very satisfactory.

The alkalinity is obtained by titrating 50 cubic centimeters of sewage with twentieth normal sulphuric acid, using methyl orange as indicator. The result is expressed in terms of normal acid per 100 cubic centimeters. The alkalinity of sewage increases slightly on standing. This is probably due to decomposition of urea. The "acid number" is obtained by titration with acid, using phenolphthalein as indicator, and is given in the same terms as the alkalinity. Sewage, and effluents from precipitation without lime, or with a small amount of lime, do not color phenolphthalein. In this case, an excess of standard lime water is added, and the excess titrated with acid. The amount of normal acid equivalent to the lime required per 100 cubic centimeters is given as the acid number with a negative sign. To prevent the loss of carbonic acid when the acid number is negative the measuring glass is filled from a tube passing to the bottom, and allowed to run over for some time, and the lime water is mixed with the sewage in the flask before pouring out for titration.*

The bacterial examinations have been made under the direction of Professor Sedgwick at the Institute of Technology in Boston.

Precipitation with Lime.

The quicklime of commerce does not have a constant composition. It has been thought best, for the purpose of these experiments, to

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* See paper on "The Determination of Carbonic Acid in Water, and the Bicarbonates of Lime and Magnesia," by Allen Hazen. Tech. Quarterly, Vol. 3, P. 182.

take an arbitrary amount of calcium oxide in solution as lime water, to represent a ton of lime, rather than weigh out lime for each experiment. This method will give strictly comparable results, while, if the lime was weighed out, there would always be uncertainty as to the composition of the portion used, as different lumps of lime from the same barrel, and even different portions of the same lump, may differ widely from each other in composition. If pure calcium oxide is dissolved in distilled water at the rate of one ton per million gallons, it will have an acid number or alkalinity of 0.86; i. e., it will require 0.86 cubic centimeters of normal sulphuric acid, 49 grams per litre, to neutralize 100 cubic centimeters. But quicklime only contains, on an average, perhaps 80 to 85 per cent. of uncombined calcium oxide, and a portion of this is difficultly soluble, so that it is impossible to make a lime water which represents the full theoretical strength of the lime. In a few experiments in dissolving lime in sewage, 10 to 15 per cent. of the lime proved to be not easily soluble. From these experiments I have assumed that lime will on the average yield 70 per cent. of its weight of calcium oxide in solution. This is believed to be a fair estimate, which can be obtained in practice. This corresponds nearly to an acid number of 0.60 for one ton per million gallons, and I have taken that as a basis for computing the amount of lime used in each experiment. The lime is slaked with a large amount of sewage, and, after settling, the acid number is obtained by titration. From this is calculated the amount of lime water to be added to the sewage.

By treating sewage with a large excess of milk of lime, the undissolved calcium hydrate, in settling, carries down the insoluble organic matter almost completely, and in a very short time.

On May 10, an experiment was made as follows: A weighed portion of lime was slaked in a barrel, and the barrel filled with sewage. After settling for a few minutes, the cleared liquid was drawn off, and the barrel again filled with sewage. This was repeated until the lime was exhausted. In all, 480 gallons of sewage were treated. The lime used was at the rate of 6,600 pounds per 1,000,000 gallons; 4.8 gallons of sludge were left, having 4 per cent. of solid matter. This process could not be used on a large scale, owing to the amount of lime required, and the excess of lime left in solution, which would slowly precipitate out on exposure to the air. The completeness with which the bacteria are removed, or killed, and the large volume of liquid which can be treated in a small tank, might render it of use in some cases for disinfection. The results were as follows: —

Results of Precipitation with Large Excess of Lime.

[Parts per 100,000.]

	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Bacteria per Cubic Centimeter.
Original sewage,	43.2	17.6	25.6	1.48	.36	5.24	1,881,400
Filtered through paper,	38.8	13.2	25.6	1.48	.22	–	–
Effluent with lime, after 5 minutes,	113.4	11.8	101.6	1.48	.18	5.35	12
Effluent after 1 hour,	95.8	8.0	87.8	1.48	.19	5.26	17
Effluent after 24 hours,	93.4	10.2	83.2	1.37	.18	5.31	5
Effluent from another sewage, 5 minutes,	155.2	17.2	138.0	1.92	.29	5.70	774
Sludge representing 100 times its volume of sewage,	4067.0	414.0	3653.0	3.60	21.4	6.56	100

The action of smaller amounts of lime is quite different. Calcium carbonate is then formed with the carbonic acid of the sewage, and it is thus the carbonate instead of the hydrate which clarifies the sewage. Calcium carbonate is somewhat soluble in water or sewage containing carbonic acid. To obtain a precipitate, it is necessary to add enough lime to combine with the greater part of the carbonic acid.

The amount of calcium carbonate precipitated in any experiment can be computed in three ways: —

First, from the alkalinity. If we add the alkalinity of the sewage to that of the lime used, we obtain the total alkalinity of the mixture. As calcium carbonate precipitates, the alkalinity becomes less, and the decrease multiplied by 50, the equivalent weight of calcium carbonate, gives the amount of the precipitate. Thus, if sewage has an alkalinity 0.29, and we add 1,500 pounds of lime, $=0.45$, and the precipitated sewage has an alkalinity 0.51, we have $(.29+.45-.51)\ 50=11.5$ parts per 100,000 calcium carbonate precipitated.

Second, from the solids. One ton of lime per million gallons is equal to 30 parts per 100,000 calcium carbonate. If we add the weight of the lime used to the fixed residue of the filtered sewage, and deduct the fixed residue of the precipitated sewage, we shall obtain the amount of the precipitate. Thus, filtered sewage having a fixed residue of 24.6 parts, and precipitated sewage with 1,500 pounds of lime 35.2 parts, the precipitate $=24.6+22.5-35.2=11.9$ parts.

Third, from the carbonic acid. The difference between the acid number with phenolphthalein and the alkalinity represents one-half of the total carbonic acid, and the decrease in carbonic acid represents the calcium carbonate precipitated. Thus, sewage having an acid number -0.11 and an alkalinity 0.29, and precipitated sewage an acid number 0.23 and an alkalinity 0.51, we have $(2[.29-(-.11)]-2[.51-.23])50=12$ parts.

These three processes usually give fairly concordant results, and in the following tables the average of the three results is given. The different methods are quite independent of each other, and the possible sources of error are entirely different. The first and second are affected by the accuracy of the measurements of the sewage and lime, while the third is entirely independent of those measurements.

On the following pages are given the results of four series of experiments with different amounts of lime. Seven barrels in each case were filled from the same tank of sewage, and the amounts of lime stated, added to the different barrels. Each vertical line on the diagram shows one of these experiments.

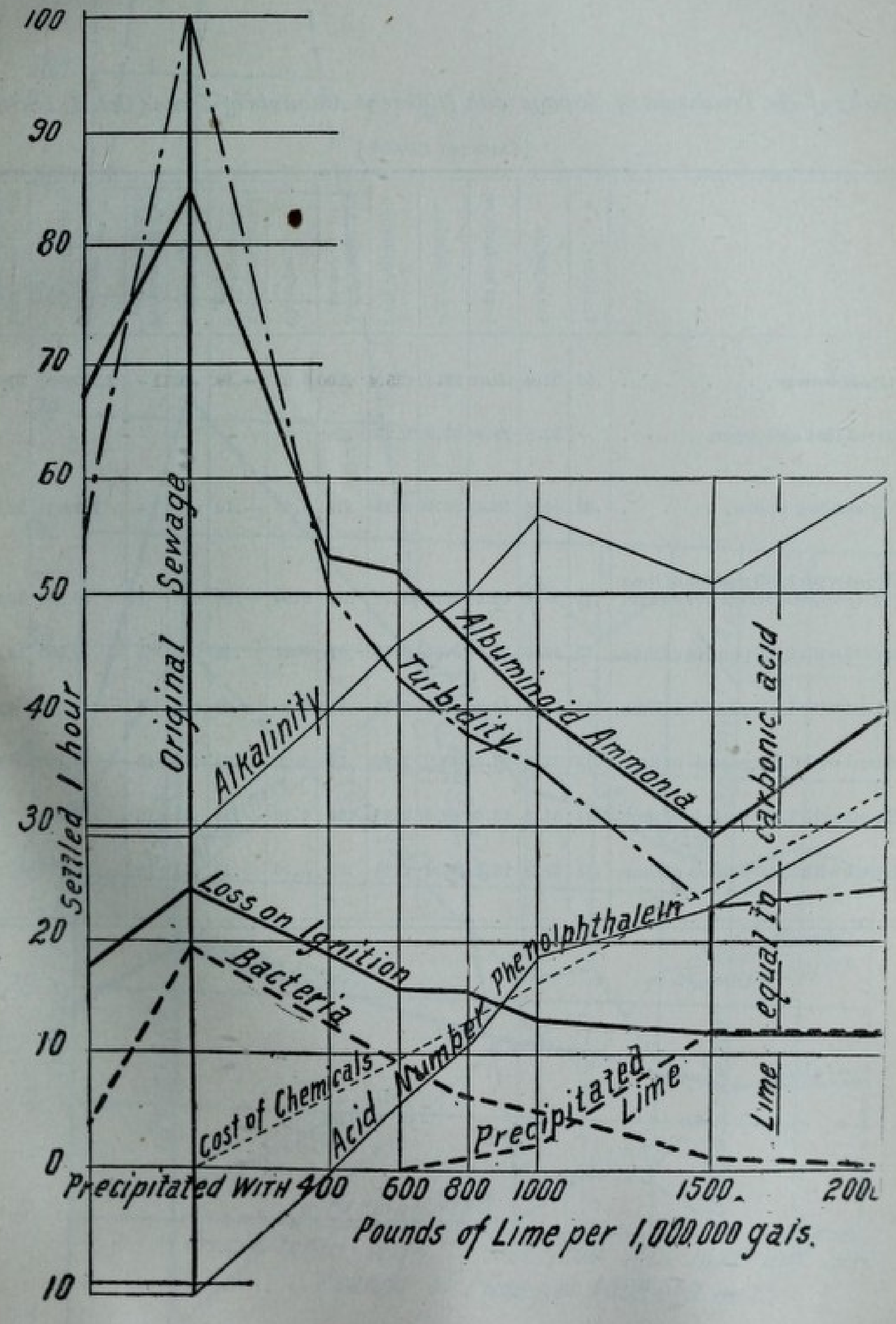
Results of the Treatment of Sewage with Different Amounts of Lime (Oct. 2, 1889).

[Parts per 100,000.]

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Precipitated Calcium Carbonate.	Bacteria per Cubic Centimeter.
Original sewage, ...	1.00	59.6	24.2	35.4	2.00	.85	4.58	-0.11	.29	-	196,000
Filtered through paper, . . .	-	36.6	12.0	24.6	1.90	.40	-	-	-	-	-
After settling 1 hour, . . .	.55	49.8	17.6	32.2	1.85	.67	4.58	-0.11	.29	-	123,200
Effluent with 400 pounds of lime per 1,000,000 gallons sewage, .	.50	53.6	18.8	34.8	1.85	.53	4.70	0	.40	0	-
Effluent with 600 pounds of lime,	.43	53.0	16.0	37.0	1.75	.52	4.60	+.06	.46	0	95,000
Effluent with 800 pounds of lime, .	.38	53.0	15.6	37.4	1.75	.46	4.59	.11	.50	1.	65,000
Effluent with 1,000 pounds of lime, .	.35	51.0	13.2	37.8	2.00	.40	4.64	.19	.57	2.	50,000
Effluent with 1,500 pounds of lime, .	.23	47.2	12.0	35.2	1.85	.29	4.69	.23	.51	12.	12,180
Effluent with 2,000 pounds of lime, .	.25	55.4	11.8	43.6	1.85	.40	4.70	.31	.60	12.	3,150

Sewage treated with Different Amounts of Lime, Oct. 2, 1889.

Scales.		*Scales.*	
Loss on ignition,	10 = 10 parts.	Precipitated lime,	10 = 10. parts.
Albuminoid ammonia,	10 = 0.10 part.	Bacteria,	10 = 100,000.
Turbidity,	10 = 0.10	Cost of chemicals, annually for each inhabitant.	10 = 10 cents annually for each inhabitant.
Alkalinity,	10 = 0.10		
Acid number,	10 = 0.10		



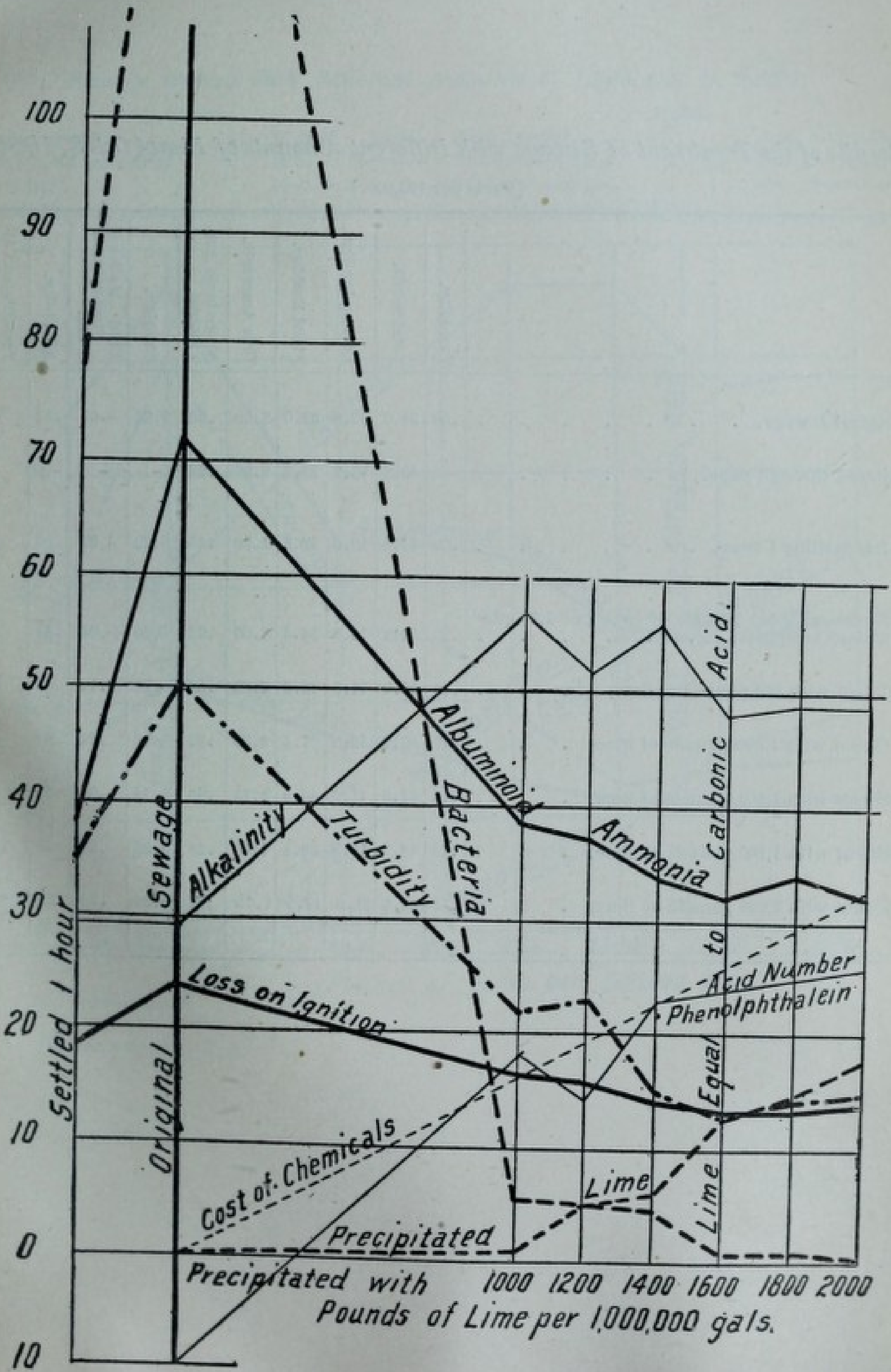
Results of the Treatment of Sewage with Different Amounts of Lime (Oct. 4, 1889).

[Parts per 100,000.]

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Precipitated Calcium Carbonate.	Bacteria per Cubic Centimeter.	Yeast Cells per Cubic Centimeter
Original sewage, ...	.50	52.0	23.6	28.4	2.25	.72	5.23	—.10	.29	-	1,572,000	32,700
Filtered through paper, . .	-	39.6	14.4	25.2	2.25	.38	-	-	-	-	-	-
After settling 1 hour, . . .	.33	44.4	18.4	26.0	2.15	.38	5.25	—.10	.29	-	783,200	30,500
Effluent with 1,000 pounds of lime per 1,000,000 gallons of sewage,	.22	55.4	16.6	38.8	2.15	.38	5.20	+.18	.57	1.	55.200	10,200
Effluent with 1,200 pounds of lime,	.23	50.4	16.0	34.4	2.15	.37	5.21	.14	.52	5	49,500	13,350
Effluent with 1,400 pounds of lime,	.15	54.8	14.0	40.8	2.15	.34	5.22	.23	.56	6	44,000	4,500
Effluent with 1,600 pounds of lime,	.13	52.6	13.4	39.2	2.25	.32	5.23	.24	.48	13	11,448	450
Effluent with 1,800 pounds of lime,	.14	54.2	13.6	40.6	2.25	.34	5.19	.25	.49	15	12,300	700
Effluent with 2,000 pounds of lime,	.15	50.2	13.8	36.4	2.15	.32	5.19	.26	.49	18	5,920	0

Sewage treated with Different Amounts of Lime, Oct. 4, 1889.

Scales.		*Scales.*	
Loss on ignition, ...	10 = 10 parts.	Precipitated lime, . . .	10 = 10 parts.
Albuminoid ammonia, . .	10 = 0.10 part.	Bacteria, ...	10 = 100,000.
Turbidity, ...	10 = 0.10	Cost of chemicals, . . .	10 = 10 cents annually for each inhabitant.
Alkalinity, ...	10 = 0.10		
Acid number, ...	10 = 0.10		



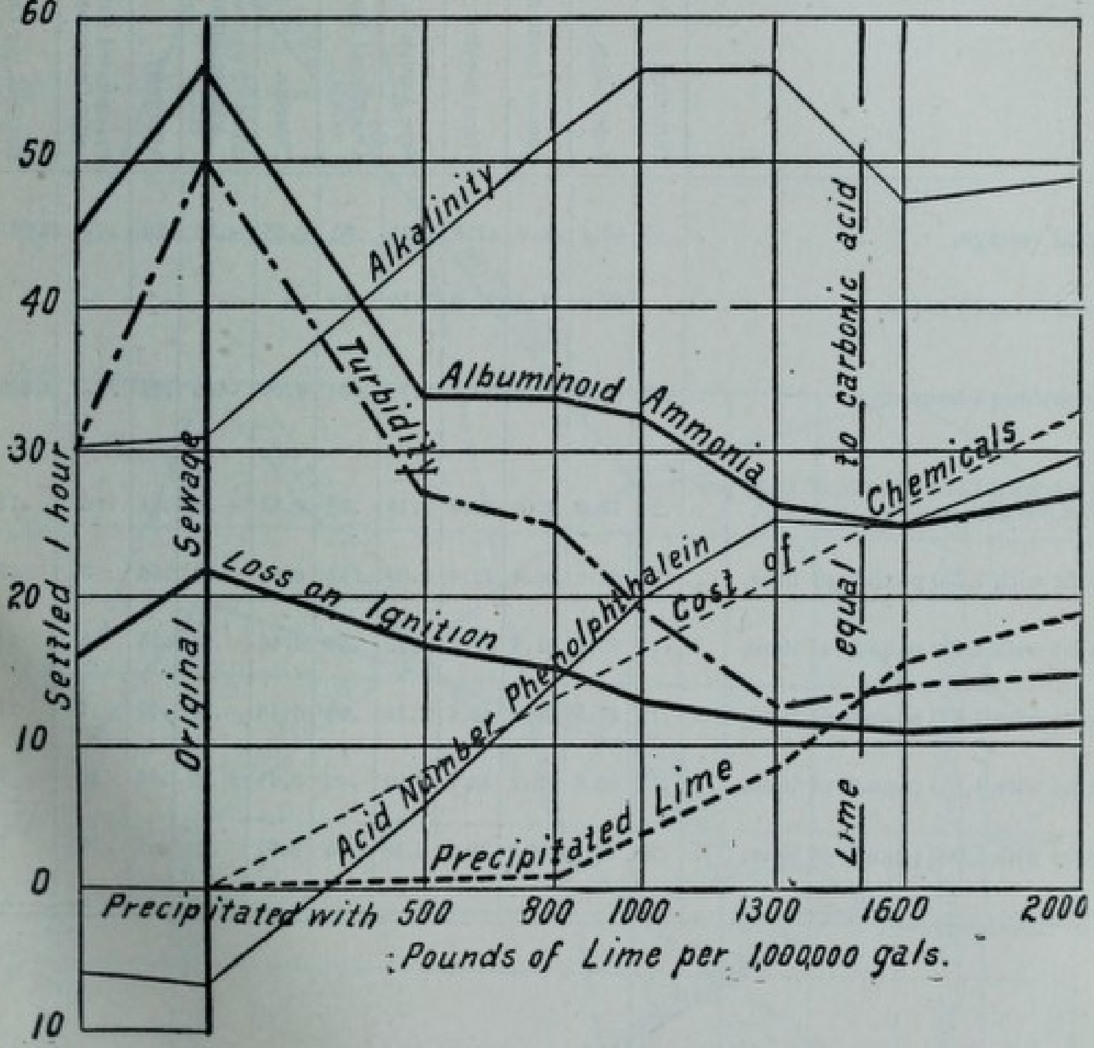
Results of the Treatment of Sewage with Different Amounts of Lime (Oct. 8, 1889).

[Parts per 100,000.]

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Precipitated Calcium Carbonate.
Original sewage,	.50	54.0	22.0	32.0	2.00	.56	5.23	−.07	.31	-
Filtered through paper,	-	42.8	13.2	29.6	2.00	.28	-	-	-	-
After settling 1 hour,	.30	44.8	16.0	28.8	1.90	.45	5.22	−.06	.30	1
Effluent with 500 pounds of lime per 1,000,000 gallons sewage,	.27	51.2	16.8	34.4	1.90	.34	5.20	+.05	.44	1
Effluent with 800 pounds of lime,	.25	55.0	14.8	40.2	2.00	.34	5.20	.14	.52	1
Effluent with 1,000 pounds of lime,	.19	50.2	12.8	37.4	2.00	.32	5.16	.20	.56	4
Effluent with 1,300 pounds of lime,	.13	51.6	11.6	40.0	1.75	.26	5.14	.25	.56	8
Effluent with 1,600 pounds of lime,	.14	48.8	10.8	38.8	1.85	.25	5.05	.25	.47	16
Effluent with 2,000 pounds of lime,	.15	53.6	11.0	42.6	1.75	.27	5.09	.30	.49	19

Sewage treated with Different Amounts of Lime, Oct. 8, 1889.

Scales.		*Scales.*	
Loss on ignition, ...	10 = 10 parts.	Acid number, ...	10 = 0.10 part.
Albuminoid ammonia, . .	10 = 0.10 part.	Precipitated lime, . . .	10 = 10 parts.
Turbidity, ...	10 = 0.10	Cost of chemicals, . . .	10 = 10 cents annually for each inhabitant.
Alkalinity, ...	10 = 0.10		



Results of the Treatment of Sewage with Different Amounts of Lime (Oct. 9, 1889).

[Parts per 100,000.]

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Precipitated Calcium Carbonate.	Bacteria per Cubic Centimeter.
Original sewage, ...	.60	86.4	44.8	41.6	2.25	.90	6.58	-.10	.29	-	1,364,000
Filtered through paper, ...	-	58.4	31.4	27.0	2.15	.50	-	-	-	-	
After settling 1 hour, ...	.37	63.2	33.2	30.0	2.15	.68	6.59	-.09	.29	-	1,440,000
Effluent with 1,000 pounds of lime per 1,000,000 gallons sewage, . . .	.24	74.0	35.0	39.0	2.15	.53	6.53	+.15	.54	2	71,400
Effluent with 1,200 pounds of lime, .	.20	64.8	26.4	42.0	2.00	.55	6.54	.19	.56	3	49,500
Effluent with 1,400 pounds of lime, .	.16	70.0	27.8	42.2	2.25	.48	6.48	.23	.58	5	24,208
Effluent with 1,600 pounds of lime, .	.12	67.0	23.6	43.4	2.15	.40	6.46	.27	.60	7	21,120
Effluent with 1,800 pounds of lime, .	.12	65.8	23.2	42.6	2.00	.40	6.41	.29	.56	12	7,384
Effluent with 2,000 pounds of lime, .	.10	61.8	23.6	38.2	2.15	.35	6.37	.29	.52	18	1,484

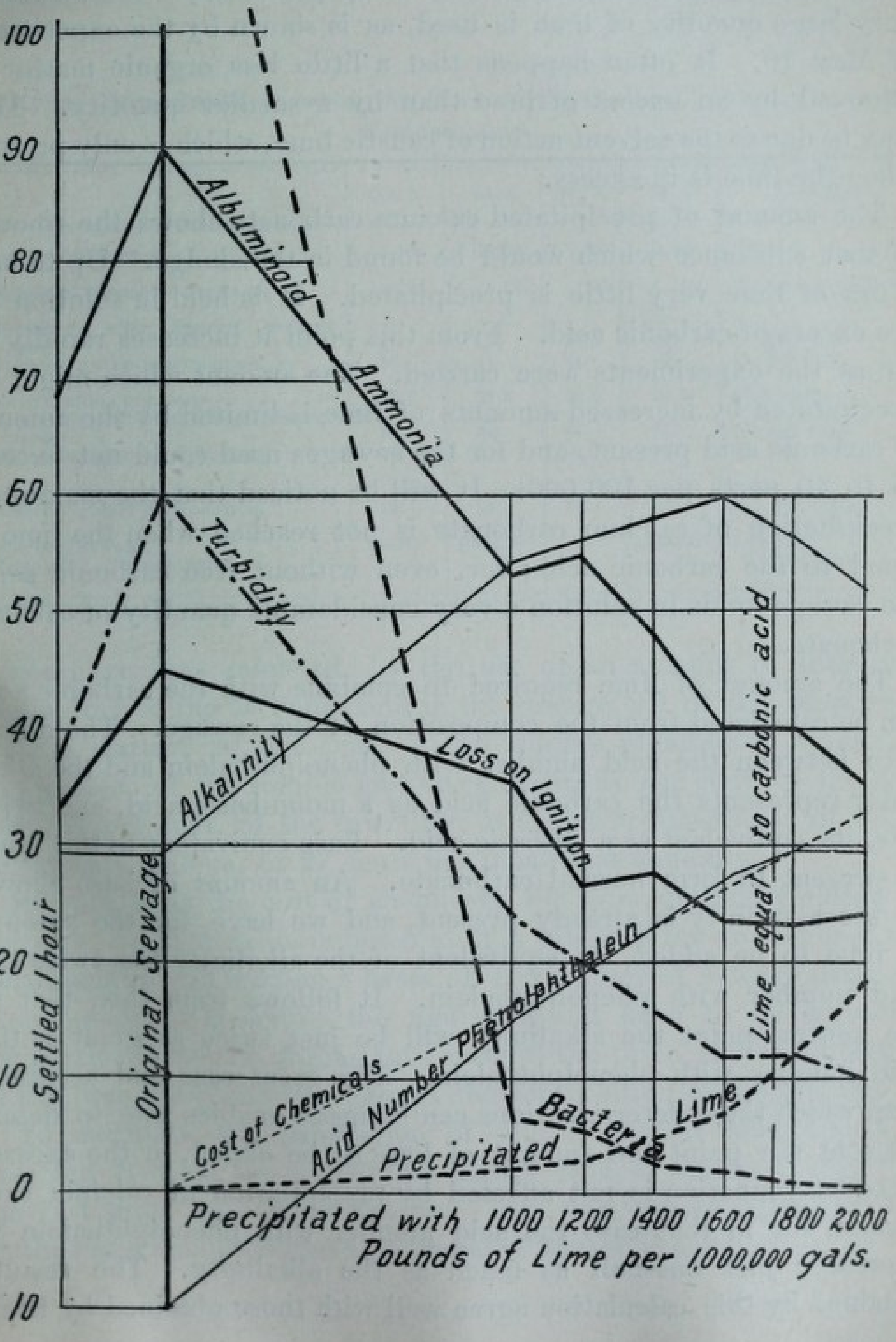
Sewage treated with Different Amounts of Lime, Oct. 9, 1889.

Scales.

Loss on ignition, ...	10 = 10 parts.
Albuminoid ammonia, . . .	10 = 0.10 part.
Turbidity, ...	10 = 0.10
Alkalinity, ...	10 = 0.10
Acid number, ...	10 = 0.10

Scales.

Precipitated lime, ...	10 = 10 parts.
Bacteria, ...	10 = 100,000.
Cost of chemicals, ... nually for each inhabitant.	10 = 10 cents an-



It will be seen from the diagrams that, with increased amounts of lime, there is a regular improvement in the effluent until the point is reached where the lime is equal to the carbonic acid.

The addition of a larger amount of lime than this does not usually remove any more organic matter. An increase of lime does, however, kill the bacteria, the effluent being practically sterile where a very large quantity of lime is used, as is shown by the experiment of May 10. It often happens that a little less organic matter is removed by an excess of lime than by a smaller quantity. This may be due to the solvent action of caustic lime, which is only present when the lime is in excess.

The amount of precipitated calcium carbonate shows the amount of that substance which would be found in the sludge. Up to half a ton of lime very little is precipitated. It is held in solution by the excess of carbonic acid. From this point it increases rapidly as far as the experiments were carried. The amount which might be precipitated by increased amounts of lime is limited by the amount of carbonic acid present, and for the sewages used could not exceed 35 to 40 parts per 100,000. It will be noticed that the maximum precipitation of calcium carbonate is not reached when the lime is equal to the carbonic acid; for, even without free carbonic acid, the sewage holds in solution a very considerable quantity of calcium carbonate.

The amount of lime required to combine with the carbonic acid can be calculated from the composition of the sewage. The difference between the acid number with phenolphthalein and the alkalinity represents the carbonic acid as a mono-basic acid, and twice this, its equivalent as a di-basic acid. Base equivalent to this must be present to form normal carbonate. An amount of base shown by the alkalinity is already present, and we have, for the amount of lime to be added, the equivalent of the alkalinity less twice the acid number with phenolphthalein. It follows from this, that at the neutral point the alkalinity will be just twice as great as the acid number with phenolphthalein. The great ease and accuracy with which these determinations can be made enables one to determine at any point the amount of lime to be added, or the excess. This determination is not affected by precipitation of calcium carbonate, for in that case the acid number with phenolphthalein is decreased just one-half as much as the alkalinity. The results obtained by this calculation agree well with those obtained by trial.

Thus, on October 9, the calculated amount was .29–2(–.10)=.49 for the equivalent of lime, or 1,633 pounds. By trial 1,600 pounds was found to be too little, and 1,800 pounds too much, the point coming, it is judged, from these determinations, at 1,750 pounds.

In the following table is given the result of the experiment in each series in which the lime was nearest equal to the carbonic acid:—

Results of Precipitation in which the Lime used was equal, or nearly so, to the Carbonic Acid.

	Oct. 2.	Oct. 4.	Oct. 8.	Oct. 9.	Average.
Amount of lime used,	1,500	1,600	1,600	1,800	1,625
Albuminoid ammonia of sewage,	.85	.72	.56	.90	.76 parts per 100,000
Remaining after filtering through paper,	47.	53.	50.	55.	51. per cent.
Remaining after precipitation,	34.	44.	44.	44.	41. per cent.
Loss on ignition of sewage,	24.2	23.6	22.0	44.8	28.6 parts.
Remaining after filtering through paper,	50.	61.	60.	70.	60. per cent.
Remaining after precipitation,	50.	56.	49.	50.	51. per cent.
Turbidity of sewage,	1.00	.50	.50	.60	0.65
Remaining after precipitation,	23.	26.	28.	20.	24. per cent.
Bacteria of sewage,	196,000	1,572,000	–	1,364,000	1,044,000
Remaining after precipitation,	6.2	.73	–	.55	2.5 per cent.

We have thus removed, by the use of an amount of lime corresponding to the carbonic acid in the sewage, all of the suspended organic matter, 20 per cent. of the soluble albuminoid ammonia, 15 per cent. of the soluble loss on ignition, 97 per cent. of the bacteria, 76 per cent. of the turbidity, at a cost for chemicals of $7.31 per million gallons, or 27 cents per inhabitant annually.

In calculating the cost of chemicals, the price of lime yielding 70 per cent. calcium oxide is taken at $9 a ton, and the annual cost per inhabitant is reckoned on a basis of 100 gallons of sewage daily for each person. Of course the figures would have to be corrected for particular places, taking into account the price and composition of the lime used, and the amount and composition of the sewage.

To calculate the proportion of soluble matter removed, it is assumed that all the suspended matter is first removed, and that the rest must be soluble matter. This very nearly represents the truth, but a small amount of suspended matter is always left.

Precipitation with Copperas.

Copperas, or ferrous sulphate, occurs in commerce in a nearly pure form. Its value for the treatment of sewage depends upon the precipitation of ferrous hydrate or carbonate. The experiments of May and June indicated that it is necessary to add lime with copperas, in order to get the best result. The following experiments were designed to ascertain how much lime is required, and the effect of different amounts of copperas, and whether the sewage should be first mixed with the lime or the copperas: —

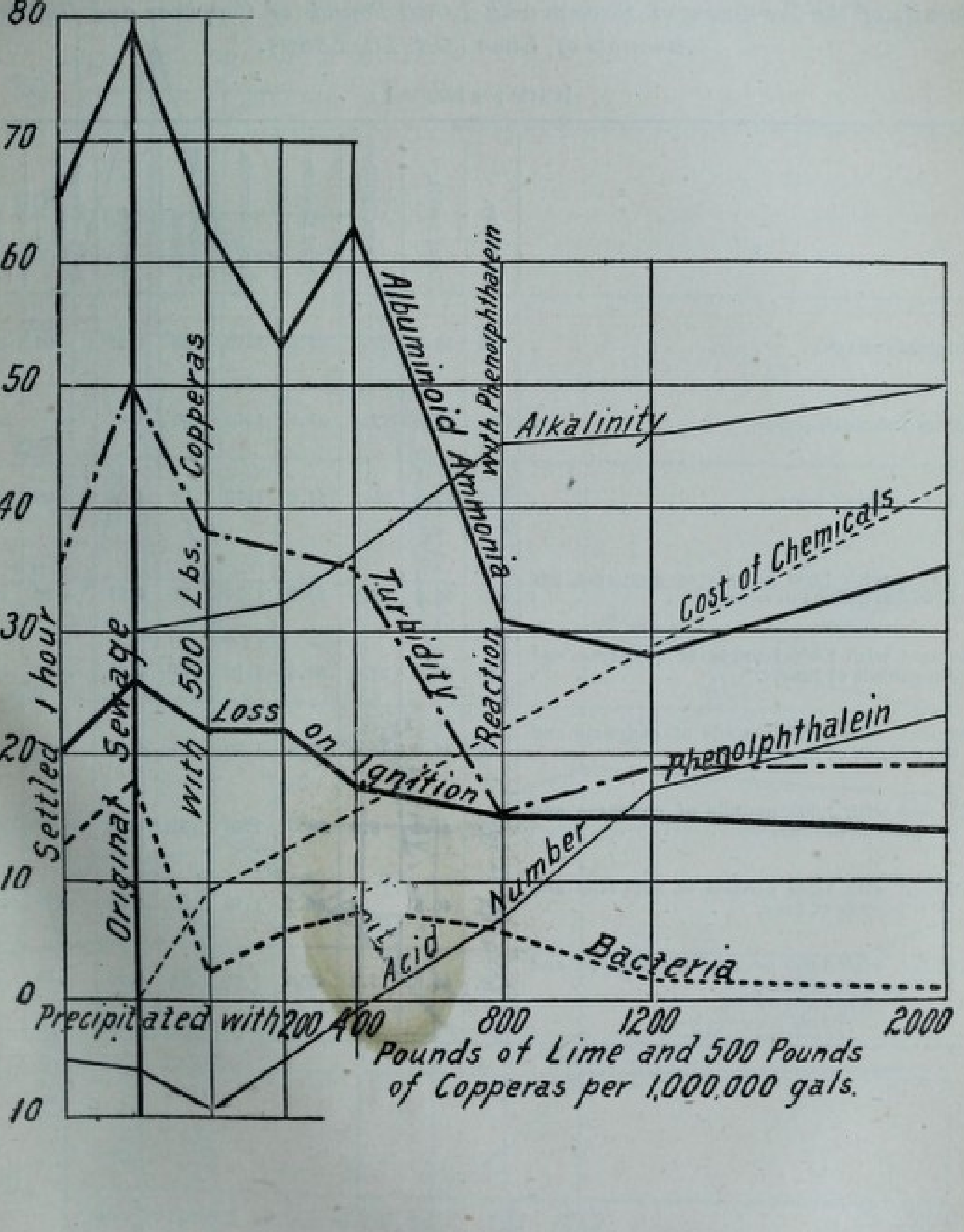
Results of the Treatment of Sewage with 500 Pounds of Copperas and Different Amounts of Lime (Oct. 11, 1889).

