City of Leeds.

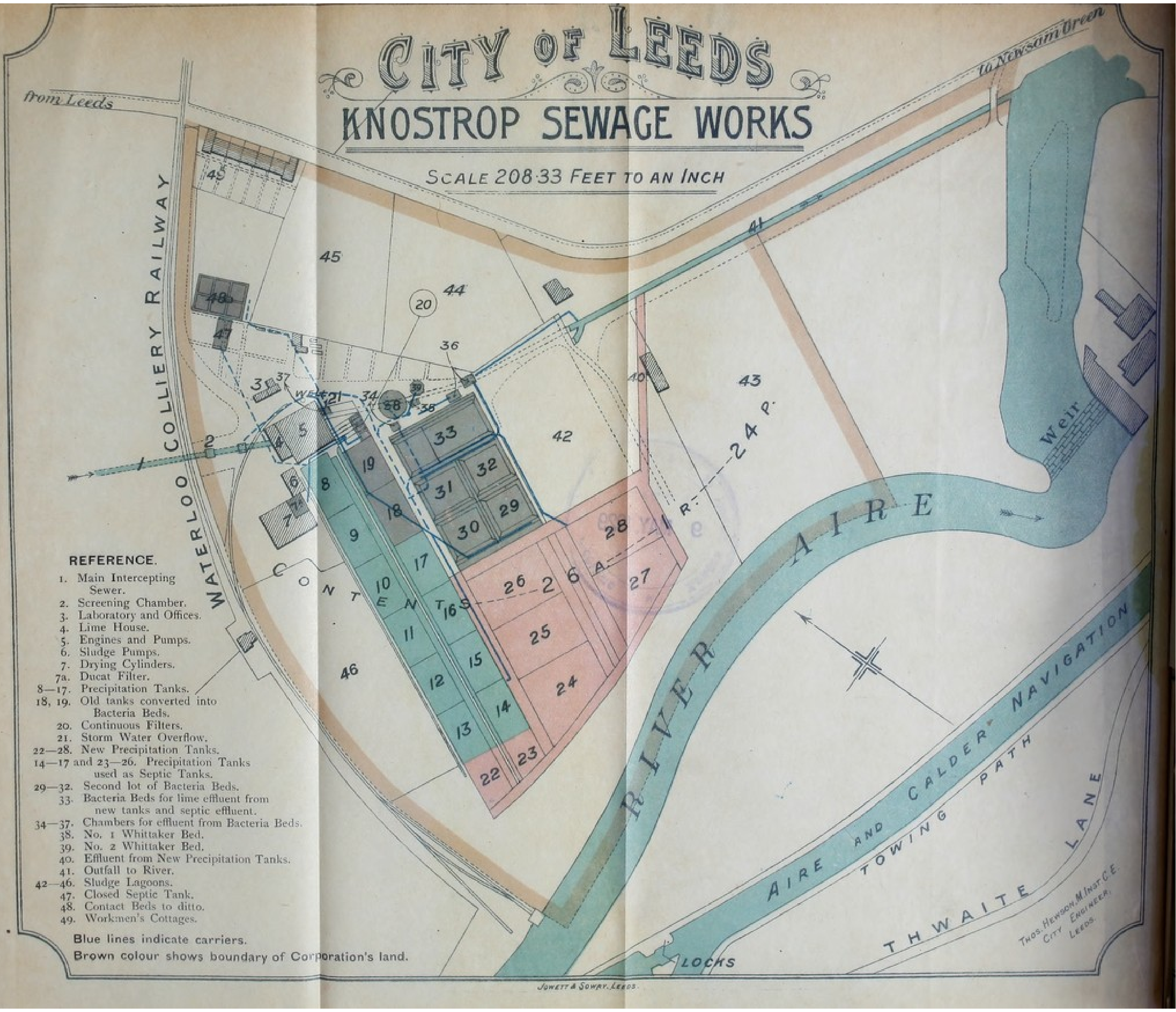
REPORT

ON

SEWAGE DISPOSAL.

JULY, 1900.

Leeds:
JOWETT & SOWRY, PRINTERS & LITHOGRAPHERS, ALBION STREET.
1900.


CITY OF LEEDS
KNOSTROP SEWAGE WORKS
SCALE 208·33 FEET TO AN INCH
from Leeds
to Newsam Green
WATERLOO COLLIERY RAILWAY
RIVER AIRE
AIRE AND CALDER NAVIGATION
TOWING PATH
THWAITE LANE
LOCKS
Weir
CONTENTS
26 A. 1 R. 24 P.
REFERENCE.
1. Main Intercepting Sewer.
2. Screening Chamber.
3. Laboratory and Offices.
4. Lime House.
5. Engines and Pumps.
6. Sludge Pumps.
7. Drying Cylinders.
7a. Ducat Filter.
8—17. Precipitation Tanks.
18, 19. Old tanks converted into Bacteria Beds.
20. Continuous Filters.
21. Storm Water Overflow.
22—28. New Precipitation Tanks.
14—17 and 23—26. Precipitation Tanks used as Septic Tanks.
29—32. Second lot of Bacteria Beds.
33. Bacteria Beds for lime effluent from new tanks and septic effluent.
34—37. Chambers for effluent from Bacteria Beds.
38. No. 1 Whittaker Bed.
39. No. 2 Whittaker Bed.
40. Effluent from New Precipitation Tanks.
41. Outfall to River.
42—46. Sludge Lagoons.
47. Closed Septic Tank.
48. Contact Beds to ditto.
49. Workmen's Cottages.
Blue lines indicate carriers.
Brown colour shows boundary of Corporation's land.
THOS. HEWSON, M.INST.C.E. CITY ENGINEER, LEEDS.
JOWETT & SOWRY, LEEDS.

City of Leeds.

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PREFACE.

This Report embodies some details given in the former report of December, 1898. Necessarily this is only an interim report, the experiments being as yet incomplete.

To meet the desire for information of Local Authorities and others who are studying the question of sewage disposal, the data connected with the various experiments are given in detail. The summary and conclusions, so far as they have been reached, will be found in the General Observations on Contact Beds, page 58; on Septic Tanks, page 81; on Continuous Filtration, page 95; and Concluding Notes, page 103.

INDEX.

City of Leeds.

REPORT

ON

SEWAGE DISPOSAL.

Statistical and Historical Notes.

The City of Leeds contains within an area of 21,572 acres a population estimated at this date to be 420,000. Population.

The district is hilly, varying in level from 70 feet above the sea at the river, to over 500 feet. It is traversed by the River Aire. The whole of the City, excepting Rodley and a portion of Bramley, is in one sewerage system, of which the outfall is in the Thorp Mill Pool, at Knostrop, 2½ miles from the Town Hall. For the excepted parts, which together have an estimated population of 4,500, a system of irrigation works is now being laid out on 60A. 1R. 23P. of land, adjoining the River Aire, at Newlay. The system of sewerage in both parts is that known as the combined, there being no separate drains for surface water. System of Sewerage.

It is estimated that three-fourths of the population use water closets or trough (water) closets, but the privies used by the remainder are being replaced by water closets, which in new buildings are now compulsory. Domestic Sewage.

Trade Effluents.

Most of the trade liquid refuse finds its way into the sewers. Some of the trade effluents are of large volume, and seriously affect the treatment of the sewage, as for instance, those from Tanneries, Wool Scouring and Dyeing, Copper and Galvanizing works. While the policy of the Council has been to encourage trade by receiving trade effluents into the sewers, it is evident that their admission should be conditional upon (1) effective means being taken by traders to precipitate the solids in their refuse; (2) the discharge being so regulated that there should be no sudden rush of a considerable volume, but rather a gradual and steady flow spread over the 24 hours; (3) that an inspection manhole shall be provided; (4) that no discharge should be allowed, which, either by its temperature or other character, would injure the sewers, promote decomposition, or prejudicially affect the treatment of the sewage.

The chief difficulties arise from iron liquor, wool fibre, and dye water.

Water Supply.

Leeds possesses an abundant supply of good water, the present consumption being at the rate of upwards of 17 million gallons a day, five of which millions are supplied for trade purposes and eleven millions are consumed for domestic purposes. This works out to 40 gallons per head of population. Almost the whole pours into the sewers.

Volume of Sewage.

The volume of sewage varies, of course, from hour to hour. Apart from rainfall, the maximum flow occurs at about mid-day, and the minimum flow at night. The normal dry weather flow may be taken at the present time to average 16 million gallons for the 24 hours. The rate of flow rises to over 25 million gallons in the day, and falls to below nine million gallons in the night. The volume of the sewage is, of course, very largely affected by rainfall, a very slight rain, say $\frac{1}{20}$ of an inch per hour, will increase the flow to a rate of 60 million gallons per 24 hours, and this is the maximum capacity of the main outfall sewer, which is for the last 1,500 yards, 8 feet wide and 7 feet 9 inches high, with a gradient of 1 in 1634. To prevent greater rainfalls reaching the outfall sewer than it can take, a system of overflows and leaping weirs is carried out in the City. By these each drainage area discharges its rainfall into the river after the sewage has been many times diluted with it.

From 1842 the question of constructing a system of main drainage was under consideration by the Corporation. In 1850 contracts were let for main sewers in accordance with a scheme by Mr. Leather, and the works were completed in 1855. The sewage of the dense part of the City having thus been brought to one outfall, complaints began to be made of the serious nuisance arising in the river, which was then relatively free from impurities. In 1867 Mr. Filliter, C.E., was consulted, and a scheme was proposed to carry the sewage by a gravitation conduit 27 miles long to 2,000 acres of land at Thorne Waste. The cost of the scheme was estimated at near £292,000. This does not seem to have been approved, and in 1869 and 1870 deputations visited London, Birmingham, and other places. Early in 1870, the Corporation having proposed to sewer the out-townships, riparian owners below the sewage outfall became alarmed, and obtained an injunction restraining the Corporation from allowing sewage to flow to the Aire until it had been purified, so as not to create a nuisance or become injurious to the public health. Historical.

Immediate steps were now taken to deal with the matter, and from 1870 to 1874 a number of experimental systems were tried, the most important of which was that known as the A B C system. These were all ultimately abandoned, and the present works of precipitation by lime were completed in 1874. Since then the length of sewers has been continuously added to, the total length being now about 416 miles. Up to March, 1897, the works remained without structural alteration or extension.

Description of Old Works.

Land.

The area of the site of the Sewage Works at Knostrop is 26A. 1R. 24P., the cost of which was £5,196, or about £200 an acre.

OLD WORKS.

Buildings and Machinery.

There are 12 workmen's houses, offices, engine and boiler house, and 12 precipitation tanks. On account of the low level of the outfall it is necessary to lift the sewage by pumping into the tanks. There are two pairs of horizontal condensing engines, driving two Gwynne's No. 18 Centrifugal Pumps, each capable of lifting 20 million gallons in 24 hours, or 40 million gallons for the two. There is, as a stand-by, a similar pump driven by a direct-acting high-speed engine. This pump, working alone, can lift 12 millions, but working in combination with the others, will only pump six millions, thus making a total pumping capacity of 46 million gallons per day. The delivery pipes from the three pumps unite in one of 3 ft. diameter, and the average lift is 12 ft. Lime only is now used to promote precipitation. Four grinding pans are available, with revolving rollers 4 ft. diameter. The ground lime passes to iron tanks, where it is agitated and more thoroughly mixed with water, and its flow to the sewage as it passes to the pumps is regulated by sluices.

Tanks.

The tanks in which the sludge is precipitated are 12 in number, arranged six on either side of a central channel. At the water level the tanks are 100 ft. long by 60 ft. wide, except the twelfth which is 88 ft. by 60 ft. The depth of each varies, but the average depth of the whole is 6 ft., the first being the deepest. Each tank is divided from the one adjoining it by a brick wall coped with stone, the top of each being two inches lower than the one behind it so as to give a draught to the flow of the sewage through the tanks. In order to prevent the sewage flowing in a thin sheet over the stagnant and subsiding sewage, cross walls are built in No. 3 and No. 7 tanks to the full height of the tanks, and eight openings provided at the bottom, by which means the sewage is forced downwards and upwards, and so more satisfactorily mixed. The 12 tanks have an united water area of 71,280 square feet, or about $1\frac{3}{5}$ acres, and have a capacity of $2\frac{1}{2}$ million gallons. Any tank can be thrown out of work so as to allow for the removal of the deposited sludge. This is passed through a sluice and conduit to a well, whence it is pumped into and flows along movable wooden shoots into one of the sludge lagoons which are formed with earthen banks. From these the water drains off, and the sludge, when sufficiently dry, is turned over, cut into blocks, and after further drying is given away to farmers, &c.

Cost of Works.

The total cost of the works completed in 1874, including the site, the buildings, engines and boilers, settling tanks, sludge pump, &c., was £57,524.

Working Expenses.

From 1874 no change has taken place in the system adopted, or in the general method of working. With the growing quantities of sewage to be dealt with, the annual cost has grown from year to year.

In	1894	it was	£5,660.
„	1895	„	£6,100.
„	1896	„	£6,700.
„	1897	„	£6,364.
„	1898	„	£6,772.
„	1899	„	£7,800.
„	1900	„	£6,671.

Results

The results obtained by this system of chemical precipitation consist mainly in the removal of the greater part of the solids originally in suspension in the sewage, and which remain behind as sludge.

INSUFFICIENCY OF WORKS.

In the earlier years after 1874, when the volume was much less than that which now has to be dealt with, this precipitation of the solids in suspension was fairly well accomplished, but now that the volume has grown considerably, the old settlement area is insufficient, and the effluent from the tanks is generally turbid and unsatisfactory; while as soon as the normal mid-day flow is expanded to more than double by rain, which it often is, notwithstanding the storm-water outlets in the City before referred to, it is found impossible to deal with it with the present machinery, and the excess of sewage, diluted by the rain, then flows untreated into the channel leading to the river.

Pressure from West Riding Rivers Board.

For the last four years there has been much pressure put upon the Corporation from the West Riding Rivers Board to at once improve the treatment at Knostrop, and to devise a more satisfactory scheme or process for dealing with the whole sewage of the City.

Increased Area for Settlement.

Accordingly, in the spring of 1897, as a provisional measure pending the settlement of a general scheme, the Council sanctioned the expenditure of £28,000 for the building of seven new precipitation tanks, having together an area of two acres, and a capacity of three million gallons. The effect of this increased precipitation area was to produce a better effluent; an effluent, that is, from which a larger proportion of the solid matters in suspension had been removed. This was, however, at the cost of a much larger production of sludge, amounting, in fact, to over 400 tons a day (90 per cent. water). It was soon found that it was impracticable to deal with this huge amount of sludge on the present site, and therefore it has not been possible to utilise as such all the settling tanks. With those actually in use, some 300 tons of sludge is produced.

THE SLUDGE DIFFICULTY.

It was thought some years ago that this sludge would command a price in the market, but its manurial value is too low to induce farmers to pay for it, though they are found willing to fetch it away when dry enough to be spaded, if it is loaded for them. It is therefore necessary, there being at present no sludge-pressing or sludge-drying plant, to have ample lagoon area, because it takes from six to twelve months before the sludge is dry enough to be carted away, and storage space is also necessary because the sludge is fetched away irregularly, and scarcely at all at times of the year. At certain periods, the accumulation of sludge has been a source of serious anxiety, but now that the lagoon area has been so largely reduced by the building of additional settling tanks, the question of sludge storage has become so acute that it has been impossible to use all the tanks without first providing means of dealing with the increased quantity of sludge which would result from their working.

It should be added that owing to the small tonnage of boats on the Leeds Navigation, and the distance from the sea, it would be very costly to carry the sludge to sea, as is done in London and Manchester.

Something required beyond Settlement.

But even if by the acquisition of land and the provision of an adequate sludge pressing plant, it became possible to remove the pressure of the sludge difficulty, it is necessary to point out that a process of precipitation, useful so far as it goes, is quite insufficient for sewage purification. The effluent, though it should be fairly clear and free from smell as it flows from the precipitation tanks, contains much organic impurity in solution, and is liable to decomposition and putrefaction.

Indeed, only about one-half of the impurities are removed by precipitation.

SLUDGE DIFFICULTY.

It is now generally recognised that further purification is necessary, and that precipitation must be followed by land filtration, or where suitable land is not available, by artificial filtration, so that besides the removal of impurities in suspension those in solution shall also be greatly reduced.

It became necessary, therefore, for the Corporation of Leeds to look out for a new and larger site for Sewage Purification Works, and to consider what system should be adopted in order to reduce the production of sludge and to secure more complete purification, especially of the organic matter in solution.

Broad Irrigation.

In 1894 a deputation visited the most important Sewage Disposal Works and Sewage Farms in the County, and formed the opinion that Broad Irrigation, that is, dealing with the sewage upon land without previous precipitation or sludge production, was the best process of sewage purification. It was found that for a large and growing population of Leeds, some 4,000 acres would be required, and on enquiry it was found impossible to obtain so large an area of suitable land within practicable distance of the City. The cost of such a scheme was found to be very large, in view, not only of the area required, but of the necessity of pumping the large volume to be dealt with, or of making a very long and costly conduit if a gravitation scheme was to be adopted.

Precipitation followed by Land Filtration.

A scheme by which the present process of lime precipitation should be followed by land filtration reduced the required area to about 400 to 500 acres, but at that time there was no suitable site available, and beside the cost of pumping, or a long conduit, there would remain the present sludge difficulty, and the serious expenses connected with its drying or pressing and removal.