[Parts per 100,000.]

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Bacteria per Cubic Centimeter.	Yeast Cells per Cubic Centimeter.
Original sewage, ...	.50	50.0	25.8	24.2	2.00	.79	4.97	—.06	.30	176,000	128,200
Filtered through paper, . . .	-	38.8	17.2	21.6	2.00	.43	-	-	-	-	-
After settling 1 hour, ...	.35	44.4	20.2	24.2	2.00	.65	4.98	—.05	.30	126,500	143,900
Effluent with 500 pounds of copperas per 1,000,000 gallons of sewage, .	.38	48.8	22.0	26.8	2.00	.63	4.97	—.09	.31	24,500	114,600
Effluent with 500 pounds of copperas and 200 pounds of lime, . . .	.37	47.8	21.8	26.0	2.00	.53	4.99	—.05	.32	56,000	125,700
Effluent with 500 pounds of copperas and 400 pounds of lime, . . .	.35	49.0	17.2	31.8	2.00	.63	4.94	—.01	.36	72,000	83,900
Effluent with 500 pounds of copperas and 800 pounds of lime, . . .	.15	47.2	14.8	32.4	2.00	.31	4.90	+.07	.45	56,000	10,200
Effluent with 500 pounds of copperas and 1,200 pounds of lime, . .	.19	49.6	14.8	34.8	1.90	.28	5.18	.17	.46	16,128	500
Effluent with 500 pounds of copperas and 2,000 pounds of lime, . .	.19	55.6	13.6	42.0	2.00	.35	5.11	.23	.50	10,176	50

Sewage treated with 500 Pounds of Copperas and Different Amounts of Lime, Oct. 11, 1889.

Scales.		*Scales.*	
Loss on ignition, ...	10 = 10 parts.	Acid number, ...	10 = 0.10
Albuminoid ammonia, . .	10 = 0.10 part.	Bacteria, ...	10 = 100,000.
Turbidity, ...	10 = 0.10	Cost of chemicals, ...	10 = 10 cents annually for each inhabitant.
Alkalinity, ...	10 = 0.10		



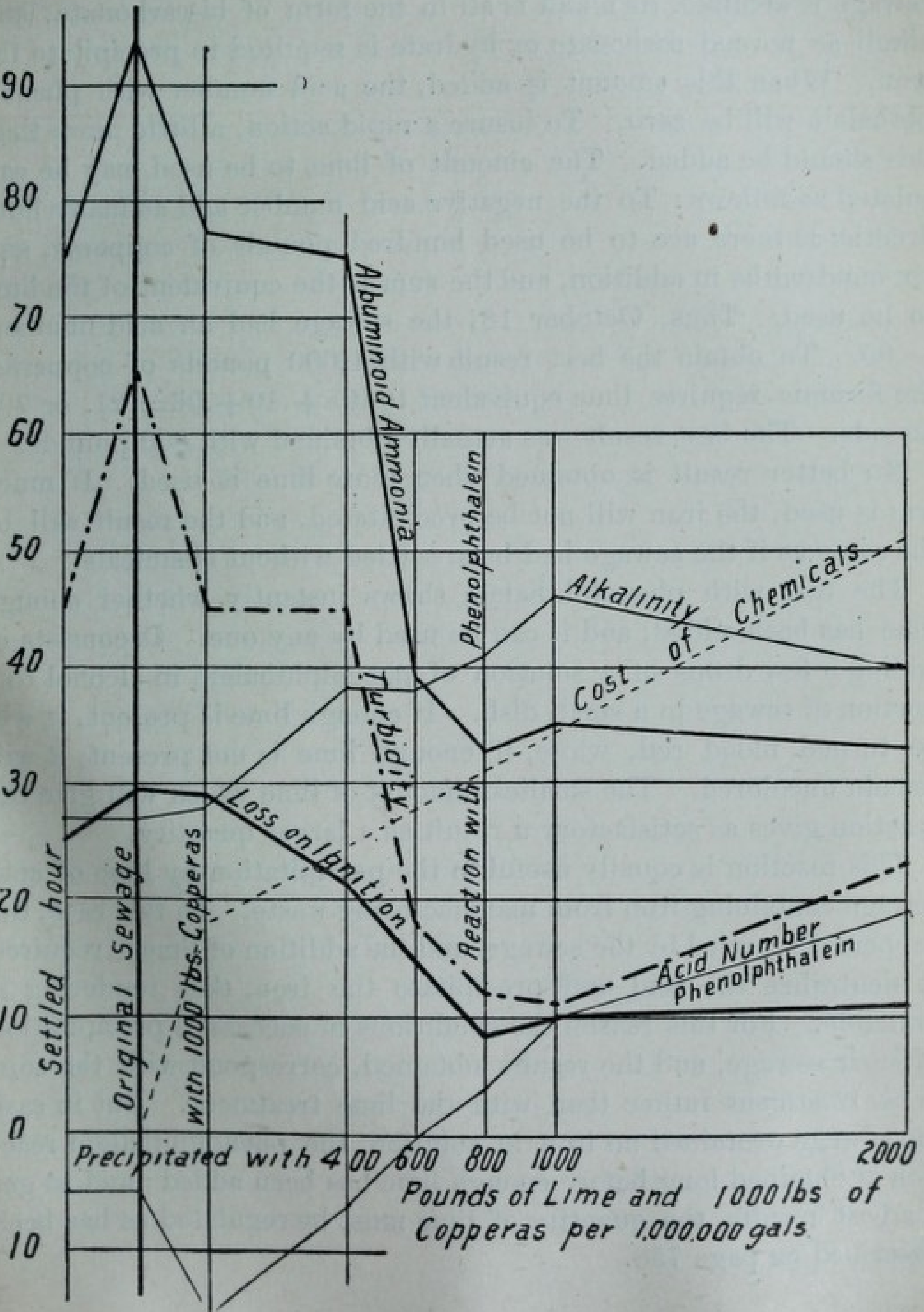
Results of the Treatment of Sewage with 1,000 Pounds of Copperas and Different Amounts of Lime (Oct. 16, 1889).

[Parts per 100,000.]

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.
Original sewage, ...	.65	52.8	29.2	23.6	1.70	.94	4.27	-.05	.27
Filtered through paper, ...	-	47.6	22.4	25.2	1.75	.66	-	-	-
After settling 1 hour, ...	.45	49.2	25.2	24.0	1.70	.75	4.25	-.05	.27
Effluent with 1,000 pounds of copperas per 1,000,000 gallons of sewage, ...	.45	58.0	28.8	29.2	1.70	.77	4.27	-.16	.28
Effluent with 1,000 pounds of copperas and 400 pounds of lime, ...	.45	55.0	21.6	33.4	1.70	.75	4.25	-.06	.38
Effluent with 1,000 pounds of copperas and 600 pounds of lime, ...	.18	48.8	15.0	33.8	1.70	.39	4.26	.00	.38
Effluent with 1,000 pounds of copperas and 800 pounds of lime, ...	.12	44.2	8.6	35.6	1.70	.33	4.26	+.04	.41
Effluent with 1,000 pounds of copperas and 1,000 pounds of lime, ...	.11	46.8	[illegible]	36.8	1.75	.35	4.26	.10	.46
Effluent with 1,000 pounds of copperas and 2,000 pounds of lime, ...	.23	54.8	11.2	43.6	1.75	.33	4.29	.19	.40

Sewage treated with 1,000 Pounds of Copperas and Different Amounts of Lime, Oct. 16, 1889.

Scales.		Scales.	
Loss on ignition, ...	10 = 10 parts.	Acid number, ...	10 = 0.10
Albuminoid ammonia, . .	10 = 0.10 part.	Cost of chemicals, ... nually for each inhabitant.	10 = 10 cents annually for each inhabitant.
Turbidity, ...	10 = 0.10		
Alkalinity, ...	10 = 0.10		



These two series show clearly, that, when copperas is added to sewage alone, no precipitation takes place, and the result is no better than when sewage settles alone. The addition of enough lime to combine with the excess of carbonic acid over the amount required to form bi-carbonates, and to combine with the sulphuric acid of the copperas, is necessary for precipitation; for, while sewage is alkaline, its alkali is all in the form of bi-carbonate, and alkali as normal carbonate or hydrate is required to precipitate the iron. When this amount is added, the acid number with phenolphthalein will be zero. To insure a rapid action, a little more than this should be added. The amount of lime to be used may be calculated as follows: To the negative acid number add as many hundredths as there are to be used hundred pounds of copperas, and six hundredths in addition, and the sum is the equivalent of the lime to be used. Thus, October 18, the sewage had an acid number, —.05. To obtain the best result with 1,000 pounds of copperas, the formula requires lime equivalent to $.05+.10+.06=.21$, or 700 pounds. The best result was actually obtained with 800 pounds.

No better result is obtained when more lime is used. If much less is used, the iron will not be precipitated, and the result will be the same as if the sewage had been settled without chemicals.

The test with phenolphthalein shows instantly whether enough lime has been added, and it can be used by any one. It consists of adding a few drops of a solution of phenolphthalein in alcohol to a portion of sewage in a small dish. If enough lime is present, it will be turned blood red, while, if enough lime is not present, it will remain uncolored. The smallest amount of lime which will give the reaction gives as satisfactory a result as a larger quantity.

This reaction is equally useful in the precipitation by lime of acid sewage containing iron from manufacturing waste. In this case, the copperas is carried by the sewage, and the addition of lime is required to neutralize the acid and precipitate the iron, thus rendering it available. For this reason the conditions of successful precipitation of such sewage, and the results obtained, correspond with the copperas treatment rather than with the lime treatment. But in case the sewage contained no iron in solution, the phenolphthalein reaction is obtained long before enough lime has been added; and to get the best results, the quantity of lime must be regulated as has been described on page 758.

To determine the effect of different amounts of copperas, when used with the proper amount of lime, as determined by the reaction with phenolphthalein, the following experiments were made : —

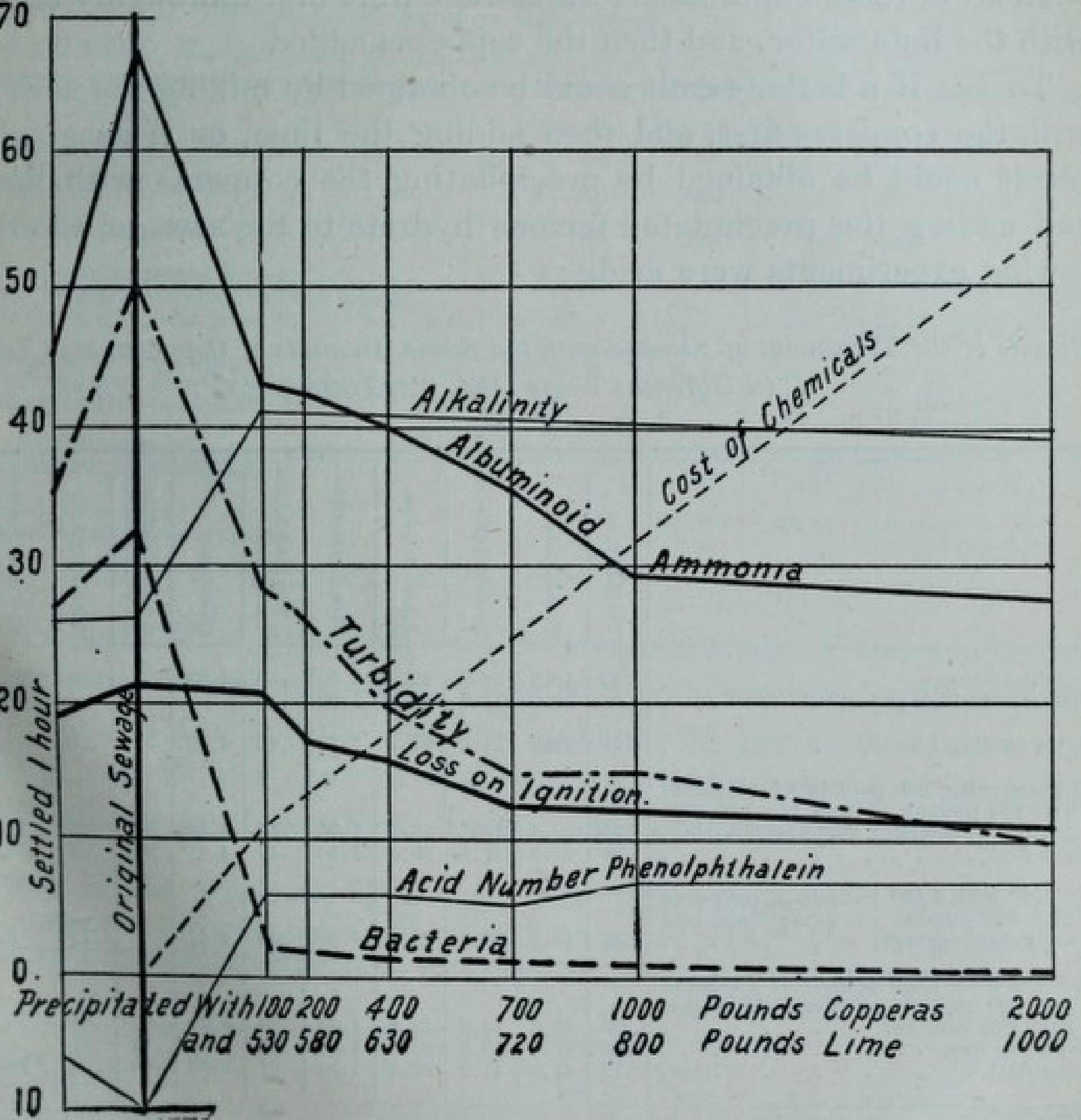
Results of the Treatment of Sewage with Different Amounts of Copperas and Corresponding Amounts of Lime (Oct. 18, 1889).

[Parts per 100,000.]

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Bacteria per Cubic Centimeter.
Original sewage, ...	.50	44.8	21.2	23.6	1.90	.67	4.94	-.10	.26	322,400
Filtered through paper, ...	-	40.0	16.0	24.0	2.00	.40	-	-	-	-
After settling 1 hour, ...	.35	45.0	18.8	26.2	1.90	.45	4.96	-.06	.26	271,400
Effluent with 100 pounds of copperas and 530 pounds of lime per 1,000,000 gallons sewage, ...	.28	51.4	20.8	30.6	1.90	.43	4.95	+.06	.41	20,620
Effluent with 200 pounds of copperas and 580 pounds of lime, . . .	.26	49.2	16.8	32.4	1.85	.42	4.95	.06	.41	16,640
Effluent with 400 pounds of copperas and 630 pounds of lime, . . .	.20	47.8	15.6	32.2	1.90	.40	4.91	.06	.40	7,370
Effluent with 700 pounds of copperas and 720 pounds of lime, . . .	.15	45.8	12.2	33.6	1.90	.35	4.87	.05	.40	9,204
Effluent with 1,000 pounds of copperas and 800 pounds of lime, . . .	.15	47.6	12.0	35.6	2.00	.29	4.87	.07	.40	6,972
Effluent with 2,000 pounds of copperas and 1,100 pounds of lime, . . .	.10	49.2	10.6	38.6	2.00	.27	4.82	.07	.39	1,269

Sewage treated with Different Amounts of Copperas and Corresponding Amounts of Lime, Oct. 18, 1889.

Scales.		*Scales.*	
Loss on ignition, ...	10 = 10 parts.	Acid number, ...	10 = 0.10
Albuminoid ammonia, . .	10 = 0.10 part.	Bacteria, ...	10 = 100,000.
Turbidity, ...	10 = 0.10	Cost of chemicals, ...	10 = 10 cents annually for each inhabitant.
Alkalinity, ...	10 = 0.10		



The diagram shows that, with increased amounts of copperas, the effluent was regularly better, but nearly all the advantage was obtained with half a ton. One hundred pounds of copperas gave a result very slightly better than sewage settled alone.

Five hundred pounds of lime were used to combine with the carbonic acid, leaving a slight excess of lime. That the amount of lime used more than this was almost exactly equal to the sulphuric acid of the copperas, is shown by the acid number and alkalinity remaining so nearly constant.

In all of these experiments the sewage were first thoroughly mixed with the lime water, and then the copperas added.

To see if a better result could be obtained by mixing the sewage with the copperas first, and then adding the lime, or if as good a result could be obtained by precipitating the copperas with lime, and adding the precipitated ferrous hydrate to the sewage, the following experiments were made: —

Results of the Treatment of Sewage with the Same Amounts of Copperas and Lime in Different Ways (Oct. 22, 1889.)

[Parts per 100,000.]

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Bacteria per Cubic Centimeter.
Original sewage,	.60	46.2	23.8	22.4	1.90	.66	4.93	–	.26	507,800
Filtered through paper,	–	39.2	17.0	22.2	1.90	.45	–	–	–	–
After settling 1 hour,	.45	42.2	21.0	21.2	1.70	.62	4.92	–	.26	422,400
Effluent with 500 pounds of copperas and 650 pounds of lime, per 1,000,000 gallons of sewage; copperas first,	.35	52.4	19.2	33.2	1.75	.45	4.87	.07	.42	15,950
Lime first,	.22	42.4	12.6	29.8	1.90	.40	4.91	.06	.41	15,800
Effluent with 1,000 pounds of copperas and 300 pounds of lime; lime and copperas together,	.35	46.2	16.6	29.6	1.90	.45	4.91	–	.29	9,476
Effluent with 1,000 pounds of copperas and 800 pounds of lime; lime and copperas together,	.35	49.0	14.2	34.8	1.90	.36	4.94	.07	.41	12,576
Copperas first,	.19	44.4	10.8	33.6	1.90	.26	4.94	.08	.41	9,944
Lime first,	.17	44.6	11.2	33.4	1.90	.27	4.96	.06	.38	10,406

In the two experiments, with 500 pounds of copperas and an equivalent of lime, the best result was obtained when the sewage was first mixed with the lime, *i.e.*, in the way the preceding series had been made. With 1,000 pounds of copperas the difference between these two ways of mixing was insignificant. When the copperas was precipitated by lime before adding it to the sewage, the result was unsatisfactory, both when the amount of lime used was the same as in other experiments, and when only enough was used to combine with the sulphuric acid of the copperas. We may conclude, then, that neither of these ways of mixing is more advantageous than that which was used for the preceding experiments.

In the following table are given those results with 500 and 1,000 pounds of copperas, where the lime was best adjusted to the copperas, and also of the last series, on October 22, when the lime was first mixed with the sewage: —

Results of the Treatment of Sewage with about 500 Pounds of Copperas per 1,000,000 Gallons, and an Amount of Lime best adjusted to the Copperas.

	Oct. 11.	Oct. 18.	Oct. 22.	Average.
Amount of copperas used,	500	400	500	467 pounds.
Amount of lime used,	800	630	650	693.
Albuminoid ammonia, sewage,	.79	.67	.66	.71 parts per 100,000.
Remaining after filtering through paper,	54	60	68	61 per cent.
Remaining after precipitation,	39	60	60	53 per cent.
Loss on ignition sewage,	25.8	21.2	23.8	23.6 parts.
Remaining after filtering through paper,	67	75	71	71. per cent.
Remaining after precipitation,	57	73	53	61. per cent.
Turbidity of sewage,	.50	.50	.60	.53
Remaining after precipitation,	30	40	36	35. per cent.
Bacteria of sewage,	176,000	322,400	507,800	335,000.
Remaining after precipitation,	32	2	3	12. per cent.

We have thus removed by this treatment all of the suspended organic matter, 13 per cent. of the soluble albuminoid ammonia, 14 per cent. of the soluble loss on ignition, 65 per cent. of the turbidity, and 88 per cent. of the bacteria, with a cost for chemicals of $5.44 per million gallons, or 20 cents annually per inhabitant.

Results of the Treatment of Sewage with 1,000 Pounds of Copperas per 1,000,000 Gallons, and an Amount of Lime best adjusted to the Copperas.

	Oct. 16.	Oct. 18.	Oct. 22.	Average.
Amount of copperas used,	1,000	1,000	1,000	1,000 lbs.
Amount of lime used,	800	800	800	800 lbs.
Albuminoid ammonia sewage,	.94	.67	.66	.76 parts per 100,000.
Remaining after filtering through paper,	70.	60.	68.	66 per cent.
Remaining after precipitation,	35.	43.	41.	40 per cent.
Loss on ignition sewage,	29.2	21.2	23.8	24.7 parts.
Remaining after filtering through paper,	77.	75.	71.	74. per cent.
Remaining after precipitation,	30.	57.	47.	45. per cent.
Turbidity of sewage,	.65	.50	.60	.58
Remaining after precipitation,	18.	30.	28.	25. per cent.
Bacteria of sewage,	-	322,400	507,800	415,000
Remaining after precipitation,	-	2 per cent.	2 per cent.	2. per cent.

We have thus removed, by this treatment, all of the suspended organic matter, 39 per cent. of the soluble albuminoid ammonia, 39 per cent. of the soluble loss on ignition, 75 per cent. of the turbidity, and 98 per cent. of the bacteria, with a cost for chemicals of $8.60 per million gallons, or 31 cents per inhabitant annually.

Precipitation with Ferric Salts.

Ferric salts have the advantage over ferrous salts, in that ferric hydroxide is more readily precipitated and more completely insoluble than ferrous hydroxide.

The following experiments were made to determine whether it is necessary to add lime to obtain the best results with ferric salts, and, if so, how much should be used; and also to find the effect of different amounts of ferric oxide.

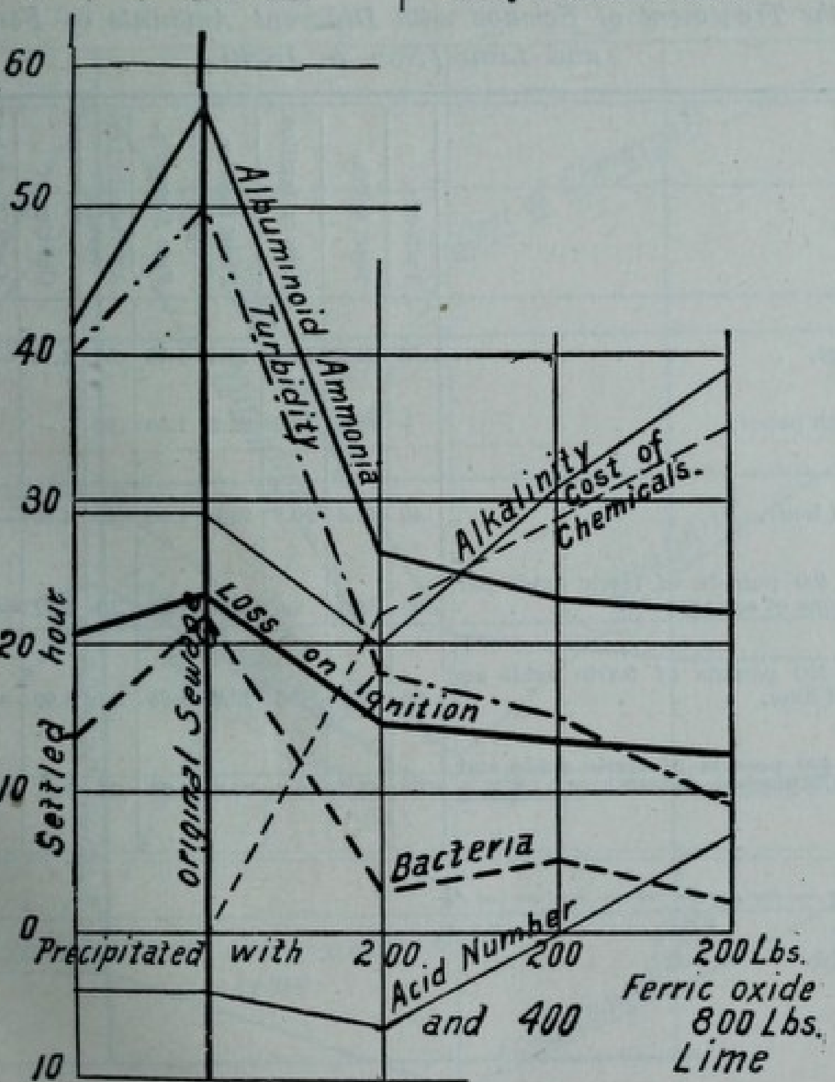
The salt used for these experiments was ferric sulphate, but there is every reason to suppose that exactly the same results would be obtained with ferric chloride containing an equal amount of iron.

Results of the Treatment of Sewage with Different Amounts of Ferric Sulphate and Lime (Nov. 5, 1889).

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Bacteria per Cubic Centimeter.
Original sewage,	.50	45.2	22.8	22.4	1.75	.57	4.70	—.04	.29	218,960
Filtered through paper,	-	38.2	16.0	22.2	1.50	.32	-	-	-	-
After settling 1 hour,	.40	43.4	20.6	22.8	1.50	.42	4.69	—.04	.29	132,480
Effluent with 200 pounds of ferric oxide per 1,000,000 gallons of sewage,	.18	40.6	14.8	25.8	1.65	.26	4.89	—.06	.20	30,442
Effluent with 200 pounds of ferric oxide and 400 pounds of lime,	.15	43.6	13.2	30.4	1.65	.23	4.91	.00	.31	49,025
Effluent with 200 pounds of ferric oxide and 800 pounds of lime,	.09	47.6	12.2	35.4	1.65	.22	4.91	+.07	.39	22,000
Effluent with 400 pounds of ferric oxide,	.09	34.8	8.0	26.8	1.50	.19	5.11	—.12	.11	6,080
Effluent with 400 pounds of ferric oxide and 500 pounds of lime,	.09	37.8	8.6	29.2	1.65	.17	5.09	—.05	.23	9,800
Effluent with 400 pounds of ferric oxide and 1,000 pounds of lime,	.08	47.4	9.6	37.8	1.65	.17	5.11	+.02	.33	8,940

Sewage treated with 200 Pounds Ferric Oxide as Sulphate and Different Amounts of Lime, Nov. 5, 1889.

Scales.		*Scales.*	
Loss on ignition, . . .	10 = 10 parts.	Acid number, ...	10 = 0.10
Albuminoid ammonia, . .	10 = 0.10 part.	Bacteria, ...	10 = 100,000.
Turbidity, ...	10 = 0.10	Cost of chemicals, . . .	10 = 10 cents annually for each inhabitant.
Alkalinity, ...	10 = 0.10		

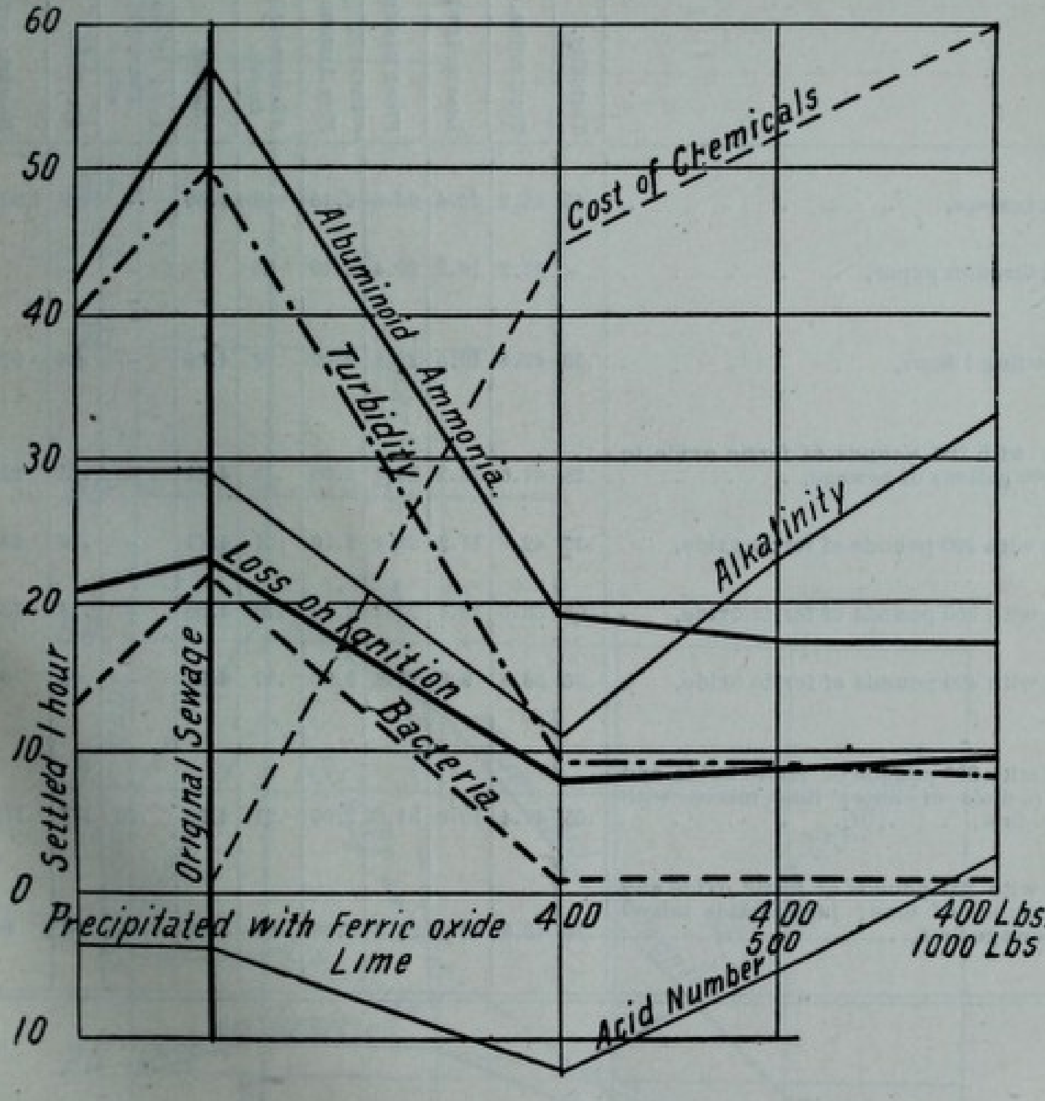


Results of the Treatment of Sewage with Different Amounts of Ferric Sulphate and Lime (Nov. 5, 1889.)

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Bacteria per Cubic Centimeter.
Original sewage, ...	.50	45.2	22.8	22.4	1.75	.57	4.70	—.04	.29	218,960
Filtered through paper, ...	-	38.2	16.0	22.2	1.50	.32	-	-	-	-
After settling 1 hour, ...	.40	43.4	20.6	28.8	1.50	.42	4.69	—.04	.29	132,480
Effluent with 400 pounds of ferric oxide per 1,000,000 gallons of sewage, ...	.09	34.8	8.0	26.8	1.50	.19	5.11	—.12	.11	6,080
Effluent with 400 pounds of ferric oxide and 500 pounds of lime, ...	.09	37.8	8.6	29.2	1.65	.17	5.09	—.05	.23	9,800
Effluent with 400 pounds of ferric oxide and 1,000 pounds of lime, ...	.08	47.4	9.6	37.8	1.65	.17	5.11	+.02	.23	8,940

Sewage treated with 400 Pounds Ferric Oxide as Sulphate and Different Amounts of Lime, Nov. 5, 1889.

Scales.		*Scales.*	
Loss on ignition, . . .	10 = 10 parts.	Acid number, ...	10 = 0.10
Albuminoid ammonia, . .	10 = 0.10 part.	Bacteria, ...	10 = 100,000.
Turbidity, ...	10 = 0.10	Cost of chemicals, . . .	10 = 10 cents annually for each inhabitant.
Alkalinity, ...	10 = 0.10		

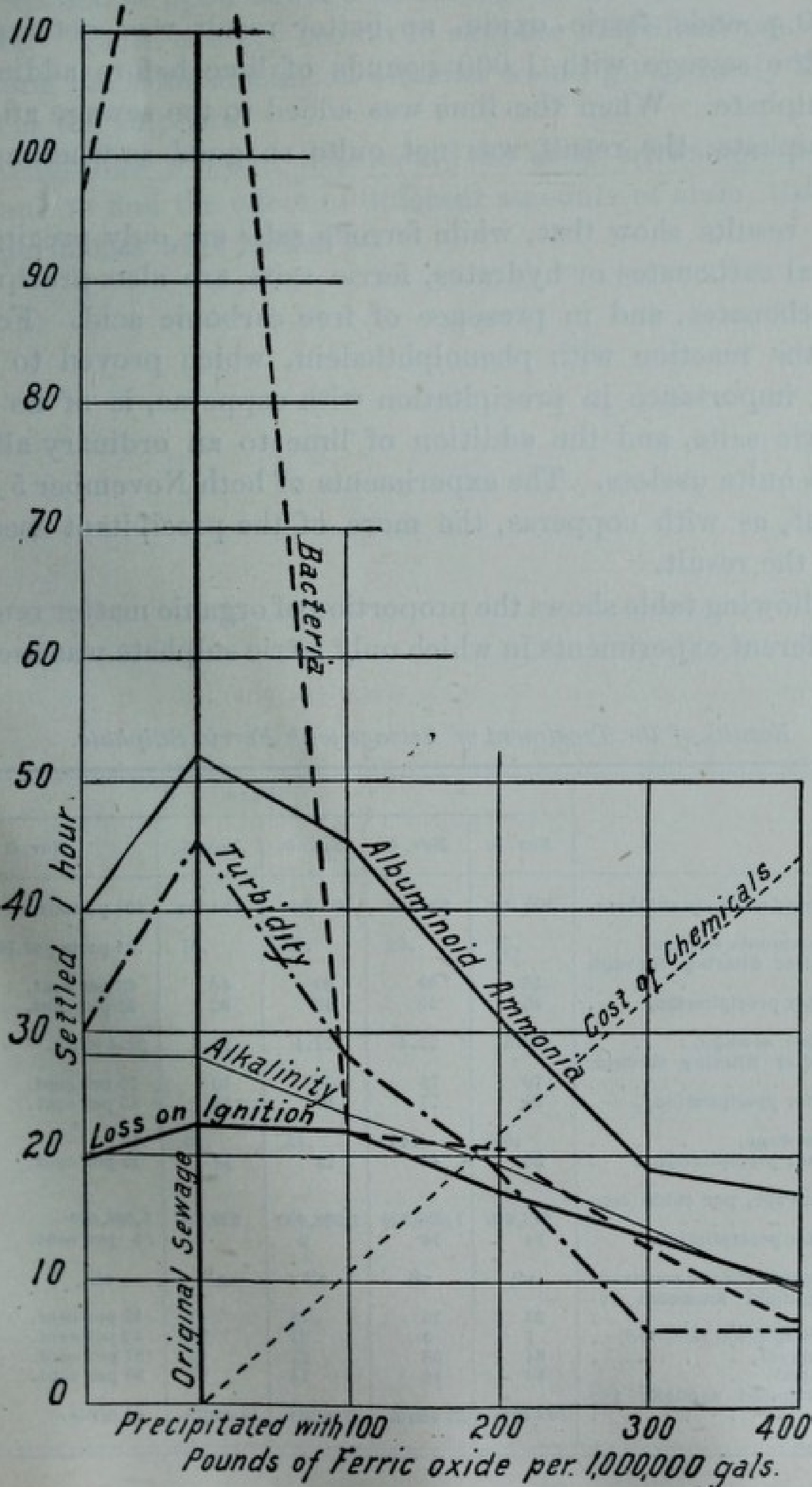


Results of the Treatment of Sewage with Different Amounts of Ferric Sulphate and with Ferric Sulphate and Lime (Nov. 6, 1889).