The Council hesitated to incur an expenditure in connection with land treatment which might amount to from £500,000 to £750,000.

SCHEMES PROPOSED.

Biological process at Sutton.

This was the position of affairs at the end of 1896, when the Committee's attention was attracted to the artificial filtration process being tried at the Barking (London) Sewage Works, and at Sutton (Surrey). These works were visited by the Committee twice. On both occasions they were pleased not only with the success of the purification of the sewage, but also with the cheap and simple nature of the works. At Barking, it was a process of intermittent or biological filtration following precipitation, and seemed to offer a comparatively simple issue out of the difficulties connected with land treatment, while the experiments of Mr. Dibdin, at Sutton, pointed to the possibility of treating sewage on biological lines without production of sludge. Although treatment on a biological scheme, if found successful, would evidently involve a large outlay, to deal effectively with the large volume of Leeds Sewage, it was felt that the outlay would be much less than that required for land treatment.

General observations on the Biological treatment of Sewage.

Land filtration is an intermittent process. Sewage cannot continuously flow over the same land. After a period, varying with circumstances, the sewage is turned off and flows over another area.

During recent years scientific investigations have shown that the chemical changes which take place in land treatment of sewage are brought about by enormous numbers of micro-organisms in the upper layers of the soil. Similar transformations take place in the soil of gardens when manure is dug in, the decaying organic matter being changed into compounds which are absorbed in the structure of plants.

In some cases, where clay land only has been available, it has been shewn that only the six inches or so of top land is of any service in sewage filtration; and, for instance at Wimbledon, this upper surface has been deepened and rendered more suitable for the purpose by the addition and mixing of ashes.

NOTES ON BIOLOGICAL PROCESS.

In such a case, where an area of land is specially modified, the area may be looked upon as a transition from *Land* towards what is known as *Artificial Filtration.*

In artificial filtration there is used an area specially prepared wholly of material suitable for the purpose, such as burnt clay, coke, clinkers, &c., and of a depth usually of 3 feet, but in some cases as great as 6 feet, and no attempt is made to use the area for raising crops. The action is of the same character as land filtration. The process is not new. What is new is our recently much extended knowledge of the chemical changes that are brought about, of the micro-organisms which are the agents; and of the necessity for effective aeration in order to bring about conditions in which the organisms and the filter can work permanently.

Action of Beds.

The term filter, as applied to sewage treatment on aerated material, is somewhat misleading. It is, no doubt, to some extent a mechanical process of straining, by which the solids in suspension are left behind in the body of the so-called filter, but it is much more. In intermittent artificial filtration, that is, biological treatment, as now carried out, the filtering material, during the period of rest, when the sewage has been allowed to flow out, is exposed to the air which is drawn in from the top as the liquid flows out and from the drains in the bottom when empty; and this absolutely necessary aeration permits of the existence and development of the micro-organisms which, during this rest, break up and transform the organic matter left behind in the filter. It should be added that during the stay of the sewage in the filter the organisms effect considerable changes also in the organic matters in solution, so that the effluent is different in character from from that which is simply sewage with the suspended solids removed.

NOTES ON BIOLOGICAL PROCESS.

Sewage Constituents.

"Let us consider the character of those substances predominating in foul water. First, then, sewage may be considered as containing animal substances, largely composed of fibrine, gelatine, chondrine, albumen, &c., and, secondly, vegetable substances, such as starch and woody fibre (cellulose), gummy matters, with tannin, &c. In the first instance we have to deal with matters which speedily undergo decay by putrefaction when there is not a sufficient supply of oxygen, in which case, however, the decomposition takes place by the action of organisms opposed in general character to those which are the active agents in bringing about the process of purification unaccompanied by offensive adjuncts. These aërobic organisms, as they were called by Pasteur—in contradistinction to the anaërobic organisms—live only in the presence of air, as their name implies, whilst the anaërobic organisms live in the absence of air. When air is freely present, and the conditions generally favourable, the aërobic organisms destroy the organic matters in an inoffensive manner. The nitrogenous matters are resolved with either the production of ammonia or the oxides of nitrogen, or possibly the evolution of uncombined nitrogen. The oxygen and hydrogen, forming a considerable portion of the matters, are recombined into water, and the carbon into "carbon dioxide," or carbonic acid gas, as it is generally called. Similar transformations take place with these elements in vegetable matters, but a longer time is usually required for the completion of the process than is the case with animal substances, as they do not form so suitable a medium for the support of the microbic life. Woody fibre, especially paper pulp, is more refractory, and will require a much longer time for its disruption, but in the end the same transformation occurs, and carbonic acid, water, &c., are formed as a result."*

* From Mr. Dibdin's book on "Purification of Sewage."—2nd edition, pages 6 and 7.

NOTES ON BIOLOGICAL PROCESS.

Bacteria.

The micro-organisms referred to are of various kinds, as bacteria, fungi, algæ, protozoa. Bacteria are minute low forms of life, which, in the light of their products, are now generally referred to as vegetable rather than animal. Under high powers of the microscope they appear as small dots or short lines, either straight, curved, or spiral, varying in size from $\frac{1}{5000}$th to $\frac{1}{25000}$th of an inch. They are mostly endowed with active motion. These elementary germs exist in nature in countless myriads. They abound in the upper layers of the soil and in foul water. Millions of them have been counted in a cubic centimetre (about a thimbleful) of sewage. Under favourable conditions they develop at an amazing rate. Some of the forms have been identified as disease germs (Pathogenic Bacteria), but for the most part, their action is not only beneficent, but is part of the necessary processes by which continued life is possible on the earth. By their agency all animal and vegetable decay is removed by transformation into products which go to build up the life of plants, and through them the life of animals, so keeping up a circulation of indestructible but changeable matter.

Where artificial filtration is carried on in such a way as to bring about conditions favourable to the chemical changes due to the action of living organisms, the process is now generally referred to as " Biological Treatment " or " Bacterial Treatment," the micro-organisms in question being known for the most part as Bacteria, and the filtration areas are now often called Bacteria Beds rather than Filters.

The work of Mr. Dibdin and Mr. Cameron, and others.

In the United States the Massachusetts Board of Works has for several years carried on very interesting and valuable experiments in the Biological treatment of sewage, but recent practical developments have been largely due to the work of Mr. W. J. Dibdin, the eminent chemist, at Barking and at Sutton; to the experiments of Mr. Cameron, at Exeter; of Colonel Ducat, Mr. Scott-Moncrieff, Mr. Whittaker, and others.

In his experiments at Barking in 1895 (in connection with London Sewage), Mr. Dibdin found that by passing the effluent from the process of lime precipitation continuously over a filter bed of coke breeze about 3 ft. deep, and well underdrained, and about one acre area, excellent results were at first obtained, but that after a week the purification gradually became less and less until the purifying action ceased, and the bed itself became putrid. The work was stopped, and after some weeks the bed was found on examination to be sweet again, and capable of effectually purifying sewage passed over it. This shewed that *aeration* was essential to maintain the conditions under which bacterial action could be carried on, and experiments were then made in passing sewage into the beds intermittently; the sewage was allowed to flow until it appeared on the surface of the coke breeze, to rest in the bed for some two hours, and then was discharged, the bed resting empty for several hours to secure aeration; about eight hours were thus required to deal with one filling, and the process could therefore be repeated thrice in the 24 hours. In this way it was hoped that the action of the bed might be carried on indefinitely, and that if the bed shewed signs of overwork it could be restored to efficiency by a special period of several days' rest.

The Barking Experiment.

In this experiment the bed was dealing with sewage from which the solids in suspension had been mostly removed by a process of chemical precipitation, which of course involved the production of a large volume of sludge. It occurred to Mr. Dibdin that it would be useful to try whether Bacteria Beds would be found to deal with crude sewage. At Sutton (Surrey) he was able to try this very interesting experiment. Two Bacteria Beds were used; one of coarse coke; and one of small coke (coke breeze). The method of working was in eight hour cycles, similar to that already described. The sewage passed to the coarse bed was crude except that a half inch iron screen kept back the larger solids.

The Sutton Experiment.

NOTES ON BIOLOGICAL PROCESS.

The effluent from this bed was then passed over the fine bed, and the resulting final effluent was said to be practically free from matters in suspension, slightly opalescent, and quite free from smell. On being kept it was said to become quite clear, and to remain sweet, the purification, as measured by the oxygen test, being over 80 per cent. for the joint action of both beds.

The experiments of Mr. Dibdin, at Sutton, attracted much attention, suggesting as they did, the possibility of purifying sewage by a natural process, without production of sludge; for it was stated that if the usual period of rest provided was insufficient for the digestion of the sludge in the coarse bed, it could at any time be restored to efficiency by an exceptional and relatively longer rest. At Sutton, however, they were dealing only with domestic sewage. Would the process work with sewage like that of Leeds, which is a compound of domestic sewage and a large variety and volume of trade effluents from Chemical Works, Tanneries, Wool Washing, Dyeing, etc.?

Leeds Experiments.

Mr. Dibdin called in to advise.

In July, 1897, the Committee concluded that whether or not the Biological process would successfully deal with the Leeds sewage, could only be ascertained by experiment. They called in Mr. Dibdin to advise them, and he undertook, on their behalf, to make some laboratory experiments on small coke filters, with samples of average Leeds sewage, and with samples of specific trade effluents, notably effluents from Tanneries and the iron liquor from Chemical Works.

First Small Experiment.

His report, dated August 23rd, 1897, states that he found in dealing with the iron liquor by itself, there was at first considerable oxidation of the iron salts, but this result was obtained at the expense of the efficiency of the beds, which soon became unfit for further work. The iron liquor exerted

Iron Liquor.

a strong anti-septic or sterilizing action. When the liquor however was diluted with domestic sewage, the bacterial action, though to some extent checked, was not stopped, but nitrification did not proceed with its usual ease, oxygen being absorbed by the iron salts, and to that extent not available for oxidizing the organic matter.

Average Leeds Sewage.

With samples of average Leeds sewage, containing iron liquor, tan refuse, and other trade effluents diluted with domestic sewage, good results were obtained on the small experimental beds, giving 80 per cent. of purification as the measure of the work of the double beds.

Tan Liquor.

In the case of tan liquors alone, undiluted by sewage, it was found that the effect of this double treatment, first on a coarse and then on a fine bed, gave nearly 80 per cent. purification, and removed the solids in suspension.

First Bacteria Beds.

Encouraged by this report the Committee decided to proceed to a practical experiment on Bacterial Treatment at the Knostrop Works, and the Council having approved, Mr. Dibdin was asked over to Leeds in the beginning of September, 1897, to advise upon the matter. Acting upon his suggestion it was decided to construct a coarse bed and a fine bed, each of about one-eighth of an acre area. Two of the old Precipitation Tanks, Nos. 11 and 12, were used for the purpose; No. 11 was raised 1 ft. 6 in. for the fine bed, and No. 12 was raised 8 ft. 8 in. by filling up the bottom and raising the walls so as to form a coarse bed at such level that its contents could be emptied on to the fine bed.

The coarse bed was filled with coarse coke not less than 3 in. diameter, and the fine bed with coke not less than $\frac{3}{16}$ in. diameter and not more than $1\frac{1}{2}$ in. diameter. The floors of the beds are paved with old bricks, grouted with cement,

CRUDE SEWAGE EXPERIMENT.

and are formed with a fall to the outlet end of the beds. Upon them are laid 3 in. agricultural tile drains 2 ft. apart, connected at their low ends with a brick collecting drain, which conveys the drainage to the outlet valves. In both rough and fine beds these drains are surrounded with specially large pieces of coke.

The size of the coarse bed is, at top 90 ft. × 65 ft., and at bottom 88 ft. × 63 ft., and the depth is 5 ft. The size of the fine bed is 100 ft. × 61 ft. at top, and 99 ft. × 51 ft. at bottom, and the depth is 6 ft. The average area of each bed is about 620 square yards, or roughly, one-eighth of an acre.

Measurement of Charges.

The charges of the beds are measured by an iron tank, having an effective capacity of 13,187 gallons, and which is graduated.

Experiments with Crude Sewage.

First Experiment October 2nd, 1897, to February 2nd, 1898.

The sewage was first turned on to the beds on October 2nd, 1897. Absolutely crude sewage was used, the only matters kept back being those retained by the iron grating in the screening chamber on the main intercepting sewer, which iron grating consists of vertical bars with one inch spaces, and the beds were worked in this way for four months till February 2nd, 1898.

From October 2nd to December 17th, 1897, the beds received two charges a day, but from that date, arrangements having been made to fill and to empty the beds more quickly, they received three charges in the 24 hours until February 2nd, 1898.

In the whole period, from October 2nd to February 2nd, the beds received 284 charges of crude sewage.

From December 17th the time table for both beds was as follows :— CRUDE SEWAGE EXPERIMENT.

1	hour	filling.
2	„	standing full.
1	„	emptying.
4	„	standing empty.
8	hours × 3 fillings in 24 hours.	

The amount of purification shewn by the final effluent, after the beds had become established, was considered satisfactory, and proves that, notwithstanding iron liquor and other trade effluents mixed with the sewage of Leeds, it can be treated on Bacteria beds so as to produce a really good effluent. Results as regards Purification.

Constant analyses were made, and, taking the oxygen absorbed in four hours, and the albuminoid ammonia present, as measures of the work done by the beds, the figures shew for the average over the whole period 73·6 % of purification in regard to the latter, and 82·3 % of purification in regard to the former.

The action of the beds as they got into condition steadily improved, until in December the analytical results obtained were very good ; and, notwithstanding the increased work thrown upon the beds by the triple fillings per day, the results for January shewed no falling off. Period of Incubation.

The effluents from the fine bed had no smell, except at times a slight earthy odour. The first flow from the fine bed was always cloudy, and in some cases turbid, but it cleared more or less soon according to the varieties of sewage being treated ; the latter part of the flow was always very clear. The average samples were for the first month cloudy, later opalescent, and in December and January almost clear when drawn off. On being kept they always cleared within 24 hours, but the clearing was coincident with a deposit in the bottles of a reddish-brown flocculent matter, which on Effluent from Fine Bed.

examination proved to be largely oxide of iron. This, as the effluent comes off, is in solution in the ferric state, and precipitates, when the effluent stands, as hydrated ferric oxide. The deposit is due to the very large quantity of iron liquor which comes down with the sewage, and is not objectionable from a sanitary point of view. To remove this deposit by sand filtration would be quite possible but costly.

Physiological Tests.

In order to make a physiological test of the effluent, arrangements were made for the final effluent to remain in the effluent basin to a depth of about 18 inches, and on November 30th, 1897, some carp were put into the basin. More than half died within the month, but it is believed that this was due to the rush of the effluent carrying them against the outflow grating. Provision was made to protect the fish from the full pressure of the rush, and two carp, which were living at the time this was done, survived to the end of the first period of the experiment (February 2nd, 1898), and indeed are still alive at the date of this Report (July, 1900), having been continuously in the effluents, good and bad, which have passed through the basin for over two years.

Green confervoid growths, generally looked upon as a sign of effective oxygenation, soon began to appear. No sewage fungus has been found about the basin.

Sludging up by Suspended Matter.

The final effluent having given good results, there remained to consider whether the beds were really digesting the large quantity of suspended matter brought down in the sewage, or whether this was accumulating in the beds.

The gross capacity of the rough bed is 174,800 gallons.

The net or liquid capacity, after filling in the coke, was estimated to be 83,300 gallons.

Original Working Capacity.

On December 2nd, when the beds were considered to have reached a good working condition, a careful measure of capacity was made which shewed that the rough bed had been reduced to 63,400 gallons. This reduction was expected, because, as the beds get into working order, the coke becomes charged and coated with a black gelatinous slime consisting of the bacteria or living micro-organisms established in the beds, and organic matter in process of transformation.

CRUDE SEWAGE EXPERIMENT.

Normal Capacity.

It has been estimated that the working capacity of a Bacteria Bed when fully established is about two-thirds of the original water capacity. In this case this would work out to 55,000 gallons.

Reduction of Capacity.

The capacity on December 16th, 1897, the day before the triple fillings a day were started, was reduced by ...	4,600 galls. to	58,800
On Dec. 30th, the capacity was reduced by	1,700 galls. to	57,100
Jan. 13th, 1898, capacity was reduced by	6,000 galls. to	51,100
„ 27th, „ „ „	5,700 galls. to	45,400

February 2nd, at the 284th filling, the work was suspended.

Sludging up.

The rough bed was unmistakably sludging up beyond expectation. This was considered to be mainly due to the fact that the organic matter in suspension in the sewage was not being digested fast enough. But it no doubt was also due to some extent to the falling or breaking up, or settling of the coke, evidenced by the necessity for placing additional coke to raise the bed to its original level, and to some extent also to the grit or mineral which at first passed on to the bed, and which it is essential to keep out, as bacterial action cannot reduce it.

Quantity of Sludge Digested.

The sewage varies from day to day, and hour to hour, but from the analysis made in 1898 of a large number of samples of crude sewage, it appeared that the average amount of matter in suspension in the crude sewage of Leeds was then 37·2 grains per gallon.

CRUDE SEWAGE EXPERIMENT.

Effluent.

The analysis of the effluent from the rough bed during the same period gives 11·9 grains per gallon as the amount of solids in suspension, so that 25·3 grains per gallon were kept back by the rough bed.

The fortnightly measure of the capacity of the rough bed during the period in question gave the following results:—

Quantity of Sludge Digested.

October 2nd, 1897, Original water capacity (estimated)				83,300 galls.
„ 15th (estimated)				79,000 „
„ 30th	do.			74,000 „
November 15th	do.			69,000 „
December 2nd	(measured)			63,400 „
„ 16th	do.	reduction	4,600	58,800 „
„ 30th	do.	do.	1,700	57,100 „
January 13th, 1898,	do.	do.	6,000	51,100 „
„ 27th	do.	do.	5,700	45,400 „

The average measure of the fillings during this first period may therefore be taken at 64,600 gallons per filling, and as there were 284 fillings we have a total of 18,346,400 gallons treated.

It has been noted above that the amount of solid matter left behind in the rough bed was 25·3 grains per gallon, and this gives for the 18,346,400 gallons 66,309 lbs. of dry solid matter, which, taken as sludge containing 90°/ₒ water, would give 663,090 lbs. of sludge, which, taking the density of sludge as 10·2 lbs. per gallon, would occupy a space represented by 65,000 gallons.

Now the original estimated water capacity of the rough bed was	83,300 galls.
and this had been reduced on Jan. 27th, 1898, to	45,400 „
That is by	37,900 „

CRUDE SEWAGE EXPERIMENT.

Deducting this accumulation in the bed from the 65,000 gallons of sludge left in the bed by the sewage treated in the period, we have 27,100 gallons as the amount which has been digested by the rough bed, and which has passed away in liquid or gaseous form. This is only about 42 per cent. of the whole, but it must not be lost sight of that before a bed can get into condition, several weeks must pass, during which the material becomes, once for all, permanently coated with black gelatinous matter. After allowing for this, however, it seemed clear that the beds could not be *continuously* worked with triple fillings of crude unscreened Leeds sewage. The experiment was therefore stopped.

Effect of rest on the Beds.

The beds were now allowed to rest empty a fortnight, from February 4th to February 18th, 1898. It is evident that during this period the chemical change or digestion of the accumulated matter was proceeding, just as it does in a hot bed, for after the fortnight's rest, and before re-charging, the temperature at the bottom of the rough bed was 77° Fahr., the atmospheric temperature at the time being 38½° Fahr. On re-starting the work, a measure was taken, not at the first, but, as is usual, at the second filling, and the capacity was found to be 55,900 gallons, or an increase by the rest of 10,500 gallons.

This pointed to the possibility of treating crude sewage and consuming the sludge, if periods of rest were provided, say two weeks out of five, the accumulation in the winter months having been at the rate of about 2,000 gallons a week.

Accumulation of fibre, paper, &c., on surface of Rough Bed.

There is another difficulty which was met with in dealing with crude sewage, that especially in the neighbourhood of the distributing channels, the surface of the rough bed became coated with a felted mass consisting of fragments of paper, a large quantity of fibre which comes down from wool works, and other solids mixed with the smaller particles which usually go to form sludge, and that this mass spreading over the

Trenching Beds.

surface of the bed, prevented the sewage, with its suspended matters, passing down into the body of the bed, and to a great extent also interfered with effective aeration. From time to time it became necessary to turn over the coke to a depth of one or two feet, so as to bury the surface accumulations, and to bring to the top a new surface of coke. This, together with the evidence that the rough bed could not, without special periods of rest, digest all the solid matters brought to it by the sewage, pointed to the necessity for some preliminary straining which should keep back paper, fibre, tea leaves, matches, and other grosser solids which are too slowly disintegrated and broken down, especially if they are retained on the surface.

It was therefore decided to provide straining screens, and until they were prepared, to try the experiment of passing on to the beds the effluent from the old lime precipitation works.

Experiment with the Effluent from Lime Precipitation.

Experiment with the effluent from lime precipitation.

The experiment with lime effluent was begun on February 18th (after the fourteen days' rest), and with the 285th filling. This effluent was the somewhat turbid result of precipitation over an inadequate settling area. No note was made at the time as to the quantity of solids in suspension, but from analyses of the lime effluent made since, it is probable that it contained in fine particles, about twelve grains of suspended solids per gallon. No difficulty was found in the distribution of the effluent over the rough bed such as had been met with in crude sewage, and the results as regards the final effluents were very good, though it is worth while noting, that in December, 1897, and January, 1898, results nearly as good were obtained with crude sewage. There was, however, an increased production of nitrates in dealing with the lime effluent. The experiment was only continued for 14 days, pending the provision of the screening apparatus, and was too short to permit of the results being taken as decisive. The fact, that after working 13 days with lime effluent containing only twelve grains per gallon of suspended solids, the capacity of the rough bed was reduced by 3,700 gallons, was a matter of some surprise ; but whereas, with crude sewage, the rough bed effluent contained 11·9 grains of suspended solids, it only contained 2·4 in dealing with lime effluent, and the effluent from the fine bed was quite clear and free from turbidity.

LIME EFFLUENT EXPERIMENTS.

Experiments with Screened Sewage.

Process.

The experiment with screened sewage was begun on March 4th, 1898. After several trials the following plan was adopted: a screen of perforated zinc with one-eighth inch holes was fixed to the top edges of the main carrier, so as to form a shallow horizontal perforated trough or gutter 3 ft. wide, about 12 in. deep, and some 40 ft. long. On starting a filling, the crude sewage flowing along the gutter rapidly fell through the perforations in a fine rain, the stream reaching only a few feet forward. Paper and other solids were washed forward to the edge of the flow, and the arrangement might have proved automatic but for the large quantity of wool fibre brought down in the sewage, which gradually choked the perforations at the entrance end of the gutter, and caused the flow to extend along the trough. By the occasional use of a brush, however, the attendant was able to clear the perforations and keep the flow under control. It would have been easy to devise an automatic arrangement with a perforated trough 4 ft. wide and 6 ft. long, cleaned by a rotating brush, and actuated by the flow of the sewage itself. This would, however, have involved delay and expense and was not considered urgent in the experimental stage of the work.

SCREENED SEWAGE EXPERIMENT.

Screenings.

The screening was found very effective in removing the paper (mostly in very small pieces), vegetable matter, and fibre, and the difficulties of distribution of the sewage over the rough bed which had been met with in dealing with the unscreened sewage were very much reduced. Although the quantity of the solids kept back by the screen appeared bulky, they were found, on careful measurement, as brushed from the screen, only to amount to an average of 2¼ cubic feet, or about 14 gallons per filling in the day, and only half a cubic foot, or about 3 gallons, in the night. The screenings, consisting as they did mainly of paper, woody matter and fibre, were found to be easily burned when dry, and no difficulty was found as to storage, for gardeners were glad to fetch them away for use in garden frames.

Result.

It was anticipated that by screening, and thus improving aeration, the accumulation in the rough bed would be considerably reduced, but the results in this direction were somewhat disappointing.

Two days before beginning the experiment, the measured capacity, March 2nd, was ... ... 52,100 galls.

During the fixing of the screen there were several stoppages, amounting in all to perhaps three days, and the measure on March 14th was ... 52,300 „

(An increase of 200 gallons, due no doubt to the three days' rest, and a digging over of the surface of the bed).

On March 26th the capacity was reduced by ... ... 6,200 galls to 46,100 galls

On April 9th it was reduced by ... 3,200 galls to 42,900 „

On April 23rd „ „ ... 2,800 galls to 40,100 „

On April 27th the work was suspended, and the beds were given a rest of seven days.

On May 5th, this rest was found to have increased the capacity by ... 5,700 galls to 45,800

This experiment was now varied, as it was thought the beds would not stand three fillings per 24 hours without special periods of rest. It is perhaps regrettable that the experiment was not continued with the three fillings, for the last two measurements shew a gradual reduction of accumulations. The change made was to two fillings a day, the beds not being filled during the night shift. The night filling is always much more free from suspended solids than the day fillings, and the omission of the third or night filling could not make very much difference; and yet the result shewed during the next six weeks' work a material reduction in the rate of accumulation. This was probably brought about by the increased bacterial action due to the warmer weather, thus :

SCREENED SEWAGE EXPERIMENT.

Change to two fillings.

Reduction of Capacity.

May 5th, after the week's rest, the capacity was 45,800 galls.
May 20th, this had been reduced by only ... ... 1,500 galls to 44,300 „
June 2nd, the capacity was increased by ... ... 300 galls to 44,600 „
June 16th the capacity was reduced by ... ... 1,400 galls to 43,200 „

So that, from May 5th to June 16th the capacity had only been reduced by 2,600 gallons, or about 500 gallons a week.

From June 16th the work was suspended for 38 days until July 25th, because it became necessary to build a large culvert alongside the beds, and in connection with the new settling tanks.

Thirty-eight days' rest.

The culvert passed at a considerable depth below the beds, and it was not considered safe to keep them full during the period of this excavation.

This enforced rest was unfortunate, but was useful in enabling the restoring effects of rest to be noted. At the end of ten days the temperature of the rough bed was found to be 82°, that of the atmosphere at the time being 55°. After

Temperature of Bed at rest.

SCREENED SEWAGE EXPERIMENT.

three weeks the rough bed was dug down to a depth of 3 ft., and the coke was found to be dry to that depth, but appeared still to have some moisture below. At the end of a month the bed was again dug down for the purpose of making a man-hole, and was found to be dry to the bottom, and no sludge was found there. It would seem that beyond the first fortnight the further rest did no good, for the drying up of the coke would probably involve the destruction of the bacterial life, and put the bed in the same condition as a new one. It was, in fact, found that for a fortnight after re-starting on July 25th, the effluent was more turbid and otherwise less satisfactory than it had been. The capacity of the rough bed when the work was stopped on June 16th was 43,200 gallons. It was thought advisable not to measure the capacity at once on beginning to work, and before doing so the beds were worked with single fillings for three days, so that by that time the pores of the coke should have been thoroughly soaked. The measure then taken on July 28th gave a result of 56,500 gallons, or 13,300 gallons increase. It is probable that this increase would have been obtained by three weeks' rest as well as by that of thirty-eight days.

Work Resumed.

Intermittent Flow of Trade Refuse.

The work of the beds was then continued with two fillings of screened sewage a day on exactly the same lines as before the interruption. At this period considerable trouble arose from the large volume of strong dye which came down pretty regularly at about the time for filling the beds. The dye which comes down occasionally at the times when vats are emptied, deeply discolours the whole volume of the sewage, and occasionally astonishing volumes of foul trade effluents have to be dealt with. In one recent instance a large quantity of what was apparently printing ink actually choked up the pumps.

It will be necessary to maintain a systematic inspection of the trade effluents flowing into the sewers, with a view to their regulation. It is possible that in some cases the flow is the result of waste unnoticed by the manufacturers themselves.

SCREENED SEWAGE EXPERIMENT.

At the end of a fortnight another measure of capacity was taken, and shewed a quite exceptional reduction of 10,700, much the largest which had been met with. The only explanation which occurs is that during this fortnight there was heavy rain after long drought, and probably large quantities of organic matter were brought down by the washing of the roads, gullies, etc., besides considerable quantities of grit and other mineral matter. Some of the mud in the distribution channels was washed and found to contain sand, fine ashes, &c.*

Sludging up erratic.

In the figures that have been given earlier in this Report, as the results of the various fortnightly measurements, it will have been noticed that the variations are erratic, and it is thought that this may be due in great part to the effect of even short showers after dry weather, and generally to the rainfall.

June 16th, capacity before the rest	...	...	43,200 galls.
July 28th, three days after restarting	...	...	56,500 „
Aug. 11th (reduction 10,700 galls)	...	...	45,800 „
Aug. 25th „ 3,400 „	...	...	42,400 „
Sep. 8th „ 1,400 „	...	...	41,000 „

In order to prevent grit from reaching the beds in future, the necessary alterations were made, so that work by the beds should be preceded by a partial settling as well as the screening.

The experiment with screened sewage had been carried on for six months from March 4th to September 8th, with seven days' rest from April 27th to May 4th, and an enforced rest of 38 days from June 16th to July 25th; in all 45 days or

* It may be worth attention that in this, as in a former case, the large increase in capacity gained by rest was to a great extent lost within a short time.

SCREENED SEWAGE EXPERIMENT.

Sludge digested.

1½ months' rest. There had been three fillings per 24 hours from March 4th to May 5th, and two fillings a day from that date to September 8th. The number of fillings during the whole period was 315. The average of the fillings was 46,000 gallons, and the total passed over the beds during the six months was 14,490,000 gallons; and after making allowance for the solids screened off, it is estimated that about 51,100 gallons of sludge were retained by the rough bed.

The capacity, March 2nd, was	52,100 galls.
The capacity, September 8th, was	41,000 „
Net loss of capacity	11,100 „

Deducting this from the estimated amount of 51,100 gallons retained by the rough bed, we have 40,000, or about 80°/ₒ, as the amount of sludge consumed in this period by the rough bed. The fine bed retained 16,700 gallons of sludge, the whole of which was consumed, the capacity of the bed not having been decreased. The total consumption by the two beds was 56,700 gallons of sludge.

Quality of Effluent.

The effluent from the fine bed during this six months, except for the first fortnight after the long rest, and during the heavy flow of dye, continued to be satisfactory. All the samples taken daily were kept for months in closed and open bottles; they all remained clear and sweet, notwithstanding the flocculent deposit in the bottles which has been already referred to. The effluent remaining in the basin became beautifully clear during the rest between the fillings, and the carp originally put in November 30th, 1897, continued in it alive and well. There was abundant green growth in the trough and no sewage fungus.

The average of the analyses over the whole period gave in grains per gallon: "Oxygen absorbed in four hours" ·61, and "Albuminoid Ammonia" ·05. Comparing these figures with those of the crude sewage we get a purification, as measured by the Albuminoid Ammonia, of 86 %; and as measured by the Oxygen absorbed, of 84%. SCREENED SEWAGE EXPERIMENT.

Per cent. of Purification.

Experiments with Settled Sewage.

In order to avoid mineral matters coming to the beds, it was decided now to try partially settled sewage. No. 1 settling tank of the old series was used for the purpose. The following trial was made to ascertain the effect of various periods of rest as regards the settling of suspended solids. The tank was filled quickly with a rush of sewage, unmixed with lime, and then allowed to rest. Samples of sewage were taken on August 30th and September 6th as it flowed into the tank, and samples were taken after a rest of half-an-hour, one hour, one hour and a half, and two hours. These were analysed by Mr. T. Fairley, City Analyst, to ascertain suspended solids, with following results:—

Sewage	42	grains per gallon.
„ after ½ hour settlement	17	„ „
„ „ 1 „	12	„ „
„ „ 1½ „	11	„ „
„ „ 2 „	11	„ „

Settled one hour.

It was decided to experiment for four weeks with sewage settled one hour. This was begun on September 9th, the capacity of the rough bed, on September 8th, being 41,000 gallons. At the end of the first fortnight, on September 22nd, it was found that the capacity had been increased to 47,000 gallons. On October 6th the capacity was 46,100 gallons. From the large quantity of sludge left in No. 1 Tank, and from the increase of capacity in the bed, it was evident that the

SETTLED SEWAGE EXPERIMENT.

beds had too little to do as regards matters in suspension, the bulk of which had remained behind in the settling tanks. The results as regards effluents were very good, the beds having only to deal with the organic matters in solution, and with 12 grains per gallon of suspended matters, instead of the 37 grains in the crude sewage.

Settled half hour.

For the next four weeks, from October 7th to November 3rd, the beds were filled with sewage settled half-an-hour.

October 6th	capacity was	46,100	gallons.
„ 20th	„ (reduction 1,200 galls.)	44,900	„
November 3rd	„ „ 800 „	44,100	„

Sludge left in tanks.

Too much sludge was still left behind in the settling tank, and from November 4th the sewage was pumped on to the beds immediately after the tank had been filled. As the filling took forty minutes, the average period of settlement in this case was twenty minutes only, and about 25 grains per gallon of suspended matter passed on to the beds.

November 3rd	capacity was	44,100	gallons
„ 17th	„ „ (reduction 1,900)	42,200	„

Sludge digested.

The experiments with settled sewage lasted from September 9th to November 18th, with two fillings a day, the night filling being omitted. There were 135 fillings in all, with an average of 44,000 gallons per filling, so that the volume treated was 5,940,000 gallons. The average of suspended matter in the sewage treated was, for the whole period, 17 grains per gallon, and that left in rough bed 10·1 grains, which for the volume treated represents 85,700 lbs. of sludge. The whole of this was consumed, for the capacity of the rough bed on September 8th was 41,000 gallons, and on November 17th 42,200, an increase of 1,200. It is probable that the addition of the night filling to the work of the beds would not seriously have affected the capacity, because in the night there is little suspended matter in the sewage.*

* See page 108.— Addendum.

SETTLED SEWAGE EXPERIMENT.

Effluents from Settled Sewage.

The effluents were very good, and although the filtrate was often opalescent, and even cloudy, the analytical results are the best obtained during the year's working of the beds. The samples always cleared in a few days and remained sweet. The effluent left in the basin after each filling rapidly cleared, so that in the four-feet deep part the bottom could be distinctly seen. The fish remained alive and well. A large frog, which found its way into the basin, has now been in for several weeks, and moves about from the shallow to the deep part apparently quite healthy. Star weed planted in the basin has grown luxuriantly.