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Bacteria per Cubic Centimeter.
Original sewage, ...	.45	45.2	22.4	22.8	2.10	.52	4.60	–	.28	1,398,600
Filtered through paper, ...	–	37.2	16.8	20.4	2.10	36	–	–	–	–
After settling 1 hour, ...	.30	42.4	19.6	22.8	2.00	.39	4.59	–	.28	970,000
Effluent with 100 pounds of ferric oxide to 1,000,000 gallons of sewage, ...	.28	47.6	22.2	25.4	2.00	.46	4.61	–	.23	223,432
Effluent with 200 pounds of ferric oxide, .	.19	42.6	17.2	25.4	2.10	.31	4.71	–	.19	204,508
Effluent with 300 pounds of ferric oxide, .	.06	36.6	13.4	23.2	2.10	.19	4.85	–	.14	130,118
Effluent with 400 pounds of ferric oxide, .	.06	36.8	9.6	27.2	2.00	.17	4.91	–	.09	66,528
Effluent with 300 pounds of ferric oxide and 1,000 pounds of lime; lime mixed with sewage first, ...	.05	42.4	10.6	31.8	2.00	.21	4.90	.06	.37	176,904
Effluent with 300 pounds of ferric oxide and 1,000 pounds of lime; ferric oxide mixed with sewage first, ...	.15	48.2	12.0	36.2	2.00	24	4.76	.06	.39	46,445

Sewage treated with Different Amounts of Ferric Sulphate, Nov. 6, 1889.

Scales.		*Scales.*	
Loss on ignition, . . .	10 = 10 parts.	Alkalinity, ...	10 = 0.10.
Albuminoid ammonia, . .	10 = 0.10 part.	Bacteria, ...	10 = 100,000.
Turbidity, ...	10 = 0.10.	Cost of chemicals, . . . 10 = 10 cents annually for each inhabitant.	



From these experiments it appears that the influence of lime on the result is very small. On November 5, with 200 pounds ferric oxide, the result was slightly better when lime was used; but the improvement does not correspond with the increased cost. With 400 pounds of ferric oxide, the lime had almost no influence. On November 6, with 300 pounds ferric oxide, no better result was obtained by mixing the sewage with 1,000 pounds of lime before adding the ferric sulphate. When the lime was added to the sewage after the ferric sulphate, the result was not quite so good as when no lime was used.

These results show that, while ferrous salts are only precipitated by normal carbonates or hydrates, ferric salts are also precipitated by bi-carbonates, and in presence of free carbonic acid. For this reason, the reaction with phenolphthalein, which proved to be of so much importance in precipitation with copperas, is of no value with ferric salts, and the addition of lime to an ordinary alkaline sewage is quite useless. The experiments of both November 5 and 6 show that, as with copperas, the more of the precipitant used, the better is the result.

The following table shows the proportion of organic matter removed in the different experiments in which only ferric sulphate was used: —

Results of the Treatment of Sewage with Ferric Sulphate.

	Date.				
	Nov. 5.	Nov. 6.	Nov. 6.	Nov. 5.	Nov. 6.
Ferric oxide used as ferric sulphate,	200 lbs.	200 lbs.	300 lbs.	400 lbs.	400 pounds.
Albuminoid ammonia sewage,	.57	.52	.52	.57	.52 parts per 100,000.
Remaining after filtering through paper,	56	69	69	56	69 per cent.
Remaining after precipitation,	45	59	36	33	33 per cent.
Loss on ignition, sewage,	22.8	22.4	22.4	22.8	22.4 parts.
Remaining after filtering through paper,	70	76	76	70	76 per cent.
Remaining after precipitation,	65	77	60	35	43 per cent.
Turbidity of sewage,	.50	.45	.45	.50	.45
Remaining after precipitation,	26	42	13	18	13 per cent.
Bacteria in sewage, per cubic centimeter,	218,960	1,398,600	1,398,600	218,960	1,398,600
Remaining after precipitation,	14	14	9	3	5 per cent.
Suspended organic matter removed,	all	all	all	all	all.
Soluble albuminoid ammonia removed,	20	15	48	41	52 per cent.
Soluble loss on ignition removed,	7	0	21	50	43 per cent.
Turbidity removed,	64	58	87	82	87 per cent.
Bacteria removed,	86	86	91	97	95 per cent.
Cost per inhabitant annually for chemicals,	22 cents.	22 cents.	33 cents.	44 cents.	44 cents.

Precipitation with Aluminum Salts.

Aluminum sulphate or crude alum is now made for use in the dye-house, for decolorizing peaty waters, and for sewage precipitation. Its action upon sewage is analogous to the action of ferric sulphate. There is every reason to suppose that aluminum chloride containing the same amount of alumina would give exactly the same results as the sulphate.

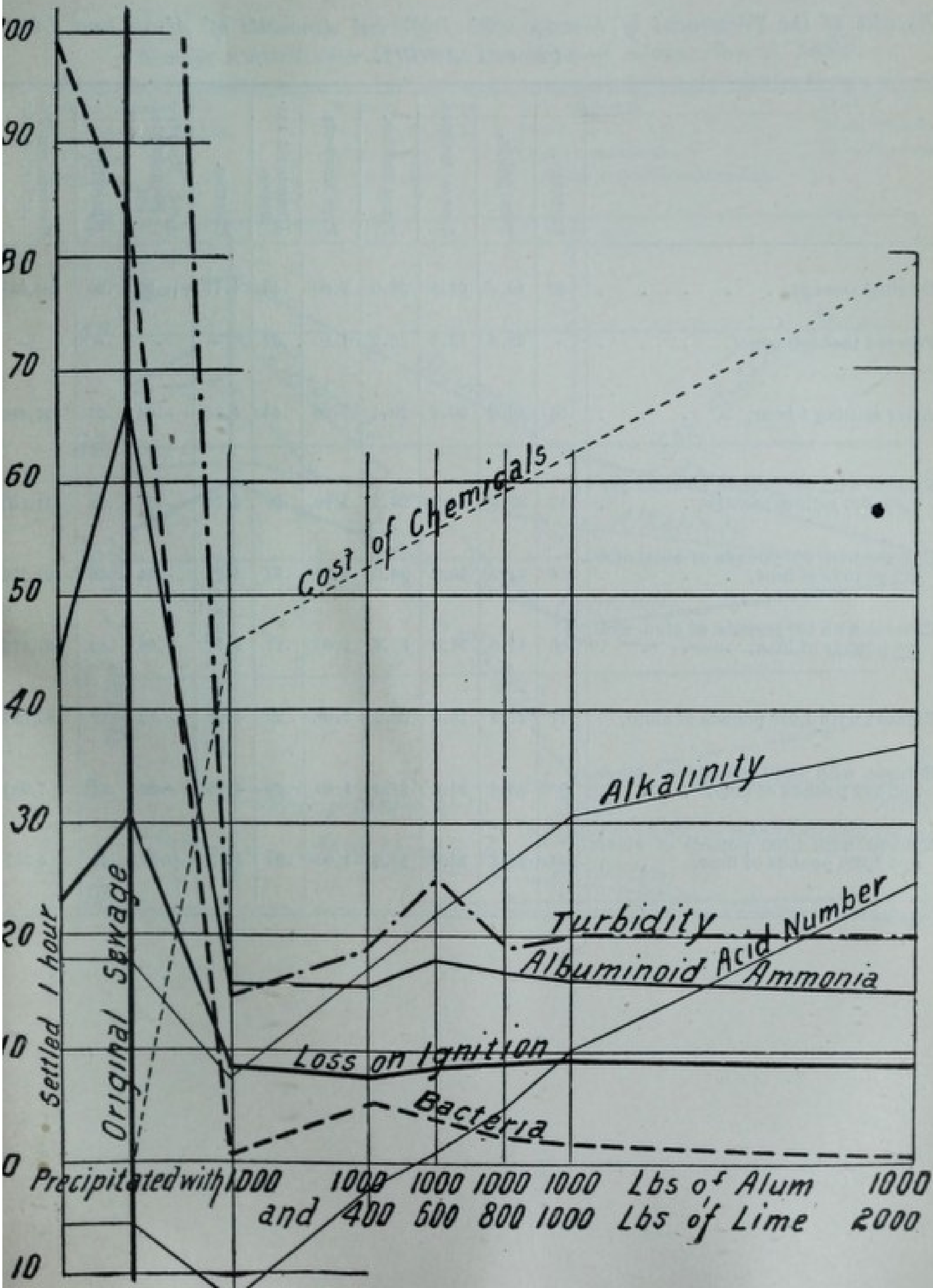
To determine whether lime could be used advantageously with alum, and to find the effect of different amounts of alum, the following experiments were made: —

Results of the Treatment of Sewage with 1,000 Pounds of Alum to 1,000,000 Gallons and Different Amounts of Lime (Oct. 29, 1889).

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid number Phenolphthalein.	Alkalinity.	Bacteria per Cubic Centimeter.
Original sewage, ...	2.00	89.2	30.4	58.8	.85	.67	3.79	—.05	.18	835,200
Filtered through paper, ...	-	56.4	17.2	39.2	.85	.39	-	-	-	-
After settling 1 hour, ...	1.20	73.2	23.2	50.0	.85	.44	3.80	—.05	.18	994,500
Effluent with 1,000 pounds of alum, ...	.15	28.4	8.8	19.6	.85	.16	3.77	—.12	.08	7,200
Effluent with 1,000 pounds of alum and 400 pounds of lime, ...	.19	33.2	7.6	25.6	.85	.16	3.84	—.02	.17	54,280
Effluent with 1,000 pounds of alum and 600 pounds of lime, ...	.25	41.0	8.6	32.4	.85	.18	3.86	+.01	.22	42,090
Effluent with 1,000 pounds of alum and 800 pounds of lime, ...	.19	39.8	9.0	30.8	.85	.17	3.91	.05	.26	25,872
Effluent with 1,000 pounds of alum and 1,000 pounds of lime, ...	.20	42.8	9.2	33.6	.95	.16	4.00	.10	.31	19,236
Effluent with 1,000 pounds of alum and 2,000 pounds of lime, ...	.20	49.2	8.8	40.4	.95	.15	4.09	.25	.37	520

ewage treated with 1,000 Pounds of Alum and Different Amounts of Lime (Oct. 29, 1889).

Scales.		*Scales.*	
)ss on ignition, . . .	10 = 10 parts.	Acid number, ...	10 = 0.10
lbuminoid ammonia, . .	10 = 0.10 part.	Bacteria, ...	10 = 100,000.
ırbidity, ...	10 = 0.10	Cost of chemicals, . . .	10 = 10 cents annually for each individual.
lkalinity, ...	10 = 0.10		

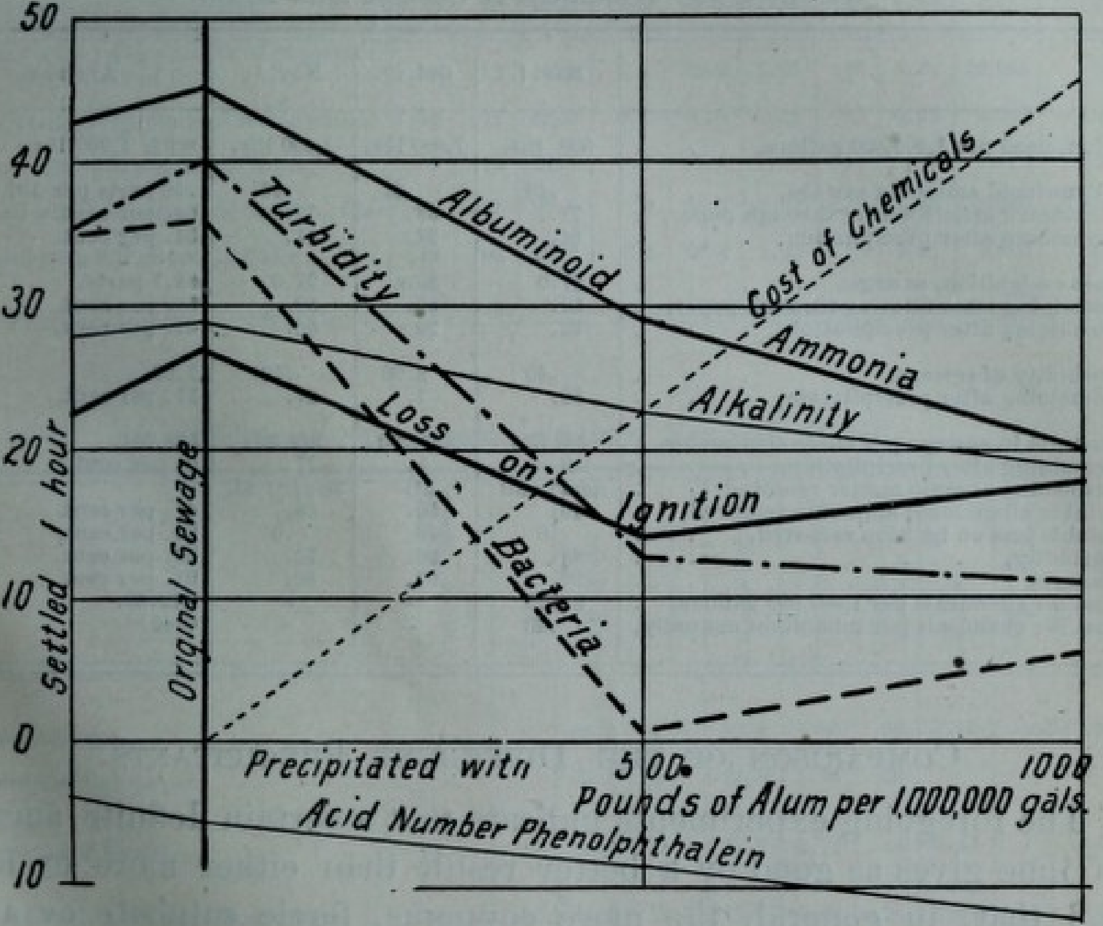


Results of the Treatment of Sewage with Different Amounts of Alum and Lime (Nov. 1, 1889).

	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.	Bacteria per Cubic Centimeter.
Original sewage, ...	.40	50.0	27.0	23.0	2.00	.45	4.77	-.05	.29	361,328
Filtered through paper, ...	-	38.8	13.6	25.2	1.90	.32	-	-	-	-
After settling 1 hour, ...	.35	42.8	22.4	20.4	1.90	.43	4.78	-.04	.28	347,600
Effluent with 500 pounds of alum per 1,000,000 gallons sewage, . . .	.13	37.4	14.2	23.2	1.90	.29	4.78	-.08	.23	11,160
Effluent with 500 pounds of alum and 400 pounds of lime, ...	.16	44.2	15.2	29.0	1.90	.31	4.77	-.01	.36	92,250
Effluent with 500 pounds of alum and 800 pounds of lime, ...	.08	51.6	14.0	37.6	1.90	.27	4.77	+.08	.52	31,375
Effluent with 1,000 pounds of alum, .	.11	41.2	18.0	23.2	1.90	.20	4.76	-.12	.19	63,750
Effluent with 1,000 pounds of alum and 500 pounds of lime, . . .	.08	43.4	14.8	28.6	1.80	.20	4.75	-.02	.31	7,900
Effluent with 1,000 pounds of alum and 1,000 pounds of lime, . .	.04	50.4	13.6	26.8	1.90	.21	4.73	+.08	.44	4,760

Sewage treated with Different Amounts of Alum, Nov. 1, 1889.

Scales.		*Scales.*	
Loss on ignition, ...	10 = 10 parts.	Acid number, ...	10 = 0.10.
Albuminoid ammonia, . .	10 = 0.10 part.	Bacteria, ...	10 = 100,000.
Turbidity, ...	10 = 0.10.	Cost of chemicals, . . . nually for each inhabitant.	10 = 10 cents annually for each inhabitant.
Alkalinity, ...	10 = 0.10.		



These experiments indicate that, as with ferric sulphate, lime has little or no effect. With lime the precipitation is a little more rapid, but the short time gained by its use would hardly compensate for the extra cost.

The result with 1,000 pounds to the 1,000,000 gallons is, on the whole, somewhat better than with 500 pounds, but the difference is much less marked than with corresponding quantities of copperas or ferric sulphate.

The results of those experiments in which alum only was used are as follows : —

Results of the Treatment of Sewage with Alum.

	Nov. 1.	Oct. 29.	Nov. 1.	Average.
Alum used per 1,000,000 gallons,	500 lbs.	1,000 lbs.	1,000 lbs.	with 1,000 lbs.
Albuminoid ammonia sewage,	.45	.67	.45	.56 parts per 100,000.
Remaining after filtering through paper,	71.	58.	71.	64. per cent.
Remaining after precipitation,	64.	24.	44.	34. per cent.
Loss on ignition, sewage,	27.0	30.4	27.0	28.7 parts.
Remaining after filtering through paper,	50.	56.	50.	53. per cent.
Remaining after precipitation,	52.	29.	66.	47. per cent.
Turbidity of sewage,	.40	2.00	.40	1.20.
Remaining after precipitation,	32.	7.	27.	17. per cent.
Bacteria in sewage per cubic centimeter,	361,328	835,200	361,328	598,264.
Remaining after precipitation,	3.	1.	17.	9. per cent.
Suspended organic matter removed,	nearly all	all	nearly all	
Soluble albuminoid ammonia removed,	10.	59.	38.	47. per cent.
Soluble loss on ignition removed,	.0	48.	.0	24. per cent.
Turbidity,	68.	93.	73.	83. per cent.
Bacteria,	97.	99.	83.	91. per cent.
Cost for chemicals per 1,000,000 gallons,	$6.25	–	–	$12.50.
Cost for chemicals per inhabitant annually,	.23	–	–	0.45.

Comparison of the Different Precipitants.

The foregoing experiments indicate that a certain definite amount of lime gives as good or a better result than either more or less; and that, in general, the more copperas, ferric sulphate or alum used, the better the result; and that ferric sulphate and alum usually require no lime for complete precipitation, while with copperas a definite amount of lime must be used.

It now remains to compare the results obtained with the best amount of lime, and with equal value of the other chemicals, upon the same sample of sewage when used under the most favorable conditions.

Two series of experiments were made in this way, with the following results : —

Results of Treatment of Sewage with Equal Values of Different Chemicals (Nov. 22, 1889).

	Cost of Chemicals.*	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Bacteria per Cubic Centimeter.	Yeast Cells per Cubic Centimeter.
Original sewage, ...	–	.40	43.0	18.0	25.0	1.25	.40	4.86	25,840	20,700
Filtered through paper, ...	–	–	34.8	11.2	23.6	1.25	.26	–	–	–
After settling 1 hour, ...	.0	.30	38.8	13.6	25.2	1.25	.28	4.82	10,920	16,700
Effluent with 1,800 pounds of lime per 1,000,000 gallons of sewage, . .	$.30	.08	45.6	10.2	35.4	1.25	.19	4.83	1,911	1,650
Effluent with 1,000 pounds of copperas and 700 pounds of lime, . . .	.30	.12	46.4	9.2	37.2	1.25	.17	4.80	16,044	400
Effluent with 270 pounds of ferric oxide,	.30	.08	38.0	8.0	30.0	1.25	.18	4.92	2,047	1,000
Effluent with 650 pounds of alum, .	.30	.10	34.4	8.0	26.4	1.50	.19	4.88	2,475	3,700
Effluent with 360 pounds of ferric oxide,	.40	.07	37.6	5.8	31.8	1.25	.15	4.96	1,980	1,000
Effluent with 870 pounds of alum, .	.40	.09	38.2	9.6	28.6	1.25	.19	4.81	1,800	2,200

The Same Experiments repeated Nov. 26, 1889.

	Cost of Chemicals.*	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Acid Number Phenolphthalein.	Alkalinity.
Original sewage, ...	–	.50	53.8	20.4	33.4	1.65	.50	8.40	–.06	.30
Filtered through paper, ...	–	–	43.2	13.6	29.6	1.75	.29	–	–	–
After settling 1 hour, ...	.0	.35	49.2	18.0	31.2	1.75	.44	8.44	–	.29
Effluent with 1,800 pounds of lime, . .	$0.30	.13	54.8	14.8	40.0	1.60	.24	7.47	.29	.46
Effluent with 1,000 pounds of copperas and 700 pounds of lime, ...	.30	.15	54.8	10.4	44.4	1.65	.22	8.01	.06	.40
Effluent with 270 pounds of ferric oxide,	.30	.09	46.0	10.0	36.0	1.65	.19	8.42	–	.17
Effluent with 650 pounds of alum, . .	.30	.11	43.2	9.6	33.6	1.65	.25	8.36	–	.23
Effluent with 360 pounds of ferric oxide, .	.40	.09	45.6	8.0	37.6	1.60	.17	8.43	–	.13
Effluent with 870 pounds of alum, . .	.40	.12	47.2	10.0	37.2	1.65	.20	8.32	–	.20

* Per inhabitant annually.

The Per Cent. of Soluble Organic Matter removed by Chemicals of Equal Value.

CHEMICALS USED.		Thirty Cents.				Forty Cents.	
		Lime.	Copperas and Lime.	Ferric Sulphate.	Alum.	Ferric Sulphate.	Alum.
Soluble albuminoid ammonia removed.	Nov. 22,	27	35	31	27	42	27
	Nov. 26,	17	24	34	14	41	31
	Average,	22	29	32	20	41	29
Soluble loss on ignition removed.	Nov. 22,	9	18	29	29	48	14
	Nov. 26,	0	24	26	30	41	26
	Average,	4	21	28	30	45	20
Turbidity removed.	Nov. 22,	80	70	80	75	83	78
	Nov. 26,	74	70	82	78	82	76
	Average,	77	70	81	77	83	77
Bacteria removed, Nov. 22,		93	38	92	91	93	93
Yeast removed, Nov. 22,		92	98	95	82	95	90

If we take the percentage of albuminoid ammonia removed to represent organic matter, we find that, in addition to all the suspended matter, the following amounts of soluble organic matter have been removed : —

Soluble Organic Matter removed by Chemicals at Different Costs.

With lime costing 30 cents per inhabitant, annually,	22 per cent.
With copperas and lime costing 30 cents,	29 per cent.
With ferric sulphate costing 30 cents,	32 per cent.
With aluminum sulphate costing 30 cents,	20 per cent.
With ferric sulphate costing 40 cents,	41 per cent.
With aluminum sulphate costing 40 cents,	29 per cent.

The earlier results of October and November, expressed in the same way, are as follows : —

With lime costing 27 cents per inhabitant, annually,	20 per cent.
With copperas and lime costing 20 cents,	13 per cent.
With copperas and lime costing 31 cents,	39 per cent.
With ferric sulphate costing 22 cents,	17 per cent.
With ferric sulphate costing 33 cents,	48 per cent.
With ferric sulphate costing 44 cents,	46 per cent.
With aluminum sulphate costing 33 cents,	10 per cent.
With aluminum sulphate costing 45 cents,	47 per cent.

These earlier results, while agreeing with the others in the main, and confirming them, cannot be compared with each other as can the later ones, for each of these was obtained on different samples of sewage, while in the later series the same samples of sewage served for each process.

The proportion of organic matter removed, as indicated by the loss on ignition, usually agrees fairly well with that obtained from the albuminoid ammonia; but the results are not regarded as so sure an indication of purification as is the albuminoid ammonia. By far the greatest difference was with lime, where 22 per cent. of the soluble albuminoid ammonia was removed, and only 4 per cent. of the soluble loss on ignition.

THE COMPARATIVE ADVANTAGES OF THE DIFFERENT PRECIPITANTS.

The removal of bacteria is due in part to the mechanical action of the precipitate carrying them down, and in part to the chemical action of the precipitant in killing them. In the latter case, even if the bodies remain, they are not counted, for dead bacteria do not affect the method of determination used.

The yeast, on the other hand, is a measure of the completeness with which exceedingly small insoluble bodies are removed from the sewage; for, even if killed, the dead yeast cells are nevertheless counted as well as the living ones by the microscope. It will be seen, from the few series in which the yeast cells have been counted, that the yeast is never completely removed. This indicates, as does the turbidity, that a small amount of suspended matter is always left. This suspended matter consists largely of minute particles of the precipitate, which have either escaped the first rapid settling, or have been precipitated after it. The particles are usually present in only small amounts, and when the effluent is so clear that a pin can be seen through a foot or more of it, as is the case in a successful experiment, they cannot be regarded as of any practical importance. The color of the effluent is, however, affected by them in a marked manner. When alum is used, the particles are white and almost invisible, while if copperas is used they are greenish, turning red on exposure to the air, and with ferric sulphate they are red from the first. These particles of ferric hydroxide, too small to be seen individually, give the whole liquid a light-red color.

It does not seem to me that the slight color given by the use of iron should be considered an objection in judging the merits of the different processes. It should be remembered that, when alum is used, a small portion of the alumina is really present in the effluent, but, being white, it is not noticed as is a corresponding amount of iron.

The lime process has little to recommend it. Owing to the large amount of lime water required, and the difficulty of accurately adjusting the lime to the sewage, very close supervision would be required to obtain a good result, and, even then, the result is inferior to that obtained in other ways.

Precipitation by copperas is also somewhat complicated, owing to the necessity of getting the right amount of lime mixed with the sewage before adding the copperas. When this is done, a good result is obtained. The amount of iron left in the effluent is much greater than with ferric sulphate, owing to the greater solubility of ferrous hydroxide.

Ferric sulphate and alum have the advantage over both lime and copperas, that their addition in concentrated solution can be accurately controlled, and the success of the operation does not depend upon the accurate adjustment of lime or any chemical to the sewage.

The results with ferric sulphate have been, on the whole, more satisfactory than those with alum. This seems to be due in part to the greater rapidity with which precipitation takes place, and in part to the greater weight of the precipitate. It is probable, from the greater ease with which ferric sulphate is precipitated, that it would give a good result with a sewage that was not sufficiently alkaline to precipitate alum at once.

It is quite possible that the same process would not give equally good results upon all kinds of sewage. Special sewages may require special treatment. For this reason, and also on account of changes in the prices of the several chemicals, it is impossible to say that one precipitant is universally better than another.

Purity of Effluent.

In the later experiments, from 25 to 43 per cent. of the soluble organic matter, as shown by the albuminoid ammonia and loss on ignition, was removed by copperas, ferric sulphate or alum, costing from 30 to 40 cents per inhabitant, annually. In addition to this, all of the suspended matter was removed.

The average composition of the sewage used for these experiments, and also the average analysis of 262 samples of sewage, from Nov. 1, 1888, to Oct. 31, 1889, evenly distributed throughout the year, is as follows: —

Average Composition of the Sewage used.

Parts per 100,000.

	In the Experiments.	For the Year.
Turbidity,	.65	
Loss on ignition, total,	25.4	19.1
In solution, filtered,	16.6	12.1
In suspension, difference,	8.8	7.0
In suspension,	35 per cent.	37 per cent.
Albuminoid ammonia, total,	.66	.53
In solution, filtered,	.39	.267
In suspension, difference,	.27	.263
In suspension,	41 per cent.	50 per cent.
Free ammonia, total,	1.83	1.82
In solution,	1.81	1.77

In the sewage used for the experiments, 41 per cent. of the organic matter, as shown by the albuminoid ammonia, was in suspension, while in the year's sewage the proportion was 50 per cent. Let us take 45 per cent. as the average. If we can remove 30 per cent. of the soluble organic matter, and all of the suspended, we shall leave only 70 per cent. of the 55 per cent. soluble organic matter, or 38 per cent. of the whole; while, if we remove 40 per cent. of the soluble organic matter, the amount left will be only 33 per cent. of the whole.

Of the other substances present, the insoluble inorganic matters, mainly sand, are removed almost completely, while the soluble salts, including chlorine and free ammonia, are not affected in the least, excepting that the acid of the precipitant remains in solution, in combination with the alkali of the sewage. A very large proportion of bacteria and of the other organisms is removed. This is all that can be done by chemical precipitation.

Relations of Sewage and the Effluents from Chemical Precipitation to the Growth of Bacteria and Algæ.

When a nuisance is produced by sewage in any way, the direct cause is usually the development of organisms fed by the organic matter and nitrogen compounds of the sewage. To secure the absence of organisms in any pond or stream, where food is present, is a hopeless task. It thus happens that, while the organisms are the real cause of the trouble, their removal from sewage is often of less importance than the removal of the matter in the sewage on which they feed. The proportion of organic matter removed does not necessarily represent the proportion of food for organisms removed, for some kinds of organic matter are no more suitable food for bacteria than is sawdust for horses. An effluent from a sewage filter, where nitrification is complete, containing 2 per cent. of the total organic matter of the sewage, will not serve as food for bacteria, because it has been worked over already by bacteria in the filter, and nearly everything available has been removed. If, on the other hand, sewage is mixed with fifty times its volume of pure water, so that it contains the same amount of organic matter as the effluent, the bacteria will increase enormously for a few days. From this point of view, the effluent is many times purer than is indicated by the ratio of its organic matter to that of the sewage.

With sewage precipitation the case is entirely different, for here there is no bacterial action. There is, however, some reason to think that the organic matter left is not so good a food, and therefore not so dangerous, as that removed. Sewage settled alone will keep turbid with organisms, and in a day or two masses of zoöglœa (dead or resting bacteria) separate from it. Sewage precipitated by either copperas, ferric sulphate, or alum in suitable quantities, has repeatedly remained so clear that the bottom of the barrels could be distinctly seen through more than two feet of liquid, for one or two weeks. In these cases no flakes of zoöglœa so characteristic of untreated sewage has been seen, and the odor is much less than that of sewage alone.

This question of the quality of the organic matter left by precipitation has not been sufficiently investigated, but the indications are, that it is more objectionable than the same amount in the effluents from sewage filtration through sand, but less objectionable than that in sewage.

When untreated sewage is put into a small stream or pond, it often happens that the suspended matters settle out, forming considerable deposits, which, putrefying out of contact of the air, give rise to very offensive gases. It is hardly probable that well-precipitated sewage would do this, for almost no suspended organic matter is present when it leaves the settling tank, and very little soluble matter is precipitated on exposure to the air.

Another nuisance which might be caused by putting precipitated sewage into a stream or pond, is the growth of algæ, — green plants fed by the ammonia of the sewage. It may be said, however, that this growth would be no greater than that caused by the crude sewage, and probably not much greater than that caused by filtered sewage; for, in the latter case, while the ammonia is removed, nearly an equivalent of nitrate is formed, and this serves as food for algæ almost as readily as ammonia.

A number of fishes were put into precipitated sewage. In each case the fish died within five minutes. This sudden death cannot be due to the chemicals used, for it was found that the fishes lived for a considerable time in solutions of the chemicals much stronger than those present in the sewage. The fishes died for want of air. Sewage contains no dissolved oxygen, and, if any is absorbed from the air, it is quickly taken up by the organic matter. The precipitated sewage also contains no oxygen.

Conclusions.

Using lime as a precipitant, we have found that there is a certain definite amount of lime, depending upon the composition of the sewage, which gives a better result than less, and as good or a better result than more. This amount of lime is that which exactly suffices to form normal carbonates with all the carbonic acid of the sewage. It is possible in a few minutes, by simple titration, to determine approximately the amount of uncombined carbonic acid present in sewage, and how much lime will be required to combine with it. It is also possible to determine in a similar way, after mixing, whether enough or too much lime has been added. The amount of lime required by Lawrence sewage averages about 1,600 pounds per million gallons.

Ordinary house sewage is not sufficiently alkaline to precipitate copperas, and a small amount of lime must be added to obtain good results. The quantity of lime required depends both upon the composition of the sewage and the amount of copperas used, and can be calculated from titration of the sewage. Very imperfect results are obtained with too little lime, and, when too much is used, the excess is wasted, the result being the same as with a smaller quantity.

After mixing the sewage with both copperas and lime, if enough or too much lime has been used the mixture will color phenolphthalein red, while, if too little has been used, no color will be produced. This test can conveniently be used by people having no knowledge of chemistry, and affords an easy and very accurate method of applying enough lime, and of avoiding a useless excess.

Using in each case a suitable amount of lime, the more copperas used the better the result; but, with more than one-half a ton per million gallons, the improvement does not compare with the increased cost.

Some acid sewages contain a considerable amount of iron in solution, and in these cases precipitation by lime is really the rendering available of the copperas already in the sewage, and so is properly classed as an iron treatment rather than a lime treatment. In this case the reaction with phenolphthalein shows the presence of enough lime.

In precipitation by ferric sulphate and crude alum, the addition of lime was found unnecessary, as ordinary sewage contains enough alkali to decompose these salts. Within reasonable limits the more of these precipitants used the better is the result, but with very large quantities the improvement does not compare with the increased cost.

Using equal values of the different precipitants, applied under the most favorable conditions for each, upon the same sewage, the best results were obtained with ferric sulphate. Nearly as good results were obtained with copperas and lime used together, while lime and alum each gave somewhat inferior effluents. The range of these results was, however, comparatively narrow; and it may be that, with sewage of a different character, or with variations in the prices of the chemicals, it would be advantageous to use copperas with lime, or even alum. When lime is used there is always so much lime left in solution that it is doubtful if its use would ever be found satisfactory except in case of acid sewage.

It is quite impossible to obtain effluents by chemical precipitation which will compare in organic purity with those obtained by intermittent filtration through sand.

It is possible to remove from one-half to two-thirds of the organic matter of sewage by precipitation, with a proper amount of an iron or aluminum salt, and it seems probable that, in some cases at least, if the process is carried out with the same care as is required in the purification of sewage by intermittent filtration, a result may be obtained which will effectually prevent a public nuisance.

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I. Micro-Organisms: Microscopical and Bacterial. Introductory.

Organisms, the proper subjects of biological study, as they occur in drinking-water or in sewage may be either animal or vegetable, either alive or dead. They are generally microscopic in size, and belong, therefore, almost without exception, to the group of "micro," i. e., "small," organisms. The term micro-organisms is, indeed, often enough employed in a much narrower sense; e. g , as a synonym for the bacteria, or for a miscellaneous collection of bacteria and protozoa. In this report, however, the term micro-organisms will be used only in its strictly etymological, or most general and indefinite, significance, comprehending all *small* organisms; and, for greater precision, it will be considered that MICRO-ORGANISMS *include all organisms, whether plants or animals, invisible, or barely visible, to the naked eye.*

The micro-organisms might be subdivided into "animal forms" and "plant forms," or otherwise; but the most convenient subdivision for practical purposes is based upon the two entirely different methods by which they are detected, counted and studied.

Of all the micro-organisms those appear to be the most important which are the smallest; namely, the *Schizomycetes* or bacteria. These are so small that, although they are all "microscopic," i. e., invisible to the naked eye, they cannot be satisfactorily studied by the microscope. Consequently, for them the ordinary methods of microscopical study have to be abandoned, or at least so much supplemented by other methods that they become entirely secondary. The method of first importance in the study of these organisms is the method of "cultures," which consists, essentially, in the observation of the organisms, not as individuals, but as masses or colonies of individuals, growing upon certain nutritive substances. The forms and habits of these "colonies," together with their effects upon such substances as beef-jelly, bouillon, boiled potato, milk, etc., furnish important data which enable the investigator to analyse, enumerate and differentiate the various kinds of bacteria. It is upon this simple method of "cultures"—i. e., the naked-eye observation of the organisms collectively, or in "colonies," when it is impossible, even with the microscope, to study them effectively as individuals—that the new science of bacteriology, created by the genius of Louis Pasteur and of Robert Koch, chiefly rests.

All the micro-organisms excepting the bacteria may be studied more or less effectively, without the use of the method just described, by means of the microscope and such apparatus as is familiar to microscopists. It is therefore reasonable to designate these organisms as "microscopical," and to define the limits of the group as including all micro-organisms excepting the bacteria. This extremely simple arrangement has been found very convenient in the practical work of the Lawrence Experiment Station, for which it was devised, as well as in the examinations of the public water-supplies of Massachusetts, both under the auspices of the State Board of Health. It is exhibited in a tabular form as follows: —

MICRO-ORGANISMS. Organisms, either plants or animals, invisible or barely visible to the naked eye.	*Microscopical Organisms.* Not requiring special "cultures." Easily studied with the microscope. Microscopic in size, or slightly larger. Plants or animals. *Bacterial Organisms.* Requiring special cultures. Difficultly studied with the microscope. Microscopic or sub-microscopic in size. Plants.

The biological work of the Lawrence Experiment Station has been arranged throughout along the lines indicated above. The sewage and water treated have been constantly regarded as containing not only bacteria, but also other micro-organisms, such as yeast and other fungi, diatoms and algæ, among the plants; and rhizopods, infusoria, rotifers, etc., among the animals. Accordingly, not only bacterial, but also microscopical, analyses have been repeatedly made; and, as the outcome of experience, or to meet the exigencies of new investigations, old methods have, in some cases, been improved, and new methods have been devised.

During the first eight months the bacteriological work was in charge of Dr. E. K. Dunham, with the assistance of Mr. H. L. Grant, who, upon the resignation of Dr. Dunham, continued the work until it was taken in charge by Mr. G. R. Tucker. During the entire second year it has been done under my personal direction, in the biological laboratory of the Massachusetts Institute of Technology. My chief assistant in this department of the work has been my friend and former pupil, Mr. Edwin O. Jordan, who has devoted himself, with enthusiasm and marked ability, to the work in general, and especially to the difficult subject of characteristic bacteria in the water, sewage, sands, effluents, etc. Upon these he has prepared a special Report, which is included herewith (see section V.). In co-operation with Mrs. Ellen H. Richards, one of the chemists of the Board, he has also arrived at highly important results upon nitrification, and a special Report by them concludes this volume. I have also been assisted on this side of the work, at different times, by Messrs. Frederic S. Hollis, S. B., and James L. Deming, S. B.

The microscopical examinations for the first eighteen months were in charge of Mr. G. H. Parker, of the Museum of Comparative Zoölogy of Harvard University, with the assistance of Mr. C. B. Davenport. During the last six months, i. e., since June 1, 1889, this work has been done, under my direction, at the station. The actual analyses have been made by Mr. George L. West of Harvard University, who has employed for the work a new quantitative method (see pp. 803–811). To Dr. R. R. Andrews of Cambridge, Mass., we are ander obligations for his excellent photographs of the bacteria described beyond. The photogravures of these, appended to this report, testify to his skill and his success.

The aim of the biological work has been to discover the origin, functions and fate of the various organisms concerned in sewage disposal; to differentiate the functions of the organisms involved, so as to learn the conditions of their usefulness, or, if necessary, of their removal; and to co-operate to the fullest possible extent with the engineers and chemists of the Board in the solution of mixed problems, for the sake of arriving at improved and safer methods of sewage disposal and water supply. The results already obtained and herewith reported are believed to have justified the endeavor; but, with the knowledge and the experience hitherto gained, still better results may be anticipated in the future.

I desire to acknowledge my sense of personal obligation to the Chairman of the Committee on Water Supply and Sewerage, Mr. Hiram F. Mills, the member of the State Board of Health resident in Lawrence, who has not only contributed to the investigations of the Board, without remuneration, his well-known engineering attainments, but has also personally devoted the greater part of his time to the co-ordination of the work of the Lawrence Experiment Station, so that whatever of permanent value has been achieved, even in a department like this, perhaps the remotest from his own, is largely due to his suggestive guidance and criticism.

II. Methods of Microscopical Analysis.

Although microscopical analyses (so called) of water or sewage have often enough been undertaken, the methods employed have hitherto been so imperfect that little importance has been attached either to the examinations themselves or to the results.

The methods used have generally involved the direct microscopical examinations of a very small portion of the water itself, e. g., of one drop at a time upon a slide; or, still more often, of a small amount of the sediment deposited by the water upon standing for some hours or even days. Results obtained by either or both of these methods are necessarily only roughly qualitative, and, though often interesting and sometimes important, could never be even approximately exact.

A.—Methods Employed Hitherto.

The first systematic microscopical examination of water from the sanitary stand-point appears to have been made by Hassall,* upon the river Thames, and the London water supply. A condensed account of his results was published in the "Lancet" for March, 1850. A more complete summary, illustrated by wood-cuts, appeared in the same journal in 1851, and is also quoted in a volume by Hassall, entitled, "Food and its Adulterations" (London, 1855). The complete account was also published as an octavo *brochure*, with colored plates.†

It does not appear exactly how Hassall's analyses were made, beyond the bare facts that a "wine-bottle" full of the water was taken, and that, "on allowing the heavier particles contained in a test tube filled with this water to subside, and examining a drop of the sediment," other data were obtained. In what follows it must not be overlooked that, until 1881, microscopical analyses always included the bacterial organisms. Since that time the methods of culture introduced by Koch have tended to draw attention away

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* Hassall, Arthur Hill. "Memoir on the Organic Analysis or Microscopic Examination of Water Supplied to the Inhabitants of London and the Suburban Districts." The Lancet, 1850, I, 230.

† "A Microscopic Examination of the Water Supplied to the Inhabitants of London and the Suburban Districts." London, 1850.

from the microscopical, and to fix it upon the bacterial, organisms. Previous to 1881, however, all microscopical analyses included also, as far as possible, the bacterial analyses.

Hassall begins his earliest paper as follows: "In the chemical analyses of water generally given we find, under the heading, 'Organic Matter,' the word 'traces;' and this, in the majority of instances, is the only information we obtain from the chemist in reference to the most important contamination to which water is liable. . . . In the course of this investigation it will become apparent that these traces are not inconsiderable in amount, that they are complex in organization, endowed with life, and in many cases possessed of action powers of locomotion," etc.

A year later Hassall wrote: "We have dwelt thus long and fully on the *organic impurities* of water, because of their extreme and primary importance; for it is on these that the deleterious properties of impure water for the most part depend. Until very recently chemists did not in general attach sufficient importance to these organic contaminations; and in most of their analyses we find the different kinds of organic matter, vegetable and animal, living and dead, all lumped together, and included under the word 'traces.' Indeed, chemistry is but ill adapted to investigate the nature of these organic matters; it gives but a very rough estimate only of their gross amount, and does not discriminate, as we have said, the animal from the vegetable, the dead from the living; and tells us nothing about the families, genera and species to which the numerous living productions contained in impure waters severally belong, or of their habits and modes of life, etc. This inquiry belongs rather to the naturalist, the physiologist and the microscopist; and to ourselves belongs the credit of having first applied the resources of these, extensively, and in a practical as well as scientific manner, to an examination of the actual condition of water in general, and particularly the state of that now in use in the metropolis." ("Lancet," 1851. "Food and its Adulterations," p. 55. London, 1855.)

In 1865 Radlkofer* published an account of a microscopical investigation of the organic substances found in certain well waters of the city of Munich. No statements are given as to the method employed; but it would appear that Radlkofer examined the water

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* Radlkofer, Ludwig. "Mikroscopische Untersuchung der Organischen Substanzen im Brunnenwasser." Zeitschrift für Biologie, I (1865), 26.

and the mud of the wells simply by the direct observation of small portions, microscopically, upon a slide.

During the cholera epidemics of 1852 and 1866 the wells of Breslau, in Silesia, were regarded with suspicion. Water from some of the worst wells was officially submitted for microscopical examination to Dr. F. Cohn,* who has described his method and discussed his results in what is perhaps the most important and suggestive paper hitherto published upon the microscopical, as distinguished from the bacterial, analysis of water. The method employed consisted, however, simply in the direct microscopical examination of a few drops of the water, and of the sediment obtained from the water after it had stood for some hours, or even days.

Cohn writes as follows: "While the number and the accuracy of the chemical analyses of water is steadily increasing year by year, the number of microscopical investigations of drinking water is still extraordinarily small. . . . At the same time, there is no doubt that microscopical examinations of drinking waters, properly conducted, will support and supplement chemical examinations, at the most essential points, besides throwing light upon certain questions which the reagents of the chemist are powerless to answer. . . . The plants living in water remove from it, sometimes, during their growth, the minutest traces of calcium carbonate which may be detected as crystals between their filaments. . . . The presence of traces of iron in water, and sometimes of sulphuretted hydrogen, is directly discoverable in certain microscopic algæ. But, above all, microscopical analysis gives direct and positive evidence of the kinds and conditions of the nitrogenous substances present, information — both qualitative and quantitative — which chemical analysis but incompletely supplies." Reference will be made to other portions of this paper hereafter, especially in the interpretation of results. As a key to the literature of the subject previous to 1870, and as a memoir of the first importance, it should be in the hands of every sanitary biologist.

In 1879 Hirt,† of Breslau, published an article upon the principles and the method of the microscopical analysis of water, in which

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* Cohn, F. "Ueber den Brunnenfaden (*Crenothrix polyspora*) mit Bemerkungen über die Mikroscopische Analyse des Brunnenwassers." Beiträge zur Biologie der Pflanzen. I (I), 108. Breslau, 1870.

† Hirt, Professor Dr. L. "Ueber den Principien und die Methode der Mikroscopischen Untersuchung des Wassers." Zeitschrift für Biologie, XV. (1879), 91.

the method recommended consists in (1) the direct observation of numerous samples of the water taken, a drop at a time, while the sample is fresh: twenty to thirty drops being thus successively mounted and scrutinized; and (2) of an examination of the sediment (if any) deposited by the sample on standing for two to six days; as well as (3) a study of the surface pellicle (if any) which sometimes forms upon the sample after standing. Thirty to forty preparations of the sediment and pellicle are recommended to be made from each sample, and these must be studied till the investigator has clearly made out their character and significance. "Although I must frankly admit that this method of the microscopical investigation of water is still imperfect; that it cannot escape among numerous objections, especially this, — that the amount of water or sediment actually examined is always very small in comparison with the quantity to be tested, — still, on the other hand, I can testify that serious errors do not occur, provided one follows the method closely; and, further, that, so long as no better method exists, biologists will do well to employ this one with confidence." Professor Hirt expressly says that this was the method employed in Cohn's laboratory at that time (1879), and it appears also to have been employed by Hirt and others in a systematic study of the river Oder and the water supply of Breslau, between 1877 and 1881, the results of which have been published in an important paper by Hulwa.* The interesting tables which accompany this paper give the microscopical results side by side with the chemical, and probably indicate the highest point reached by such work hitherto, and previous to the introduction of the more exact methods of bacteriology, in 1881.

Macdonald's "Guide to the Microscopical Examination of Drinking Water" † was published (in the first edition) in 1875. The method recommended in the edition of 1883 consists in the collection of the sediment, as follows (p. 4): A tall glass vessel is "filled with the water to be examined, and a circular disk of glass, resting on a horizontal loop at the end of a long aluminum wire, lowered to the bottom, when the whole arrangement, tightly covered, must be set aside for twenty-four or forty-eight hours, as

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* Hulwa, Dr. Franz. "Beiträge zur Schwemmkanalization und Wasser-Versorgung der Stadt Breslau." Centralblatt für allegemeine Gesundheitspflege, Ergänzungshefte, I, 89. Bonn, 1885.

† Macdonald, J. D. "A Guide to the Microscopical Examination of Drinking Water," etc. London, 1883.

the case may be. At the end of the specified time, the water should be siphoned off with a piece of india-rubber tubing, so as to leave only a thin stratum of the liquid over the glass disc. This should now be carefully raised and laid upon blotting paper, to dry its under surface and remove the surplus moisture, when it may be at once transferred to the microscope, with a large piece of covering glass so placed upon it as to exclude all air-bubbles. An ordinary watch glass may in some cases be substituted for the disc alluded to, with advantage. . . . Another good plan, which is perhaps the better of the two, is to siphon off the water until only a sufficient quantity remains to permit the sediment to be shaken up with it and poured into a tall conical glass, from which, after standing again for a short time, portions may be taken up by means of a pipette, and placed on slides for examination."

To the foregoing outline of the literature of the methods of the Microscopical Analysis of Waters, it only remains to add that the latest, and, without doubt, the best, summary of water analysis hitherto published ("Untersuchung des Wassers." Tiemann und Gärtner, 1889), has no better method to propose.

Meanwhile, the development of special methods for the study of the bacteria, and, above all, the introduction by Koch of the method of "solid cultures," have simplified the problem of the microscopical examination of water, by relieving it of its heaviest burden. In the more absorbing pursuit of bacteriology this is not yet generally recognized; but the fact is, that, by the removal of the necessity for detecting bacteria by the microscope, it has become a comparatively simple matter to enumerate and examine the remaining micro-organisms.

B.—New Methods: With a Special Account of the Methods of Microscopical Analysis Employed at The Lawrence Experiment Station, and in the Monthly Analyses of the Drinking Waters of the State.

In the establishment of the Lawrence Experiment Station, the attempt was made to control all the conditions. The engineering problems were well in hand, the chemical problems were thoroughly conceived, the bacterial organisms in water or sewage could be counted and examined; but, at the outset, the microscopical organisms could not be compared, because there was no known method for their *quantitative* study.

The paradoxical condition actually existed that the extremely minute bacteria (if alive) could be easily estimated as to their numbers, though with difficulty as to their kinds; while the infinitely larger metazoa and algæ could indeed be arranged as to their kinds, but not determined as to their numbers. The microscopical organisms in sewage or water were easily classified as "Yeast," "Synedra," "Paramoecium," etc.; but, for quantities, expressions such as "abundant," "scarce," "very abundant," "very scarce," had to be employed. It was obvious, however, that, if a similar systematic and thorough study was to be made of these as of the bacteria, the ammonia, the amounts of liquid applied and recovered, etc., some quantitative method must be devised.

At the request of the chairman of the Committee (Mr. Mills), Mr. G. H. Parker, then biologist to the Board, undertook the examination of the filtered and unfiltered water. The object of these examinations was to determine whether any of the larger organisms, algæ, etc., which were known to occur in the unfiltered water, made their way through the filters, and escaped in the filtered water. In order to ascertain whether this were true or not, the following method was employed: Cotton cloth, similar to that by which the organisms in the unfiltered water were detected, was firmly tied over the open ends of the escape-pipes from the filters, and the filtered water allowed to strain through this cloth. When possible, five gallons of water was strained; in many instances, owing to the slowness with which the water traversed the filter, this amount could not be conveniently strained, and the examination was then necessarily made upon smaller amounts. The cloth, after having been removed from the pipe, was inverted (turned inside out) over the lower end of a glass tube, to which it was held firmly, while the worker applied the cloth to an ordinary slide, and blew smartly through the tube from above, down upon the slide. The organisms originally detained upon the *inside* of the cloth are now upon the outside (after the inversion of it), and are therefore comparatively easily removed from the cloth by a stream (of air) in the reverse direction to that which lodged them upon the cloth. A drop of moisture usually adheres, or may be added, to the cloth, and aids in the detachment. Once upon the slide in a drop of water, the organisms are distributed as evenly as possible, are covered by a piece of thin glass, and examined with the microscope. The number of gallons thus strained being known, and the number of organisms observed being counted, or computed, it became possible to make a rough approximation to the number of organisms actually present.

A modification and improvement of this method, which was devised by Mr. Parker, and was known to the investigators of the Board as the "Cloth method," was employed for some months in the microscopical examinations of the drinking waters, ice, etc., of the State, and will be found fully described in Volume I. of the present Report, pp. 581–582. It was superseded by the method now to be described, and known as the "Sand method," on June 1, 1889.

In the autumn of 1888, Mr. Alexander L. Kean, at that time a special student in my laboratory, was invited to make, for the Boston Water Works, a series of tests of the efficiency of certain sand filters, in respect to the removal of microscopical organisms; and, being familiar with the methods of the bacteriological examination of air by means of filters of sugar and of sand, he determined to employ a modification of these methods in his work upon water. The necessary concentration of the organisms in the water is effected here, as in the case of air, by filtration through sand, supported, in this case, upon a brass gauze stop, in the stem of a funnel. After withdrawing the stop, the sand is washed down into a watch glass by one cubic centimeter of distilled water, delivered from a pipette. Upon stirring the contents of the watch glass, the sand settles to the bottom, and the organisms for the most part remain in the supernatant fluid. A thousandth part of a cubic centimeter of this, with its contained organisms, is then transferred to a slide having upon its surface a concavity containing, when covered, one cubic millimeter. The bottom of the concavity is ruled in squares, which facilitate the counting or computation of the total number of organisms present. It is afterwards only necessary to multiply by one thousand the result obtained from the actual count of the organisms upon the slide, to obtain the number present in the entire cubic centimeter, *i. e.*, removed by filtration from the sample to be examined. An account of this method was published in "Science," of Feb. 15, 1889.* To Mr. Kean, therefore, belongs the credit of having first devised and employed for practical purposes a quantitative method for the microscopical examination of water. If, for example, 100 cubic centimeters were filtered, and yielded 23 organ-

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* KEAN, A. L. "A New Method for the Microscopical Examination of Water."

isms in the cubic millimeter, then $\frac{23 \times 1000}{100} = 230$ is the number per cubic centimeter in the original sample.

The most serious defect of this method is that the amount actually examined is too small, compelling the use of a large factor of multiplication, and so limiting the amount actually scrutinized that important organisms may easily be overlooked. Since it is necessary to multiply by 1,000, an error of one in the counting becomes an error of 1,000 in the result; or of 10 per cubic centimeter, if 100 cubic centimeters were originally taken. Moreover, if only one be found in the counting, it must be interpreted to indicate 1,000 in the cubic centimeter in the watch glass, or at least 10 per cubic centimeter if 100 cubic centimeters were originally taken. It is impossible to get a number between 0 and 10 per cubic centimeter, unless more than 100 cubic centimeters be filtered. It would be necessary to filter as much as a liter, in order to get 1 per cubic centimeter.

Suspecting that this method yielded too high results, I placed the watch-glass directly under the microscope, and soon became satisfied that it did not contain quite as large numbers as were indicated by Kean's method. Moreover, it was apparent that, if all the sand and its contents could be directly observed with the microscope, it would be an immense advantage. Accordingly, I constructed a chamber or cell suitable for receiving the sand and the organisms held back, and permitting them to be evenly and thinly distributed over the surface. In reality, this was simply enlarging the cell employed in the previous method, for here, also, the bottom of the cell was ruled in squares; yet the advantage was very great, since the new cell or plate was large enough to permit the examination of all the organisms removed by filtration.

The cell, or counting plate, actually fixed upon after numerous trials, is 50 millimeters in length and 20 millimeters in width, and contains, therefore, an area of 1,000 square millimeters. It is bounded by a brass border, one or more millimeters high and four or five millimeters wide. This rectangular brass border is firmly cemented to an ordinary glass slide of the English form, upon which originally were ruled with a dividing engine 1,000 squares, each one millimeter in area.* If the filtration be done as before,

* For the patient and skillful elaboration of these details, and for the actual construction of a number of accurately ruled plates, I am indebted to Miss C. A. Woodman, formerly a student in my laboratory.

and 100 c. c. of water be taken, all the sand and the organisms detained by it are washed down into the counting plate or cell, with enough of distilled water, directed from a wash-bottle, to ensure the covering of the entire bottom. From one to two cubic centimeters are usually employed for this purpose. The sand and the organisms are now evenly distributed over the bottom by a needle or a piece of wire, care being taken by a rapid survey to make sure of the evenness of distribution, and are then examined directly with a rather low power, *e. g.*, the BB objective and 2 or 4 ocular, of Zeiss. It is now theoretically possible to count the contents of every square millimeter upon the plate; in practice, however, this is neither possible nor necessary. From the start it was found that 20 squares, taken from representative portions of the cell, were as many as could conveniently be counted, though the fact that the entire surface can be rapidly scrutinized is a conspicuous advantage, as affording a check upon the results obtained from the 20 squares. The total number of organisms found in the 20 representative squares must, obviously, be multiplied by 50 to get the number upon the entire surface of the plate. This method, therefore, ordinarily requires the use of 50 as a factor of multiplication, instead of 1,000 as in the previous method. The quantity of water thus really examined is $\frac{1}{50}$ of the quantity originally taken, instead of $\frac{1}{1000}$. Thus, if 100 cubic centimeters be filtered, $\frac{100}{50} = 2$ cubic centimeters are actually scrutinized, as against $\frac{100}{1000} = \frac{1}{10}$ cubic centimeter, by the previous method. If only a single organism were found, the result would be $1 \times 50 = 50$ in 100 cubic centimeters, *i. e.*, 0.5 organisms per cubic centimeter. Obviously, the method gives no certain means of detecting quantities between 0 and 0.5 organisms per cubic centimeter, unless more than 100 cubic centimeters be concentrated. The possible error may be appreciated in another way. Supposing that there were but one organism in the entire 100 cubic centimeters taken, and that this were found among the 20 squares, the result would be 50 organisms, where but one really existed. If it were not found in the 20 squares or by the rapid scrutiny of the entire surface, the result would be zero, and this result would, clearly, be much more likely to be obtained than the other.

After the method had been thoroughly tested in a series of experiments conducted under my supervision by Miss C. A. Woodman, it was introduced into the work of the Board on June 1, 1889, and has since that time been in use at the Lawrence Experiment Station, as well as in the regular microscopical examinations of drinking waters from all parts of the State.

On June 11, 1889, the new method was fully described at the annual meeting of the New England Water Works Association in Fall River, and a brief account of it was afterwards published.* It was adopted during the summer of 1889 by the experts of the State Board of Health of Connecticut, and has been used by them in a long series of investigations of the water supplies of that State. At about the same time Mr. Geo. W. Rafter, C. E., began a novel and elaborate series of microscopical investigations, under the direction of Desmond Fitzgerald, Esq., C. E., Superintendent of the Western Division of the Boston Water Works. The method just described was demonstrated to them in my laboratory, and they were furnished with a counting plate. Mr. Rafter soon after introduced valuable improvements in the details of the method, an account of which has since been published.†

The first important improvement introduced by Mr. Rafter consisted in the substitution of a ruled square in the eye-piece, for the ruling upon the plate. This is obviously a great gain, since it removes the necessity of the expensive plates, specially ruled by a dividing engine. The plan adopted by Rafter is to place within the eye-piece a disk of glass, precisely similar to that used for ordinary ocular micrometers, excepting that, in the place of the usual scale, it has upon it a ruled square. This is chosen of such a size that it covers one square millimeter upon the ordinary slide. I have found it as well or better to employ, in place of the glass disk, a blackened metal disk, with a square hole cut out of its centre, since it is not only cheaper and more durable, but allows only the area that is to be counted to be seen.

The only disadvantage of the eye-piece square is that it must be carefully standardized, i. e., made to coincide in outline with a square millimeter actually upon the slide. With different powers this involves some loss of time. It is, then, simply necessary to have for this work, besides the filter and the microscope, (1) a metal eye-piece diaphragm perforated by a square hole of such size that, with the objectives used, it shall easily cover one square millimeter

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* W. T. SEDGWICK. "Recent Progress in Biological Water Analysis." Journal of the New England Water Works Association. September, 1889.

† GEO. W. RAFTER, C. E. "The Biological Examination of Potable Water." Proceedings, Rochester Academy of Sciences. 1890. Rochester, N. Y.

upon the slide; (2) a stage micrometer, ruled in millimeters, or, better, in millimeter squares; (3) slides of the ordinary pattern, to each of which is cemented a rectangular brass border, inclosing an area 50×20 millimeters.

The second improvement suggested by Mr. Rafter is equally important, since it seeks to do away with the presence of the sand during the counting. I have made very numerous experiments in this direction, trying to find some substance which should serve as a filter and afterwards dissolve. No such substance, however, has been found. Prof. S. W. Williston, microscopist to the State Board of Health of Connecticut, informs me that he has introduced precipitated silica in the place of sand, finding that it filters rapidly, yet thoroughly, and distributes itself well upon the counting plate. By working in a different direction, Mr. Rafter has been more successful. He advises the use of larger funnels and comparatively coarse sand, and recommends that 300 to 500 cubic centimeters of the water to be examined be filtered. The sand and organisms are then washed down into a test-tube with 3 to 5 cubic centimeters of distilled water. The tube is shaken thoroughly, and the sand allowed, for an instant, to settle. The water is then quickly decanted, and carries with it most of the organisms. One cubic centimeter of this water is then transferred to the counting plate, covered with a piece of thin glass, and examined in the usual way. The use of a brass border one millimeter high, provides a chamber holding exactly one cubic centimeter. It will be observed that the principle here involved is the same as that in Kean's method of agitation in a watch glass, and the examination of a portion of the supernatant liquid in a special cell. The advantage of this mode of procedure is obvious. The sand, which constitutes an obstacle in counting, is avoided; the low brass border allows the use of higher powers; and the fatigue of counting 20 squares is diminished. The greatest disadvantage is the surrender of the possibility of inspecting the entire result of filtration. The quantity actually observed remains the same as before, but it is a sample of the material held back by the sand, instead of the entire mass. Some experiments still in progress lead me to believe, however, that this disadvantage is less real than appears from a theoretical consideration alone; and it appears to me that these several modifications introduced by Mr. Rafter are improvements of the greatest value. Mr. Rafter has also devised a simple mechanical stage by which the counting plate is moved one millimeter at a time from side to side, or at right angles to this direction. This is undoubtedly a convenience, and it aids in the unbiassed selections of squares to be counted — a point of much importance; but it appears to me of less importance than the improvements already described.

The sand used should be sharp quartz sand, completely clean. "Berkshire" sand is perhaps the best for the purpose. I have been accustomed to use much finer sand than Mr. Rafter; namely, for ordinary drinking waters such as would pass through a sieve having 80 meshes to the linear inch, but not through one having 100. Such sand may be described as "80 to 100 sand." For the effluents at the Lawrence Experiment Station a still finer sand has been frequently used; viz., finer than 140; i. e., sand which will pass through a sieve having meshes making (nominally) 140 to the linear inch. In order to separate the sand by quickly decanting, as described above, a rather coarse sand must be used; but, on the other hand, more of it can readily be employed. The worker must be left to determine in any particular case the degree of fineness advisable; but a high degree of accuracy is, apparently, never consistent with very rapid work.

The sand is conveniently supported, either by a rolled plug made of fine brass gauze, or, better, by a platform of No. 140 brass gauze, made by pushing a strip of the gauze up from below into the funnel stem, by means of a tight-fitting cylindrical punch, such as a glass rod or a piece of coarse wire. The funnel stem must be of even bore, and not flaring.

The greatest care must be taken to secure an average sample of the water to be examined. It must be remembered that diatoms, algæ, infusoria and the like, are suspended bodies of different specific gravity, and that they are whirled about by currents, tend to collect in eddies, and in other ways behave far differently from substances in solution. The same considerations should warn us against the expectation of high quantitative accuracy, either in these methods or in those of bacteriology. There is every reason to believe, however, that quantitative results may be obtained by this method of microscopical examination, quite as accurate and trustworthy for the microscopical organisms, as by the methods of bacteriology for the bacteria.

It is obvious that the method permits the direct observation and examination of water, sewage, etc., since it is only necessary to place upon the counting plate or cell, one cubic centimeter of the liquid to be examined. This method is, in fact, employed with sewage, since in it the organisms are abundant; but for water or effluents it is of no use, since the quantity actually inspected is too small to be a fair sample, viz., $\frac{1}{50}$ of one cubic centimeter. With certain modifications the method is also available for the microscopical examination of sands.

Mr. Rafter has done me the honor to state that this new method for the microscopical examination of water should bear my name (*op. cit.*); but, inasmuch as his own improvements now form a most important and indispensable part of it, I venture to suggest that his name be joined to mine in referring to the method. A careful investigation of the Sedgwick-Rafter method, with numerous tests by G. N. Calkins, Microscopist to the Board, is already nearly completed, and will appear in the Twenty-second Annual Report of the Board.

III. — Methods of Bacteriological Analysis.

The methods employed in the bacteriological work have been usually those of the Koch school, with such modifications as the peculiar needs of the work have required.

At the outset the routine planting and counting began, and for nearly a year continued, in Dr. Dunham's laboratory on Tremont Street, Boston. During the period when Mr. Tucker had charge of the work, it was done in his private laboratory in the Boston City Hospital. Since Nov. 1, 1888, the bacteriological work has been carried on in the biological laboratory of the Massachusetts Institute of Technology, in Boston, where it has continued without interruption during the entire second year covered by this report. A section of the laboratory has from the first been set apart for a culture room. This was specially prepared for bacteriological work, with a view to minimizing the danger from error by air contamination. The ceiling and walls are dust proof, and the entrance is through a tightly sliding door. The shelves, walls and floor are kept scrupulously clean, the whole room being washed with corrosive sublimate at frequent intervals. Only the apparatus actually in use is allowed in the room, and every precaution is taken to render the air of the culture room practically free from germs.

The samples of water, sewage, effluents, etc., have been regularly collected at the Lawrence Experiment Station, in tightly stoppered glass bottles, each having a capacity of fifty cubic centimeters. The bottles are first sterilized, or made germ free, by heating them to a temperature of 165° to 195° C., for an hour and a half, in a way shortly to be described. The samples of water collected in these sterilized bottles have been brought to the laboratory as quickly as possible, and there samples withdrawn and immediately planted. In warm weather only a very few hours have usually elapsed between collection and planting; and when for any reason the water was obliged to stand, after collection, it has been carefully kept at a low temperature, to preclude increase in the number of germs. Numerous control experiments have been made by planting samples of water at Lawrence while carrying duplicate samples to Boston, and allowing still others to remain for some time in Lawrence at the low temperature prescribed. These control experiments have uniformly given satisfactory results.

There has been, in the collection of the samples, a possible source of error, which, although slight, could not be overlooked. In some cases the effluent from certain sewage tanks drops so slowly that it is necessary to expose the collecting bottle, sometimes for several minutes, before obtaining a sufficient quantity of water for examination. Meanwhile, there is obviously a possibility that germs may drop into the bottle, and appear in the table of results as if they had come directly from the effluent. A number of experiments have been made, with a view to ascertaining the amount of this error of collection; and it has been found to average considerably less than 2 germs per cubic centimeter. In by far the larger number of cases, however, there has been exposure to the air for a few seconds only.

For the sake of ascertaining the error due to this exposure, during collection, bottles of sterilized water were exposed on Nov. 16, 1888, to the air of the experiment station, while the effluents from some of the tanks were being collected. Each bottle of sterilized water remained exposed by the side of a corresponding bottle, into which the effluent from a sewage tank was dropping. The results were as follows: —

Date.	Filter Tank.	Bacteria in one Cubic Centimeter of Sterilized Water.	Bacteria in one Cubic Centimeter of Effluent.
1888.			
Nov. 16,	No. 11,	1	66
16,	12,	0	7
16,	13,	3	27
16,	14,	1	618
16,	15,	0	55
16,	16,	1	12
16,	17,	4	3
16,	20,	2	22

Another experiment of the same kind gave : —

1888.			
Dec. 17,	No. 11,	1	12
17,	12,	1	39
17,	13,	2	10
17,	14,	1	154
17,	15,	2, 1 mold.	198
17,	16,	3	17
17,	17,	1, 1 mold.	5
17,	20,	3	5

Still another resulted as follows : —

1889.			
Jan. 8,	No. 1,	1	1,306
8,	2,	2	9
8,	3,	0	1
8,	4,	1	9
8,	5,	0, 1 mold.	2
8,	6,	0	874
8,	7,	1	0
8,	8,	5	16
8,	9,	0	0
8,	A bottle not exposed,	0	-

These control experiments were then arranged so as to imitate more closely the conditions actually existing at the time a sample was taken. Sterilized water was blown from a wash bottle guarded by a cotton plug, into sterilized collecting bottles. This was done at the spot where the regular effluents were being collected, and as much time was taken to discharge the sterilized water as was required to collect a sample of the effluent.

DATE.	FILTER TANK.	Bacteria in one Cubic Centimeter of Sterilized Water.	Bacteria in one Cubic Centimeter of Effluent.
1889.			
Jan. 22,	No. 1,	4	41
22,	2,	1	19
22,	3,	1	99
22,	4,	2	12
22,	5,	0	15
22,	6,	2	3,612
22,	7,	2	16
22,	8,	2	20
22,	9,	3	4

These results satisfied us that the danger of contamination during collection was slight. Extreme caution is of course always necessary in collecting the water, and the samples are taken by assistants carefully trained to avoid contaminating them. The bottles have been carried in closely fitting tin cases, and, when necessary, have been capped with tin-foil or rubber.

The water, sewage, effluents, etc., collected at Lawrence with all precautions, have thus been brought more or less directly to the laboratory, and there planted. The method used in cutivating the germs was the familiar method of "gelatin plate culture," devised by Koch in 1881. One cubic centimeter of the water is thoroughly mixed in a test tube with a much larger amount of melted nutrient gelatin already previously sterilized, and the mixture is then poured out on a carefully levelled glass plate. This is protected from the air, and is set away under suitable conditions of temperature and moisture. Each living germ originally present in the water, finding itself under remarkably favorable conditions for development, multiplies rapidly, and eventually forms a little group or colony about itself in the stiffened gelatin. In the course of two or three days these colonies are visible to the naked eye, and are counted and examined with special apparatus. If desirable, portions of the individual colonies are transferred to fresh nutrient media, for study as "pure cultures." A full description of the methods employed in the study of such systematic cultivations will be found in the Report of Mr. Jordan, in section V.

At the suggestion of Dr. T. M. Prudden, we have more recently adopted, in place of the glass plates above mentioned, small double dishes (the so-called Petri dishes), having an inner diameter of about 10 centimeters, and a depth of 1.0 centimeter. These are found to save a very large amount of time in planting, but are slightly more inconvenient when it is necessary to count the colonies. Esmarch roll-tubes have not been used, because of the awkwardness and delay in handling large numbers of samples, because of the very serious drawbacks from liquefying colonies, and the difficulty of counting.

All pipettes, plates, double dishes and other pieces of apparatus used are first carefully sterilized, by heating to 165° to 195° C., for an hour and a half. At the outset this sterilization was done with the ordinary hot-air sterilizer; but this was soon discarded for a simple form of gas stove. The stove is of the pattern known as the "Cone," and is sold by the Dinsmore Manufacturing Company, Boston. Apart from the comparatively small cost of this stove, we have found it distinctly more satisfactory than the hot-air sterilizers commonly in use.