The average figures for the period were in grains per gallon :—

Albuminoid Ammonia	...	·048
Oxygen absorbed in 4 hours		·44

Per cent. of purification.

These show a purification of 86·6 per cent., as measured by the albuminoid ammonia, and of 88·6 per cent., as measured by the oxygen absorbed.

Proposed Modification.

As the quiescent settlement used during these experiments is an abnormal condition, unlikely to be adopted in any permanent scheme, and as No. 1 tank contained nearly five times the volume required for a filling, it is difficult to estimate with accuracy what would be the sludge production due to the normal settlement of one filling of the bacteria bed. It was therefore decided to let the beds rest from November 18th till the end of the month, to permit meanwhile of arrangements being made to obtain the results from a continuous, but varying quantity of flow through No. 1 tank, the sewage being mixed with lime (three grains per gallon). By regulating the volume of this flow any amount of settlement could be attained, and the amount of sludge left behind carefully gauged.

From October, 1897, to October, 1898, the analyses were made at the Laboratory of Mr. Dibdin, in London. These

SETTLED SEWAGE EXPERIMENT.

were corroborated by occasional analyses made by the City Analyst and the West Riding Rivers Board.

Laboratory established.

In October, 1898, the Corporation established a Laboratory of its own at the Knostrop Works, and appointed to the charge of it, and general superintendence of the works, Mr. W. H. Harrison, M.Sc. (Vic.), who is responsible for all the analytical results given from that date in this report.

Experiments with Settled Sewage (flowing).

After resting from November 18th to December 2nd the beds were restarted. The sewage used was taken from the main flow as it leaves the pumps. No. 1 tank of the old series was used for settlement, and such flow was passed through it as would allow not only grit but the grosser solids to be settled.

The sewage drawn from the outflow of this tank, and passed on to the rough Bacteria bed, contained an average of 20·7 grains suspended solids per gallon, that is only about half the suspended solids in the crude sewage.

Rate of Fillings.

This experiment was continued at the rate of three fillings a day, including Sundays, to January 1st, 1899, and thence with three fillings a day, except on Sundays, until February 20th. No other rest was given.

The filtrate from the rough bed was found to contain an average of 7·9 grains per gallon solids in suspension.

The average analysis of this filtrate gave (inclusive of solids in suspension):—

Free Ammonia	·55	grains per gallon.
Alb. do.	·18	do.
Oxygen absorbed (4 hrs. 80°)	1·59	do.

The filtrate from the fine bed gave average results as follows, the analysis being inclusive of solids in suspension:— SETTLED SEWAGE EXPERIMENTS.

Total solids	62·1	grains per gallon.
Suspended solids	1·35	do.
Free Ammonia	·21	do.
Alb. do.	·065	do.
Oxygen absorbed (4 hrs. 80°)	·43	do.
Nitrogen as Nitrates ...	·36	do.

The results were very good, the final filtrate remaining in the basin very clear, and the subsequent deposit inappreciable.

From December 2nd to January 6th the sewage contained lime (2·8 grains per gallon) and thenceforward to February 20th the use of lime was discontinued. It was thought the filtrate was rather clearer when lime was being used; there was no appreciable difference in the analysis.

Experiments with Crude Sewage, Feb. 20th to March 18th, 1899.

From February 20th the experiment was continued under the same conditions to March 18th, except that from February 20th the full volume of the Leeds Sewage was passed through the No. 1 settling tank with the result that a much larger proportion of the solids in suspension in the sewage passed on to the beds, than when only a limited flow was used.

Thus the sewage passed on to the rough bed contained an average of 38 grains of suspended solids per gallon.

At this period the crude sewage gave an average of 40 grains of solids in suspension; therefore the deposit of grit and grosser solids left in the settling tank represented only an average of 2·6 grains per gallon, so that during this period the beds were dealing with practically crude sewage.

It should be noted that the rainfall during this period was only ·2, and except during rain following dry weather very little grit came down in the sewage.

CRUDE SEWAGE EXPERIMENTS.

The effect of putting this crude sewage at three fillings a day, with only the Sunday rest, was soon apparent in the deterioration of the analyses of the filtrates, and in the appearance of the filtrate, which was cloudy, and upon standing was found to precipitate a buff-coloured flocculent deposit, which occasionally made the filtrate remaining in the basin so muddy that the fish could not be seen in a depth of 18 inches, and the weeds and green growths were covered with it. How far this occasional condition during this period was due to overwork, and how far to other causes, such as unusual quantities of iron liquid coming through, it was not possible to determine.

In these circumstances it was considered advisable to rest the beds for a fortnight, as they had now been continuously working with three fillings a day for 3½ months, but as the Royal Commission were to visit the works on March 21st, it was only practicable to rest them for 2½ days from March 17th to 20th, and they were restarted on that day so as to be in operation on the 21st.

Reduction of Capacity.

During the whole period of these two experiments, from December 21st, 1898, to March 18th, 1899, the capacity of the beds was considerably reduced.

The object of this experiment had been partly to see how far the reduction of capacity would go on by working the beds without rest during the winter months. It was intended, so long as the quality of the filtrate was maintained, to push on the work in order to note what the ultimate issue might be as to the sludging up, and to see whether it would be possible to go on without rest to the warmer weather, when probably some capacity would be recovered, and any way to determine whether, when sludged up, the beds could be restored by rest.

The capacity of the rough bed on November 18th, 1898, was 42,000 gallons, and after the fortnight's rest, from

November 18th to December 2nd, was 45,000 gallons, an unusually small and disappointing increase compared with previous rest.

The capacity measurements gave the following results :—

					Galls	Loss.
Dec.	3rd, 1898.—	780th	filling	capacity,	45,000	...
„	8th, „ —		„	„	43,900	1,100
„	17th, „ —		„	„	38,700	5,200
„	30th, „ —		„	„	36,100	2,600
Jan.	14th, 1899.—	896th	„	„	33,400	2,700
„	28th, „ —	924th	„	„	32,400	1,000
Feb.	11th, „ —	959th	„	„	30,500	1,900
„	25th, „ —	994th	„	„	29,500	1,000
Mar.	15th, „ —	1,038th	„	„	27,600	1,900

It will be noticed that the rate of reduction was at first very great, and that it was after the middle of January much less, which was probably due to the Sunday rest given after February 20th.

It is important to notice that although during this series of experiments the capacity of the bed had been reduced considerably, nevertheless as large a volume was being treated as during the previous months. Thus: 45,000 gallons × 2 = 90,000, and 30,000 × 3 = 90,000.

Average of Analyses referring to the period from February 20th to March 18th, 1899.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen absorbed in 4 hours at 80° F.	Nitrogen as Nitrates.
Crude Sewage	107·9	36·8	1·32	·729	7·56	—
Filtrate from Rough Bed (No. 1)	72·9	9·5	·869	·267	1·95	—
Filtrate from Fine Bed (No. 2)	66·9	1·8	·371	·083	·524	·260
Percentage Purification...	—	95 %	71 %	87 %	93%	—

GRIT SETTLED SEWAGE EXPERIMENTS.

The quality of the filtrate was certainly better as the capacity reduced, the silting up of the coke causing it to act more perfectly as a mechanical filter, keeping back solids in in suspension.

It was not considered advisable to allow the capacity to be reduced below the figure of 27,600, which it had now reached, and it was now desired to see how far it would be necessary to reduce the fillings, that is the work of the filter, in order to maintain this capacity.*

Rest of two days out of seven.

With this intention, from March 21st, the beds were rested every Wednesday and Sunday, and three fillings per day were given on the working days. During the period sewage from which the grit only had been settled, and to which three grains of lime per gallon had been added, was used.

Appearance of Filtrate.

The filtrates obtained, during this experiment, upon the days immediately following the rests, were exceedingly good in appearance, but on the following days they were usually opalescent, and sometimes deposited iron.

This experiment extended from March 21st to May 7th, 1899.

Reduction of Capacity.

The capacity tests during this period gave the following results :—

					Galls.		Loss or Increase.
Mar. 15th,	1899	—1,038th	filling,	capacity	27,600	...	—
„ 25th,	„	—1,058th	„	„	25,200	...	−2,400
Apr. 10th,	„	—1,089th	„	„	25,800	...	+ 600
„ 24th,	„	—1,117th	„	„	24,700	...	−1,100
May 6th,	„	—1,143rd	„	„	22,700	...	−2,000

This is a total decrease of 4,900 gallons for the whole period.

* The original water capacity was 83,300 gallons. That of the empty tank, without coke, was 174,800 gallons.

The sewage during this period taken from No. 1 Tank and sent on to the Rough Bed, contained an average of 34·4 grains per gallon of solids in suspension. The crude sewage contained 39·5, showing that 5·1 grains were deposited in No. 1 Tank.

GRIT SETTLED SEWAGE EXPERIMENTS.

Purification effected.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM MARCH 21ST TO MAY 7TH, 1899.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hrs.; 80° F.).	Nitrogen as Nitrates.
Crude Sewage	116·0	39·5	1·50	·700	7·21	—
Filtrate from Rough Bed (No. 1)	78·0	12·7	1·13	·305	2·24	—
Filtrate from Fine Bed (No. 2)	67·2	1·4	·408	·073	·459	·280
Percentage Purification...	—	96%	72%	89%	93%	—

Beds rest on alternate days.

As this method of working, with two days' rest out of seven, had not prevented a further reduction of capacity, it was decided to rest the beds on alternate days, still giving three fillings on the working days. This experiment lasted from May 7th to July 5th, 1899. During the whole of this period, sewage from which the grit had been settled, and which was mixed with three grains of lime per gallon, was used.

The filtrates, generally speaking, were turbid and yellow from the deposition of iron, but upon analysis the results continued good.

Increase of Capacity.

			Loss or Increase.
Capacity on May 6th	= 22,700 galls.	...	—
„ „ 20th	= 22,900 „	...	+ 200 galls.
„ June 3rd	= 23,400 „	...	+ 500 „
„ „ 17th	= 24,300 „	...	+ 900 „
„ „ 24th	= 25,400 „	...	+1,100 „
„ July 1st	= 25,600 „	...	+ 200 „

This gives a total increase of 2,900 gallons.

GRIT SETTLED SEWAGE EXPERIMENTS.

Purification effected.

During this period the sewage sent on to the beds contained 38·1 grains of suspended matter per gallon, whilst the sewage contained 42·5 grains, shewing that 4·4 grains of solid matter per gallon had been deposited in No. 1 Tank.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM MAY 7TH TO JULY 5TH, 1899.

GRAINS PER GALLON.	Total Solids.	Solids in Suspension.	Free NH_3.	Alb. NH_3.	Oxygen absorbed (4 hrs., 80° F.)	Nitrogen as Nitrates.
Crude Sewage	113·4	42·5	2·41	·933	8·81	—
Filtrate from Rough Bed (No 1)	73·0	11·6	1·24	·311	2·33	—
Filtrate from Fine Bed (No. 2)	67·1	1·7	·337	·071	·448	·474
Percentage Purification...	—	96%	86%	92%	94%	—

Sludging up of No. 1 Bed.

Towards the end of June the surface of No. 1 Bed shewed signs of being clogged. It was covered in several places with a thick layer of mud, which seriously prevented the free access of the sewage to the interior of the filter. There was also a prolific growth of weeds and various plants upon its surface, including self-sown tomato plants.

On June 23rd the outlet valves of No. 1 Bed were opened at full on discharging the bed with the object of seeing whether or not the greater rapidity of emptying would help to wash out the bed. Although this procedure was continued until October 14th no appreciable effects resulted. Before this the valves had been opened to such an extent as would allow the bed to discharge in one hour.

It will be noticed that, with the beds working only on alternate days, three fillings being given on the working days, *i.e.*, an average of 1½ fillings per day, an increase of capacity had been obtained.

GRIT SETTLED SEWAGE EXPERIMENTS.

Beds receive only one filling per day.

From July 5th to October 14th, 1899, the beds received only one filling per day, every day from July 5th to August 1st, grit settled and limed sewage being used, but from August 1st the addition of lime was discontinued, no benefit having been noticed from its use.

The filtrates obtained during this period were strongly opalescent, and precipitated large quantities of iron until the advent of colder weather towards the end of September, from which time they were clear and bright.

Increase of Capacity.

				Loss or Increase.
Capacity on July	1st	= 25,600 galls.	...	
„ „	15th	= 26,700 „	...	+ 1,100 galls.
„ „	29th	= 26,800 „	...	+ 100 „
„ Aug.	12th	= 27,100 „	...	+ 300 „
„ „	26th	= 27,100 „	...	0 „
„ Sept.	9th	= 27,300 „	...	+ 200 „
„ Oct.	7th	= 26,900 „	...	− 400 „

A glance at the capacity tests for No. 1 Bed shews that on May 6th the capacity of the No. 1 Bed had fallen to 22,700 gallons, and that after working part of the time at the rate of 1½ fillings a day (three fillings on alternate days), and during the remainder of the term at one filling per day every day, the capacity had slowly risen to 26,900 gallons, shewing a gain of 4,200 gallons. This was more apparent than real, for owing to the longer period of rest between the fillings the beds would have time to empty themselves better. The most that can be said is that working with strong sewage, at one filling a day, with an average of 25,000 gallons per filling, the capacity of the bed had been maintained. It is important, however, to remember that this series of experiments took place during the warmer months of the year.

No. 1 Bed useless.

Towards the middle of August No. 1 Bed shewed signs of being choked up, for during filling operations it was found that the sewage accumulated at the inlet end of the bed, and only very slowly spread evenly throughout the whole bulk of the bed.

GRIT SETTLED SEWAGE EXPERIMENTS.

This clogging up became more and more evident, until on October 14th, 1899, the working of these beds in the treatment of crude sewage was stopped.

It was decided to renew the material of the rough bed, and start a series of experiments on the double filtration of Septic Tank Effluent by means of contact beds.

Purification effected.

The sewages sent on to the bed during this period varied exceedingly in strength, and in October, owing to the dry summer, they became very strong. This accounts for the high values obtained upon the analysis of these filtrates. The average amount of suspended matter in the sewage was 46·4 grains during this experiment, but owing to the beds only receiving one filling per day, and this during a portion of the day when the variations in the strength of the sewage are very great, it was found that they received an average of 55·4 grains per gallon of suspended matter, *i.e.*, a very strong sewage.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM JULY 5TH TO OCTOBER 14TH, 1899.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Crude Sewage	128·5	46·4	2·17	1·01	9·44	—
Filrate from Rough Bed (No. 1)	87·7	15·0	1·20	·375	2·96	—
Filtrate from Fine Bed (No. 2)	81·2	2·6	·365	·099	·554	·455
Percentage Purification...	—	94%	83%	90%	95%	—

Analysis of deposit in Rough Bed.

On March 21st, 1899, in order to learn what was the nature of the deposit which was accumulating in the beds, the rough bed was dug down to the bottom, and a spadeful of the coke was taken from the bottom, middle, and near the top and put into a bucket. The deposit on the coke near the top was of an earthy character, and lower down where it

GRIT SETTLED SEWAGE EXPERIMENTS.

was wetter it took the form of at first a brown, and near the bottom a black odourless slime. On analysis the deposit was found to contain 85 per cent. moisture. Of the remaining 15 per cent. about 7½ was organic matter, some of which was fibrous, and the remaining 7½ was mineral, about half of it being ferric oxide.

It was evident that this spongy deposit retains much of the water, so that the bed does not empty itself unless long periods of rest are given, and, indeed, it is found that a bed will trickle for days after the main flow has ceased. The drying up of this spongy matter during lengthened rests accounts to a great extent for the increase of capacity obtained on re-starting, which is mostly soon lost.

On October 31st another examination was made after closing the experiment last described and letting the beds rest. The No. 1 Bed was dug down and found choked with a substance closely resembling garden mould, and having no evil odour. It was found to be non-putrescible.

A cubic foot of the material of the bed, after passing through a 1½ inch mesh, was well washed in water so as to free the coke from the adhering deposit, and then sorted out into various sizes by means of riddles. The wash water containing the deposit was then passed through a $\frac{3}{16}$ inch mesh in order to retain the smaller pieces of coke, and the mud remaining was collected on canvas. This mud was dried, weighed, ignited at a red heat until all organic matter was destroyed and weighed again.

The following is the result obtained:—

	Cubic Ins.	By Vol.
Coke rejected by 1 in. mesh and passed by 1½ in. mesh	484·27	=28·01 %
" " ½ in. " " 1 in. "	231·60	=13·40 %
" " ⅜ in. " " ½ in. "	32·34	= 1·87 %
" " $\frac{3}{16}$ in. " " ⅜ in. "	34·17	= 1·97 %
	782·38	=45·25 %
The deposit on the Coke (70 % water)	352·50	=20·39 %

GRIT SETTLED SEWAGE EXPERIMENTS.

The deposit, when dry, gave the following analysis:—

Loss on ignition at a red heat for 5 minutes	= 36·50 %	by weight.
Ferric Oxide	= 30·52 %	„
Sand, &c.	= 15·54 %	„
Carbon present, as Coke	= 16·86 %	„
Other Mineral Matters	= 0·58 %	„

This last item is no doubt due to the degradation of the filtering material.

General Observations.

These will be found on page 58.

Experiments with Contact Beds Nos. 3 and 4, and Nos. 5 and 6.