The gelatin used for a nutrient culture medium is prepared according to the standard receipt. A pound of meat, freed as far as possible from fat, is allowed to soak for some twenty-four hours in a liter of water. The meat extract is then poured off, and 1 per cent. (10 grams) of peptone as colorless as possible, ½ per cent. (five grams) of salt, and 10 per cent. (100 grams) of gelatin are added. In hot weather it has been found advantageous to use 15 per cent. of gelatin. The whole mixture is boiled for thirty minutes, and then rendered slightly alkaline with sodium carbonate. After boiling for about forty five miuutes longer, the liquid is filtered through flannel, and then through several layers of absorbent cotton. The clarified gelatin is next drawn off into test tubes, which are tightly plugged with cotton, and sterilized, by heating in a steam bath for thirty minutes at a time, on three successive days. The steam sterilizer used by us for this purpose is the Arnold automatic steam sterilizer, now in use in a number of bacteriological laboratories in this country. It may be obtained from Wilmot, Castle & Co., Rochester, N. Y.

For planting sewages, and effluents suspected to contain large numbers of bacteria, we have used the method of dilution. One cubic centimeter of the substance to be examined is thoroughly mixed with 99 cubic centimeters of sterilized distilled water, and a cubic centimeter of this mixture is then planted in the usual way. The number of germs present in one cubic centimeter of the sewage may afterwards be readily estimated.

Sand samples have been treated in a similar manner. A known weight of sand — approximately a gram — is digested and mixed by agitation for a few minutes in a known weight of sterilized distilled water (99 cubic centimeters), and a cubic centimeter of this mixture is planted and counted as before. To arrive at the number of bacteria in a gram of the sand is then a matter of simple calculation. Sewage examinations are usually done in duplicate, and the average of the two counts is reported.

IV. The Micro-Organisms of Sewage.

The sources of the sewage, its chemical composition, and the details of its application to the experimental filters, have already been described (pp. 3, 4, 88–121, etc.). The micro-organisms of the sewage alone remain to be dealt with here.

A. — The Microscopical Organisms.

A review of the results of the microscopical examinations of sewage shows that, of all the organisms present (except the bacteria, which will shortly be discussed), the most constant and the most abundant in Lawrence sewage is yeast. In fact, yeast is so constant that it may safely be said that it is never absent, but varies from 1,000 to 300,000 cells per cubic centimeter. An average of thirty analyses, extending over six months, has given 32,000 per cubic centimeter, and this probably represents a fair estimate of the average number of cells. The yeast appears to be the common domesticated species (*Saccharomyces cerevisiæ*, Meyen), and in the sewage is for the most part alive, though apparently not in a normal condition, since the cells are usually small and somewhat shrunken. They come, probably, from the breweries in the city, which doubtless empty some of their surplus yeast into the sewers, as well as from the washings of beer glasses or bread bowls, and similar public and private or domestic sources.

To distinguish living from dead yeast, the following method has been employed: It is a well-known fact that living protoplasm does not ordinarily become stained with the dyes used in microscopic work. If it stains readily, as it does, for example, with iodine dissolved in potassium iodide, it is simply because the dye has almost instantly killed the protoplasm, and then quickly stained it. By the use of a dye which does not easily kill the protoplasm, we may therefore discover whether the latter is dead or alive; for, if it be alive, it will remain colorless, while, if it be dead, it will become stained. Eosine is a dye of this kind, and in weak, watery solution, is an effective test of the vital condition of protoplasm. A simple test of ordinary commercial yeast will serve to show that, while most of the cells are alive, some, here and there, stain, thus showing that they are dead. A moment's boiling, however, will serve to produce a condition in which all readily stain.

Applying this method to the yeast in fresh sewage, such as is supplied to the tanks, we find that it is mostly alive; and yeast in the same condition may often be found in abundance upon the surface sand grains of tanks composed of very fine sand, and recently flooded with sewage. It seems, however, to be very readily destroyed; for, below a depth of two or three inches in such tanks, it is seldom, if ever, detected. At the depth of half an inch it appears to be undergoing dissolution, and, by some process not yet understood, it is evidently digested, as it were, in the uppermost layer of the filters. It is continually being added in vast numbers, and apparently is as rapidly destroyed. Moreover, even from filters of coarse sand or pebbles, it escapes, if at all, only in greatly diminished numbers.

Besides yeast, sewage contains, nearly always, more or less abundant amorphous masses of a yellowish-brown color, visible only under the microscope. There is no doubt that most of these are composed of groups or "families" of living bacteria, the cells of which have been converted into an intercellular substance of a more or less gelatinous character. Such masses occur frequently under certain conditions, and are known as *zoögloea*. They may occur fresh, in gelatinous lumps, or in thin pellicles covering the surfaces of fluids; or they may be old and shrunken, distorted almost beyond recognition, and at length even deserted by the bacteria which originally formed them. They are colorless when fresh and young, but when older are apt to be tinged brownish with a deposit of the oxide of iron. The pellicles, in particular, shrivel and change so as to be scarcely recognizable, and many fragments apparently in this condition are to be found in sewage. The masses are produced by the swelling of the outer portion of the cell walls of the bacteria, and are hence believed to be closely related to cellulose in their principal chemical composition. It might be supposed, therefore, that they should be comparatively indestructible; and this appears to be the case. It is probably largely owing to their presence that a continuous filter clogs so rapidly with sewage; while their destruction by the oxidations of intermittent filtration is probably an essential condition of the successful operation of the latter.

Besides yeast, which is always present, and other fungi, such as Leptothrix, which occur not infrequently, the infusoria deserve special mention. Both ciliata and flagellata are represented, the latter perhaps most frequently. Among the ciliata, Paramœcium is specially conspicuous, while the principal representatives of the flagellata have been monads (Monas, Trachelomonas) and Euglena. We find also, rarely, Anguillula, — probably the vinegar eel, — Oscillaria, starch-grains, insect remains, and some apparently inorganic sediment. Diatoms are scarcely ever found, possibly because they have died from lack of oxygen, which is wanting in sewage, and have sunk to the bottom of the sewers along with the sand grains, etc. (See p. 34.) The entomostraca, rhizopoda and algæ are extremely rare, if they ever occur. This is not strange, since they are inhabitants of clean, fresh water, and probably require free oxygen for their existence. As long ago as 1850, Dr. Hassall observed that fishes placed in sewage died as if in the air. There is no doubt that they were suffocated by the absence of oxygen in the sewage; and by analogy we can readily conceive how certain organisms in city water, requiring (and finding there) abundant oxygen, must perish quickly in sewage. The algæ might speedily change beyond recognition, and the diatoms might settle to the bottom. By comparing the microscopical results obtained from sewage with those obtained from city water, it appears that the diatoms and algæ of the latter are almost wholly absent in the former. It is likely that the comparatively heavy diatoms are deposited in the slow-flowing streams of the sewers, and that the algæ are decomposed beyond definite recognition. Yeast and zoögloeæ are specifically light, and tend to float or to remain suspended; and hence, no doubt, are the more readily transported in the sewage.

By reference to the tables of the chemical composition of filtered and unfiltered sewage (see pp. 88–121, and, especially, p. 35), it will be seen that, as might be supposed, a portion of the albuminoid ammonia is held back by filter paper. The source of this albuminoid material is probably largely in the amorphous masses just described, — the yeast, Leptothrix, infusoria, and other organisms, including vast numbers of bacteria present in the sewage. It should not be forgotten, however, that filter paper fails to remove completely the finest particles of suspended matter, as is shown beyond in dealing with the removal of bacteria by filtering sewage. It is hoped that we shall soon be able to establish more precisely the relations between the results of microscopical examination and the albuminoid ammonia in suspension, in water or in sewage.

B. — The Bacterial Organisms of Sewage.

As has just been seen, the microscopical organisms of sewage, barring yeast, are comparatively few. When we turn to the bacterial organisms, however, we find the numbers enormous. Between November, 1888, and November, 1889, 126 bacterial analyses of Lawrence sewage were made, and the average number of living bacteria found was 708,000 per cubic centimeter. The extremes were 102,400 on Feb. 27, 1889, and 3,963,000 on April 16. Of the entire number of duplicated analyses (63), 14 contained more than 1,000,000 germs per cubic centimeter; while in 30 the numbers were below 500,000. The numbers were comparatively high in April, May and June, and comparatively low from December to April.

Among the large number of species observed, several of those that seemed to be the more important and characteristic have been selected for the most thorough study by Mr. Jordan, whose report upon them is given beyond (see section V.). It is believed that, though necessarily limited in scope, his results, illustrated as they are by photogravures prepared from actual photographs, constitute an important contribution to our knowledge of the bacteria of sewage, and must prove of great value in further investigations upon sewage purification, as well as in following the behavior of pathogenic bacteria in sewage, soils or water.

The interpretation of the foregoing results of examinations of the microscopical and bacterial composition of sewage is not difficult. The organisms, small and great alike, contribute to the large quantity of organic matter always present in sewage. Filter paper removes many of them, although some of the bacteria easily pass through it. Two experiments in this direction gave the following results : —

Removal of Bacteria from Sewage by Filter Paper.

1889.		Colonies of Bacteria per Cubic Centimeter.
Feb. 7,	Sewage unfiltered,	173,950
7,	Sewage filtered through paper,	39,100
12,	Sewage unfiltered,	134,600
12,	Sewage filtered through paper,	25,100

These figures show a reduction of 78 per cent. and 82 per cent. respectively.

The presence of bacteria in sewage in such enormous numbers is also a token of the nature of sewage. Sewage is a putrefying fluid, and the bacteria are the agents of its putrefaction. They are contained in the city water, from which sewage is largely made, to the extent of one or two hundred per cubic centimeter; but in the washings of streets, in milk and certain other food products, and in the excreta, they are much more abundant. They unquestionably multiply enormously in the upper parts of sewers, in drains, etc., under the favorable conditions which prevail there. But, although the city water contains much free oxygen, and the sewers are more or less in contact with air, so rapid is the growth of the bacteria, and so vigorous is their respiration and oxidizing power, that even fresh sewage contains no free oxygen. Yeast also respires vigorously, and doubtless does much to reduce the available oxygen arriving in the city water, or otherwise. Under ordinary circumstances, the bacteria are unable in fresh sewage to oxidize the nitrogen of organic matters. The carbon is freely oxidized, and the nitrogen of the nitrogenous bodies is carried over to free ammonia more or less completely, but no nitrites or nitrates are found in fresh sewage. On the contrary, if nitrates be added to sewage they are speedily reduced, and the living bacteria appear to be the special reducing agents, since the experiment fails if the sewage be previously sterilized. This reduction of nitrates testifies, apparently, to the powerful affinity of bacteria for oxygen, at least in the presence of organic matter. It is known that yeast will reduce the oxyhæmoglobin of arterial blood, even when separated from the blood cells by a delicate partition of goldbeater's skin; and there is good reason to believe that bacteria are equally powerful as reducing agents.

It should be added, however, that some of the bacteria in sewage appear to be able to survive for a very long time even in the complete absence of free oxygen. Bottles of sewage completely filled in order to exclude air, have shown, even after prolonged standing for several weeks, many thousands of bacteria per cubic centimeter.

Enough has been said to show conclusively that sewage is well adapted to the growth of many kinds of bacteria. It is proposed in the near future to make special studies of the behavior of disease germs in sewage. (For tables of the results of the bacterial examination of sewage, see p. 60.)

V.

A Report on Certain Species of Bacteria observed in Sewage.

By EDWIN O. JORDAN, S.B., *Chief Assistant Biologist.*

With illustrations, from photographs made by R. R. Andrews, D.D.S., Cambridge, Mass.

The identification of known species of bacteria, and the study of the new species found in the sewage and water examined, have, from the start, been recognized as matters of high importance. The press of other problems, however, of a more general and more fundamental nature, has left comparatively little opportunity for advancing this particular line of work. Nevertheless, something in the way of species investigation has been done.

I desire at the outset to acknowledge my obligation to Prof. W. T. Sedgwick. The following studies of specific bacteria, as well as the biological portion of the work upon nitrification and the nitrifying organisms, recorded beyond, have been carried out in his laboratory, and have been made possible by his constant interest and co-operation.

The methods employed have been the usual ones of the modern Berlin school. The isolation of a single species — the obtaining of a "pure culture" — has been carried out as follows: After a sample of water has been mixed with the nutrient gelatin, and the mixture poured out upon a sterilized glass plate, the living germs present in the water form groups or colonies of bacteria, which soon become visible to the naked eye. Each colony is of a single species, since it springs from a single parent germ. A small bit of one of these colonies is removed on the point of a straight, sterilized platinum needle, and transferred to a tube of melted gelatin. From this a second transfer is made, to another tube of melted gelatin, and from this again to a third tube. These three tubes of melted gelatin, which have thus been successively inoculated, are at once poured out on plates in the usual way. The colonies that appear in a few days are then studied and described, and fresh transfers are made to tubes of gelatin, agar, bouillon, milk and potato. There is now absolute certainty that we are dealing with one species, and one only, — provided, of course, the usual rigid precautions are observed. The modes of growth on the different culture media are then carefully studied, and are regarded as so many diagnostic characters, which aid in determining each bacterial species. The morphology of the bacterium, its motility and spore formation, its need of oxygen, its behavior at certain temperatures, and its physiological characters, are then studied as the individual case allows. We are thus at length enabled to give a fairly full description of a particular species, and incidentally to determine whether it has already been described and named.

It was decided to confine this work for the present mainly to the determination of the species found in sewage. Lawrence sewage might naturally be expected to contain: (*a*) species present in the water of the Merrimac River and of the wells, springs, etc., used for household purposes; (*b*) species whose home is in the various substances that go to make up sewage, *i. e.*, in putrescent matters generally; (*c*) species falling into sewage from the air, and finding there suitable conditions for development and growth; (*d*) species normally present in the upper layers of the soil. It is clear that no hard and fast line can be drawn between these several classes. The so-called "air-bacteria" are simply those bacteria which are able to resist drying, and are probably identical with species occurring in soil and in water. It does not seem likely that these "air-bacteria" find suitable conditions for development in the air itself; they are merely on the watch, as it were, for organic matter upon which to feed. Again, the group of "water-bacteria" is undoubtedly chiefly composed of species from the soil and from decaying substances. The species in these several classes are different, because their conditions of life — food, temperature, etc. — are different in the different habitats.

The sewage itself — a nutritive medium of varying composition and richness — will contain only those species capable of living and holding their own in the continual struggle for existence. So far as the conditions of life in sewage differ from conditions of life elsewhere, so far will the sewage be inhabited by species peculiarly adapted to those conditions; just as we find, for example, that, among the multitude of bacteria taken into the human alimentary canal, only a few species normally find fit conditions for development. The chemical composition of the sewage undoubtedly debars some species from taking part in the contest. Many species also which would perhaps grow in sterilized sewage are not able to exist in the presence of other and more powerful forms.

There is, then, good reason for speaking of "sewage-bacteria," *i. e.*, those bacteria normally found in sewage, and composing its special flora. Whether or not these forms constitute a class, as distinct as the "water-bacteria" and "air-bacteria," is a matter for further determination. At all events, there is much to be gained from the study of sewage-bacteria as such. It is now generally believed that they are the active agents in the purification of sewage; that they carry the organic nitrogen (albuminoid ammonia) step by step through free ammonia and nitrites to the inert, fully oxidized nitrates. It becomes, therefore, highly important to discover the organisms most active in bringing about this purification, and to determine as far as possible the conditions under which they work most efficiently. With this end in view, a number of experiments with specific bacteria have been carried on in conjunction with the chemists of the Board, and some highly interesting and valuable results have already been obtained. The length of time required for experiments of this nature, however, compels us to postpone for the present the full consideration of this branch of the work.

It is to be remembered, moreover, that from a broader sanitary point of view, much is to be gained by descriptions of sewage-bacteria. It is often essential to determine whether water has been contaminated by sewage, and in the present state of our knowledge this is generally impossible from a bacterial examination alone. It may be said, roughly, that a large number of different species of bacteria is indicative of sewage contamination. The occurrence of some few specific forms, such as *Bacillus coli commune*, for example, has been usually held to indicate the presence of sewage in the water; but it is evident that any such sweeping statement is attended with considerable risk. As regards, for example, the very group of bacteria which includes *B. coli commune*, the typhoid bacillus and other allied forms, bacteriologists themselves are in much confusion. There are at least sixteen or seventeen kinds of closely allied bacteria which give almost exactly similar colonies on a gelatin plate. We ourselves have found, in spring water which was beyond any suspicion of contamination, bacteria which, in form, size, growth on gelatin, potato, etc., were indistinguishable from *B. coli commune*. It has also been asserted recently that *B. coli commune* itself may, under certain circumstances, act as a pathogenic micro-organism.*

It is evident, then, that a study of the sewage-bacteria as such may throw light on the vexed question of the possible pollution of water supplies; for, if certain species are found to be characteristic of sewage, and are never found in uncontaminated sources, then the presence of these typical "sewage-bacteria" in any given water supply will indicate undoubted pollution. We may perhaps look forward to the time when the bacteriologist will be able to say, of a given water: Such and such species of bacteria are present, therefore, at some time sewage must have entered this water; or, on the other hand: Only those species are present which are always found in pure, uncontaminated water. Whether this comes to pass or not, it is evidently highly important, along with the study of the bacteria in sewage, to study also the kinds of bacteria living in pure, natural waters, which are beyond any suspicion of sewage contamination, and we hope soon to make a beginning in this direction.

With these practical sanitary ends clearly in view, we have made a thorough study of twelve of the more interesting species found in the sewage and filter tanks, and full descriptions, with figures, are given below. We have preferred to devote considerable time to a few species, rather than to describe imperfectly a larger number.

The problem of the distribution of different species of bacteria in the effluents, sands of the filter tanks, etc., though of great interest,

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* Centralbl. für Bakteriologie, VI., Bd. No. 16, p. 443.

is far too complex to be settled by a few scattered observations. A few general statements are all we feel justified in making at this stage of the work.

A striking and highly remarkable circumstance is the comparative absence of micrococci, or spherical bacteria, from the sewage and effluents. So far as our experience has gone, cocci rarely occur in sewage. P. F. Frankland has already noted the fact that cocci usually predominate in air, while bacilli are the prevailing forms in water. All our work goes to confirm this statement.

Moulds are found rarely in the sewage and effluents. In the sand of the tanks they have been found to the depth of two inches, but seldom below that depth. If present at all, they are, as might be expected, most numerous in the first quarter inch of the sand, and to that depth are often found in considerable abundance.

The bacterial flora of the sewage is large and varied. The two most common species in Lawrence sewage, so far as our experience has gone, are *B. coli commune* and the form we have called *B. cloacæ*. These two are always present in considerable numbers in every sample of sewage examined, and usually outnumber other forms. *B. coli commune* is a well-known species that inhabits the human alimentary canal, and would therefore be expected to occur in sewage. *B. cloacæ* is here described for the first time. The different forms of *Proteus* described by Hauser * have also been frequently observed in sewage, and occasionally in the effluents and sand from sewage tanks. Other forms of bacteria found more or less frequently by us in the sewage are described below. The work of describing and identifying the bacteria in sewage still continues.

The examination of the sands of the filter tanks has yielded some interesting facts. There is always a falling off in the numbers of bacteria on going from the surface to the bottom of the tank, and it is to be noted that this decrease is by no means equally distributed among all species. There are some species present in abundance in the top layers, which never make their appearance in sand taken from a considerable depth. In a general way it may be said that the liquefying species are fewer in proportion at the bottom. The larger number of the species which possess the power of liquefying gelatin appear to perish before reaching the lower layers of the sand. This, however, is not invariably the case.

* G. Hauser. *Ueber Fäulnissbacterien*, Leipzig, 1885.

Occasionally a single species has been found to predominate in certain layers of the sand, and has, as in one instance, been found as a "pure culture" in all samples of sand taken from twenty to thirty-six inches below the surface. That this is only a transient condition, has been proved by subsequent examinations, which have shown the same layers to be populated by several new kinds of bacteria, or even usurped by another distinct species. Probably varying conditions of food and temperature give opportunity now for one species, now for another to hold the chief place.

We have not as yet been able to trace any certain relations between the species found in the sands of the various tanks and the species found in the effluents from those tanks. All the species found in the sands have at some time or other been found in the effluents. On the other hand, some species are found in the effluents which have never been detected in samples of sand. This is the result we should naturally expect from the relatively smaller number of sand samples examined. One species — *B. delicatulus* — was at one time frequently found as a nearly pure culture, both in the sand and effluent of Tank No. VI. Other species — as *B. ubiquitus*, *B. cloacæ* and *B. hyalinus* — have been frequently found both in the sands and in the effluents of several filter tanks.

The study of the sewage-bacteria also throws light upon the question as to whether or not the bacteria come through the sand. Certain tanks — as Tank No. I. and Tank No. VI. — have shown at times unmistakable relations between the species found in the effluents and the species normally present in Lawrence sewage, — *Proteus*, *B. cloacæ*, *B. coli commune*, *et al.*, being found in abundance in the effluents. In Tank No. II., on the other hand, when in its best condition, the few species occurring in the effluent are such as might easily come from the air.

The work of identifying the forms of bacteria isolated by us, with those already described by other investigators, has been neither an easy nor a satisfactory task. Many descriptions of bacterial species are hidden away in obscure foreign journals and official reports, which have not been within our reach. Other descriptions are not merely incomplete, but are so imperfect that it is wholly impossible to determine whether or not the species so described is the same as the one we are comparing with it. We are therefore compelled to ignore entirely all such partial descriptions, since there can never be absolute certainty that we are dealing with exactly similar forms, unless all characters agree. One bacterial species may agree with another in many points, yet a difference in a single point may be enough to mark a specific distinction. The reason for this difficulty is not far to seek.

It is a well-established rule that classification must, if possible, be based on form rather than on function, the reason being that, while function can readily be changed, form is comparatively permanent. This rule holds good through all the higher forms of life. When we come to deal with bacteria, however, we find that form fails us as a basis of classification; for, even with the strongest powers of the microscope, bacteria show remarkably similar shapes.* One kind differs in form from another kind only in very slight particulars, and in many cases we are not able to detect any difference whatever. For instance, it is well known that it is very difficult to distinguish the typhoid bacillus from *B. coli commune*, and that in the last resort we must place our chief reliance on the peculiar growth of the typhoid bacillus upon potato. Thus it happens that, in the case of bacteria, organisms in which the usual data of classification are wanting, we are forced to adopt physiological characters — *i. e.*, habits, effects, etc. — as a means for distinguishing one species from another. The bacteriologist, unable to rely on the likenesses and differences shown by individuals, must study his specimens in bulk, and must distinguish between different species chiefly by their varying habits of life, and by their effects and appearances upon various nutritive media. The art of species investigation thus becomes largely a matter of naked-eye observation of masses of individuals, and of chemical tests. The peculiarities of this mode of procedure render it absolutely necessary to record a large number of the physiological characteristics of a species, if we are not to fall into endless confusion of names and descriptions. Even when this is done, a surprisingly close resemblance is found to exist between many species of bacteria. P. F. Frankland† has found that *B. subtilis* and *B. cereus*, although closely alike in most respects, differ in their ability to reduce nitrates. The highly significant work of Hueppe and Wood‡ points the same way, and leads us to emphasize the conclusion, that, *unless a large num-*

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* For example, compare Fig. 2*a*, Plate I., with Fig. 5*c*, Plate II.

† "Journal of the Chemical Society," Trans Vol. LIII, 1888, p. 378.

‡ "The Lancet," Vol. II., 1889, p. 1162.

ber of the characters of a species are recorded, it is useless to attempt systematic comparison of one species with another.

There is, then, abundant reason for refusing to consider those partial and imperfect descriptions of which there are, unfortunately, far too many. The species we are examining may happen to resemble a certain described species in form, size, and habit of growth on gelatin; but we cannot be sure that the two are really identical, unless the growth on potato, the power of reducing nitrates, etc., are also recorded. Even Flügge* and Eisenberg† in their generally excellent tables sometimes fail us in this matter of a complete description; *i. e.*, a description giving all the diagnostic characters at present within our reach.

It is only natural and proper that the attention given to the kinds of bacteria known to produce disease should be far greater than that given to the common and apparently harmless bacteria usually found in water and air. But if we are ever to have accurate knowledge of the bacteria of every-day occurrence in drinking water, sewage, etc., it is necessary that the various species should be fully and carefully described. The excellent work of the Franklands‡ is of the sort that is needed, and it has been our wish to add to descriptions of this standard.

In naming new species, it has been our aim both to give names denoting some salient characteristic, and to avoid so far as possible names already in use.

In testing the effect of the different species upon nitrates, we have used a bouillon containing 8.88 parts (per 100,000) of albuminoid ammonia (Merck's peptone), .92 parts of free ammonia, 3.5 parts of nitrate(KNO_3), and no nitrite. For various reasons, ordinary Boston-tap water ("Cochituate") has been used for making the bouillon, in preference to the solution of salts in distilled water employed by the Franklands. Our results support those of the above-mentioned investigators, in that we find a marked difference in the reducing action of different species of bacteria. Detailed experiments are in progress, regarding the effect of these and other species of bacteria upon nitrates, and these will probably be completed in the course of another year. In no case have we found the slightest

* Flügge, "*Die Mikroorganismen*," Leipzig, 1886.

† Eisenberg, "*Bakteriologische Diagnostik*," Hamburg and Leipzig, 1888.

‡ "Zeit. für Hygiene," Bd. VI., Heft 3, p. 373, 1889.

evidence that any one of the twelve species described is able to bring about oxidation of ammonia to nitrite, although numerous and prolonged experiments have been made bearing on this point. As stated above, our work on nitrification forms the basis of another special report which will be found at the end of this volume. All work with pure cultures, unless stated otherwise, has been carried on at the temperature of the culture room (21° C. to 23° C.). Comparisons of rapidity in growth, etc., have all been made at this temperature, so that 21° C. to 23° C. should be understood as the standard unless some other temperature is given.

The nutrient gelatin used in determining the growth of a species in a slightly acid medium is prepared in the same way as the standard gelatin, with the single exception that it is made slightly acid with acetic acid after neutralization. The gelatin is divided into two portions after being neutralized with sodium carbonate. To one portion is added just enough weak acetic acid to give a slight acid reaction to litmus paper; the other portion is made slightly alkaline with sodium carbonate, in the usual way. The two portions of gelatin, thus practically identical, save that one is slightly acid and the other slightly alkaline, are then inoculated with the different species. Care is of course taken to keep the growths under exactly similar conditions of temperature, moisture, etc., in order that the comparison may be strictly between acid and alkaline media.

For potato-cultures we have prepared the potato in the way suggested by Meade Bolton (" *Centralblatt für Bakteriologie*," 1887, Bd. II., p. 459). This method consists in cutting out a cylindrical piece of the potato with an apple-corer, and slicing this cylinder through diagonally, so as to obtain a flat, sloping surface. The pieces of potato are then placed in tubes closed with cotton-wool, and sterilized in the steam-bath in the usual way.

NOTE. — We regret that the admirable monograph upon water bacteria by Dr. O. E. R. Zimmermann (*Die Bakterien unserer Trink- und Nutzwässer.* Chemnitz, 1890) did not come into our hands until after this report was completed. We have therefore been unable to make as much use of his work as we should otherwise have done.

DESCRIPTION OF SPECIES.

BACILLUS UBIQUITUS. (N. Sp.)

Occurrence. — Isolated from the Lawrence sewage. Found frequently in the effluents from all of the sewage tanks. Also often found in natural waters, and occasionally in the air. Apparently abundant everywhere.

Morphology. — Small, short, plump bacilli, closely resembling micrococci. 1.1 μ to 2 μ long, about 1 μ broad. Quite variable in form. In bouillon there is shown a slight tendency to gather into short threads, but the single forms predominate. (Plate I., Fig. 1c.)

Motility. — No independent movement observed.

Temperature. — Grows as well at 37° as at the ordinary temperature of the culture room (21° to 23°).

Need of Oxygen. — Grows well under the mica plate.

Plate-cultures. — At first, small, roundish, often oval colonies of a yellowish tinge. In two days the surface colonies have assumed their characteristic appearance, — a white, glistening projection, resembling a drop of milk. These spread slowly, become somewhat irregular, and take on a dull brownish cast. With a low power the young colonies show a smooth edge and finely granular interior. (Plate I., Fig. 1*b*.)

Tubes, — Gelatin. — Good growth on the surface and along the inoculation line. In a week the growth as a whole bears much resemblance to a nail. The color changes from a lustrous porcelain white to a dull, brownish gray. The gelatin is not liquefied. Grows as well in slightly acid gelatin as in alkaline. (Plate I., Fig. 1*a*.)

Tubes, — Agar. — A good, whitish-gray growth on the surface and along the inoculation line. The surface growth has a slightly metallic lustre.

Potato-culture. — A white, shining growth, which does not spread much, and remains quite limited in extent.

Milk. — The milk is quickly coagulated (eighteen hours at 37°), and gives a strong acid reaction.

Bouillon. — The bouillon soon becomes turbid. A considerable flocculent precipitate is formed. On old cultures a thin skin forms on the top, but this falls to the bottom on slightly jarring the tube.

Effect on Nitrates. — Reduces nitrates vigorously.

Remarks. — This species apparently resembles quite closely the *Bacillus candicans* described by the Franklands (*"Zeit. für Hygiene," Bd. VI., Heft. III., p. 397*). It differs from that, however, among other respects, in its capacity for reducing nitrates, and in its mode of growth on agar and potato.

BACILLUS CIRCULANS. (N. Sp.)

Occurrence. — Found occasionally in the Lawrence tap-water (from the Merrimac River).

Morphology. — Long, slender bacilli, with well-rounded ends; generally single, but sometimes two to four cells are found loosely connected end to end. In most cultures spores are found in three or four days. These are formed in the end of the rod, are oval and small, the diameter being nearly the same as that of the rod. These spores are formed particularly well on agar and potato. The bacilli are about $2\ \mu$–$5\ \mu$ long, and about $1\ \mu$ broad. (Plate I., Fig. 2*a*.)

Motility. — The individual bacteria have a lively movement in the hanging drop.

Temperature. — Grows better at 37° than at 21°.

Need of Oxygen. — Grows nearly as well under the mica plate as it does in contact with the air.

Plate-cultures. — In two days, round, brownish colonies become visible to the naked eye. Viewed with a low power of the microscope the interior of the colony presents a very peculiar and quite characteristic appearance. The gelatin is liquefied, and the rapid motion of the individual bacteria gives to the whole fluid mass the appearance of a circulation — like the circulation of protoplasm. This is a very constant phenomenon, and is always to be observed after about forty-eight hours' growth. In three days the movement has usually ceased, and the interior has a rather coarsely granular appearance, with flocks of bacteria scattered irregularly here and there. These finally develop a round, deep, even depression, which spreads very slowly, taking several weeks to reach the diameter of a centimeter. Often the colonies show some variability, the contour being somewhat lobed, instead of being perfectly smooth and even as is generally the case. (Plate I., Fig. 2*c*.)

Tubes, — Gelatin. — A fairly slow growth, having the appearance of boring down into the gelatin in a narrow cone. A precipitate collects at the bottom of the cone, while the slowness of growth allows the liquefied gelatin to evaporate from the upper part. The upper part of the cone often has a somewhat ringed appearance. Grows well in a slightly acid medium. (Plate I., Fig. 2*b*.)

Tubes, — Agar. — A very thin, translucent surface growth; fairly good growth along the line of puncture.

Potato-culture. — A slow, scant growth, about the color of the potato itself.

Milk. — The milk is very slowly coagulated, with a slight acid reaction. This power of coagulating milk is lost, however, after the species has been cultivated for several months in artificial media.

Bouillon. — The bouillon becomes turbid in from three to four days. A considerable slimy precipitate is formed. No skin is formed on the surface.

Effect on Nitrates. — Reduces nitrates to nitrites, but not rapidly, the first evidence of reduction appearing after about fifteen to twenty days.

Remarks. — The circulation inside the colonies was at first thought to be especially characteristic of this species, but has since been observed in a number of other forms, as *B. cloacæ*, *B. delicatulus*, *et al.* It is, however, more noticeable and more constant in this particular species than in any other observed.

BACILLUS CYANOGENUS.

Occurrence. — Found frequently in the Lawrence sewage.

Morphology. — Small bacilli, with rounded ends, often oval in form. Occur in chains on all media, isolated individuals being quite the exception. The chain is usually long, and its members cohere quite firmly. On no medium has there been observed anything resembling spore formation. The individuals are about 1.3 μ long, .8 μ broad. (Plate I., Fig. 3*b*.)

Motility. — There is a slight independent movement to be observed in hanging drops. We have certainly not found this species to be "very motile."

Temperature. — Does not grow as well at 37° as at 21°.

Need of Oxygen. — Grows very scantily under the mica plate.

Plate-cultures. — The young colonies below the surface of the gelatin are usually slightly oval, with a coarsely granular interior, and an even, regular edge. Often, however, the colonies have a frayed, irregular appearance to the naked eye, and with a low power of the microscope show fine branchings from the centre. On coming to surface the colonies always spread out into a dull, dry expansion, with irregularly hacked edges. Sometimes the colonies are surrounded by a light blue-green haze, which soon changes to a faint brown; and this becomes deeper and deeper, till the whole plate is colored an intense dark brown. More often, however, in our experience, the brown color comes without a previous development of the blue. In slightly acid gelatin the blue color comes more surely and constantly than in the ordinary alkaline medium. The gelatin is not liquefied. (Plate I., Fig. 3*a*.)

Tubes, — Gelatin. — In about three days there is a thin surface growth, smooth and faintly lustrous. The contour is at first quite regular, with the edges only slightly toothed. There is only a slight growth along the inoculation line. The gelatin near the surface soon takes on a brown tint, and eventually the whole tube of gelatin is colored dark brown. The blue coloration is not observed so well in the tubes as on the plates. This species grows fairly well in acid gelatin, but not so well as in alkaline. In the former the brown color invariably comes more slowly. (Plate I., Fig. 3*c*.)

Tubes, — Agar. — In three days there is a good surface growth, white and lustrous. The agar is colored dark brown. The growth itself also assumes a brownish cast.

Potato-culture. — A very rapid growth on potato. In twenty-four hours the potato is colored a deep brown over nearly its whole surface. We have in no case observed a previous blue coloration. The growth is brownish, thin, spreading and dry.

Milk. — The milk very slowly becomes a light chocolate color. The reaction is slightly alkaline.

Bouillon. — In three days the bouillon has become slightly turbid. Month-old cultures are a deep brown, with a tough, thick skin on the surface.

Effect on Nitrates. — Nitrates are slowly reduced.

Remarks. — This species is undoubtedly the "bacillus of blue milk," described originally by Hueppe ("*Mitthheilungen aus dem Kaiserlichen Gesundheitsamte*," *Bd.* 2, p. 355), and recently the subject of thorough investigation by Heim ("*Arbeiten aus dem Kaiserlichen Gesundheitsamte*," *Bd.* 5, p. 518). Our experience with this species agrees in most respects with that of Heim. We have never found the "club-shaped forms" (Keulenformen) mentioned by Hueppe *et al.* Neither have we observed anything we can regard as true spores; and on this point we are inclined to agree with Heim that the so-called spores are vacuoles or something of the sort, and are to be relegated to the same category as the "spores" of the typhoid bacillus.

BACILLUS SUPERFICIALIS. (N. Sp.)

Occurrence. — Found frequently in the Lawrence sewage; also found occasionally in the sand of Tank No. 13.

Morphology. — Fair-sized, plump bacilli, with rounded ends. Generally occur singly, or in pairs. No spore formation observed. About 2.2 μ long, 1 μ broad. (Plate II., Fig. 4*b*.)