A grant having been made by the Council on June 1st, 1898, to extend the experiments, two pairs of contact or Dibdin Beds were ordered to be constructed.

Nos. 3 and 4 Beds.

The first pair of these beds had an area of about $\frac{1}{8}$ acre each, and a depth of 3 feet. The bottom of both beds were laid with large pieces of clinker, packed vertically, to a depth of 8 inches, and only one half of each bed was underdrained with 3 inches agricultural drain pipes, in rows two feet apart. The drain pipes communicated with a brick channel, which in turn was directly connected to the outlet valves. The remaining halves were undrained, except for the coarse clinker. The beds were emptied by means of five valves.

No. 3 Bed was filled with clinker greater than $\frac{1}{2}$ inch and smaller than one inch, whilst No. 4 Bed was filled with clinker larger than $\frac{3}{16}$ inch and smaller than $\frac{1}{2}$ inch.

Distribution.

The sewage was distributed in a thin film upon the clinker along one side of the bed, no arrangements being made for evenly distributing the sewage over the whole surface. It was found, however, that the accumulation of fibre and other substances upon the surface of the filtering material caused the sewage in time to spread over the whole surface of the bed before entering the body of the filter, and so produced in some respects a fairly efficient distribution.

GRIT SETTLED SEWAGE EXPERIMENTS.

The filtrate from the Rough Bed was allowed to fall directly on to the surface of the Fine Bed, no troughs, &c., being used to cause an even distribution over the whole surface.

PARTIALLY SETTLED SEWAGE.

These beds were started on November 19th, 1898, and from that date until February 20th, 1899, they were filled three times a day with sewage from which the grit and coarser particles had been settled. From December 2nd, 1898, to January 6th, 1899, lime was added to the sewage in the proportion of three grains per gallon.

Beds rest on Sundays.

On and after December 30th, 1898, the beds were rested on Sundays, so that they had one day's rest in seven.

Appearance of Filtrates.

At first, before the beds had matured, the filtrate from the fine bed was putrescent in character, and deposited a copious buff-coloured precipitate. Even after this precipitate had settled the supernatant liquid was very opalescent, and sometimes dark in colour. From December 6th the opalescence and precipitate decreased, until at the beginning of January the filtrates were perfectly clear and colourless. The filtrates from the Rough Bed were dark coloured and putrescent throughout the whole of this period. In the former part of December it was noticed on several occasions that the portion of No. 3 Bed, which was underdrained, removed all traces of dye from the sewage, whilst the undrained portion did not. This, no doubt, was due to the beneficial effect of the drains upon the bed whilst in a state of incubation caused by the better aeration of that portion.

PARTIALLY SETTLED SEWAGE.

Loss of Capacity.

			Loss.
Capacity on Nov. 21st, 1898,	= 51,800 galls.	...	—
„ Dec, 5th, „	= 46,600 „	...	−5,200 galls.
„ „ 19th, „	= 40,800 „	...	−5,800 „
„ Jan. 2nd, 1899,	= 38,100 „	...	−2,700 „
„ „ 16th, „	= 36,400 „	...	−1,700 „
„ „ 30th, „	= 34,800 „	...	−1,600 „
„ Feb. 13th, „	= 30,400 „	...	−4,400 „
Total loss of capacity	= 21,400 „		

Purification Effected.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM NOVEMBER 19TH, 1898, TO FEBRUARY 20TH, 1899.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Crude Sewage	104·6	34·0	1·50	·706	7·48	—
Filtrate from Rough Bed (No. 3)	75·4	6·8	·517	·171	1·36	—
Filtrate from Fine Bed (No. 4)	85·1	3·5	·776	·122	·769	·151
Percentage Purification...	—	89%	48%	82%	89%	—

During this period only 23·7 grains of suspended matter per gallon reached the beds, partially settled sewage having been used.

Beds resting one day out of seven.

From February 20th, 1899, to May 7th, the Rough Bed was filled with sewage from which the grit only had been removed, the beds being allowed to rest as before on Sundays.

Owing to the increased amount of suspended matter going on to the beds during this period, the quality of the filtrates obtained detoriated somewhat, for on March 21st the following analysis was obtained :—

Free Ammonia ...	...	·560 grains per gallon.
Alb. „ ...	...	·181 „
Oxygen absorbed	...	1·05 „
Nitrogen as Nitrates	...	·112 „

Iron was deposited from almost every filtrate, but notwithstanding this, and although the filtrates were above the provisional standard, confervoid growths were present in the channels which carried the filtrates away from the beds.

GRIT SETTLED SEWAGE.

The beds were now allowed to rest from March 30th to April 17th, 1899. During this rest the Rough Bed increased in capacity by 5,000 gallons, and the Fine Bed by 1,700 gallons. As shewing the amount of bacterial action which had gone on during this rest, it may be mentioned that the first filtrate obtained after the rest contained 2·4 grains per gallon of nitrogen as nitrates.

Beds resting.

Loss of Capacity.

				Loss or Increase.
Capacity on Feb. 13th, 1899,	=	30,400 galls.	...	—
„ „ 27th, „	=	28,700 „	...	−1,700
„ Mar. 13th, „	=	27,700 „	...	−1,000
„ „ 27th, „	=	23,600 „	...	−4,100
„ Apr. 18th, „	=	28,600 (after rest)		+5,000
„ May 2nd, „	=	21,700 galls.	...	−6,900
Total loss	=	8,700 „		

Average of Analyses referring to period from February 20th to May 7th, 1899.

Purification Effected.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Crude Sewage	116·0	39·5	1·54	·686	7·32	—
Filtrate from Rough Bed (No. 3)	92·0	12·0	1·17	·280	1·74	—
Filtrate from Fine Bed (No. 4)	86·7	3·8	·522	·116	·698	·288
Percentage Purification...	—	90%	66%	83%	90%	—

In order to see how far it would be necessary to reduce the work of the beds in order to maintain capacity, the beds,

Beds rest alternate weeks.

from May 7th to July 5th, 1899, were allowed to rest on alternate weeks, limed and grit settled sewage being used as before. The beds received three fillings per day. During this period the filtrate from No. 4 Bed was somewhat better in appearance, iron being deposited to a very much smaller extent than previously. It was also noticeable that large quantities of nitrates were produced during the resting periods.

Surface of No. 3 Bed clogged.

Owing to the accumulation of fibrous mud upon the surface of the rough bed it was found that, towards the middle of May, the sewage, during the process of filling, spread over the whole surface of the bed and in parts remained upon the surface from one filling to another. From this cause it was necessary to clean the surface, and this was done on May 25th by removing the top three inches of the filtering material and replacing it by new. At the same time a few grass seeds were sown upon a portion of the bed, and these in time grew luxuriantly.

Increase of Capacity.

			Loss or Increase.
Capacity on May 2nd	= 21,700 galls.		—
„ „ 17th	= 21,500 „	... ...	− 200 galls.
„ „ 31st	= 24,900 „	(surface cleaned)	+ 3,400 „
„ June 14th	= 23,000 „	... ...	− 1,900 „
„ „ 28th	= 22,500 „	... ...	− 500 „
Total increase	= 800 „		

Purification Effected.

Average of Analyses referring to period from May 7th to July 5th, 1899.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Crude Sewage	113·4	42·5	1·94	·922	8·12	—
Filtrate from Rough Bed (No. 3)	74·2	10·8	·990	·208	1·68	—
Filtrate from Fine Bed (No. 4)	69·9	2·3	·562	·098	·569	·245
Percentage Purification...	—	94%	71%	89%	93%	—

Analysis shewed that on the average only 2·8 grains of solid matter per gallon were removed from the crude sewage before reaching the beds.

GRIT SETTLED SEWAGE.

In the last experiment the beds rested on alternate weeks and from July 5th, 1899, to June, 1900, they were rested on alternate days, and received three fillings on each working day, *i.e.*, an average of 1½ fillings per day, of sewage from which grit only had been settled.

Beds rest alternate days. July 5th, 1899, to June, 1900.

Throughout the whole of this period, generally speaking, the filtrates, although slightly opalescent, did not deposit iron. During the cold weather from December, 1899, to March, 1900, the filtrates were exceedingly clear.

The surface of No. 3 Bed was again cleaned in March, 1900, the accumulations of fibrous mud having gradually caused the whole surface of the bed to be flooded during filling operations. To facilitate the removal of the surface mud, the beds were allowed to rest for a fortnight until the layer of fibre and mud was sufficiently dry, when it was skimmed off. During this rest the bed increased in capacity by 6,500 gallons.

Surface of No. 3 Bed clogged.

Loss of Capacity.

			Loss or Increase.
Capacity on June 28th, 1899,	= 22,500 galls.	...	— galls.
„	July 13th, „	= 23,000 „	... + 500 „
„	„ 27th, „	= 24,400 „	... +1,400 „
„	Aug. 11th, „	= 26,400 „	... +2,000 „
„	„ 24th, „	= 25,000 „	... −1,400 „
„	Sept. 7th, „	= 24,900 „	... − 100 „
„	Oct. 5th, „	= 24,200 „	... − 700 „
„	Nov. 1st, „	= 21,200 „	... −3,000 „
„	„ 30th, „	= 21,700 „	... + 500 „
„	Dec. 30th, „	= 18,100 „	... −3,600 „
„	Jan. 27th, 1900,	= 15,400 „	... −2,700 „
„	Mar. 10th, „	= 14,700 „	... − 700 „
„	„ 26th, „	= 21,200 (after rest and surface cleaned)	+6,500 „
„	Apr. 23rd, „	= 18,600 „	... −2,600 „
„	May 21st, „	= 18,100 „	... − 500 „
	Total decrease	= 4,400 „	

GRIT SETTLED SEWAGE.

This table shews that, by sufficiently reducing the number of fillings, it was possible to maintain the capacity during the warmer months of the year, but that even under these conditions the capacity could not be maintained during the winter months.

Purification Effected.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM JULY 5TH, 1899, TO JUNE, 1900.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Crude Sewage	122·8	46·0	2·34	1·41	9·71	—
Filtrate from Rough Bed (No. 3)	82·9	15·7	·875	·316	2·28	—
Filtrate from Fine Bed (No. 4)	73·0	3·5	·389	·102	·610	·291
Percentage Purification...	—	92%	83%	92%	93%	—

Nos. 5 and 6 Beds.

The pair of beds, Nos. 5 and 6, were in area and general construction similar to Nos. 3 and 4 Beds. The Rough Bed (No. 5) was filled with broken clinker larger than 1 in. and smaller than 2 in. in diameter, and No. 6 Bed with material larger than $\frac{3}{16}$ in. and smaller than $\frac{1}{2}$ in. diameter. These beds had no coarse material on the bottom as in the case of Nos. 3 and 4 Beds, and only half of each was underdrained. The drain-pipes were surrounded by coarser material than that composing the filtering material. There were five outlet valves to each bed.

The distribution was exactly similar to that described for Nos. 3 and 4 Beds.

Beds rest on Sundays.

These beds were started on February 27th, 1899, with sewage from which the grit only had been settled, the beds resting on Sundays, *i.e.*, one day in seven.

This experiment continued from February 27th to May 16th, 1899.

GRIT SETTLED SEWAGE.

The final filtrates throughout this period were very opalescent, and deposited large quantities of iron. A gradual improvement took place in the quality of the filtrate (as the beds got into condition) until towards the end of April the analysis was fairly good. When first drawn the filtrates were quite clear, but they had a strong yellow colour. On standing, the buff-coloured iron precipitate referred to previously was thrown down, leaving the supernatant liquid beautifully clear and colourless. Green growth had appeared in the effluent channels by April 12th.

Loss of Capacity.

				Loss of Capacity.
Capacity on	Feb. 28th, 1899	= 53,100 galls.	...	—
"	Mar. 14th "	= 46,600 "	...	6,500 galls.
"	" 30th "	= 42,200 "	...	4,400 "
"	Apr. 12th "	= 38,300 "	...	3,900 "
"	" 25th "	= 35,200 "	...	3,100 "
"	May 9th "	= 32,500 "	...	2,700 "
	Total decrease	= 20,600 "		

Average of Analyses referring to period from February 27th to May 16th, 1899.

Purification Effected.

Grains per Gallon.	Total Solids.	Solids in Solution.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Crude Sewage	116·0	39·5	1·54	·686	7·32	—
Filtrate from Rough Bed (No. 5)	89·0	11·6	1·27	·349	2·40	—
Filtrate from Fine Bed (No. 6)	79·6	3·7	·959	·189	1·06	·039
Percentage Purification ...	31 %	90 %	37 %	72 %	85 %	—

GRIT SETTLED SEWAGE.

Beds receive two fillings per day with four hours' contact in Rough Bed.

From May 16th to July 5th, 1899, the beds only received two fillings per day, but the sewage was allowed to remain in contact with the rough bed for four hours instead of two. This change was followed by an immediate improvement in the quality of the filtrates, although usually iron was still deposited in large amounts.

Loss of Capacity.

			Loss or Increase of Capacity.
Capacity on May 9th	= 32,500 galls.	...	— galls.
" " 24th	= 30,300 "	...	− 2,200 "
" June 7th	= 31,300 "	...	+ 1,000 "
" " 21st	= 29,300 "	...	− 2,000 "
" July 5th	= 29,400 "	...	+ 100 "
Total decrease	= 3,100 "		

Purification Effected.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM MAY 16TH TO JULY 5TH, 1869.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Crude Sewage	113·4	38·3	1·94	·922	8·12	—
Filtrate from Rough Bed (No. 5)	73·0	12·6	1·73	·426	3·58	—
Filtrate from Fine Bed (No. 6)	64·8	2·0	·534	·074	·492	·276
Percentage Purification...	42%	94%	72%	91%	93%	—

Two fillings per day with two hours' contact.

From July 5th to August 16th, 1899, the sewage was allowed to remain in contact with the Rough Bed for only two hours, the beds receiving only two fillings per day as before. This was done with the intention of determining whether or not the great improvement in the quality of the filtrate obtained during the last experiment was due to the four hours' contact in the Rough Bed.

Generally speaking the filtrates obtained during this period, although opalescent, did not deposit iron.

				Loss or Increase.
Capacity on July 5th	= 29,400 galls.	...		—
„ „ 19th	= 29,100 „	...		− 300 galls.
„ Aug. 2nd	= 29,400 „	...		+ 300 „
„ „ 16th	= 29,900 „	...		+ 500 „
Total increase	= 500 „			

GRIT SETTLED SEWAGE EXPERIMENTS.

Increase of Capacity.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM JULY 5TH TO AUGUST 16TH, 1899.

Purification Effected.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Crude Sewage	131·1	42·6	2·31	·946	10·6	—
Filtrate from Rough Bed (No. 5)	87·4	14·9	1·22	·617	3·75	—
Filtrate from Fine Bed (No. 6)	66·0	3·5	·515	·118	·672	·175
Purification effected ...	49%	91%	77%	87%	93%	—

It will be noticed that the filtrates obtained during this period were scarcely so good as those obtained during the preceding experiment. For this reason it was decided to again work the beds for a further period with two fillings per day and with four hours contact in the Rough Bed.

Beds receive two fillings per day, and four hours' contact in the Rough Bed.

From August 16th to November 23rd, 1899, the beds received two fillings per day of grit settled sewage with four hours contact in the Rough Bed. During this period the filtrates obtained were slightly opalescent, but did not deposit iron.

Beds rested to clean the surface of No. 5 Bed.

During September fibre and other substances had accumulated upon the surface of No. 5 Bed to such an extent as to seriously interfere with the effective aeration of the filter. On September 25th, 1899, the work was stopped and

GRIT SETTLED SEWAGE EXPERIMENTS.

the beds allowed to rest for 25 days. During this time the surface was removed to a depth of three inches, and replaced by three inches of finer material similar to that used in the construction of No. 3 Bed. The beds were restarted on October 21st. During this rest the capacity of the Rough Bed only increased 2,500 gallons.

Work stopped.

Owing to the choking of the surface of the Fine Bed, work was again stopped on November 23rd, 1899.

Loss of Capacity.

			Loss or Increase.
Capacity on Aug. 16th	= 29,900 galls.	...	— galls.
„ „ 30th	= 27,600 „	...	− 2,300 „
„ Sept. 13th	= 28,300 „	...	+ 700 „
„ Oct. 24th	= 30,800 (after rest)		+ 2,500 „
„ Nov. 22nd	= 25,400 „	...	− 5,400 „
Total loss	= 4,500 „		

Purification Effected.

Average of Analyses referring to period from August 16th to November 23rd, 1899.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Crude Sewage	133·4	57·4	2·60	1·25	11·1	—
Filtrate from Rough Bed (No. 5)	80·8	18·2	1·14	·426	3.50	—
Filtrate from Fine Bed (No. 6)	70·7	4·1	·666	·142	·759	·126
Percentage Purification...	47%	92%	74%	88%	93%	—

These experiments clearly shew that very little advantage is gained by increasing the time of contact from two to four hours.

The beds were rested for over three months from November 23rd, 1899, to March 6th, 1900. During this period the material of the Fine Bed was underdrained and thoroughly forked over. The increase of capacity obtained by this rest was only 2,200 gallons.

GRIT SETTLED SEWAGE EXPERIMENTS.

From March 6th to June 1st the beds received three fillings per day of grit settled sewage every day.

On restarting, the beds behaved in a very similar manner to absolutely new filters, the filtrates being at first very dark coloured and strongly opalescent. Towards the end of March iron was deposited and continued to be thrown down until June.

Towards the end of May the accumulation of fibre, &c., upon the surface of No. 5 Bed seriously interfered with the filling of the bed. The work was therefore stopped on June 1st in order to allow of the cleansing of the surface.

			Loss of Capacity.
Capacity on March 9th, 1900	= 27,600 galls.	...	—
" April 6th "	= 23,000 "	...	4,600 galls.
" May 4th, "	= 18,100 "	...	4,900 "
" June 1st, "	= 13,200 "	...	4,900 "

Average of Analyses referring to period from March 6th to June 1st, 1900.

Purification effected.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Crude Sewage	115·3	39·4	2·37	1·12	8·94	—
Filtrate from Rough Bed (No. 5)	—	—	1·31	·316	2·52	—
Filtrate from Fine Bed (No. 6)	—	—	1·11	·159	·814	·084
Percentage Purification...	—	—	53%	85%	90%	—

Contact Beds, Nos. 7 and 8.

Contact Bed, No. 7.

In addition to the two pairs of double contact beds last referred to, two single contact beds were constructed. The largest of these, known as No. 7, was intended for experiments in the filtration by single contact of the effluent from the Lime Precipitation process, in which the sewage passes through a series of precipitation tanks, where it leaves behind over three-quarters of the solids in suspension, so that on an average 9 grains per gallon of solids in suspension come out in the effluent. As compared with the original crude sewage this effluent shews a purification of from 45 per cent. to 55 per cent.

Construction.

The Bed No. 7 has an area of about 900 square yards, and a depth of 3 feet 6 inches. It was filled with clinker smaller than 1 inch and larger than $\frac{3}{8}$ inch. The bed was not underdrained. No special system of distribution was adopted. The lime effluent was allowed to enter the bed at one corner, and in time, as the surface in that corner began to become clogged, the liquid spread further over the bed until, after six months' working, it spread over two-thirds of the surface before finally disappearing.

Work started March 8th, 1899.

The bed was started on March 8th, 1899, and was worked with three fillings per 24 hours, and with two hours' contact, until October 20th, *i.e.*, for rather over seven months.

Quality of Filtrate.

The filtrates first obtained were strongly opalescent, but as the bed improved in condition the filtrates also improved, though they had a strong yellow colour, and on standing deposited a copious buff-coloured precipitate which consisted chiefly of iron. The last runnings from the bed were usually very clear. The results, however, never reached the standard obtained by the double contact treatment of crude sewage on Beds Nos. 1 and 2, nor even those attained on Beds Nos. 3

and 4, and 5 and 6. The following table gives the average analyses over the whole period:—

AVERAGE OF ANALYSES.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Lime Effluent	81·1	9·4	1·76	·434	4·53	—
Filtrate from No. 7 Bed	68·5	4·5	1·25	·165	1·02	·053
Purification effected ...	15%	52%	29%	62%	77%	—

It will be seen that, though the results are rather above the provisional standard, and though the greater part of the samples were found to putrefy on incubation, they shew, however, a purification of from 62 to 77 per cent. on the effluent put on to the bed, which is equivalent to about 85 per cent. on the original sewage by the effect of both processes. That this effluent was well aerated was evidenced by the presence of green growths in the effluent channels, and by the complete absence of sewage fungus.

It had been anticipated that in filtering the effluent containing only nine grains per gallon of suspended solids, the rate of sludging up would be very small. The result, however, was disappointing, for the reduction of capacity was as large, indeed larger, than that of the rough beds which were dealing with crude sewage. Reduction of Capacity.

					Loss of Capacity.
Capacity on	March 24th,	1899	= 55,700	galls. ...	—
„	April 7th,	„	= 53,800	„ ...	1,900 galls.
„	April 21st,	„	= 50,308	„ ...	3,500 „
„	May 5th,	„	= 48,600	„ ...	1,700 „
„	June 2nd,	„	= 43,600	„ ...	5,000 „
„	June 30th,	„	= 38,100	„ ...	5,500 „
„	July 28th,	„	= 33,600	„ ...	4,500 „
„	Aug. 25th,	„	= 29,300	„ ...	4,300 „
„	Sept. 21st,	„	= 26,900	„ ...	2,400 „
„	Oct. 20th,	„	= 21,600	„ ...	5,300 „
	Total diminution		= 34,100	galls.	

As it was impossible to account for this unexpected large reduction of capacity, the experiment was stopped at the end of October, 1899. The bed was rested for two months, and during this period it was dug down, turned over, thoroughly loosened, and completely underdrained with 3 inch agricultural drain pipes. The effluent which had been going on to the bed contained 9·8 suspended solids, and the filtrate 4·8, so that 5 grains remained behind in the bed. These 5 grains reckoned on the total volume of sewage dealt with in the seven months was far from accounting for the reduction of capacity, even if none of it had been digested. It was found in fact that there was very little accumulation of matter in the bed, but the material of the bed had sunk and become consolidated, so as to form almost one mass, as a consequence, no doubt, of the alternate filling and emptying of the bed, and the slight rise and settlement of the material at each turn of work; in short, the reduction of capacity appeared to be due very much to this cause.

On re-starting on Jan. 3rd, 1900, the capacity was found to be 53,500 gallons, that is within 2,200 of the original capacity. The turning over of the material had raised the level of the bed some 4 inches. From Jan. 3rd it was worked as before with three fillings a day until the date of this report.

The capacity is being reduced at about the same rate as before, and no doubt from the same cause. It remains to be seen whether other material than clinker, or clinker of larger size, will give better results in this respect.

The analyses were similar to those already given for the earlier part of the experiments.

Bed No. 8.

The second of the single contact beds (known as "No. 8") was intended for experiments in the single contact filtration of septic effluent.

The bed has an area of about 480 square yards, and a depth of 3 feet 6 inches, and it was filled with smaller clinker than already described for No. 7. It was underdrained with 3 inch agricultural drain pipes. Construction.

Work was started on March 20th, 1899, with three fillings per 24 hours, and two hours contact. The septic effluent put on the bed contained at first an average of 9 grains per gallon of solids in suspension, that is, about the same as the lime effluent put on No. 7 Bed.

Quality of Effluent.

The results as to purification, and as to reduction in capacity were very similar to those obtained with No. 7 Bed.

Average of Analyses from March, 1899, to June, 1900.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen Absorbed.	Nitrogen as Nitrates.
Septic tank effluent ...	77·6	13·0	1·83	·445	4·18	—
Filtrate from No. 8 bed...	71·5	6·7	1·24	·164	1·06	·047
Percentage purification...	—	48 %	32 %	63 %	74 %	—

Reduction of Capacity.

					Loss or Increase.
March 23rd, 1899	...	capacity	29,500 galls.	...	— galls.
April 6th, „	...	„	29,800 „	...	+ 300 „
„ 20th, „	...	„	28,500 „	...	− 1,300 „
May 4th, „	...	„	27,100 „	...	− 1,400 „
June 2nd, „	...	„	23,000 „	...	− 4,100 „
„ 29th, „	...	„	18,800 „	...	− 4,200 „
July 27th, „	...	„	16,100 „	...	− 2,700 „
Aug. 24th, „	...	„	12,900 „	...	− 3,200 „
Sept. 21st, „	...	„	10,700 „	...	− 2,200 „
Total loss	...	...	18,800 gallons.		

The bed was rested for about six weeks, the material dug down and turned over, and the deposit was found concentrated mostly on the upper 2 inches. Below that depth the clinker was comparatively clean. Much reduction of capacity was again found to be due to the consolidation of the filtering material.

On re-starting the capacity was found to have increased by 17,100 gallons, and since November 10th, 1899, the bed has been worked as before, with similar analytical results, and an even greater reduction of capacity.

					Loss or Increase.	
Sept. 21st, 1899 ...	capacity	10,700	galls.	...	—	galls.
Nov. 10th, „ ...	„	26,900	„	...	+ 16,200	„
Dec. 19th, „ ...	„	20,500	„	...	− 6,400	„
Jan. 16th, 1900 ...	„	17,800	„	...	− 2,700	„
March 8th, „ ...	„	15,600	„	...	− 2,200	„
April 5th, „ ...	„	13,200	„	...	− 2,400	„
May 4th, „ ...	„	12,200	„	...	− 1,000	„
June 1st, „ ...	„	9,800	„	..	− 2,400	„

Total loss since November 10th, 1899 = 17,100 galls.

General Observations on Experiments with Contact Beds.

Sewage contains in suspension and in solution organic and mineral matters.

If a sample of Leeds sewage is filtered through filter paper, the withdrawal of the solids in suspension gives a purification of about 50 per cent.

Chemical precipitation brings about a similar result, from 45 to 50 per cent. purification, though in some cases somewhat better results are obtained on account of the action of the precipitant in throwing down some of the matters in solution.

After the solids in suspension have been removed from sewage there remains a liquid, which is often clear and free from smell when it first leaves the tanks, but which still contains in solution about 50 per cent. of the impurities originally in the sewage. This liquid on standing or being turned into a stream becomes dark coloured, putrefies, and gives off offensive smells.

OBSERVATIONS ON EXPERIMENTS.

The treatment of sewage therefore resolves itself mainly into two parts:—

1. Dealing with matters in suspension.
2. Dealing with those in solution.

Chemical precipitation deals mainly with the first, and in actual practice accomplishes little in regard to the second; and its effect in regard to the first is at the cost of great production of sludge which has to be dried, or pressed, and removed, and has little or no agricultural value.

Object of Experiments.

The object of the experiments was therefore:—

1. To bring about a higher degree of purification than can be attained by mere precipitation with or without chemicals.
2. To see how far it might be possible by bacterial action to do away with sludge production, or at least to reduce it.

The experiments were chiefly with double contact beds, a rough and a fine bed working in pairs, numbers 1 and 2, 3 and 4, and 5 and 6.

Quality of Effluents.

This system of artificial filtration was found to bring about a purification of from 75 to 95 per cent., but it is more effective in regard to matters in solution than to those in suspension which are more slowly reduced, and of which the undigested or indigestible portions tend to accumulate and choke the beds.

The filtrate from the rough beds, which is an intermediate and not a final result, was always dark coloured, with some smell, and was usually putrescent in character. The last flow shewed signs of anærobic fermentation, and sometimes

OBSERVATIONS ON EXPERIMENTS.

deposited sulphur. This would lead to the conclusion that the process is not, at least in the lower portions of the rough bed, a strictly ærobic one.

The first flow from the fine beds is usually somewhat turbid and unsatisfactory, owing to insufficient aeration in the lower parts of the beds, and in the channels and pipes; and also to accumulation of solid matter in the neighbourhood of the outlet valves. On the other hand, the last part of the flow is exceptionally good, and therefore all the samples analysed are the average of the whole flow, spreading over an hour, and taken every ten minutes.

As a rule, the rough beds were found to keep back from 65 to 75 per cent. of the solids in suspension, and the filtrate shewed a purification of about 65 per cent. The filtrates from the fine beds shewed a purification on the crude sewage of from 75 per cent. to 95 per cent.

The solids in suspension in this final filtrate amounted to:—
3·51 grains per gallon when dealing with crude sewage.
2·19 „ „ „ „ screened sewage.
1·3 „ „ „ „ partially settled sewage,

and these differences account for the turbidity noticed in connection with the first flow while dealing with crude or screened sewage, and for the improved appearance of the effluent in dealing with partially settled sewage; and there can be no doubt that with thoroughly settled sewage admirable results would be obtained by double filtration.

From experience gained during over two years in treating Leeds sewage on contact beds, it was found that whether dealing with crude sewage, screened sewage, or partially settled sewage, variable but very good effluents could be obtained, much superior to those from lime precipitation. Their chemical analyses gave results which were generally well within the limit of one grain per gallon oxygen absorbed and ·1 of albuminoid ammonia; limits which have in recent years been accepted by the Lancashire and Yorkshire Rivers Boards as a provisional standard of purity for effluents going into a stream not used for drinking purposes.

OBSERVATIONS ON EXPERIMENTS.

The following are the average analytical results obtained over long periods, as detailed in the preceding pages:—

Table shewing the Average Analyses of the Crude Sewage and the various Filtrates from Nos. 1, 2, 3, 4, 5, and 6 Contact Beds.

Grains per Gallon.	Date.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed.	Nitrogen as Nitrates.
Crude Sewage	Oct. 27th, 1898, to Oct. 9th, 1899.	117·0	40·7	1·72	·809	8·04	—
Filtrate from Bed No. 1		75·3	11·5	1·09	·318	2·48	—
,, ,, No. 2		68·4	1·9	·318	·081	·50	·392
Percentage Purification effected by Bed No. 1		—	71 %	36 %	60 %	69 %	—
Percentage Purification effected by Beds Nos. 1 and 2		—	95 %	81 %	90 %	93 %	—
Crude Sewage	Nov., 1898, to June, 1900.	118·4	42·9	2·03	·964	8·80	—
Filtrate from Bed No. 3		82·3	12·6	·920	·289	2·07	—
,, ,, No. 4		73·0	3·3	·581	·108	·655	·261
Percentage Purification, Bed No. 3		—	70 %	54 %	70 %	76 %	—
Percentage Purification, Beds Nos. 3 and 4 ...		—	92 %	71 %	88 %	92 %	—
Crude Sewage	Mar., 1899, to Nov., 1899.	124·8	46·8	2·02	·997	9·12	—
Filtrate from Bed No. 5		81·9	13·7	1·23	·397	2·91	—
,, ,, No. 6		71·5	3·3	·666	·141	·790	·127
Percentage Purification, Bed No. 5		—	70 %	39 %	60 %	68 %	—
Percentage Purification, Beds Nos. 5 and 6 ...		—	92 %	67 %	85 %	91 %	—

OBSERVATIONS ON EXPERIMENTS.

These results were obtained notwithstanding the large volume and variety of trade effluents mixed with Leeds sewage. The chief difficulty occurred in connection with large quantities of iron liquor (ferrous sulphates and chlorides) coming down in this sewage, and representing as much as five tons of metallic iron per 24 hours. Generally a large part of this iron was retained by the beds, but at times, especially in summer, some of it came through in solution and afterwards settled out as a buff-coloured flocculent hydrated ferric oxide.

Aeration.

The final effluent evidently contained abundant dissolved oxygen, for it was found to support fish life; coarse fish, such as carp and gold fish living in it for long periods, some of them for over 2½ years; while there was much green growth in the basin and channels. Mention may be made of Vaucheria, an alga which grows in swift flowing and therefore well aerated streams. The usual pond life was also represented in great variety in the basin, including larvæ of Chironimus, Nais, Cyclops, small worms, &c. In the body of the filter were earth worms and great numbers of Podura aquatica. These evidences of aeration are a special and valuable feature of biological effluents, which, unlike the effluents from chemical precipitation, are rarely liable to subsequent putrefaction, but on the contrary contain elements of further purification, and improve on passing to the streams.

Incubation.

It was found that new beds required about six weeks to get into condition, the early effluents being unsatisfactory and putrescent; but at the end of this period a rapid and permanent improvement in the filtrate took place.

Process free from smell.

The process of treatment of sewage on these contact beds was found free from nuisance, and even on digging deep into the beds which had received sewage for long periods, there was no smell but that peculiar to garden soil. It was found that stray seeds falling on the coke beds led to luxuriant growth of grass and other plants.

In these experiments analyses never shewed any important percentage of Nitrates, which, indeed, only began to appear after two months' work, and never exceeded ·6 per gallon, the average being considerably less. This was probably due to the composition of Leeds sewage which includes readily oxidisable trade effluents.

OBSERVATIONS ON EXPERIMENTS.

Nitrification.

As bacterial action is only possible within a limited range of temperature, careful records were kept to determine if in cold weather the temperature of the beds was liable to fall below that limit.

Temperature.

An examination of these records shews that the temperature of the beds is determined by the sewage, and only in a very minor degree by the atmosphere. This is illustrated in the following table:—

Average Temperature of Sewage, Atmosphere, and Rough and Fine Dibdin Beds during a period of six months.

(Temperatures are in degrees F.)

Average Temperature from	Temp. of *Sewage* sent on to Rough Bed.	Rough Bed (No. 1).					Fine Bed (No. 2).				
		Temp. of *Atmosphere* at time of filling.	Temp. of *Bed* immediately before filling.	Temp. of *Bed* when full.	Temp. of *Filtrate*	Temp. of *Bed* when empty.	Temp. of *Atmosphere* at time of filling.	Temp. of *Bed* immediately before filling.	Temp. of *Bed* when full.	Temp. of *Filtrate*	Temp. of *Bed* when empty.
Dec. 17th to Dec. 30th, 1898	54·7	38·8	56·1	55·5	55·3	55·2	41·3	54·8	54·8	55·1	55·0
Dec. 31st to Jan. 13th, 1899	52·0	39·2	51·9	51·7	51·9	51·5	39·4	50·9	51·1	51·2	50·9
Jan. 14th to Jan. 27th, ,,	51·9	36·7	51·9	51·2	51·4	51·3	37·7	50·9	50·9	51·0	50·9
Jan. 28th to Feb. 10th, ,,	52·9	38·5	53·0	51·9	52·3	52·4	39·4	51·4	51·8	51·5	51·3
Feb. 10th to Feb. 24th, ,,	54·6	39·7	54·0	53·6	53·8	53·5	40·2	52·5	52·8	52·6	52·5
Feb. 25th to Mar. 14th, ,,	58·9	41·3	57·1	57·2	57·5	57·2	41·6	54·3	54·5	54·8	54·3
Mar. 15th to Mar. 25th, ,,	56·5	35·7	56·4	56·7	56·9	56·5	34·8	54·8	57·3	57·1	56·1
Mar. 26th to Apr. 8th, ,,	55·1	47·3	55·3	55·0	55·2	55·1	47·6	55·1	55·1	55·2	54·8
Apr. 10th to Apr. 21st, ,,	55·3	42·4	54·4	54·8	54·9	54·6	42·2	53·7	53·4	53·9	53·9
Apr. 22nd to May 6th, ,,	58·5	52·7	57·3	57·8	58·2	57·7	47·9	56·1	57·3	57·3	56·8
Average	55·0	41·2	54·7	54·5	54·7	54·5	41·2	53·4	53·8	53·9	53·6

OBSERVATIONS ON EXPERIMENTS.