Motility. — Shows independent movement in a hanging drop.

Temperature. — Grows better at 37° than at 21°.

Need of Oxygen. — Grows feebly under the mica plate.

Plate-cultures. — The colonies become plainly visible to the naked eye in about two days. With a low power of the microscope the colony itself is seen to be approximately round, but is divided by irregular lines into angular lumps, giving a somewhat cracked appearance to the whole colony. On coming to the surface, a regular, round, homogeneous, finely granular expansion is formed. To the naked eye the colony then appears as a projecting translucent drop. The colony grows slowly, and slowly liquefies the gelatin. When the liquefaction has proceeded for several days, the colony has a yellowish-brown opaque centre, and a translucent edge. (Plate II., Fig. 4*c*.)

Tubes, — Gelatin. — A very slow growth, taking about ten days to liquefy the gelatin to the walls of the test-tube. The growth is almost wholly on the surface, and there is only the scantiest growth along the inoculation line. Even after standing for several weeks, only the gelatin in the upper part of the test-tube is affected by the growth. Grows well in acid gelatin. (Plate II., Fig. 4*a*.)

Tubes, — Agar. — On agar there is a moist, lustrous, gray translucent growth. After several weeks the growth is still smooth and shiny, and has assumed a light brown tint.

Potato-culture. — Potato does not seem to be a favorable medium for the development of this species. Repeated trials at different temperatures have failed to induce a growth on potato.

Milk. — There is no visible change in twenty days. The reaction, however, is slightly acid.

Bouillon. — Becomes turbid very slowly. A scant white precipitate is usually formed after some time. No skin.

Effect on Nitrates. — There is no reduction to be observed in forty days. It should be remarked, however, that the tests with this species were with specimens that had been under artificial cultivation for some time, and might not hold with a freshly isolated growth.

BACILLUS RETICULARIS. (N. Sp.)

Occurrence — Found in the effluent of Tank 8, through which Lawrence city water is filtered.

Morphology. — Long, rather slender bacilli, with slightly rounded ends. They often grow in strings of eight to ten loosely connected individuals. No true spore formation has been observed, although in many of the bacilli there are large vacuoles with strongly refracting edges. About 5 μ long, 1 μ broad. (Plate II., Fig. 5*c*.)

Motility. — The bacteria show a slow, sinuous motion in the hanging drop, but at no time are they very lively.

Temperature. — This species grows much better at 37° than at 21° to 23°.

Need of Oxygen. — Grows very scantily under the mica plate.

Plate-cultures. — The young colonies below the surface of the gelatin send out long spiral filaments, which give a hazy appearance to the colony, when viewed with the naked eye. With a low power of the microscope the colonies with their radiating filaments resemble so many jelly-fish with streaming tentacles. The gelatin is slowly liquefied. On coming to the surface, a considerable irregular expansion is formed, but eventually a highly characteristic appearance is produced. The gelatin is liquefied so slowly that the liquid evaporates almost as soon as formed. The colonies then resemble slight hollows or cups in the gelatin. The surface of these cups presents a mottled appearance, as if it were covered with fine, irregular net-work or reticulations. (Plate II., Fig. 5*a*.)

Tubes, — Gelatin. — In two days the upper part of the growth has the appearance of a cup with flaring edges. The gelatin is liquefied very slowly in the middle of the cup, and evaporates almost as fast as formed, so that this appearance is preserved for some time. The cup has the same reticulated structure described above. In three days fine filaments begin to shoot out from along the inoculation line. These, however, do not often reach a very great length. (Plate II., Fig. 5*b*.)

Tubes, — Agar. — On agar there is a dull, dry, projecting growth on the surface, quite slow. A poor growth along the line of inoculation.

Potato-cultures. — In two days a good growth, — white, dull and dry. In five days the growth has assumed a characteristic woolly appearance.

Milk. — The milk is coagulated slowly, — after fifteen to twenty days at the temperature of the room, — and gives an acid reaction.

Bouillon. — The bouillon slowly becomes turbid, with the formation of a slight, stringy precipitate.

Effect on Nitrates. — Rapidly reduces nitrate to nitrite.

BACILLUS RUBESCENS. (N. Sp.)

Occurrence. — Isolated from the Lawrence sewage.

Morphology. — Large, long bacilli, with well-rounded ends. Often occur in pairs and in short strings. Many of the individual bacilli are slightly curved. No spore formation observed. About 4 μ long and .9 μ broad. (Plate II., Fig. 6*b*.)

Motility. — A slow, sluggish movement.

Temperature. — Grows better at 21° than at 37°.

Need of Oxygen. — Grows very poorly under the mica plate.

Plate-cultures. — A slow growth. The young colonies beneath the surface of the gelatin are usually round, sometimes oval. On coming to the surface, they rise into a projecting porcelain-white drop. The colonies increase in size slowly, and eventually take on a slight brownish cast. (Plate II., Fig. 6*a*.)

Tubes, — Gelatin. — The growth is slow, and mainly on the surface, where a porcelain-white, nail-head projection is formed. There is only a slight growth along the line of inoculation. There is a good growth in slightly acid gelatin. (Plate II., Fig. 6*c*.)

Tubes, — Agar. — There is a rapid surface growth, white and lustrous. At first the growth is smooth, but later becomes crinkly, and the whole skin is much wrinkled. In cultures about three weeks old a slight pinkish tinge can be seen.

Potato-cultures. — There is a rapid, luxuriant growth upon potato. At first the color of the growth is light brown, but this slowly changes to pink. In three weeks there is a luxuriant, projecting growth, tinted a delicate flesh-pink. The potato itself is not colored.

Milk. — The milk is not coagulated, and gives a good alkaline reaction. In long-standing cultures a slight pinkish tinge is observed at the surface of the milk.

Bouillon. — The bouillon becomes slightly turbid, and a heavy white precipitate is formed. In several weeks a thick, tenacious skin forms on the surface. The main body of the bouillon is then clear.

Effect on Nitrates. — No change in the nitrates after fifty days.

BACILLUS HYALINUS. (N. Sp.)

Occurrence. — Isolated from the sand of Tank 13 at a time when the tank was nitrifying well. Found in large numbers in the sand.

Morphology. — Large, long, stout bacilli, with rounded ends. Usually gathered in short strings. No spore formation observed. About 3.6 μ to 4 μ long, 1.5 μ broad. (Plate III., Fig. 7*a*.)

Motility. — Lively movement.

Temperature. — Grows better at 37° than at 21° to 23°.

Need of Oxygen. — Grows very well under the mica plate.

Plate-culture. — Fast-growing; in twenty-four hours the colonies can be plainly seen with the naked eye. In all, even in the smaller colonies, there is a dark centre, surrounded by a broad translucent zone, which gives a hazy appearance to the colonies. With a low power of the microscope the interior is seen to be coarsely fibrillar, with short fibrils radiating from the edge. In two days the colonies are large, — about one and one-half centimeters in diameter; the contour is evenly round, the interior slightly translucent; the rim is distinct, opaque, yellowish; the edge still shows radiating fibrils. (Plate III., Fig. 7*b*.)

Tubes, — Gelatin. — In two days a long, narrow, funnel-shaped growth. The gelatin is rapidly liquefied, and is at first cloudy, with a precipitate at the bottom of the funnel. In about eight days the tube has assumed a highly characteristic appearance: a lustrous, tenacious, white scum, a slight flocculent precipitate, and perfectly transparent liquefied gelatin between. Grows very well in acid gelatin. (Plate III., Fig. 7*c*.)

Tubes, — Agar. — A rapid, dry, grayish growth, spreading. Dull, tough and rather thin. When about four to five days old, small warty projections appear. Good growth along the inoculation line.

Potato-cultures. — In two days the growth is just visible; in four days, good, spreading, dry, whitish-gray growth. Later, small protuberances appear on the surface.

Milk. — In seven days, strongly coagulated. Acid reaction.

Bouillon. — Soon becomes cloudy; a stringy precipitate, and a thick skin on the surface.

Effect on Nitrates. — Reduces nitrates vigorously and rapidly.

BACILLUS CLOACÆ. (N. Sp.)

Occurrence. — Isolated from the Lawrence sewage. Found also in the effluents from some of the tanks, notably Tank No. 1, at a high rate of flow. One of the most common bacteria in sewage.

Morphology. — Short, plump, oval bacilli, with well-rounded ends. No spore formation observed. Quite variable in size; slightly longer and thicker on potato than on agar. Are frequently grouped in pairs. About .8 μ to 1.9 μ long, .7 μ to 1 μ broad. (Plate III., Fig. 8*c*.)

Motility. — Very lively movement.

Temperature. — Grows slightly better at 37° than at 21° to 23°.

Need of Oxygen. — Grows very scantily under the mica plate.

Plate-cultures. — In twenty-four to forty-eight hours a round, yellowish colony becomes visible in the gelatin. On coming to the surface, this forms a slight bluish expansion, with irregularly notched edges, and almost immediately begins to liquefy the gelatin. With a low power of the microscope the colony is seen to have a dark centre, an outer translucent zone and a darker edge; the interior is finely granular. The whole plate is soon liquefied (in from three to four days). (Plate III., Fig. 8*a*.)

Tubes, — Gelatin. — A rapid growth, liquefying the gelatin. A good growth along the inoculation line. An iridescent scum on the surface, and a heavy, flocculent, whitish precipitate. Grows as well in slightly acid gelatin as in the ordinary alkaline medium. (Plate III., Fig. 8*b*.)

Tubes, — Agar. — A moist, slimy, porcelain-white surface growth. Excellent growth along the inoculation line.

Potato-cultures. — In two days a very good yellowish-white growth; rapid, projecting.

Milk. — In about four days the milk is coagulated, and gives a strong acid reaction.

Bouillon. — The bouillon becomes very cloudy in two days. In ten to fourteen days considerable whitish precipitate is produced. A slight skin forms on the surface, but falls to the bottom on disturbing the tube. After some time — two to three weeks — the bouillon is still cloudy.

Effect on Nitrates. — Reduces nitrates in bouillon vigorously.

BACILLUS DELICATULUS. (N. Sp.)

Occurrence. — Isolated from the effluent of Tank 6, where it has been found frequently. Obtained also from the sand composing Tanks 6, 1 and 4. Occasionally found in the effluents from nearly all of the tanks.

Morphology. — Medium-sized, plump bacilli, often joined in pairs and in short strings. Spore formation was not observed on any of the media used. 2 μ long, 1 μ broad. (Plate III., Fig. 9*b*.)

Motility. — Very lively movement.

Temperature. — Grows slightly better at 37° than at 21°.

Need of Oxygen. — Does not grow at all under the mica plate

Plate-cultures. — When young, whitish, homogeneous, with a regular, radiating edge. In two days, at the temperature of the room, the gelatin becomes liquefied; later, the centre becomes darker than the surrounding zone. (Plate III., Fig. 9*c*.)

Tubes, — Gelatin. — In two days the gelatin is liquefied well down into the inoculation line. The gelatin is completely liquefied in about seven days; there is a thick, whitish skin on the surface, and a heavy, flocculent, brownish precipitate at the bottom; the liquefied gelatin is cloudy. Grows nearly as well in slightly acid gelatin as in alkaline. (Plate III., Fig 9*a*.)

Tubes, — Agar. — At first a crinkly, grayish growth, which when older becomes porcelain-white and glistening. Grows well both on the surface and below.

Potato-cultures. — A gray, spreading growth, — not projecting.

Milk. — The milk is coagulated, and gives a strong acid reaction.

Bouillon. — Soon becomes cloudy. A white precipitate and white scum.

Effect on Nitrates. — Reduces nitrate to nitrite very rapidly and completely.

Remarks. — This species is very sensitive to low temperatures. At about 15° it refuses to grow at all, this being a peculiarity observed in none of the other species described by us. The cultures in tubes appear to live only a short time, for after several weeks a seemingly vigorous growth on agar or gelatin fails to yield a single living germ.

BACILLUS VIOLACEUS LAURENTIUS. (N. Sp.)

Occurrence. — Found in large numbers in the effluent of Tank 1.

Morphology. — Short, slight bacilli, with rounded ends. Often occur in pairs, sometimes in chains of four or five. No spore formation observed. About 3 μ to 3.6 μ long, 7 μ broad. (Plate IV., Fig. 10c.)

Motility. — Very lively movements.

Temperature. — Grows better at 21° than at 37°.

Need of Oxygen. — Grows as well under the mica plate as it does outside. There is no production of color, however, when the air is excluded.

Plate-cultures. — In about two days small, rounded, coarsely granular colonies appear in the deeper parts of the gelatin. They generally have a radiating edge and a dark centre. On coming to the surface, the colonies spread out into a small, thin, irregular expansion. This expansion never spreads, and the gelatin is almost immediately liquefied in its neighborhood. A rounded spot of violet gathers in the centre of the colony, and around this is a zone of slightly cloudy liquefied gelatin. The liquefaction proceeds quite rapidly, but the central, round, violet clots do not increase materially in size. (Plate IV., Fig. 10*a*.)

Tubes, — Gelatin. — The gelatin is liquefied rapidly throughout the whole length of the inoculation line. The liquefied gelatin is a cloudy violet color, and there is a heavy, dark violet precipitate at the bottom of the tube. There is no skin on the surface, even in long-standing cultures. Grows as well in acid gelatin as in alkaline. (Plate IV., Fig. 10*b*.)

Tubes, — Agar. — There is an excellent growth on agar, with abundant production of dark violet color, which soon deepens into jet black.

Potato-cultures. — Potato is an excellent medium for the growth of this bacillus. The growth spreads over the whole surface, forming a dark violet color, which very soon, except on the edges, becomes jet black.

Milk. — Milk seems to be an especially favorable medium for this bacillus. There is a rapid and luxuriant growth, coloring the milk a deep blue-violet, and soon causing it to coagulate. The coagulated milk gives a strong acid reaction.

Bouillon. — The bouillon becomes cloudy very slowly, and at no time shows more than a slight turbidity. In the ordinary meat-extract-peptone bouillon there is no sign of a violet coloration. In the broth containing nitrates, however, there is a luxuriant growth, the broth becoming very turbid, and a rich violet color being produced.

Effect on Nitrates. — Reduces nitrate to nitrite rather slowly.

PROTEUS ZENKERI. (HAUSER.)

Occurrence. — Isolated from the Lawrence sewage. Found frequently in the sewage, and occasionally in the effluents from some of the sewage tanks.

Morphology. — Very variable in form. Sometimes short, oval bacilli, closely resembling micrococci; and again long, thread-like, leptothrix forms. Between these two extremes occur almost all sizes of rods, and rarely spiral forms. The rods are not infrequently curved, at times resembling "comma-bacilli." (Plate IV., Figs. 11*c*, 11*d*.)

Motility. — Exhibits true independent movement in some stages of development, while in other phases it is apparently without this power.

Temperature. — Grows better at 21° to 23° than at 37°.

Need of Oxygen. — Grows fairly well under the mica plate, but not so well as where it is exposed to the air.

Plate-cultures. — Grows rapidly. In two days the colonies are large, plainly visible to the naked eye, to which they appear as if surrounded by a halo or faint haze. With a low power of the microscope the hazy appearance is seen to be due to fine threads radiating in every direction from the opaque centre. The threads then have the very characteristic "cork-screw" arrangement, and the rounded knots, also characteristic of the *Proteus* group, are just beginning to be formed.

Later is developed the highly remarkable knotted, twisted and generally complicated structure figured by Hauser. The older branches strongly resemble rolls of coins placed side by side. The gelatin is not liquefied, even when the plates stand for weeks. (Plate IV., Fig. 11*b*.)

Tubes, — Gelatin. — Grows rapidly both on the surface and along the line of inoculation. Fine threads radiate in every direction from the central cone, giving to the whole growth the appearance of an inverted pine-tree. The growth is more vigorous at the top of the tube. Grows capitally in slightly acid gelatin. (Plate IV., Fig. 11*a*.)

Tubes, — Agar. — A good, gray-white growth, rather limited. Excellent growth along the inoculation line.

Potato-cultures. — A very slow, scanty growth, resembling the potato in color. Not projecting.

Milk. — No apparent change in milk after thirty days.

Bouillon. — Becomes slowly cloudy; a slight precipitate, but no skin is formed.

Effect on Nitrates. — No effect on nitrates in a peptone solution, after forty days' growth.

Remarks. — This species is probably identical with the form described by Hauser as *Proteus Zenkeri* (Gustav Hauser, "*Ueber Fäulnissbacterien,*" Leipzig, 1885, p. 44).

BACILLUS JANTHINUS. (ZOPF.)

Occurrence. — Isolated from the effluent of Tank 1. Found several times in abundance in the effluent of this tank, but not observed in fresh sewage.

Morphology. — Very small, slender bacilli, often occurring in short strings. About 2 μ long, .5 to .6 μ broad. In preparations from most media portions of the cells appear deeply stained. These more deeply staining portions, however, are probably not true spores, since there are usually two and often four in a cell. With staining fluids they do not, moreover, give the recognized tests for spores. (Plate IV., Fig. 12*b*.)

Motility. — In the hanging drop they are seen to possess true independent movement.

Temperature. — Grows best at 21° to 23°; does not grow well at 37°.

Need of Oxygen. — Grows very poorly under the mica plate.

Plate-cultures. — The young colonies below the surface of the gelatin are round, sometimes oval, with smooth edges and generally even contour. On coming to the surface they spread out into a broad, irregular expansion, with deeply notched edges. This expansion is at first thin, but later becomes quite thick and projecting. A deep violet color soon appears, sometimes near the centre of the colony, sometimes around its edges. The colony is only rarely colored over its whole expanse, a portion being usually whitish-gray. The gelatin is liquefied very slowly. (Plate IV., Fig. 12*a*.)

Tubes, — Gelatin. — Grows slowly, forming a thin, violet-colored expansion on the surface. A scanty growth along the line of inoculation. The gelatin is slowly liquefied, and in old cultures is slightly colored violet, but is quite clear. There is no skin on the surface, but a heavy, dark violet precipitate is formed. (Plate IV., Fig. 12*c*.)

Tubes, — Agar. — Grows rather rapidly, and produces a deep, black-violet color. Spreads over the surface in a tough, coherent skin.

Potato-cultures. — Grows rapidly, spreading over the surface of the potato in all directions. A deep, black-violet color is produced. The growth has a beaded appearance, as if covered with small, shining black beads. This appearance readily distinguishes it from B. violaceus Laurentius. The potato is now covered with a tough skin, which can be detached only with difficulty.

Milk. — Grows vigorously in milk, coloring it a deep violet. The milk is not coagulated.

Bouillon. — In the ordinary bouillon grows only slightly. In the broth containing nitrates (see p. 828), however, there is a luxuriant growth, the bacillus showing a tendency to form violet zoöglœal sheets, although the broth itself is cloudy also. The broth, however, is not colored.

Effect on Nitrates. — Reduces nitrate to nitrite very rapidly and completely.

Remarks. — This species is undoubtedly identical with the species originally descriped by Zopf as *Bacillus janthinus* ("*Die Mikroorganismen*," p. 291, C. Flügge, Leipzig, 1886). This species has also been found more recently by Plagge and Proskauer in their work on the Berlin filters ("*Bericht über die Untersuchungen des Berliner Leitungswassers in der Zeit vom 1 Juni, 1885, bis 1 April, 1886;*" Plagge und Proskauer, "*Zeitschrift für Hygiene*," Bd. II., p. 463). It was noticed earlier than this by Hüppe, and was observed also in the "Göttinger hygienischen Institut." It is a question whether or not the bacillus described by Rosenberg as "Bacterium h" ("*Ueber die Bacterien des Mainwassers*, Bernhard Rosenberg, *Archiv für Hygiene*," Bd. V., p. 458), which also produces a violet color, is identical with *B. janthinus*, with the *B. violaceus* of Frankland, or with the form described by us as *B. violaceus Laurentius*. The narrow yet constant differences between these three species leave us in doubt as to what Rosenberg's violet bacillus really may have been, since his description of "Bacterium h" leaves something to be desired in the matter of completeness.

Differences between B. JANTHINUS and B. VIOLACEUS LAURENTIUS.

1. The growth on gelatin is very different in the two species. *B. janthinus* liquefies gelatin very slowly; *B. violaceus Laurentius*, on the other hand, liquefies

it quite rapidly. On the gelatin plate, the small colonies are quite unlike in their appearance under a low power of the microscope. (Plate IV., Figs. 10*a* and 12*a*.) The growth in tubes of gelatin is also noticeably different. (Plate IV., Figs. 10*b* and 12*c*.)

2. On agar, *B. janthinus* forms a tough skin; *B. violaceus Laurentius*, on the contrary, gives a moist and slimy growth.

3. On potato there is the same difference as that observed in the growths upon agar; and, moreover, the growth of *B. janthinus* upon potato always has a beaded appearance, due to its being covered with small, shining projections. The growth of *B. violaceus Laurentius* on potato is always smooth and might almost be called slimy.

4. In the nitrate broth (p. 828) *B. janthinus* grows vigorously, and renders the broth exceedingly turbid; but the broth itself does not assume a violet color, although the huge zoöglœal sheets that are formed are themselves richly colored. *B. violaceus Laurentius*, on the other hand, does not form the zoöglœal sheets, but does color the broth a deep violet. That is to say, the coloring matter produced by the latter is soluble in water; that produced by the former is apparently not so soluble.

5. One of the most marked differences between these two species is in their action upon milk. *B. violaceus Laurentius* coagulates the milk quite rapidly, and makes it strongly acid. *B. janthinus* does not coagulate milk; and, after two or three weeks' growth, the milk is usually slightly alkaline, sometimes strongly so, but it is never acid.

Differences between B. VIOLACEUS and B. VIOLACEUS LAURENTIUS.

1. *B. violaceus Laurentius* shows a very lively, independent forward movement; the *B. violaceus* described by the Franklands (*"Zeitschr. für Hygiene," 1889, Bd. VI., Heft III., p. 394*) shows "*nur vibrirende oder rotirende Bewegungen.*"

2. *B. violaceus Laurentius* grows rapidly and luxuriantly upon potato; *B. violaceus* does not grow at all upon that medium.

3. The appearance of the two kinds of colonies upon a gelatin plate is widely different. We have never observed the growth which is represented by the Franklands as being characteristic of *B. violaceus*.

It is of course an open question as to whether these three distinct kinds of bacteria, all of which agree in producing a violet color on proper media, should be classed as mere varieties or as distinct species. The present state of bacteriological classification does not warrant a decided opinion in either direction.

EXPLANATION OF THE PLATES.

The photographs from which the illustrations have been made were all executed by Dr. R. R. Andrews of Cambridge, Mass., and their success is due largely to his untiring labors in moments taken from a busy professional life. The photographs of the bacterial preparations — stained with aniline oil fuchsin, after Löffler (*"Centralbl. f. Bakt.," Bd. VI., 1889, p. 209*) — were taken with the Zeiss 2 mm. apochromatic objective and the No. 12 compensation ocular; those of the colonies on gelatin plates, with the 16 mm. objective and the No. 6 compensation ocular; the test-tube cultures are all of natural size.

I wish also to acknowledge my obligations to Mr. E. O. Cockayne of the Boston Photogravure Company for the interest and care with which he has attended to the details of the reproduction.

PLATE I.

FIG. 1*a*. — **Bacillus ubiquitus**. — Stick culture in gelatin, eight days old. (Natural size.)

FIG. 1*b*. — **Bacillus ubiquitus**. — Young colonies, gelatin plate two days old. (x 80.)

FIG. 1*c*. — **Bacillus ubiquitus**. — Preparation from a two days' old agar culture. (x 1,000.)

FIG. 2*a*. — **Bacillus circulans**. — Preparation from a five days' old agar culture. (x 1,000.)

FIG. 2*b*. — **Bacillus circulans**. — Stick culture in gelatin, four days old. (Natural size.)

FIG. 2*c*. — **Bacillus circulans**. — Young colony, gelatin plate, about thirty-six hours old. (x 80.)

FIG. 3*a*. — **Bacillus cyanogenus**. — Young colony, gelatin plate, about three days old. (x 80.)

FIG. 3*b*. — **Bacillus cyanogenus**. — Preparation from a four days' growth on potato. (x 1,000.)

FIG. 3*c*. — **Bacillus cyanogenus**. — Stick culture in gelatin, four days old. (Natural size.)

PLATE II.

FIG. 4*a*. — **Bacillus superficialis**. — Stick culture in gelatin, eight days old. (Natural size.)

FIG. 4*b*. — **Bacillus superficialis**. — Preparation from a three-days' growth on agar. (x 1,000.)

FIG. 4*c*. — **Bacillus superficialis**. — Young colonies, gelatin plate. (x 80.)

FIG. 5*a*. — **Bacillus reticularis**. — Very young colony, gelatin plate. (x 80.)

FIG. 5*b*. — **Bacillus reticularis**. — Stick culture in gelatin, three days old. (Natural size.)

FIG. 5*c*. — **Bacillus reticularis**. — Preparation from a seven days' old agar culture. (x 1,000.)

FIG. 6*a*. — **Bacillus rubescens.** — Young superficial colonies, gelatin plate. (x 80.)

FIG. 6*b*. — **Bacillus rubescens.** — Preparation from a three days' growth on agar. (x 1,000)

FIG. 6*c*. — **Bacillus rubescens.** — Stick culture in gelatin, about five days old. (Natural size.)

PLATE III.

FIG. 7*a*. — **Bacillus hyalinus.** — Preparation from a three days' growth on potato. (x 1,000.)

FIG. 7*b*. — **Bacillus hyalinus.** — Young colony, gelatin plate, about thirty-six hours old. (x 80)

FIG. 7*c*. — **Bacillus hyalinus.** — Stick culture in gelatin, fourteen days old. (Natural size)

FIG. 8*a*. — **Bacillus cloacæ.** — Young superficial colony, gelatin plate. (x 80.)

FIG. 8*b*. — **Bacillus cloacæ.** — Stick culture in gelatin, three days old. (Natural size.)

FIG. 8*c*. — **Bacillus cloacæ.** — Preparation from a two days' growth on potato. (x 1,000.)

FIG. 9*a*. — **Bacillus delicatulus.** — Stick culture in gelatin, three days old. (Natural size.)

FIG. 9*b*. — **Bacillus delicatulus.** — Preparation from a two days' growth on potato. (x 1,000.)

FIG. 9*c*. — **Bacillus delicatulus.** — Young colonies, gelatin plate, about two days old. (x 80.)

PLATE IV.

FIG. 10*a*. — **Bacillus violaceus Laurentius.** — Young colonies, gelatin plate, about three days old. (x 80.)

FIG. 10*b*. — **Bacillus violaceus Laurentius.** — Stick culture in gelatin, four days old. (Natural size.)

FIG. 10*c*. — **Bacillus violaceus Laurentius.** — Preparation from a four days' old agar culture. (x 1,000.)

FIG. 11*a*. — **Proteus Zenkeri.** — Stick culture in gelatin, five days old. (Natural size.)

FIG. 11*b*. — **Proteus Zenkeri.** — Very young colony, gelatin plate. (x 80.)

FIG. 11*c*. — **Proteus Zenkeri.** — Preparation from a six days' growth on agar. (x 1,000.)

FIG. 11*d*. — **Proteus Zenkeri.** — "Klatsch-Präparat," from a gelatin plate-culture. (x 1,000.)

FIG. 12*a*. — **Bacillus janthinus.** — Young colonies, gelatin plate, about four days old. (x 80.)

FIG. 12*b*. — **Bacillus janthinus.** — Preparation from a four days' growth on agar. (x 1,000.)

FIG. 12*c*. — **Bacillus janthinus.** — Stick culture in gelatin, four days old. (Natural size.)

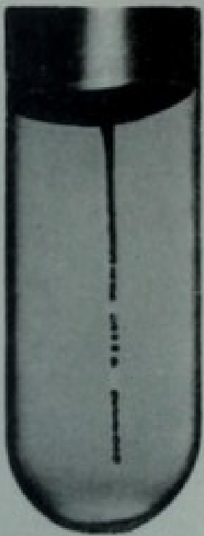

FIG 1a.

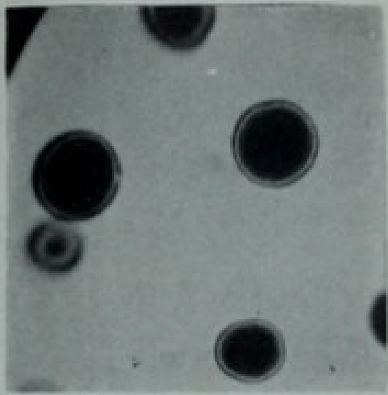

FIG. 1b.

FIG. 1c.

FIG. 2a.

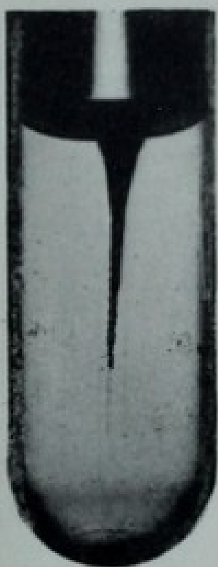

FIG. 2b.

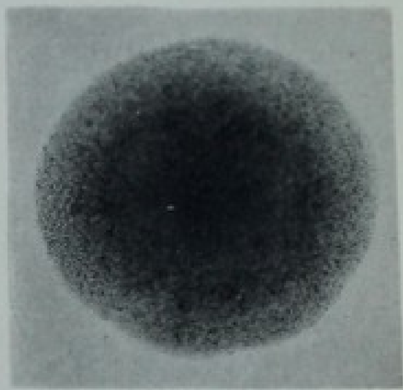

FIG. 2c.

FIG. 3a.

FIG. 3b.

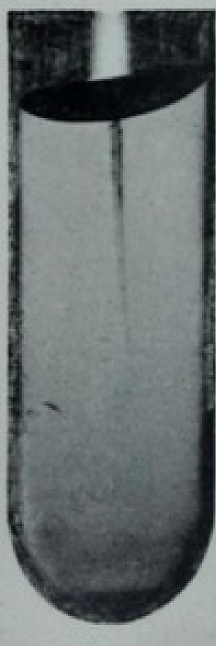

FIG. 3c.

Fig. 4a.

Fig. 4b.

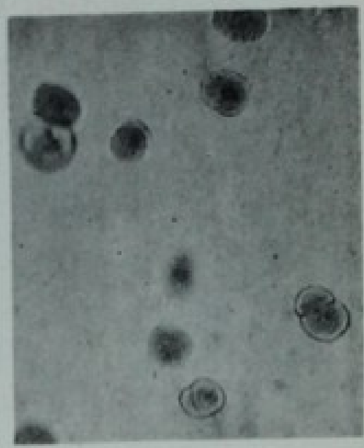

Fig. 4c.

Fig. 5a.

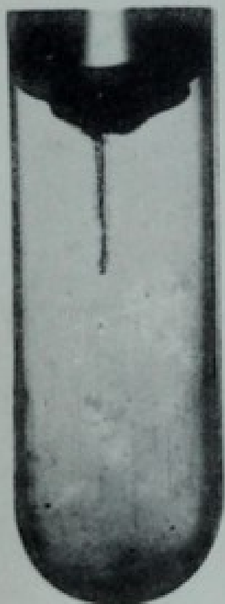

Fig. 5b.

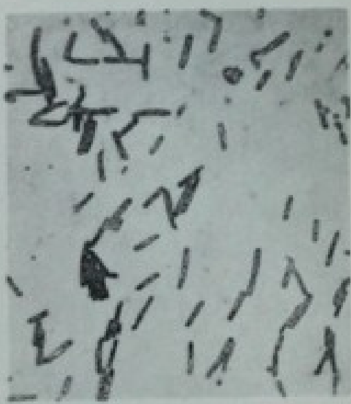

Fig. 5c.

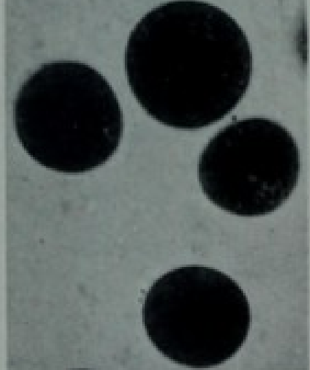

Fig. 6a.

Fig. 6b.

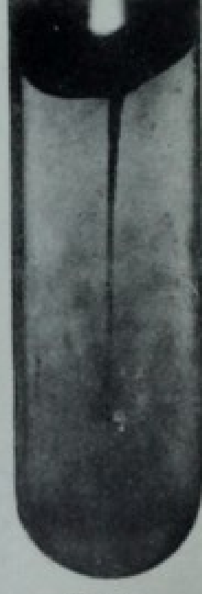

Fig. 6c

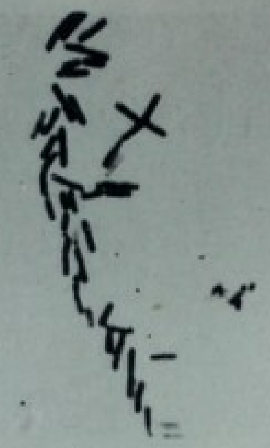

Fig. 7a.

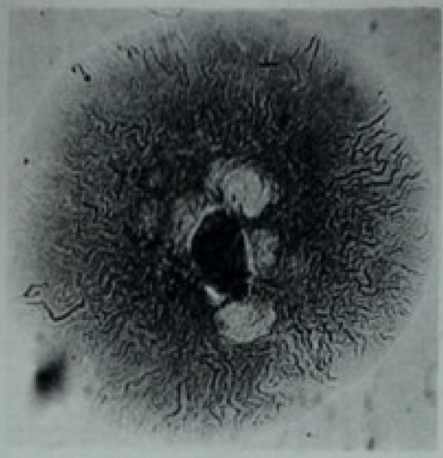

Fig. 7b.

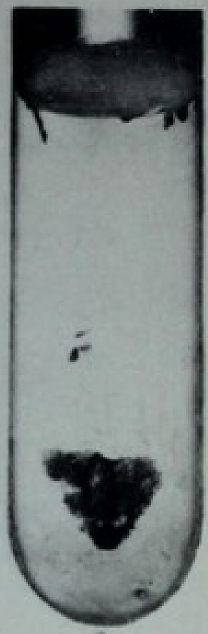

Fig. 7c.

Fig. 8a.

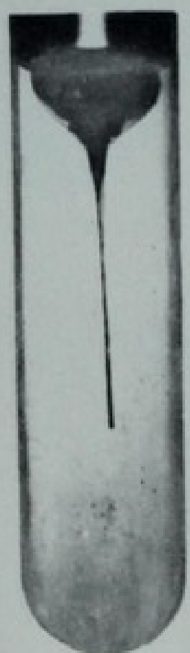

Fig. 8b.

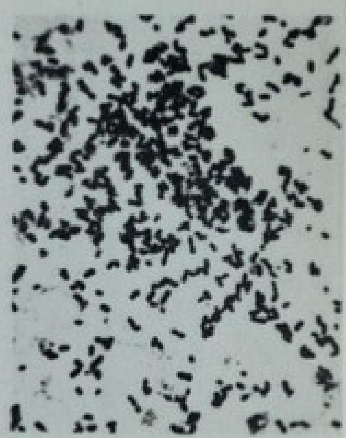

Fig. 8c.

Fig. 9a.

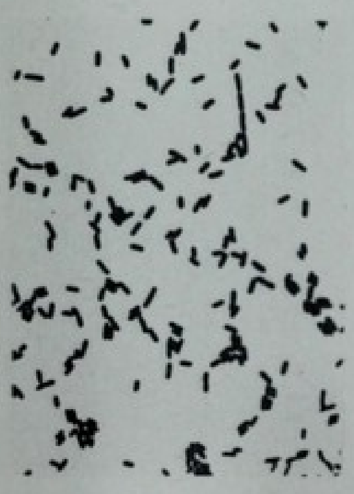

Fig. 9b.