It will be seen that in the eight hours occupied in passing through both beds the loss of temperature from the sewage to the final effluent was only $1\frac{1}{2}$ degrees. During periods of rest the heat in the beds rose to 70 and 80 degrees.

During the past few years the winters have not been severe, and it was only during last winter that any valuable data bearing upon this subject could be collected. They shew that during fairly cold winters the purification effected by this process of contact filtration is not appreciably checked.

Loss of Capacity of Beds.

The process then was reliable to give satisfactory effluents, and the real difficulty was found to be the impossibility of maintaining the capacity of the rough beds except with such a slow rate of work, that the area of rough beds required would be very costly.

Causes of Loss of Capacity.

The loss of capacity was due to the following causes, some of which are remediable, and others not:—

1. *The passing of sand, coal dust, and road detritus into the bed.*

   These matters must be kept out, for bacterial action cannot reduce them. The sewage must be passed first through a grit tank at such speed that only the heavier matters, with some of the grosser organic solids, are left behind.

2. *The degradation of the material of the filter.*

   It is found that coke, though at first carefully sorted to larger size, soon becomes broken down. No doubt this arises to a less extent with clinker, which, however, is apt to take the form of slabs, and is not very suitable for a coarse bed. Burnt ballast is very liable to reduction.

3. *The consolidation of the material of the bed.*

   As pointed out in connection with the single contact beds, Nos. 7 and 8, the loss of capacity in those cases

TABLE SHEWING EFFECT OF FROST UPON THE BEDS.

(Temp. = °F.)

DATE. Fortnight ending	State of Weather.	Rough Bed (No. 3).						Fine Bed (No. 4).					Percentage Purification as calculated on Alb. NH_3 Test.	Percentage Purification as calculated on Oxygen absorbed Test.
		Temp. of Sewage.	Temp. of Atmosphere.	Temp. of Bed before filling.	Temp. of Bed when full.	Temp. of Filtrate.	Temp. of Bed when empty.	Temp. of Atmosphere.	Temp. of Bed before filling.	Temp. of Bed when full.	Temp. of Filtrate.	Temp. of Bed when empty.		
Dec. 8th, 1899 ...	No Frost	58·9	45·5	56·3	57·2	56·7	55·9	45·5	54·8	54·8	54·6	54·5	90 %	93 %
Dec. 8th to Dec. 29th	Frost	53·1	31·2	49·8	49·8	49·4	49·2	31·9	47·4	46·1	46·1	46·0	91 %	92 %

was largely due to this cause. The material of a bed must be of very even size, or gradually the smaller pieces, by the slight movement due to filling and emptying, tend to fit themselves in between the larger, so as to approximate to a solid mass. As we have seen, even equal sized material in course of time becomes broken down into unequal, and so consolidation takes place.

4. *More organic solids coming on to the bed than the bed can digest.*

Fibre and certain vegetable matters are very slowly dissolved, and tend to accumulate in the beds, unless the rate of working is very slow. The screening-off of some of these matters can be accomplished within reasonable cost.

5. *The presence in the sewage of matters which cannot be reduced by bacterial action*, other than the sand and road detritus which it is suggested can be settled in the grit tank.

Whether such matters exist in the sewage in an originally irreducible form, or whether such irreducible form is reached as a result of change in the bed, it is difficult to determine. But it is certain that a coarse bed which has been long at work is found to contain a large quantity of matter akin to humus or garden soil, and which cannot be further reduced. The same result was found in connection with the deposit in septic tanks and the suspended solids in their effluents.

6. *The retention in the bed of mineral solids originally in solution, but which, by the oxidising action of the beds, come into suspension:* as, for instance, the iron liquors containing ferrous sulphates and chlorides, a large part of which are found to be retained in the beds, the pieces of coke being often heavily coated with red iron deposit.

It may be said that such matters should be kept out of the sewers. This is easier said than done, and it is of course to the interest of Municipalities not to put difficulties into the way of trade; and the treatment of these liquors so as to deposit the iron before they are allowed to pass into the sewers would be a costly process for which many manufacturers have not land available.

OBSERVATIONS ON EXPERIMENTS.

When the experiments with No. 1 Bed were stopped, the material was taken out, and that coke only replaced which could not pass through 1½ inch mesh. This was found to only half fill the bed, so that what passed through 1½ inch mesh and was rejected, represented half the contents of the bed. Now a reference to Page 41 will shew that a careful examination of this rejected matter gave a volume of 45·25 per cent. as made up of broken up coke. Therefore, if a material could have been used not liable to degradation, probably one-third of the loss of capacity would have been avoided. 20·39 per cent. by volume of the remainder was true deposit, but contained 70 per cent. water. It had been to some extent dried or drained by the resting of the bed, and no doubt in working conditions the deposit would contain nearly 90 per cent. of water. Every grain of matter retained by the bed holds up 9 grains of water, so that the accumulation consists largely of water retained by the spongy matter. This matter itself, as shewn by the analysis on Page 42, was to the extent of 46·6 per cent. ferric oxide and sand, and 36·5 was organic matter.*

Analysis of Accumulations.

It is noteworthy that as the rough bed became choked, it became in effect a finer bed, and gave improved filtrates; but, on the other hand, it on that account more readily kept back solid matters, and towards the end the choking proceeded at a more rapid rate. If, when the capacity of the bed had fallen to 45,000 gallons, the rate of work had been reduced to one

(* See page 108 Appendix.)

OBSERVATIONS ON EXPERIMENTS.

filling a day, as was done when the capacity had fallen to 25,000, no doubt the No. 1 Bed might have gone on working very much longer.

It should be noted that the fine coke bed of the first series, No. 2, which has been working for 2½ years, has not given much cause for anxiety as to the maintenance of capacity. The clinker fine beds, Nos. 4 and 6, on the other hand, have been appreciably reduced in capacity, which may be due to consolidation brought about by the greater specific gravity of the clinker as compared with coke.

The general conclusion, then, in reference to the Leeds experiments with contact beds, is, that in the conditions at Leeds, and with the material used, it was found impracticable to deal with crude, or with partially settled sewage, not because good effluents could not be obtained, but because the capacity of the rough bed could not be maintained: and when accumulations arose, a large part of them having reached an irreducible stage, could not be consumed by resting the beds.*

If, therefore, contact beds are to be used for Leeds sewage in future, the problem will be:—

1. To find material of perfectly even size not liable to degradation.
2. To reduce as far as possible the solid matters put on to the rough bed.
3. To exclude and treat separately the iron liquors.

Another point suggests itself, whether it would be possible to construct the beds in such a way that the undigested or indigestible solids shall be expelled from the beds with the effluents. This suggestion is dealt with later in this Report in reference to experiments in continuous filtration.

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* See Tables of Capacity, Appendix.

Septic Tanks.

SEPTIC TANKS.

As it was found impossible to deal with crude sewage on contact beds without rapid sludging up of the rough beds, it was decided to try experiments with closed and open septic tanks, as a process preparatory to filtration, by which the bulk of the solids in suspension might be kept off the bed, and probably to a great extent be dissolved in the tanks.

No. 1 Open Septic Tank.

The first open septic tank was started on February 27th, 1899. It was one of the old precipitation tanks, and had an area of 6,000 square feet, an average depth of 7 feet 7 inches, and a capacity of 250,000 gallons. Sewage absolutely crude was sent into the tank by means of seven pipes, which delivered at a depth of 3 feet below the surface. The effluent was withdrawn by means of six pipes, which drew off the liquid at a depth of 2 feet below the surface.

Rate of Flow.

The flow of sewage through the tank was such that it would fill it in 24 hours, *i.e.*, the sewage was allowed to flow through the tank at such a rate that each particle might be supposed to take 24 hours for the passage.

Early Conditions.

At first an ordinary settlement of the suspended solids of the sewage took place, the effluent being in every respect similar to the effluent from the lime precipitation works. No real septic action took place in the tank until the end of April. Previous to this, only isolated and small bubbles were evolved, and no solid matters were brought to the surface. From the end of April to the end of May, 1899, the evolution of gas became more evident, and at the same time paper, wool fibre, matches, &c., rose to the surface, and collected in large floating patches, but no fine, black sediment could be seen.

Tank resting.

From May 30th to June 14th, 1899, in order to bring about septic conditions more rapidly, the flow was stopped, and the tank allowed to rest. During this rest it became much more

SEPTIC TANKS.

actively septic. Black sooty matter rose from the bottom with a violent evolution of gas, and then spread over the surface of the tank, some of it floating and carried to windward, forming a scum at one side of the tank. It was noticed that the colour of the liquid in the tank changed to a dark hue owing to the formation of sulphides of iron and the solution of some of the products of bacterial action. On re-starting the flow, this violent action abated within the first day, and the tank remained only moderately septic until the warmer days towards the middle of July. From July 10th to July 28th the surface of the tank was covered with a thin frothy scum, which was easily disturbed by winds. From the latter date this scum gradually became thicker until a thickness of nearly a foot was reached in September, 1899.

Decrease of Flow.

As it was found that more solids in suspension came out than were desired, the daily flow of sewage through the tank was reduced from August 14th to September 21st, 1899, to 125,000 gallons, in order to see if by this means the amount of solids in the effluent could be reduced. So far as could be determined in this short space of time, no alteration was produced, for on July 27th the suspended solids in the filtrate were 14·3, and on August 26th they were 14·2 grains per gallon.

Fluctuation of Solids.

On September 21st the flow was again increased to 250,000 gallons per day. From August to October, 1899, the effluent was very black, and contained a considerable amount of suspended matter. Towards the middle of October these solids decreased considerably in amount, and continued so until November, when the effluent again became black and turbid. From November 9th to November 13th the effluent was clear, but became turbid again on the 20th. These fluctuations of solids have continually occurred since then. No reason for these changes could be noticed, the evolution of gas being no greater when these flushes occurred.

Analyses of Suspended Solids in Sewage, and Septic Tank Effluent.

Date.	Suspended Solids in Crude Sewage (Grains per Gallon).	Date.	Suspended Solids in Effluent from Open Septic Tank (No. 1). (Grs. per Gall.)
Mar. 22nd, 1899	48·3	Mar. 13th, 1899	11 9
April 5th, ,, ...	36·5	April 5th, ,, ...	2·9
,, 19th, ,, ...	37·6	,, 17th, ,, ...	6·6
May 4th, ,, ...	35·7	May 4th, ,, ...	15·3
June 1st, ,, ...	42·5	July 13th, ,, ...	6·9
July 14th, ,, ...	39·3	,, 27th, ,, ...	14·3
,, 26th, ,, ...	46·0	Aug. 26th, ,, ...	14·2
Aug. 28th, ,, ...	58·8	Sept. 26th, ,, ...	15·4
Oct. 3rd, ,, ...	41·8	Oct. 12th, ,, ...	4·4
,, 24th, ,, ...	69·5	Nov. 12th, ,, ...	28·2
Nov. 16th, ,, ...	59·5	,, 29th, ,, ...	15·1
Dec. 14th, ,, ...	35·5	Dec. 26th, ,, ...	12·8
Jan. 9th, 1900	50·6	Jan. 30th, 1900	12·5
Feb. 13th, ,, ...	40·0	Feb. 22nd, ,, ...	7·6
Mar. 6th, ,, ...	36·6	Mar. 5th, ,, ...	12 3
,, 21st, ,, ...	25·9	,, 15th, ,, ...	8·1
April 30th, ,, ...	50·5	,, 24th, ,, ...	16·4
May 28th, ,, ...	44·9	Apr. 2nd, ,, ...	17·8
		,, 24th, ,, ...	18·5
		May 7th, ,, ...	21·7
		June 11th, ,, ...	12·1
Average	44·4	Average	13·1

Towards the middle of December, 1899, the scum became much thinner, owing, no doubt, to the advent of cold weather. During the sharp frost from February 2nd to February 15th, Effect of Frost.

SEPTIC TANKS.

1900, this scum was frozen so hard at the outlet end of the tank as to easily bear the weight of a person walking upon it. Upon several occasions this frozen scum was raised up into a dome by the accumulation of gas beneath it. As the frost did not penetrate deeper than this scum, it would appear that this surface layer is a bad conductor of heat, and so to some extent would help to conserve the heat of the sewage during cold weather. During the month of February, 1900, the average amount of heat lost by the passage of the sewage through this tank was only 1·6° F. Since this last period of frost the scum became much thinner, and not so coherent.

Increase of Solids in Effluent.

Analyses of the effluent shew that the amount of suspended solids in the effluent became greater the longer the tank was worked :—

March to June, 1899	= 9·1	grains per gall.,	suspended solids.
July to October, „	= 11·0	„	„
Nov., 1899, to Feb., 1900	= 15·2	„	„
March to June, „	= 15·2	„	„

This fact points to the necessity of removing from these tanks periodically some of the accumulation, part of which is incapable of being further split up into gases and soluble solids. As yet nothing has been removed, and there is no experience as to the offensiveness, or otherwise, of septic sludge in drying.

Purification effected.

Average of all analyses referring to No. 1 open septic tank from February, 1899, to January 15th, 1900:—

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen absorbed (4 hours 80° F.).
Crude Sewage	120·8	44·4	2·15	1·02	9·08
Septic Tank Effluent (No 1) ...	77·6	13·1	1·83	·455	4·18
Purification effected	—	70 %	14 %	55 %	53 %

The increasing proportion of solids in suspension coming out of the tank in the effluent pointed to the gradual accumulation of sludge. If the flow had originally been regulated to fill the tank in 24 hours, so that particles should take 24 hours for their passage through it; and if now, after 16 months working the tank was half full of sludge, then evidently the water capacity was reduced to half, and the flow was really a 12 hours' and no longer a 24 hours' flow.

Estimation of Sludge in Tank.

A bridge had been provided over one corner of the tank, from which to gauge the tank with a rod as far as possible from the edge. It was found that the rod passed down with scarcely appreciable resistance, and that the concrete bottom could be readily tapped with it. On bringing it out it bore the marks of black sludge for about one-third depth, with lighter sludge above. It was felt that no reliable estimation of the solids in the tank could be got from this measurement, the density of the sludge at different depths being unknown. The following method of calculation was therefore adopted.

Amount of Sludge digested.

From the volume of the sewage treated the amount of suspended matter which it contains, the amount of suspended matter present in the effluent, and the amount of insoluble solids actually present in the tank, it is possible with fair accuracy to gauge the amount of solids which have been converted into gases and soluble substances by the action of this septic tank.

In order to find the amount of solid matter in the tank, 12 sections of the tank were taken at the four corners and at equal distances around the sides by means of a long glass tube one inch internal diameter, passed very slowly down to the bottom and then corked. These samples amounting together to over six gallons were thoroughly mixed together, and the amount of solid matter estimated. This gave a proportion of 5,587 grains of suspended matter to the gallon

SEPTIC TANKS.

and this number multiplied by the volume of the tank, 250,000 gallons, gives the amount of solids actually present in the tank = 1,396,750,000 grains, or 199·535 lbs. From the table given above it is evident that out of every 44·4 grains of suspended matter in the sewage 31·3 grains remain in the tank. Therefore the amount of matter deposited in the tank per day will be 31·3 multiplied by 240,000 gallons, which is the average of the daily flow over the whole period = 7,512,000 grains, or 1,073 lbs., and this multiplied by 432 days, from February 27th, 1899, to June 15th, 1900 (less stoppages), gives as the total deposited in the tank ... ... 463,536 lbs.
And as on June 15th, 1900, we had in the tank ... 199,535 „

It follows that there had been digested ... ... 264,001 „
or 56·9 per cent. of the suspended matters deposited in the tank, and this represents 40·1 per cent. of the suspended matters in the crude sewage.

It will be seen therefore that the open septic tank accomplishes the mixing and equalising of the sewage—which is an important advantage for the subsequent process—and digests a considerable amount of the solid matters, so that the sludge production will be to that extent reduced. The tank should not be emptied, but arrangements should be made from time to time to draw off some of the sludge from the bottom. Considerable quantities of suspended solids come out with the effluent.

Open Septic Tank, No. 2.