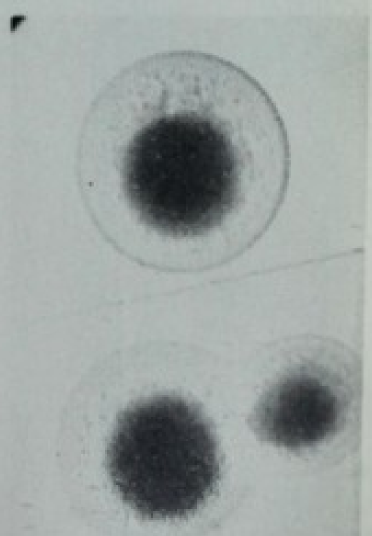

Fig. 9c.

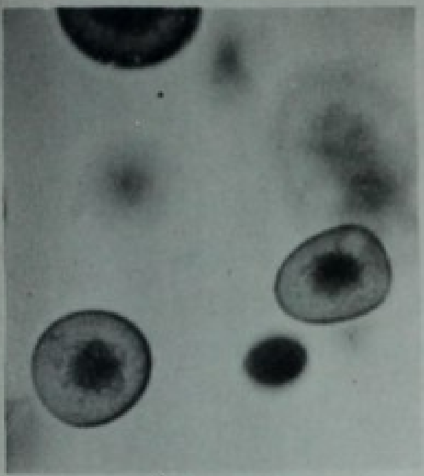

FIG. 10a.

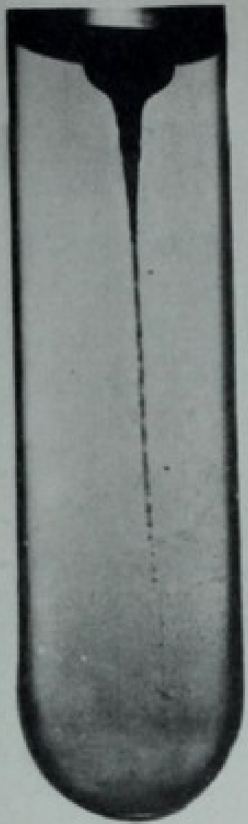

FIG. 10b.

FIG. 10c.

FIG. 11a.

FIG. 11b.

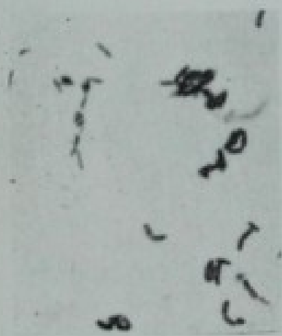

FIG. 11c.

FIG. 11d.

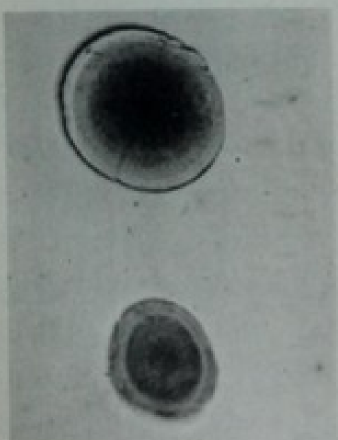

FIG. 12a.

FIG. 12b.

FIG. 12c.

VI. A General Account of the Biological Phenomena Observed in the Intermittent Filtration of Sewage.

The purification of sewage by intermittent filtration involves not only the fate of the vast numbers of micro-organisms in sewage (see p. 816), but also the functions of those micro-organisms to the activity of which the purifying mechanism — the so-called "filter" — chiefly owes its potency (see p. 7). Constant watch has been kept, therefore, upon the biological composition of the sewage applied to, and of the effluents recovered from, the several filters, in order to discover the effects of filtration upon the sewage organisms, while in addition, portions of the filters themselves have, from time to time, been withdrawn and subjected to examination, in order that we might learn not merely the changes wrought upon the liquid to be purified, but also the constitution of the purifying mechanism.

In the course of these repeated observations certain important phenomena have come to light, common to all the filters, while others equally important to the theory of sewage disposal by this method, though less general in their application, have also been discovered. These have been discussed already in the foregoing report of Mr. Mills, but, from the biological point of view, may be further considered here.

The Fate of the Microscopical Organisms.

The microscopical organisms (see p. 816), such as yeast, Leptothrix, the infusoria, the algæ, etc., occurring in sewage, appear normally to perish in the filters. Some of the smallest forms, such as yeast and Chlorococcus, moving with the most forward particles of the sewage, may, when the sewage is applied to a tank of coarse sand after a considerable interval, pass by the films of liquid held upon or between the sand grains, and, displacing air, sink quite rapidly to the floor of the tank (see p. 410). Furthermore, the spores or ova of these larger micro-organisms, which are usually smaller and better able to resist unfavorable conditions, may survive and escape from the filters, when the adult forms are detained and destroyed. On the other hand, the extremely small numbers of these organisms in the effluents (see, *e.g.*, pp. 47–51, 258, 316, 414, etc.); their complete absence from the body of the filtering material of the several tanks; the direct evidence of flourishing animal and vegetable life in the underdrains, etc., obtained by examination of the drains of Tank No. 5 (see p. 365); the results obtained by washing out the underdrains and discharge pipes of certain tanks (p. 49); and the character of the fauna and flora of the effluents, which indicates their origin in drains, pipes, etc. (p. 50), — all, taken together, prove that very few, if any, of the microscopical organisms applied in the sewage survive to escape in the effluents. Moreover, studies of the uppermost layers of the tanks prove that these organisms are destroyed soon after they pass below the surface.

The history of yeast in this connection is specially instructive, and probably typical. As has been shown above, the sewage applied to the tanks contains large numbers of living yeast cells (see p. 817). A microscopical examination of the sand composing the surface layer of a tank of fine sand (Tank No. 2) shows also the presence of abundant living yeast cells. Sand taken from a layer only a few inches lower shows no yeast cells whatever; and, between the two, the cells are found in a disintegrated condition. This is particularly the case at a depth of half an inch to one and one-half inches. Processes are obviously at work here which first kill, and then disintegrate beyond the possibility of recognition, the yeast cells arriving in the sewage. The presence of fragments of algæ, of living infusoria, etc., at the surface of such a tank, is also easy to recognize; but at the depth of a very few inches no such organisms are ordinarily found. On the other hand, there is no evidence of accumulation of these forms upon the surface. They are apparently removed as rapidly as they are applied. The "scum" or "scurf," referred to above, upon some of the tanks has not been due to a deposit strained out of the sewage, but rather to a new growth of Ulothrix, Oscillaria, or some similar filamentous algæ, which have found the intermittently irrigated sand a favorable dwelling-place. It has occurred but seldom, and has been easily killed out by prolonging the intervals between the applications of sewage, by exposure to the sunshine, etc.

The presence of abundant bacteria in the uppermost layers of the sand of the several tanks, coinciding as it does with the disintegration of these solid, and even living, elements of the sewage, suggests that the destruction of the latter at this level is really due to an active fermentation or decomposition, effected by the ordinary bacteria. In sewage these are doubtless hindered in their work by the absence of oxygen; but in the upper layers of the filters they find all the conditions which are necessary for their full activity. Further studies are now being made upon the precise nature of these important processes.

The Fate of the Sewage Bacteria.

One of the most striking phenomena of intermittent filtration is the almost total disappearance of the sewage bacteria in the filters. A comparison of the numbers of bacteria applied in the sewage (see p. 60) with those in the effluents (see pp. 60, 147, 246–247, 263, 301, 318, 396, etc.) suffices to show the enormous reduction of bacteria during filtration, and it only remains to observe that the numbers present in the filters, though large, are totally inadequate to account for the difference, in order to perceive that the filters do not merely detain, but actually destroy, the greater part of the ordinary bacteria arriving in the sewage (see pp. 59, 155, 269, 413, etc.). The practical consequences of these facts are so important that much time and thought have been spent in discovering if it be not possible to remove all bacteria by intermittent filtration. The discussion of the experiments bearing upon this question, and the conclusions thus far reached, are given beyond (pp. 850–855). It may be said here, however, that the methods at present available for the detection of the bacteria are of somewhat limited application, and that the question involves difficulties of considerable magnitude.

One phase of the disappearance of the bacteria deserves special notice. It is most marked during the process of nitrification. Previous to the beginning of nitrification, in the several tanks, the bacteria found in the effluent, though usually extremely small percentages of those applied in the sewage, were still present in considerable numbers. But, with the beginning of nitrification, the bacteria in the effluent declined; and, the more complete the nitrification, the more scanty have been the bacteria. This is well shown in the discussion of Mr. Mills upon the results obtained in Tanks No. I. and No. II. (pp. 54, 262, etc , and especially, in the General View of the Results, pp. 582–597). The cause of the death of the ordinary sewage bacteria in the tanks, especially during nitrification, is not yet entirely clear. It may be that the activity of the nitrifying organisms is of itself inimical to the ordinary bacteria; but further experiments will be necessary in order to explain all of the facts in our possession.

Another peculiarity, common to nearly all of the tanks, is the fact that, when sewage is first applied to a sand filter, it is but slightly purified chemically, and the bacteria in the effluent are more abundant than at any later time (see pp. 52–54, 60, 147). This is true even when the sand has been previously freed from bacteria, or sterilized (see p. 502). It is not yet entirely clear as to the cause of this phenomenon, but it does not appear likely that the explanation of a similar phenomenon observed by Piefke in continuous filtration, and suggested by him to account for it, will suffice in this case. Piefke considers the discharge in some cases, of more germs than are applied, as due to a liquefaction or solution of the superficial deposit of bacteria, or of a portion of it Here, however, there is no such deposit, and it appears rather as if the sewage bacteria, finding abundant food and oxygen in the sand, survived at first, or even increased slightly, while afterwards they found the conditions less favorable, and mostly perished.

The Biological Composition of the Filters.

Besides the bacteria found in the materials of which the filters are made, the microscope reveals a variable quantity of brown flakes, or flecks, of amorphous matter, which appear to be largely a peculiar form of bacterial jelly, mycoderm or zoöglœa. This is so constant throughout all the tanks, and apparently so characteristic, that it demands special consideration. From what has been said above, it is evident that it is the only organic material, visible with the microscope, which occurs throughout the tanks, from top to bottom. It cannot be regarded as an accidental accumulation of *débris*, since it is essentially uniform in character, and is attached to the sand-grains as if it had formed there, rather than as if it had been accidentally detained. From its connection with the sand-grains and its microscopical appearance, there is no reason to doubt that it is, for the most part at any rate, the peculiar gelatinous condition of bacterial development known as mycoderm or zoöglœa. Its abundance in the sands is remarkable, nearly every grain, in some cases, being clothed with a mantle of zoöglœa. We have reason to believe that in this stage the bacteria are still alive and active, though they may not grow upon our gelatin plates. We also have some indications that a sand filter is ineffective until this zoöglœa has begun to form, although it appears that a mature filter is not a mechanical purifier, but rather a respiratory mechanism. The analogy of fermentation by yeast, in which a large amount of chemical change is effected by a relatively small amount of yeast, naturally suggests itself, inasmuch as the chemical changes effected by a mature filter are enormous, and out of all obvious proportion to the discoverable changes in the zoöglœa, or the nitrifying organism. The analogy is entirely reasonable, since the fermentations produced by bacteria are known to resemble closely those produced by yeast.

It is also possible that the zoöglœa in the filters represents the nitrifying organism in a peculiar phase of its life history. Experiments upon the character, distribution, and functions of this zoöglœa, etc., are still in progress, and will be continued.

VII. Variations in the Bacterial Composition of Certain Effluents after an Application of Sewage.

On assuming the direction of the biological portion of the investigations of the Lawrence Experiment Station in 1888, I was confronted with the fact that the numbers of bacteria found in the effluents varied greatly not merely, as was to be expected, in different effluents, but even in the same effluent on successive occasions. This was naturally considered as tending to show that no special importance could be attached to the bacterial analyses, especially since the chemical analyses exhibited no such irregularities, but showed as constant composition of the effluents as might have been expected. Accordingly, I set to work upon a filter which had shown great variation in the bacterial contents of its effluent, namely, Tank No. 14, and collected a series of samples of the effluent, beginning just before the application of sewage, and continuing at intervals for some hours. The results of this and numerous similar experiments conclusively proved that there is a time, not long after the application of sewage to this tank and to others containing similar material, when the number of bacteria discharged per unit volume is many times greater than at any other time. Moreover, inasmuch as this period coincides in a general way with the period of rapid flow, it follows that a majority of all the bacteria discharged during the day escape during a comparatively limited time. A sample taken at this time differs widely from one taken before flowage, or long after.

In this way the irregularities previously found were easily accounted for, and a regular and highly important variation in the bacterial discharge was discovered. Henceforwards *the rate of flow*, expressed in numbers of cubic centimeters per minute, was added as one of the necessary data of collection. Numerous "series" of this kind have been taken, and in some cases variations of a marked character have been found in the corresponding chemical analyses. Examples of such "series" are to be found on pp. 84–87, 408, 411. In tanks composed of finer sand such variations are much less marked, or altogether absent. It still remained to explain the source of these variations, although their regularity and importance had become evident; but, until Mr. Mills brought to bear upon the physical aspects of the problem his well-known attainments in hydrology, no consistent explanation was brought forward. Mr. Mills's theory, which may be found briefly stated upon p. 410, appears to me to be highly probable, and of the utmost importance, since it enables us to advance one step nearer to the physiological action of the filter, giving us a picture of the intrinsic mechanical arrangements of the filtering apparatus, and showing how the sewage is disposed during its purification, how some sewage, in coarse sand filters, passes almost directly through, while the rest is almost instantly subjected to the purifying process.

Upon this theory it is easy to see why the bacterial fluctuations are more readily detected than the chemical. It is because, since only a little sewage reaches the bottom, the enormous numbers of bacteria mingling with a fluid containing very few, make a relatively great impression; while the ammonias, etc., differing less from those of the effluent than the sewage bacteria differ from the effluent bacteria, produce a correspondingly slight impression. This has been confirmed by a more recent experiment, in which a tank of coarse sand, filtering city water, was flooded with sewage. The arrival of the sewage in the effluent was indicated first by the arrival of larger numbers of bacteria, and next by the increase in chlorine (see pp. 45, 46, 85). It is plain that, if the theory referred to be correct, filters of fine sand which retain a large amount of fluid should show less fluctuation of bacteria with varying rates of flow. Experiments upon Tank No. 2 have shown that this is actually the case (see pp. 272, 273).

VIII. The Passage of Bacteria, and Especially of *Bacillus Prodigiosus*, Through Certain Sand Filters.

From what has been said above (p. 847), it is clear that a very large percentage of the organisms of the sewage perish in the filters, during intermittent filtration. The question naturally arises, Do any of the sewage organisms live to pass through, or are they all destroyed within the filters? those that are found in the effluent being accounted for as having come from the discharge pipes, underdrains, tank floors, etc., or from the air. The hygienic importance of this question is obvious, when we consider the extreme desirability of removing all pathogenic germs from the sewage. At the same time, the difficulty of solving the problem was great in some cases, inasmuch as the kinds of bacteria likely to occur in the air, in sewage, in pipes and drains, are very similar, or perhaps even identical; and consequently the comparison of the species in the sewage and the effluents, apart from its inherent difficulty, was not likely to yield immediate results. It was, therefore, decided to experiment directly with rich cultures of a species of the bacteria foreign to the station, which could be applied in the sewage, and detected, if present, in the effluents.

For this purpose Bacillus prodigiosus was chosen. This species has never been observed in the sewage or effluents, and is said not to exist native in this country. It is tolerably hardy, and owing to its exceedingly rapid growth upon gelatine, and its production of a bright-red color in well-developed colonies, is comparatively easy to recognize. Luxuriant vegetations of this species were prepared either in the usual "gelatine tubes" or in the ordinary "bouillon," and, after attaining the extraordinary development of which it is capable, so that a single cubic centimeter of the fluid contained millions of the individual germs, it was ready to be applied to the tanks. One or two liters of this fluid, swarming with the germs of Bacillus prodigiosus, were then added to the ordinary charge of sewage, for the larger tanks, and thirty cubic centimeters or thereabouts, to that for the smaller tanks, after which the mixture was poured upon the surface. The smaller tanks of coarse mortar sand were first experimented with, and samples of the effluent were collected, beginning several hours after the application. From data obtained since that time it appears likely that these collections did not begin early enough to secure the largest discharge of germs.

The results proved conclusively, however, that Bacillus prodigiosus passes through these tanks of coarser sand. The number of germs discharged, as compared with the number applied, was extremely small, which indicated, so far as it went, that most of those applied had perished in the sand, precisely as those from the sewage mostly perish, during the ordinary operations of intermittent filtration. In the first experiment Tank No. 14 was used, and three tubes of gelatine, already liquefied by the culture, in all some thirty cubic centimeters, were added to the sewage charge. This tank had previously been fitted with side taps at different levels, in order to test the bacterial composition of the descending fluid, step by step. Whenever it was desired to use these taps, they were first sterilized by directing against them the flame of a plumber's naphtha burner. In the present experiment the fluid collected from such a tap, one foot from the surface, seven minutes after the application, contained Bacillus prodigiosus. The outflow from the same tap, three minutes later, also contained this species, as did that from a tap thirty inches from the surface, twelve minutes after the application. It was not looked for in the effluent on this day (Nov. 21, 1888), but was found in the effluent of the 22d on three separate trials, as well as in that from the thirty-inch side tap. It was also found in the effluent of the same tank three days after the application (November 24) and seventeen days after (December 8). It was not found at any later time, and, although hundreds of examinations of the effluent of this tank, and of the sand composing it, have been made, it has never been found since. The conclusion is inevitable that it speedily died out.

The next experiment was upon a tank of similar material, Tank No. 13, on Dec. 5, 1888. As before, three tubes, or thirty cubic centimeters of a rich culture of B. prodigiosus, were applied in the sewage charge. On the 7th this species was found in the effluent, and also on the 8th, after which it disappeared completely. Apparently it died out even more speedily than in the first experiment.

It should be observed that these experiments, proving the direct passage of bacteria through intermittent sand filters, were made several months before those of Fraenkel and Piefke upon continuous sand filters, and are probably the first ever made, in which the possibility of the passage of a particular species through a sand filter was indubitably established. It is also interesting to remark that the belief, which appears to have been widespread, that bacteria cannot survive to pass through sand filters (those observed in the effluents being considered as due to contaminations of one sort or another), is shown by our experiments to be as fallacious in the case of intermittent filtration as it has been shown to be in the case of continuous filtration by the experiments of Fraenkel and Piefke.*

Fraenkel and Piefke employed in their experiments Bacillus violaceus instead of B. prodigiosus. Two or more varieties of this species occur in our effluents at the Lawrence Experiment Station (see p. 841), so that B. violaceus was obviously less adapted for our use than B. prodigiosus.

The foregoing experiments having shown that bacteria may pass through filters composed of coarse mortar sand (see pp. 14, 122), and escape in the living condition in the effluent, though in very small numbers in comparison with those applied to the surface, other experiments were made in the following spring and summer upon the larger tanks out of doors. Thus, upon May 21, 1889, an experiment was begun upon Tank No. 1 (see pp. 55, 56); but, although the number applied was enormous, and the effluent was repeatedly examined, no colonies of B. prodigiosus were found in the effluent. A similar experiment was made upon this tank on June 20; but, although the examinations of the effluent were frequent and long continued, no B. prodigiosus was found.

In these two experiments upon Tank No. 1, the bouillon containing the bacteria was mingled with the sewage as the latter flowed on for the regular charge. Despairing of detecting the test germs by this method, a large quantity of liquid, containing, in all, by estimate, 11,000,000,000 of these organisms, was applied to one square foot of the surface of Tank No. 1 (see p. 56); and, to give it every opportunity, the uppermost inch of sand was previously scraped off. But, even when thus introduced into the body of the filter, as it were, only two colonies were ever recovered from the effluent. Some of the germs may have passed out before examinations began (see p. 56); but inasmuch as the effluent from this tank is still being repeatedly examined, and no B. prodigiosus appears, it is fair to conclude that it speedily died out here as before. An experiment similar to those upon Tanks No. 13 and 14, and the first two upon Tank No. 1, was made on March 6, 1889, upon Tank No. 2, composed of fine sand; and on May 23 upon Tank No. 6, composed of mixed coarse and fine sand; but no colonies of B. prodigiosus were, either then or since, detected upon the culture plates from

* Fraenkel, Dr. C., and Piefke, C. "Die Leistungen der Sandfiltration," Zeit. für Hygiene, Bd. 8, 1890. Bertschinger. "Untersuchungen über die Wirking der Sandfilter d. Städt. Wasserwerke in Zürich." Vierteljahresschrift d. Naturforsch. Gesellschaft in Zürich. 1889.

their respective effluents. Thus it became clear that, while a foreign species of bacteria, if applied in sufficient numbers to tanks of coarse sand, may survive to escape in exceedingly diminished numbers in the effluent, there was, as yet, no evidence whether or not an indigenous species might pass more or less readily through similar tanks, or through tanks of finer sand. Such direct evidence as had been thus far obtained indicated that, if such species pass through at all, it is only in vastly diminished numbers.

But if the bacteria do not live to pass out in the effluent, they must originate upon the floor of the tank, in the underdrains or in the discharge pipes. The direct examination of the drains of Tank No. 5 (p. 365) had already proven the existence there of conditions favorable to vegetation; direct examinations of the discharge pipe of one of the tanks with purest effluent (Tank No. 2) had established the presence there of large numbers of bacteria (see p. 268); while the multiplication of "series" had shown that, in a general way, the greatest numbers of bacteria are discharged during the greatest velocity of flow (see p. 849). It seemed plausible, therefore, to suppose that, upon the assumption of no bacterial discharge from the tanks, the bacteria found in the effluents had been washed away by the effluent stream from their sources of origin upon the floor or within the drains of the tanks or from the discharge pipe. Naturally, the greater the velocity of the stream, the more bacteria would be dislodged and carried out, while the gentler stream, giving low rates of flow, would be ineffective in itself, and in comparison with its more rapid predecessor.

At this juncture a new series of experiments was devised and suggested by Mr. Mills, by which the problem was approached from an entirely different direction. Inasmuch as the effluent at low rates of flow brings comparatively few bacteria, Mr. Mills proposed that we should put a cap over the effluent pipe, and hold back, or accumulate, the water arriving at a low rate of flow, until it was sufficient to fill the pipe and the underdrains, and to cover the floor of the tank. It was then to be allowed to flow out at a rapid rate; and, if the bacteria of the effluents are really dislodged by the velocity of the ordinary effluent, they should be dislodged equally well by the water thus let out. It was not claimed that the experiment exactly duplicated the conditions present at the time of rapid flow from the tanks, but it was believed to imitate those conditions sufficiently for our purpose. In some cases, instead of causing a slow accumulation of the effluent itself, filtered water of known bacterial composition was run in, and then allowed to flow rapidly out. The details of these experiments are given above (pp. 47–49, 56, 57, 85–87, 269–271). They showed that the number dislodged mechanically by a rapidly flowing stream is far too small to explain the discharge of bacteria in the ordinary effluents of the tanks of coarser sand, as being due to a similar cause. The only alternative is to conclude that these bacteria are chiefly derived, not from the pipe or drains or floor of the tank, but from the body of the tank itself.

These considerations, however, obviously do not settle the problem for tanks, such as Tank No. 2, which discharge but few bacteria, sometimes for a long period. It is still somewhat uncertain whether or not all the sewage bacteria are destroyed by this filter; but it is hoped that a systematic and specific comparison of the bacteria discharged, with those observed in the body of the tank, may eventually enable us to settle the question.

IX. Effects of the Application of Bouillon, Peptone, Salt-Sugar, Ammonium Chloride, and Sulphuric Acid, upon the Bacterial Discharge from the Filters.

In the course of the foregoing experiments upon the passage of Bacillus prodigiosus through the filters, it was noticed that the ordinary bacteria were unusually abundant in the effluent. This result appeared to be a consequence of the addition of one liter of bouillon to the charge of city water. Moreover, although this bouillon was full of B. prodigiosus, but few, comparatively, appeared to survive the passage. As the culture was a "pure" one, *i.e.*, contained only the foreign species, and as the city water contained at most but a hundred or two of bacteria per cubic centimeter, it was plain that the large numbers present upon the plates must have come from the body of the filter itself. The question arose, Does the addition of the food materials of the bouillon produce a proliferation of the bacteria living in the sand? In order to answer this question, a similar quantity of bouillon prepared in the same way, but thoroughly sterilized, was applied to the tank. A similar result followed (compare pp. 151–152).

The bouillon employed consisted of beef tea enriched with peptone, — the ordinary nutrient bouillon of bacteriologists. Undoubtedly it supplied the bacteria resident in the sand with an abundant supply of rich food, and enabled them to multiply enormously. As this wave of food material subsided, the bacteria also declined.

Peptone, the principal nutritive constituent of bouillon, is a soluble, and therefore specially available, form of nitrogenous food. It is probably superior in nutritive availability and value to most of the substances found in sewage. It is therefore probable that even a rich sewage would never have an equal, although it might have a similar, effect upon the discharge of bacteria from sand filters. The suggestion is obvious, however, that the temporary effect of increased food materials arriving in the sewage may be to increase the discharge of bacteria. A permanent increase would probably have no such effect. The filter would soon adapt itself to its new work. This is well shown in the experiments instituted by Professor Drown and Mr. Hazen, and described on pp. 498–500, 503, 726. To Tank No. 11, which had been filtering city water, there was suddenly applied, on March 9, 1889, a solution of peptone (see p. 498) in city water. On March 12 the bacteria in the effluent were found to be 18,819, and on March 19, 13,377; but on March 23 only 60, and on March 26, 18, the dose meanwhile continuing the same. Higher numbers were found at times, but during June the filter had so perfectly accommodated itself to its new work that the average discharge for the month was, in four examinations, 2.5 bacteria per cubic centimeter. It must be borne in mind that comparatively few bacteria were here applied. The result may be taken to prove that no inordinate multiplication of bacteria took place permanently within the filter. After the filter had adapted itself to its work, that work was practically perfect, both chemically and bacteriologically (see pp. 522 and 530).

The effect of applying peptone to an intermittent filter appears, therefore, to be as follows: at first there is an increased discharge of bacteria, and an incomplete oxidation, but this condition gradually changes to one of almost complete oxidation, and the discharge of very few, if any, bacteria. This series of events appears to be due to the temporary over-feeding of the filter, and consequent increase of the bacteria, followed by a new balance of supply and demand. It follows also that peptone is readily and completely oxidized by micro-organisms.

These experiments with peptone upon Tank No. 11 were followed by a similar experiment with common salt (see pp. 500–505, 530, 729). The sudden application of a large quantity of salt caused nitrification to cease, and the ordinary bacteria to be discharged in increased numbers. Gradual increase to the same amount showed no such effect, a gradual adaptation, or tolerance, being established. It would be difficult to find more characteristic testimony to the fact that a filter is essentially an organism demanding a certain regimen for its most efficient operation (see p. 25, "Regimen Essential to Success").

The effect of the application of sugar (pp. 134, 152, 730) in city water to Tank No. 12, was to cause an increased discharge of bacteria which was followed by a decrease. Meanwhile, nitrification ceased also. It is plain that the increase at the start may have been caused by the cessation of nitrification, since this is the usual effect of such cessation; but it is not so easy, at first sight, to explain the subsequent decline in bacteria. It is possible that, with the vigorous bacterial vegetation of the first period, the available nitrogenous matter of the filter was used up, and that afterwards we were virtually filtering city water. Sugar contains no nitrogen; and, if this element were lacking, it would probably be of little avail that a carbohydrate were present. In the dietaries of higher organisms sugar is of no value unless supplemented by nitrogenous food of the right kind. When, at a later period, the tank was filtering and nitrifying sewage effectively, the addition of sugar appeared again to inhibit nitrification to a certain extent, but without causing meanwhile an increase in the ammonias. At the same time, the sugar was mostly used up or retained, while previously it had mostly passed through unchanged. It would appear from these experiments that sugar is of little use to the bacteria, perhaps being even injurious to the organisms of nitrification; and this is not opposed to our knowledge of the physiology of the bacteria in general.

The experiments of Professor Drown and Mr. Hazen upon the nitrification of ammonium chloride furnished an unusually favorable opportunity to witness the effects of this salt upon the bacteria (see pp. 138–139, 154–157, 726, 727), and the results are highly significant. They may be briefly stated as follows: Tank No. 13, composed of coarse mortar sand, was receiving and nitrifying satisfactorily its regular dose of sewage, when, on Jan. 14, 1889, its dose of sewage was withdrawn, and in its place a solution of ammonium chloride and sodium carbonate in city water was applied. This solution contained 1.00 part per 100,000 of free ammonia; but this quantity was gradually increased until it reached, on April 30, 34.00 parts. From August 1 it contained 68.00 parts per 100,000 (see tables, pp. 198–212). It will be observed that this inorganic substance was dissolved in city water, which contains but small amounts of organic matter adapted to support bacteria, although the filter contained a certain limited amount of stored nitrogen (see p. 726). In spite of this obvious scarcity of organic nitrogen, the organisms within this filter were able, without difficulty, not only to convert this vast quantity of free ammonia into nitrites and nitrates, *i.e.*, to nitrify the charge, but also to maintain their own numbers in the sand, and to discharge regularly a small output of bacteria (see pp. 154–157). The organisms of nitrification must also have been extraordinarily abundant; but these are probably not shown by the ordinary methods of bacteriology. There can be no question that in this experiment the free ammonia served as food for the bacteria. Here, also, every change in the dose caused more or less chemical and biological disturbance. *Regimen* was again shown to be essential to success.

Experiments instituted by the chemists of the Board upon the effect of acids upon nitrification gave an opportunity for a study of the effect of acid upon the discharge of bacteria from an intermittent filter (compare pp. 552, 553, 728). The acid used was exceedingly dilute sulphuric acid, and in this strength (an excess of 0.16) the nitrification is decreased, but not wholly stopped. The bacteria appear to be few as long as there is much nitrification, but to increase as the nitrification falls very low. It would appear as if the nitrifying organisms are inhibited in their activity by acid, while the ordinary bacteria are less affected, and increase with the decrease of purification.

Reference must also to be made to the elaborate and careful experiments of the chemists of the Board upon the effect of insufficiency of oxygen, and total exclusion of oxygen, upon nitrification (compare pp. 144, 160, 730–734). To this process oxygen appears to be absolutely indispensable, and yet a very small quantity will suffice. It does not follow, however, that the organisms of nitrification perish with the exclusion of oxygen, although these experiments would indicate that they are probably aerobic. The ordinary bacteria appear to survive, many of them, at least, for a good while, without a trace of free oxygen. This is shown by their abundance in sewage, which is destitute of free oxygen, and by their survival in it for weeks, even in bottles completely filled and tightly stoppered.

X. Micro-organisms in the Filtration of Water and in the Chemical Precipitation of Sewage.

1. In the Filtration of Water.—Tables showing the bacterial composition of the city water of Lawrence are given above (p. 616). The results obtained by the intermittent filtration of this water through five feet in depth of material, arranged as described on p. 602, are shown in the monthly averages, pp. 603–605, as well as on p. 617; and the whole subject has already been discussed in the report of Mr. Mills, pp. 602–615. Reasons are there given for believing that no microscopical organisms have passed through this tank (p. 612). The numbers obtained for the bacteria indicate also that very few if any of these live to pass through. The percentages removed appear smaller than in the case of sewage filtration, largely because of the small numbers in the city water at the start. The truth probably is that no bacteria pass through, and that those observed are derived from the drains, the pipe, and the floor of the tank.

The results of other experiments upon the more rapid filtration of water are detailed upon pp. 653, 654, 663.

2. In the Chemical Precipitation of Sewage.—The micro-organisms of sewage are described above (pp. 816–830). In the experiments conducted by Mr. Hazen upon the chemical precipitation of sewage, samples were frequently taken by him, and afterwards submitted to the biologists of the Board for microscopical and bacteriological examination. The results of these examinations are recorded in the report of Mr. Hazen (compare, more especially, pp. 759, 770, 776, 782–789). An interesting feature of the biological portion of the work was the discovery that the yeast cells of the sewage afford by their numbers a test of the completeness of the removal of suspended matters in a state of fine subdivision. The successful application of this test may be regarded as emphasizing the value of our new method of making microscopical examinations (p. 808). (See, also, p. 668.)

XI. Biological Aspects of the Theory of Intermittent Filtration.

The simplest theory of the working of any filter is that its action is mechanical. Filters which are merely strainers are familiar, and the word "filter" has come to mean ordinarily a more or less perfect strainer. This primitive idea, however, does not apply to filters such as we have been dealing with in this Report. A field of sandy soil may, it is true, be a very effective strainer; but, if worked intermittently, it is much more than this. A mere strainer soon chokes, and must be cleaned; but an intermittent filter does not choke, and is self-cleaning. This is a phenomenon which can actually be witnessed. When sewage began to be applied to the several tanks outside the station, even the most intelligent of the workmen predicted that these would quickly choke, and become a nuisance; but, after two years of actual operation, nothing more remarkable or objectionable could be seen upon them than upon other fertile land. This simple ocular demonstration is confirmed by the results of analysis; and the mechanical theory is readily disproved by a comparison of the chemical composition of the affluent with that of the effluent. In the life-history of an intermittent filter there may be a period at the outset when there is but little if anything more than a mechanical purification; but, under the best conditions, there speedily begins a change of the profoundest significance. The dissolved organic matters no longer pass out as they came in; the suspended matters for the most part cease to accumulate; and both appear in the effluent under other forms. Obviously, mechanical processes alone could not effect such a change, and, besides, these changes may occur under conditions which exclude entirely the purely mechanical hypothesis.

A most striking example of this kind is to be found in the operation of Tank No. 16A (pp. 563–567). This tank is composed of small stones, the spaces between which are, as compared with much of the organic matter of sewage, of infinitely large size; yet the changes wrought by this filter are far more extensive, and the purification is far more complete, than in filters of peat or garden soil, which are mechanically nearly perfect strainers. It would be hard to find a better example of the possibilities of sewage filtration than this tank supplies; yet this tank testifies in the clearest manner to the absolute insignificance of any merely mechanical factor in the purification of sewage by intermittent filtration.

A theory, much more reasonable than the mechanical hypothesis, is that the action of an intermittent filter is fundamentally chemical. Of the powers of intermittent filters to effect chemical changes there is no question, as the pages of this volume abundantly testify. Moreover, the transformations effected are so thorough that the analogy of purification by fire must occur to every thoughtful observer. Very early, however, the existence of an additional factor began to be recognized. Thus Frankland,* in his experiments upon intermittent filtration, although insisting upon the chemical character of the purification obtained, referred to the process as an act of *respiration*, adding, almost unconsciously, the vital to the purely chemical idea: "From all of these experiments, then, it appears that the action of the filter must not be considered as merely mechanical. The process carried on in it is also chemical. . . . A field of porous soil irrigated intermittently virtually performs an act of respiration." It has now been definitely established, however, that micro-organisms are an indispensable element in the constitution of a successful intermittent filter, so that the essentially chemical theory has given place to one essentially vital, or biological.

Upon the biological theory, an intermittent filter is no longer regarded as a mechanical strainer; nor is it merely a chemical furnace; it resembles a living organism.

Biological phenomena, however, in the last analysis, depend upon chemical phenomena; and for the respiration of the filter-organism, free oxygen, in small but sufficient quantity, is indispensable. This is well established by the experiments of the chemists of the Board upon Filter Tank No. 14 (see pp. 144, 160, 730–734). The biological theory also demands the presence and activity of living micro-organisms. Strenuous endeavors have been made by ourselves and by others to isolate the particular kinds which appear to be so indispensable; and, although the problem has been hedged about by extraordinary difficulties, it is believed that a substantial beginning has been made. The report of Mr. Jordan and Mrs. Richards, which immediately follows, is believed to embody work of the first importance in the theory of sewage purification by intermittent filtration. Precisely how the organisms within the body of the filter do their work, is at present unknown. Whether it be by intra-cellular or by extra-cellular influences, is here a problem even more difficult than in the case of the fermentation of sugar by yeast cells. The chief points at present established are: that the best results are obtained in filters which are mature, and have thus become adapted to their work; that a distinct regimen is essential to success (p. 25); that free oxygen is indispensable (pp. 730–734, etc.); that the sewage is best purified when held in thin films upon or between sand grains and gravel stones (p. 578); and that the

* Rivers Pollution Reports, I., pp. 70–71. 1870.

period of greatest destruction of the ordinary sewage bacteria corresponds closely with the time of most active nitrification (pp. 262, 594, etc.). The last-mentioned fact appears at first sight to be a paradox, inasmuch as the most characteristic feature of intermittent filtration is nitrification, and nitrification appears to be effected by bacteria. If, however, the results reported in the following article are correct, it is less paradoxical than appears. The probability is there indicated that the organisms of nitrification escape detection by the ordinary methods of bacterial examination, so that these forms may prevail abundantly where others are detected in only small numbers. Another phenomenon of almost constant occurrence in the filter is the presence of the brownish masses which appear to consist chiefly of zoöglœa. The precise nature and significance of these is not yet clear, but that they play an important part seems probable.

For the more complete discussion of the theory and especially of the practice of intermittent filtration, in all its aspects, the reader is referred to the Report of Mr. Mills (pp. 577–600).

INVESTIGATIONS UPON NITRIFICATION

AND

THE NITRIFYING ORGANISM.

By EDWIN O. JORDAN and ELLEN H. RICHARDS.

INVESTIGATIONS UPON NITRIFICATION AND THE NITRIFYING ORGANISM.

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The nitrogen of organic substances is, for the most part, liberated during decay in the form of ammonia or ammoniacal compounds; and these substances yield, by oxidation, nitrous acid and finally nitric acid, which, in turn, in the form of nitrates feeds the living plant, and thus begins again the cycle of transformation.

The oxidation of the nitrogen of ammonia, and its ultimate conversion into nitric acid, is called nitrification. This change is especially active in soils near the surface, where nitrates are formed abundantly from percolating waters which contain much nitrogenous matter.

This phase of nitrification, the formation of nitrates in porous soil, has been attentively studied. But less attention has been given to the process of nitrification as it goes on in surface waters, such as streams and ponds; and it is to this side of the question, namely, nitrification as it occurs in natural waters, that our study has been chiefly directed.

Some eighty samples of water, selected from the two hundred and forty coming each month to the laboratory of the State Board of Health, were examined at intervals of from two to seven days for ammonia, nitrites and nitrates. These samples were received from all parts of the State, and included all classes of surface water, rivers, ponds and reservoirs. They were examined repeatedly during the months of June, July and August, 1888.

The results may be briefly stated as follows. The organic matter in suspension decays in about seven days, as is shown by the increase in "free ammonia." In about fourteen days this "free ammonia" has disappeared, and nitrite has taken its place, reaching a maximum in about twenty-one days. Later the nitrite too disappears, and in twenty-eight days or more all the nitrogen has been converted into the form of nitrate. When the suspended matter is removed by filtration through paper or by precipitation with alumina, no change occurs unless free ammonia were present at the outset.

These changes were so universal and so independent of the character of the water and of its condition of aeration, that it seemed important to avail ourselves of the unusual opportunity offered by the close proximity of the chemical and biological laboratories of the State Board of Health, to carry on a series of chemical and bacteriological investigations on solutions of known composition. Accordingly we began a series of experiments covering a period of nearly two years, in which the daily and weekly changes caused by the growth of bacteria were watched from both the chemical and the bacteriological stand-point, in order to determine the sequence and rate of such changes. Other points came up in the course of the work, as will appear from the following pages.

It has long been known that the first step — the decomposition of nitrogenous matter, and consequent production of ammonia — is due to the vital activity of bacteria. The early experiments of Schwann and Schultze (1839), and the later and thoroughly conclusive work of Pasteur, showed that putrefaction of organic matter is brought about solely by the small vegetable organisms known as bacteria. Even after this fact became generally known, it was some time before the importance of the complete range of this discovery was suspected. It was still maintained that the process of nitrification proper — the oxidation of ammonia to nitric acid — was of a purely chemical nature, although the burden of proof was soon thrown on those who upheld this view. The close dependence of nitrification upon a rather narrow range of temperature, the cessation of the process on the addition of antiseptics, the operation of "seeding" one solution with another, the impossibility of effecting rapid nitrification by chemicals, the analogous phenomena of putrefaction, — all pointed clearly to the fact that nitrification depends on the presence of living organisms.

The first conclusive proof that such was the case, however, came from the work of Schlœsing and Muntz in 1877.* The work of these observers rendered it practically certain that living organisms of some kind are the true agents of nitrification. "It now remains for us," they said, "to discover and isolate the nitrifying organisms." Schlœsing and Muntz, in their subsequent investigations, believed that they had succeeded in making this discovery; but, in view of the facts of modern bacteriology, we are unfortunately unable to

* Comptes Rendus, 1877, Tome 84, p. 301.

assign much value to this part of their work. It is not easy to satisfy one's self that Schlœsing and Muntz ever worked with really "pure cultures" of isolated species. While the work of these investigators established beyond all question the fact that nitrification, like the analogous phenomena of fermentation and putrefaction, is caused by living organisms, it left entirely open the precise nature of these organisms.

The first experiments with species of bacteria isolated by modern methods, and therefore undoubtedly pure cultivations, are those recorded by Heræus.* Heræus experimented with fourteen well-known species of bacteria, and with about as many others freshly isolated by himself from water and soil. He cultivated these in an ammoniacal solution, and obtained in the case of several familiar species good qualitative tests for nitrous acid. Among these species were Bacillus prodigiosus, the Finkler-Prior bacillus, the bacillus of typhoid fever, the anthrax bacillus, and others. Heræus concludes that all these organisms possess oxidizing powers, since they are thus apparently able to oxidize ammonia to nitrous acid.

The work of Adametz† and Frank,‡ on the other hand, did much to offset this positive result reached by Heræus. They found, as other investigators had found before them, that the introduction of a small quantity of common garden soil into an ammoniacal solution would produce rapid nitrification. The various species of bacteria, however, which they isolated from this same soil, and introduced as pure cultures into sterilized ammoniacal solutions, refused to nitrify. In no case was more than a trace of nitric acid observed. Frank was so influenced by his continued negative results that at a later date he went so far as to deny that living organisms had anything whatever to do with nitrification. This sceptical attitude seemed for a time to be fully justified by the experiments of Celli and Zucco. It was soon, however, demonstrated again by several skilful investigators that nitrification could not be accounted for by purely chemical influences. There was, nevertheless, no cessation in the publication of negative results. The work of Heræus was extended and elaborated by P. F. Frankland and by Warington. Frankland § failed entirely to obtain any evidence of oxidation of nitrogen by individual species of bacteria, and on this point came into direct conflict with Heræus. To use his own words: —

* Zeitschr. für Hygiene, I., 1886, p. 193.

† Untersuchungen über die Niederen Pilze der Ackerkrume. Inaug. Diss., Leipzig, 1886.

‡ Forschungen auf dem Gebiete der Agriculturphysik. X, 56.

§ Journal of Chem. Soc., April, 1888, Vol. LIII., No. CCCV., p. 373.

"The [ammoniacal] solutions were examined after forty days' growth, but in no case was anything more than a faint indication of nitrous acid obtainable with sulphanilic acid, phenol and ammonia.

"It is worthy of notice that Heræus had experimented with three of the micro-organisms which we have had under observation, viz., *B. subtilis*, *B. prodigiosus*, and *B. ramosus*. On growing these in sterilized urine, he found that *B. subtilis* alone gave no nitrous acid reaction, whilst the other two gave distinct reactions for nitrites; from this he concludes that *B. prodigiosus* and *B. ramosus* possess oxidizing powers, and that *B. subtilis* does not. My experiments, however, conclusively prove that both *B. ramosus* and *B. prodigiosus* exert a reducing action, whilst *B. subtilis* does not; and therefore that the nitrous acid reactions which he obtained in the case of the two former organisms must obviously have been due to the reduction of the nitrate in the urine, and not to oxidation of ammoniacal nitrogen, as he supposes. That nitric nitrogen is an invariable constituent of human urine has been shown by Warington (Trans. Chem. Soc., 1884, p. 669), and has in fact been long known." Frankland summarizes his results as follows: "8. None of the organisms under examination were found capable of oxidizing ammoniacal nitrogen to nitrous or nitric acids, when introduced into a nutritive solution containing ammonium chloride."

This emphatically negative result with pure cultures of single species was directly confirmed by Warington,* who wrote: "It seems to me very clear that not one of the investigators who have experimented with isolated species of bacteria has obtained in his solutions more than a trace of nitrous or nitric acid; *no one has obtained an amount that could be determined quantitatively.* Another point which generally appears is that every organism tried gives nearly the same result. . . . The statement of Heræus that seven of the organisms examined commenced the nitrification of a twenty per cent. urine solution in one day is apparently due to a mistake. My own experiments show that a urine solution of that strength cannot be nitrified by soil without the addition of gypsum; the commencement of nitrification in a strong solution is also extremely slow. The nitrous acid which so speedily appeared in his solutions was doubtless due to the reduction by the organisms of the nitrates naturally present in the urine." Of his own experiments, he says: "A distinct reaction with diphenylamine was in

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* Journal of Chem. Soc., August, 1888, Vol. LIII., p. 727.

some cases obtained, but this did not appear to grow in amount, although in such cases the examination was specially prolonged. The amount of nitric or nitrous nitrogen in the solutions did not apparently in any case exceed one per million, and all of this could not be attributed to the action of the organism, as the unseeded solutions in the incubator also gave some reaction with diphenylamine. When we have discounted the trace of nitrites probably obtained from the atmosphere, there is clearly very little left that can be attributed to the action of the organism. The question whether any part of the nitrate or nitrite present was produced by the organism, I am unable to decide; but it is quite clear that none of the organisms examined possessed any nitrifying power in any way comparable with that possessed by soil. An organism which nitrifies as soil nitrifies has yet to be isolated."

There are thus several views which are held regarding the action of individual species of bacteria on nitrogenous solutions: —

1. That there is a group of bacteria capable of oxidizing ammonia to nitric acid, and another and separate group able to reduce nitrates to nitrites in the presence of organic matter. Both kinds are widely and abundantly distributed. Attendant circumstances determine whether the reducing or the oxidizing group will gain the upper hand. (*Heræus.*)

2. That all kinds of bacteria, under favorable circumstances, are capable of producing nitric acid, and that the same organisms in the presence of organic matter are capable of reducing nitrates. (*Celli and Zucco. Leone.*)

3. (*a*) That different species of bacteria vary greatly in their ability to reduce nitrates; and (*b*) that there is no reliable evidence that any individual species is able to oxidize ammonia either to nitric or nitrous acid. (*Warington. Frankland.*)

Such is a brief sketch of the divergent opinions upon nitrification which were held at the time we* began our work in the autumn of 1888. It seemed to us important to approach the subject from all sides, and we have worked accordingly not only with pure cultivations of bacteria, but also with various sands, soils, and waters containing mixtures of several kinds. We have considered it of fundamental importance to determine the distribution of the nitrifying organism, and, if possible, to ascertain the relative fre-

* The series of experiments detailed in this paper were planned and carried out jointly by the authors, the bacteriological portion of the work being done by Mr. Jordan, and the chemical portion by Mrs. Richards.

quency with which it occurs over a wide area. The question, for instance, naturally arose, is the nitrifying organism present in the Boston city water as delivered from the tap in the laboratories of the Massachusetts Institute of Technology, since this is the water used in making up our solutions. To this question we are able to give a decided affirmative. Ammoniacal solutions carefully made with tap water always nitrify. Moreover, ammoniacal solutions which have been sterilized and then inoculated with a cubic centimeter of fresh tap water always nitrify. Repeated experiments show that the nitrifying organism is invariably present in this water. When, however, ammoniacal solutions were inoculated from the separate colonies appearing on a gelatin plate culture of this water, in every instance there has been obtained only a negative result. To this matter of inoculation with pure cultures of bacteria we shall recur presently.

The average composition of the Boston (Cochituate and Sudbury) supply is as follows: —

Average Composition of Boston (Cochituate and Sudbury) Water.

	Parts per 100,000.		Parts per 100,000.
Albuminoid ammonia in solution, .	.0163	Sulphuric acid (SO_3), ...	.458
Albuminoid ammonia in suspension,	.0025	Chlorine, ...	.40
Free ammonia, ...	.0004	Carbonic acid, ...	—*
Nitrites, ...	.0002	Alumina and oxide of iron, . .	.075
Nitrates, ...	.0250	Lime, ...	.645
Total solids, ...	4.85	Magnesia, ...	.160
Loss on ignition, ...	1.00	Potash, ...	.092
Silica, ...	.304	Soda, ...	.500

* Not determined.

The mineral analysis was made upon water drawn daily from the tap, from Sept. 29 to Oct. 7, 1890. The nitrogen compounds and chlorine are averages of the two years covered by our work, from September, 1888, to September, 1890.

In many of our early experiments upon nitrification we used a mixture of one cubic centimeter of fresh urine with two litres of tap water. This mixture was found to yield, when freshly made, about .5000 free ammonia, .2000 albuminoid ammonia, .0002 nitrites and .0250 nitrates, in 100,000. This nitrogenous solution was allowed to stand at the temperature of the room (21°–23° C.), and was tested from time to time for nitrites and nitrates. The method used for the determination of nitrites has been Griess's naphthalamine method. This method is sufficiently delicate to detect the presence of one part of nitrogen as nitrite in one thousand millions. The method for determining nitrates is a modified form of the phenolsulphonic method of Grandval and Lejoux.

The following tables contain the results of a few experiments out of the many hundreds which we have made with solutions of nitrogenous substances: —

Illustrations of Nitrification in Natural Waters.

A. Ground Water.

[Parts per 100,000.]

From Westborough, 1st Sample.

	Nitrogen as			
	Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.
1888.				
June 26, . . .	.0047	.0347	.0000	.0020
After 8 days, . .	–	–	.0000	–
" 16 " . .	–	–	.0320	–
" 20 " . .	–	–	.0360	–
" 27 " . .	–	–	.0000	.0280
" 31 " . .	–	–	.0000	.0300

From Westborough, 2d Sample.

	Nitrogen as			
	Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates
1888.				
July 18, . . .	.0035	.0412	.0000	.0020
After 8 days, . .	–	–	.0001	–
" 16 " . .	–	–	.0067	–
" 20 " . .	–	–	.0400	–
" 27 " . .	–	–	.0000	–
" 31 " . .	–	–	.0000	.0320

B. Surface Waters.

[Parts per 100,000.]

Ludlow Reservoir, Springfield.

	Nitrogen as				
	Albuminoid Ammonia in Solution.	Albuminoid Ammonia in Suspension.	Free Ammonia.	Nitrites.	Nitrates.
1888.					
When collected, . . .	.0059	.0176	.0110	.0000	.0020
After 9 days, . . .	–	–	.0222	–	–
" 21 " . . .	–	–	.0145	.0060	–
" 27 " . . .	–	–	–	.0000	.0280
" 47 " . . .	–	–	–	–	–

Birch Pond, Lynn.

	Nitrogen as				
	Albuminoid Ammonia in Suspension.	Albuminoid Ammonia in Solution.	Free Ammonia.	Nitrites.	Nitrates.
1888.					
When collected, . . .	.0038	.0178	.0006	.0000	.0000
After 9 days, . . .	–	–	.0083	.0036	–
" 21 " . . .	–	–	–	.0087	–
" 27 " . . .	–	–	–	.0005	–
" 47 " . . .	–	–	–	–	.0250

Behavior of Dilute Nitrogenous Solutions in Distilled Water. One Cubic Centimeter of Urine to Four Litres of freshly Distilled Water.

[Parts per 100,000.]

	Total Organic Nitrogen.	Nitrogen as			
		Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.
1888.					
July 11,	–	.0355	.0214	.0002	.0000
July 18,	–	.0255	.0535	.0002	Not det.
July 25,	–	.0091	.0576	.0002	Not det.
Aug. 6,	–	.0214	.0675	.0002	Not det.
Aug. 20,	.3850	.0206	.0717	.0003	.0000
0.125 grms. pepsin in 8 litres of freshly distilled water.					
July 11,	–	.1128	.0170	.0002	.0000
July 18,	–	.0412	.1268	.0001	Not det.
July 25,	–	.0189	.1318	.0002	Not det.
Aug. 6,	–	.0214	.1639	.0001	Not det.
Aug. 24,	.3680	Not det.	.1697	.0002	.0000
10 cubic centimeters of juice of beef in 8 litres of freshly distilled water.					
July 11,	–	.0268	.0066	.0000	.0000
July 12,	–	.0209	.0079	Not det.	Not det.
July 13,	–	.0170	.0138	Not det.	Not det.
July 18,	–	.0066	.0280	.0000	Not det.
July 25,	.2350	.0066	.0288	.0000	Not det.
Aug. 6,	–	.0099	.0535	.0000	.0000

Progress of Nitrification in a Dilute Urine Solution in Tap Water, One Cubic Centimeter of Urine to Two Litres of Boston Tap Water.

[Parts per 100,000.]

	Nitrogen as			Nitrogen as			Nitrogen as	
	Nitrites.	Nitrates.		Nitrites.	Nitrates.		Nitrites.	Nitrates.
1888.			**1888**—Con.			**1888**—Con.		
Nov. 12,	.0002	.0250	Dec. 5,	.0800	–	Dec. 21,	.4762	–
19,	.0001	.0250	6,	.1480	–	22,	.5400	.0550
24,	.0006	Not det.	7,	.1900	–	28,	.4165	.0550
26,	.0014	–	8,	.2500	–	**1889.**		
28,	.0025	–	10,	.4444	–	Jan. 9,	.4500	.0500
30,	.0054	–	12,	.4255	–	22,	.4350	–
Dec. 1,	.0100	–	14,	.5700	–	29,	.1000	.6000
4,	.0365	–	15,	.5800	–	Feb. 6,	.0010	Not det.
A Second Sample under the Same Conditions.								
1888.			**1888**—Con.			**1889**—Con.		
Dec. 3,	.0080	.0300	Dec. 19,	.5400	–	Jan. 7,	.3845	–
6,	.0152	–	21,	.5170	–	9,	.3700	–
8,	.0666	–	22,	.4440	.0250	11,	.2270	.0850
10,	.2000	–	26,	.4440	–	13,	.0000	Not det.
11,	.3000	.0300				15,	Not det	.6000
12,	.5000	–	**1889.**					
15,	.5400	–	Jan. 3,	.4440	.0500			

Process of Nitrification of Ammonium Chloride Solutions under Different Conditions.

[2.5000 parts of ammonium chloride in 100,000, seeded with 200 cubic centimeters of the dilute urine solution, made up with tap water.]

	Kept in the Light.		Kept in the Dark.			Blank of Distilled Water to give the Correction due to the Air of the Room.		Aerated Daily.		Kept Quiet.	
	Nitrogen as		Nitrogen as			Nitrogen as		Nitrogen as		Nitrogen as	
	Nitrites.	Nitrates.	Nitrites.	Nitrates.		Nitrites.	Nitrates.	Nitrites.	Nitrates.	Nitrites.	Nitrates.
1889.											
Jan. 31,	.0230	.0300	.0230	.0300	Feb. 14,	.0007	-	.0140	-	.0120	-
Feb. 7,	.0800	.0400	.1100	.0580	16,	.0005	-	.0200	-	.0200	-
9,	.1738	-	.1332	-	20,	.0002	-	.0160	.0300	.0200	-
12,	.1880	.0280	.1200	.0600	21,	-	-	.0160	-	.0400	-
14,	.2000	.0380	.1175	.0650	27,	.0027	-	.1040	-	.2125	-
16,	.2325	-	.1425	-	March 2,	.0007	-	.2170	-	.2000	-
19,	.2125	.0280	.0950	.0500	11,	.0018	-	.1205	.1000	.0950	.0800
27,	.1495	-	.0000	-	April 11,	-	-	-	-	-	.1000
March 2,	.0150	-	.0000	-	May 2,	-	.0200	-	.1250	-	.1900
April 16,	-	.1250	-	.1200							
May 2,	-	.1750	-	.1250							
1890.											
Dec. 29,	-	-	.0000	1.0000							

If the nitrogenous solution be first sterilized and then inoculated with fresh tap water, the same course is followed, with the exception that the period of incubation is considerably lengthened. If seeded with sand from a sewage filter tank, or with garden soil, the whole process is materially quickened, and may even be wholly completed in thirty days.

Not only is the nitrifying organism present in Boston tap water, as the above experiments clearly demonstrate, but it appears to be equally common in water from all parts of the State of Massachusetts. So far as our experience has gone, any natural water, containing the ordinary amount of free or albuminoid ammonia, contains also the nitrifying organism, as is shown by our long series of tests. In these natural waters the nitrifying organism seems to be under wholly normal conditions, and to be abundantly able to effect the oxidation of the small quantities of nitrogen usually present in these waters. Waters that contain high "albuminoid ammonia," in cases where this "ammonia" comes from the nitrogen in infusoria, algæ, etc., go through the same changes as those which contain "free ammonia," but more slowly. The organisms in time die, the bacteria set free the nitrogen of their bodies, forming free ammonia, and then in turn nitrites and nitrates.

It might, perhaps, be reasonably expected that, since the nitrifying organism is undoubtedly present in all these waters, an examination of gelatin plate cultures of these waters would reveal some particular kind or kinds of colonies common to all, and in that way aid in sifting out the nitrifying organisms. Our experience has shown, however, that such a hope is unfounded. So far as the inspection of gelatin plate cultures enables us to judge, no one kind of colony is common to all these waters. This fact, on the surface, seemed to favor the view that the power of nitrification was not the property of any particular organism, but was very likely possessed in common by a number of kindred species.

The other line of bacteriological work — the inoculation of nitrogenous solutions with pure cultures of isolated bacteria — has been followed up from the outset, and was begun with full confidence in ultimate success. It is unnecessary to give a detailed account of our experiments in this direction. It is sufficient to say that the nitrogenous solutions have, from beginning to end, failed to nitrify. Nitrogenous solutions of various sorts have been used, pepsin solutions, peptone solutions, ammonium chloride solutions, Frankland's solution,* etc., all with the same unfailingly negative result. A large number of species of bacteria have been used for inoculation, not only well-known species like B. prodigiosus, B. megaterium, Proteus, etc., but many species freshly isolated from water, sewage, the sand of nitrifying filter tanks, and similar favorable situations for the nitrifying organism. The experiments have been always prolonged for several months, and in some cases for more than a year. Conditions of temperature, amount of surface exposed to the air, etc., have been varied in many directions. Nitrogenous solutions containing a single species of bacterium have been poured upon sterilized sand, and allowed to settle in such a way as to imitate closely the conditions obtaining in filter tanks. In all, more than one hundred and fifty experiments have been made, covering a period of two years. *In every case, without a single exception, there was not the slightest evidence of nitrification by any single species.*

There still remained a plausible explanation of this striking succession of negative results. It might be that, although any one species working alone was not able to effect nitrification, a number

* Zeitschr. für Hygiene, Bd. VI., 1889, p. 376.

of different species working together might be able to produce the desired result. This was certainly not an unreasonable supposition, judging from analogous fermentative processes; co-operation and combination might perhaps effect more than individual and independent action. Several experiments were accordingly made with the view of determining this point. Here again the results were invariably negative. Ammoniacal solutions, inoculated with mixtures of several species under pure cultivation, always failed to nitrify. In one experiment, for example, a nitrogenous solution, found by experience to nitrify rapidly and completely when seeded with garden soil, was inoculated with a mixture of six different species of bacteria. These six species were all isolated from soils and waters known to contain the nitrifying organism. An examination of the solution from time to time, by the method of gelatin plate culture, showed a vigorous growth on the part of all the species, but there was at no time the slightest evidence of nitrification, although the experiment continued for upwards of five months.

In the course of our experiments we have found it necessary to guard against two possible sources of error. We noticed at the outset a tendency in all our solutions, whether inoculated with pure cultures, or entirely free from bacteria, to show an increasing quantity of nitrogen as nitrite. This increase of nitrite in standing solutions is shown in the following instance. A nitrogenous solution, placed in a flask stopped with cotton wool, was sterilized in the usual way, and allowed to stand in the laboratory. At first no nitrogen in the form of nitrite was present, but after one month .0030 parts per 100,000 had appeared, and at the end of three months .0080 parts of nitrite were present. In some cases a much larger amount than this appeared, although no bacteria were in the flasks. In all these instances the nitrite was undoubtedly absorbed from the air of the laboratory. Sterilized distilled water was found to absorb nitrite with the same rapidity as did our nitrogenous solutions, in one case absorbing .0015 in a few days. If the solutions were protected from the free access of air, no increase of nitrite was noted, and there was also no increase if they were removed to a room in which little or no gas was burned. In rooms in which much gas is burned it is obvious that, with the present refined methods for detecting nitrites, this absorption from the air, unless guarded against, may lead to erroneous conclusions. This fact of nitrite absorption from the air has been already noticed by Warington and other observers.

A second possibility of misinterpretation lies in the reduction of the nitrates that may be present in the solution. This reduction takes place even when the quantity of nitrate and organic nitrogen is small, although more slowly than is the case in the presence of considerable quantities of organic nitrogen. In one example there were no nitrites and .0360 nitrates present at the beginning of the experiment in the sterilized solution. On inoculation with a certain bacterial species, afterwards found to possess a reducing action, the quantity of nitrogen as nitrite increased in a short time to .0256, while the nitrate diminished to .0150. On another occasion, with .0360 initial nitrate, the nitrites rose from nothing to .0210, and the nitrates disappeared proportionally. If larger amounts of nitrate are present, the increase of nitrite is more striking. Certainly this reducing action of many species of bacteria will go far to explain such results as those reached by Heræus (loc. cit.). An account of the reducing action of certain species will be found on pp. 830–844.

An interesting experience, and one very significant in the light of our further investigations, should here be mentioned. A nitrogenous solution prepared in the usual way was inoculated with a certain species, — Bacillus ubiquitus (p. 830), — and examined from time to time, both chemically and bacterially. The solution, on standing for several months, nitrified completely, and the gelatin plate culture showed the presence of a pure culture of B. ubiquitus. We naturally concluded that we had discovered a nitrifying organism; but repeated inoculations with a culture of this same organism, both from the flask that had nitrified and from the original growth in a test-tube, gave a negative result. No better success was had with the same organism freshly isolated from water or soil. No explanation of this perplexing occurrence could be given at the time, but subsequent events made it probable that our assumed pure culture was not a pure culture at all, but a mixture of the nitrifying organism and B. ubiquitus. Whether the nitrifying organism was introduced from the air, or, as seems more likely, accompanied the first inoculation with B. ubiquitus, is unknown. Possibly some of the investigators who have claimed a positive result with species of bacteria grown on gelatin may have been misled in a similar way.

There was, as has been intimated, one possible explanation of our failure to reach consistent positive results by the use of species of bacteria isolated by the method of gelatin plate culture. It might be that the nitrifying organism did not grow on gelatin. Everything seemed to point in this direction, and the belief was further strengthened by a very significant fact observed about this time. We had known for some time that in the history of the filter tanks at the Lawrence Experiment Station speedy nitrification was always coincident with a marked decline in the numbers of bacteria. The effluents discharged from the filter tanks, although high in nitrates, were low in bacteria; and, moreover, the more complete the nitrification, the fewer were the bacteria in the effluent. (See pp. 262, 594, etc.)

We also observed that, in an ammoniacal solution which is seeded with ordinary pond water containing several species of bacteria, there is during the first few days a rapid multiplication of the contained germs. Nitrification, however, does not as a rule begin until from ten to fourteen days have elapsed. By the time nitrification begins, the numbers of bacteria, as shown by gelatin plate cultures, have begun to decline; and, while the nitrogen in the form of nitrites in the solution is increasing, the numbers of bacteria are as steadily diminishing. Thus, in one instance, an ammoniacal solution, four days after its inoculation with a cubic centimeter of Cochituate water, contained 3,762,000 bacteria per cubic centimeter. Nitrification had not yet begun. When the first signs of increasing nitrites appeared, the numbers of bacteria had sunk to 19,200; and when the nitrites reached their maximum, the bacteria, shown by gelatin plate cultures, were only 9,454. It was certainly difficult to understand why nitrification, a process apparently dependent upon the life and activity of bacteria, should seem to flourish best under conditions in which bacteria were perishing. If, however, it were assumed that the nitrifying organism could not grow in the usual gelatin media, all the perplexing results above recorded could be more easily explained. Under these circumstances it was natural for us to make such an assumption.

There was, of course, the possibility that the nitrifying organism, by its growth on gelatin, had lost its peculiar property; but it did not seem to us likely that so fundamental a property could be parted with in so short a time. However that might be, we determined to test the other hypothesis first, since we believed it to be the more probable of the two. Accordingly, experiments were begun to attempt to isolate the nitrifying organism by the method of dilution. This is the method that was commonly used by investigators in bacteriology before the invention of solid culture media. It has, as is well known, serious practical as well as theoretical drawbacks. In our practice a small portion of an actively nitrifying solution is transferred on the loop of a sterilized platinum needle to a sterilized ammoniacal solution, and when nitrification is thus induced in the second solution a fresh transfer is made from this to a third, and so on. Rigid precautions have been taken to avoid the introduction of foreign germs. For a description of the general bacteriological methods employed see the section on "Methods" in the report of the biological work of the Lawrence Station (p. 811).

Hardly were these experiments well under way, before our interest in this method of procedure was stimulated by the publication of communications by Percy F. Frankland and Grace Frankland, and by Robert Warington.*

The Franklands, having reached a conclusion similar to our own regarding the behavior of the nitrifying organism in gelatin, had also attempted to isolate the nitrifying organism by the dilution method, and had succeeded in this attempt. They state, in their abstract of the paper read before the Royal Society, that, "after a very large number of experiments had been made in this direction, the authors at length succeeded in obtaining an attenuation consisting of about 1-1,000,000th of the original nitrifying solution employed, which not only nitrified, but, on inoculation into gelatin-peptone, refused to grow, and was seen under the microscope to consist of numerous characteristic bacilli, hardly longer than broad, which may be described as bacillo-cocci."

Warington's communication entirely confirms that of the Franklands, in so far as it relates to their earlier and negative results. He had not, however, at the time of writing, succeeded in isolating the nitrifying organism.

A paper by Winogradsky followed soon after. He appears to have discovered independently a nitrifying organism, and attributes his success largely to his microscopic examinations of the nitrifying solutions, and to his use of solutions devoid of organic matter. The following is the composition of the liquid finally adopted by him : —

Ammonium sulphate, ...	1 grm.
Potassium phosphate, ...	1 grm.
Water from the lake (at Zurich, "*très pure*"), . .	1,000 grms.

* The Chemical News, Vol. LXI., p. 135, March 21, 1890.

Each portion of 100 cubic centimeters received in addition .5 to 1 grm. of basic magnesium carbonate, suspended in distilled water. Winogradsky found that this layer of magnesium carbonate at the bottom of each flask afforded an excellent gathering place for flocks of the nitrifying organism. The "nitric ferment" does not, as the Franklands had already shown, grow well upon ordinary gelatin plate cultures; and this is probably the cause of the failure of all previous experimenters to isolate the special ferment. For Winogradsky's detailed description of the nitric ferment, and for a statement of his peculiar views concerning its function, "*de régulariser la circulation du carbone sur notre planète*," we must refer to his original papers.*

Before receiving Winogradsky's paper, in the spring of 1890, we had been using in our work, at the suggestion of Mr. Allen Hazen, an ammoniacal solution of the following composition: —

Ammonium chloride (resublimed), ...	1.9070 grms.
Sodium carbonate, ...	3 7842 grms.
Sodium phosphate, ...	.2000 grms.
Potassium sulphate, ...	.2000 grms.

These salts were dissolved in such a quantity of re-distilled water that the solution contained 100 parts of nitrogen per 100,000, and two equivalents of alkali. Ten cubic centimeters of this solution were mixed with one litre of re-distilled water, and then inoculated as desired. The flasks used have been made chemically clean by boiling with potassium permanganate, and the water used has been twice distilled. The other rigid precautions absolutely necessary in all work of this character have always been taken. The solutions thus prepared have contained from .0001 to .0010 parts per 100,000 of albuminoid ammonia.

Proceeding with this solution by the method of dilution, we at length succeeded in isolating a nitrifying organism. A flask was first inoculated with a few grains of sand from Tank No. 13, at the Lawrence Experiment Station, and when nitrification was at its height in this solution, a small portion was transferred from this to a second flask, and so on. After a large number of unsuccessful attempts, two solutions were finally obtained which nitrified well,

* Annales de l'Institut Pasteur. Tome IV., 1890, No. 4, p. 213; No. 5, p. 257.

but gave no growth upon ordinary gelatin plate cultures, although the plates were allowed to stand for seven days. Microscopic examination of these solutions showed them to be inhabited by a particular form of bacillus, and apparently by that alone. These bacilli are short, of a slightly oval shape, and vary from 1.1 μ to 1.7 μ in length; they are about .8 μ to .9 μ broad. They are grouped very characteristically in irregular clumps, and are held together by a jelly-like material. Each aggregation is indeed a typical zoöglœa. The aggregations of bacteria were found chiefly on the bottom of the flasks, as was also the case with the organism described by Winogradsky. These masses of zoöglœa, obtained as a pure culture from a nitrifying solution, resemble significantly the zoöglœa discharged in considerable quantities from the filter tanks at Lawrence (see p. 848). The bacilli stain with some difficulty with the usual aniline dyes. We have not observed independent movement. Owing to the lack of the usual means of diagnosis, it is difficult to determine in a short time whether this species is the same as the one described by the Franklands and by Winogradsky. On one important point there appears to be a difference between our results and those reached by the above-mentioned investigators. The organism discovered by them oxidizes ammonia to nitrite, but carries it no farther. Our own flasks give complete oxidation to nitrate. Whether this be due to a difference of conditions, a difference in the virility of the organisms, or a specific difference in the bacteria, we are not at present prepared to say. The short time at our disposal has made it impossible to settle this and many other questions to our own satisfaction. We are not even prepared to say that there may not have been a mixture of two or more species in our flasks, all agreeing closely in morphological characters, and in giving no growth on gelatin, but differing in important physiological respects. Further investigation is necessary to settle this and other important points regarding the relations of this organism to the process of nitrification.

Whether or not we accept the views of Winogradsky, it is certainly worthy of remark, as he observes, that an organism should exist, which, without chlorophyll and in the apparent absence of organic nitrogen and of organic carbon, should be able to multiply and thrive upon wholly inorganic compounds. It may well be doubted, we think, whether this is really the case. It seems more reasonable to suppose that exceedingly minute quantities of organic nitrogen and carbon are actually present, and escape detection by our present methods of chemical analysis, although in reality sufficient to nourish generations of bacteria.

Our own experience, as well as that of previous investigators, seems to be a warning against a too confiding use of the gelatin plate culture in bacteriological work, since in this instance such confidence has left us for a long time in ignorance of a common and widespread as well as highly important organism.

SEPTEMBER, 1890.

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