The second open septic tank has an area of 6,000 square feet, an average depth of 7 feet 7 inches, and a capacity of 250,000 gallons. Crude sewage was allowed to flow into the tank by means of seven pipes, which delivered at a depth of three feet below the surface. The effluent was withdrawn by means of 32 pipes, at a depth of one foot below the surface. These pipes in turn deliver into a long narrow channel running along the side of the tank, and from which the effluent flows in a thin stream over a long lip. This arrangement was made with the intention of obviating wire-drawing within the tank.

SEPTIC TANKS.

Rate of Flow.

The tank was first filled with crude sewage on April 28th, 1899, when a current of sewage equal to 125,000 gallons per day was sent through the tank. On May 12th this was increased to 250,000 gallons per day, which would fill the tank in 24 hours.

Early Conditions.

From the beginning of May until the middle of June, 1899, the septic action was very feeble, but towards the end of June matters were thrown up from the bottom, and on July 11th had accumulated to such an extent that half the surface of the tank was covered with a thick brown scum. On July 17th this thick scum had given place to a thinner but more uniform scum, which covered the whole of the surface, whilst bubbles of gas and black sooty matter were continually breaking through it. From this point the scum gradually thickened until at the end of July it had reached a thickness of 5-6 inches.

Part of Scum removed.

On October 30th, 1899, 6 square yards of the scum were removed experimentally. The matter removed was quite spadeable, and was in a condition to be at once carted away. When dried it was found very full of fibre. By November 4th a new scum was beginning to form on this cleared space, and by November 22nd it was as thick as the scum covering the rest of the tank.

On December 18th, 1899, as it was desired to see the effect of a slower flow through a septic tank, the flow was reduced to 125,000 gallons a day, which would fill the tank in 48 hours, so that each particle may be supposed to take 48 hours to pass through. This rate of flow has been continued up to the present, and analyses made upon this effluent have so far shewn that this reduction of flow has had very little effect upon the quality of the effluent produced.

SEPTIC TANKS.

This will be referred to again in the general observations upon the septic tanks. Since February, 1900, the scum upon the surface of the tank has become quite earthy in character, mosses and grasses growing upon it. Like Tank No. 1 the amount of suspended matter in the effluent fluctuates very much.

No. 3 Open Septic Tank.

The construction of the third septic tank is similar in every respect to No. 2 tank.

Rate of Flow.

This tank was started on May 3rd, 1899, a flow of 125,000 gallons of crude sewage being at first sent through it every 24 hours. On May 12th, 1899, the rate of flow was increased to 250,000 gallons per day.

Towards the end of July, septic conditions appeared, large volumes of gas being evolved, but no scum was formed. On August 19th the surface of the tank was covered with patches of paper, &c., connected together with a thin frothy scum. This scum gradually increased in thickness until the former part of September, 1899, it had an appearance similar to that on the other tanks.

As the No. 1 tank was working at the 24 hours' rate, and No. 2 at the 48 hours' rate, it was decided to work No. 3 at a 12 hours' rate, which was begun on December 18th, 1899, when the daily rate of flow was increased to 500,000 gallons. The change immediately caused the effluent to become worse in every respect, much more suspended matter being present than formerly. At the same time the scum gradually became much thinner.

During May, 1900, the scum gradually thickened again until it was stronger than that in No. 1 tank, but not so strong as that in No. 2.

Septic Tanks in series Nos. 4, 5, 6, and 7.

A further experiment was made with open septic tanks working in series, four of the newly constructed precipitation tanks being used for this purpose. Their collective capacity was 2,000,000 gallons, and the flow of sewage was regulated at 2,000,000 gallons per 24 hours, the whole flow passing through the first tank, and in succession through the series. The sewage was taken from Nos. 1 and 2 precipitation tanks, so that all the grit and some of the grosser solids were there first settled.

It was anticipated that working in series the greater part of the sludge would be retained by the earlier tanks, and that the effluent passing from the last tank would be more free from solids in suspension than the effluent from tanks acting independently. Work was started on June 12th, 1899, and before two months were completed the experiment was necessarily stopped on August 4th, because the first tank of the series was absolutely choked with very heavy sludge, some of it rising in islands above the water level, leaving channels through which the sewage flowed forward to the other tanks. No septic action had arisen in the first tank, though a few bubbles began to rise in the others.

The flow being at a rate to fill the above series of tanks in 24 hours, the flow through the first was at four times that rate, and the settlement was so rapid that the first tank became full before even septic conditions had arisen. As it was inconvenient at the time to deal with so large a volume of sludge, the tank was not emptied, but was left resting until it would be possible to deal with it. At the end of a month it was found that the accumulations had become levelled, that a scum had formed, and that a slow septic action had developed. The experiment was then tried of allowing a small flow from one of the active septic tanks to go into this choked tank, to see if septic action could be hastened, and the accumulation could to any extent be digested. As a result, very active fermentation took place, violent evolutions of gas, and a thick scum being formed.

SEPTIC TANKS.

After a fortnight this septic flow was replaced by a small flow of sewage of 50,000 gallons a day. The resultant effluent was very offensive, in fact worse than Leeds sewage, the thick deposit became thinner, a very active evolution of gas continued, and, no doubt, as the sludge became thinner, much of it passed away in the effluent to the other tanks. After a month the flow of sewage at the 24 hours' rate was resumed, and has since been continued, and nothing has been removed from either the first choked tank or the later ones.

The sludge now in the front tank is of normal depth, and the effluent similar to that from the other septic tanks.

The later tanks of the series, receiving less sludge, have thinner scums, and the scum of the last one is very thin indeed, only spreading after 12 months over a part of that tank, but suspended solids in the effluent are not reduced.

Closed Septic Tank.

The closed septic tank, constructed upon designs submitted by the Septic Tank Syndicate, of Exeter, consists of two rectangular tanks, 54 feet long by 10 feet broad, and a depth of 9 feet at the deepest point. Both are covered in by brick-work arches. The mean water level in the tanks is about 6 feet 6 inches from the bottom of the tank. These two tanks together will treat 40,000 gallons of crude sewage per day. On June 6th, 1899, they were filled with sewage from which the grit had been settled, and were allowed to stand full until June 9th, when a continuous current of 40,000 gallons per day of sewage was sent through them at the 24 hours' rate.

By June 18th septic conditions had developed, the effluent being dark in colour, whilst a large number of small bubbles were continuously arising from the liquid in the tank. The surface was covered with a thin frothy scum. These conditions became more and more developed until a maximum was obtained on August 16th, 1899, and the surface became covered with a very thick layer of fibre, &c. This surface layer is similar in composition to that on the open tanks, but very light brown in colour. Since August, 1899, no appreciable change has taken place. SEPTIC TANKS.

Average of Analyses referring to the Closed Septic Tank. Purification effected.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hrs., 80° F.).
Crude Sewage	120·2	45·4	2·34	1·13	9·64
Effluent from Closed Septic Tank	77·9	12·8	1·87	·437	4·82
Purification effected	—	71%	20%	61%	50%

The effluent from the closed septic tank passes over six filter beds. Four of the beds are filled with fine coke, and two with fine clinker about half inch in thickness. Of the six beds, only five are in use each day, so that the beds are allowed to rest in rotation for one day in six. Eight beds are filled every 24 hours, three of the beds receiving two fillings, and two only one filling, during that period ; so that, taking the day's rest into account, the beds average 1⅓ fillings per 24 hours. The process of filling and discharging is brought about by means of an ingenious automatic gear, actuated by an arrangement of buckets and syphons. The septic tank effluent is distributed over the beds by three channels running across the filter, and collected by drains laid on the bottom.

These beds were permanently started on September 22nd, 1899, but were only allowed to work during the day. From October 5th, 1899, the process has been carried on throughout the 24 hours.

The filtrates obtained at first were dark coloured and very opalescent, and continued so until November, when an improvement took place, although the filtrate, when seen in

SEPTIC TANKS.

bulk, was very dark coloured. Since then there has been little change noticed in the character of the filtrates, which, however, are non-putrefactive.

Purification effected.

ANALYSES REFERRING TO PERIOD FROM SEPTEMBER 22ND, 1899, TO JUNE 24TH, 1900.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen absorbed (4 hours 80° F.).	Nitrogen as Nitrates.
Septic tank effluent ...	77·9	12·8	1·87	·436	4·82	—
Filtrate from Beds ...	17·9	3·1	·988	·157	·953	·242
Percentage purification on septic effluents ...	—	75 %	47 %	64 %	80 %	—

This is a purification of 86 % upon the crude sewage in Alb. NH_3, and 90 % in oxygen absorbed.

Reduction of Capacity.

DATE.	CAPACITY IN GALLONS.					
	Bed No. 1.	Bed No. 2.	Bed No. 3.	Bed No. 4.	Bed No. 5.	Bed No. 6.
Sept. 22nd to Sept. 29th, 1899	4,770	5,750	5,810	5,240	5,200	4,890
Oct. 23rd to Oct. 26th, ,,	4,680	4,980	5,140	4,770	4,940	4,350
Nov. 27th to Dec. 2nd, ,,	4,220	4,600	4,670	4,420	4,450	3,900
Jan. 1st to Jan. 6th, 1900 ...	4,350	4,700	4,700	4,350	4,520	4,030
Jan. 29th to Feb. 3rd, ,, ...	4,250	4,580	4,660	4,220	4,450	4,000
Mar. 5th to Mar. 10th, ,, ...	4,270	4,490	4,610	4,340	4,350	3,980
Apr. 9th to Apr. 16th, ,, ...	4,230	4,380	4,460	4,630*	4,770*	4,310*
May 7th to May 12th, ,, ...	4,190	4,298	4,370	4,530	4,450	4,170
June 11th to June 16th, ,, ...	4,050	4,090	4,300	4,370	4,330	4,140
Total decrease in Gallons...	720	1,660	1,510	870	870	750

* Surface forked previous to test.

OBSERVATIONS UPON SEPTIC TANKS.

The total capacity of the six beds at starting was 31,600 galls.
At the end of three months it was on Jan. 1st, 1900, 26,650 „
„ nearly six months more on June 16th, „ 25,280 „

so that the capacity fell in the first three months by 5,010, or about one-sixth, but during the next six months it only fell by 1,370 galls., and at present the beds shew 80 % of their original capacity after nine months' working, with $1\frac{1}{3}$ fillings.

General Observations upon Septic Tanks.

When a septic tank is first started, a simple deposition of the suspended matters occurs, the effluent obtained being in reality only settled sewage. Soon, however, a fermentation of the deposited solids takes place, and a large volume of gaseous products is evolved. The period elapsing between the starting of the tanks, and the occurrence of the phenomenon, varies with the state of the weather, being shortest in Summer. This evolution of gas gradually increases until sufficient has accumulated in the deposit to raise large portions of the latter to the surface of the liquid, where part of them remain supported by gas. These, exposed to the air and sun, become dried on the surface and hardened. They accumulate at first to the windward of the tank, and gradually spread over the whole surface; corks, matches, and the lighter matters forming part of the mass, which, during the hot summer months often attains in parts to a thickness of over one foot. During the winter months, and especially immediately after periods of severe frost, this surface layer shews a decided tendency to become thinner.

Whilst these changes have been taking place in the contents of the tank, the character of the effluent obtained has also altered. At first the outflow has all the characteristics of settled sewage, and at Leeds is yellow in colour owing to the presence of iron. As the putrefaction of the sediment in the tank proceeds, the effluent becomes darker coloured and almost black, and somewhat offensive owing to the solution of

OBSERVATIONS UPON SEPTIC TANKS.

some of the products of bacterial action, and the production of sulphides of iron.

The gases evolved are inflammable, and no doubt with a sufficient area of *covered* septic tanks, they might be used for heating and lighting purposes.

The question whether septic tanks should be closed or not, is of importance in view of the considerable extra cost of roofing them in. The advantages claimed for closed tanks are :—

1. That the roofing excludes the air from the surface and promotes better anærobic conditions.

2. That the resultant gases are under control, and can be utilised for lighting or heating.

3. That evil odours are prevented from escaping.

4. That the heat of the sewage is better maintained.

The experience of Leeds shews that whatever results were obtained from the closed septic tanks were equally well obtained by the open, and that the scum which forms on septic tanks, itself soon gives a cheap automatic roof, which is chiefly of value in preserving the heat in the sewage, the floating surface being a bad conductor.

It was found that the average loss of heat of the sewage in passing through the open septic tanks was 1·6° F., while through the closed, it was ·8° F., and the difference is too small to warrant the expense of a roof on this account.

The heating value of the gases is not great, and the roofed-in septic tanks are really gas holders, and except under proper care, may become a serious source of danger.

In the open septic tanks, the gases produced are at once dispersed. For the most part they are inodorous, no appreciable nuisance having arisen, though the effluent itself is more or less offensive. But Leeds sewage is diluted and mixed with trade effluents, and no doubt where strong domestic sewage is being treated, greater nuisance may arise, and the roofing become necessary.

OBSERVATIONS UPON SEPTIC TANKS.

In appearance the effluents obtained from the open and closed septic tanks were identical, whilst from a chemical point of view no distinct difference can be detected.

AVERAGE OF ANALYSES REFERRING TO EFFLUENTS FROM OPEN AND CLOSED SEPTIC TANKS.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hrs., 80° F.).
Effluent from OPEN Septic Tank (No. 1)	77·6	13·1	1·83	·455	4·18
Effluent from CLOSED Septic Tank (No. 1)	77·9	12·8	1·8	·437	4·82

By the putrefactive changes taking place in these tanks, a fair proportion of suspended matters present in Leeds sewage (it was 40% in No. 1 open septic tank) can be transformed into gases and soluble solids. Part is carried forward by the effluent, and is further treated upon the various filters, and part is left behind in the tanks, and there accumulates.

An analysis of the dry sludge in No. 1 Septic Tank shewed a loss on ignition of 55·4 per cent., leaving an ash of 44·5 per cent., of which 34·8 per cent. was ferric oxide, and 47·1 per cent. silica, so that nearly half of it is in a form not further reducible by bacterial action.

From time to time some of the sludge will have to be removed, but it is desirable to do so without the necessity of emptying the tank, and having to start septic action *de novo*, a process which takes several months to develop. Since there must be from time to time a removal of some of the matters in a septic tank, and since possibly some difficulty may arise from the

OBSERVATIONS UPON SEPTIC TANKS.

offensive character of the septic sludge, it may be well to work septic tanks in series. In that case, as previous pages shew, if the flow is at the 24 hours' rate through four equal tanks, it will be at four times that rate through each, and consequently there will be such rapid settlement of the heavier solids in the first tank, that it will be full before septic action arises there to any important extent. If this first tank therefore is in duplicate, it might be emptied altogether from time to time, and if it is also used as a grit tank, the sludge will be dense, with a relatively small proportion of water, and in a condition less offensive than that of the thin black septic sludge.

A point of great importance to settle is the question as to which rate of flow through these tanks gives the best results. With the intention of obtaining some data bearing upon this subject, experiments previously detailed were instituted with three tanks, similar in every respect, through which sewage was passed at rates which would fill the tanks in 12, 24, and 48 hours. These experiments have not been in progress for a sufficient length of time to allow of any definite statement being made, but so far, it would seem as if any increase of flow above what is sufficient to fill the tank in 24 hours is attended with a corresponding decrease in the quality of the effluent, whilst a reduction of speed to the 48 hours' rate gives very little advantage. If the flow is increased too much, the tank will become filled with sludge before septic action is produced.

Average of Analyses referring to the Effect of Different Rates of Flow through Open Septic Tanks.

Grains per Gallon.	12 hours' Flow.	24 hours' Flow.	48 hours' Flow.
Total Solids in effluent	88·0	78·2	78·6
Solids in Suspension in effluent ...	19·6	11·5	10·9
Free Ammonia	1·41	1·50	1·55
Alb. ,, ...	·502	·348	·377
Oxygen absorbed (4 hrs., 80° F.) ...	5·71	4·37	4·27

OBSERVATIONS UPON SEPTIC TANKS.

It has previously been stated that sulphide of iron is present in the effluent from the Leeds septic tanks, and this would lead to the supposition that a large amount of iron is precipitated in the tanks and remains there. Analysis shews, however, that only 30 per cent. of the iron in the sewage remains behind, whilst effluents have been obtained in which as much as 40 per cent. of the total iron is in solution.

Briefly, the advantages found in the use of septic tanks were :—

1. The production of a practically uniform effluent from sewage of such varying composition as that of Leeds.
2. The digestion of part of the solids in suspension, which at Leeds amounted to about 40 per cent. of those originally in the sewage.
3. The anærobic putrefaction which takes place in the septic tank facilitates subsequent filtration, rendering the filtrate less liable to secondary putrefaction.

Whittaker Beds.

Whittaker Bed, No. 1.

Councillor Whittaker, the chairman of the Accrington Sewage Committee, having brought under the notice of the Leeds Committee the advantages of continuous filtration following on septic treatment, a bed on his system was constructed for experimental purposes at Knostrop.

Construction.

The bed is circular, and not having to stand any pressure of water, is merely surrounded with wood laths kept together by iron bands. Within this light screen the clinker is piled up. The bottom consists of a circular layer of concrete, having an 18 inch collecting drain running along one diameter, and which has a fall of 1 in 45. This drain forms the main carrier for the filtrate, and is perforated on the half with small holes, and with larger holes in the sides into which 9 inch pipes run, having a fall of 1 in 22 to the larger pipe.

WHITTAKER BEDS.

These smaller pipes are also perforated half round with small holes. Between these pipes cement is placed to the level of the lowest perforations, so as to prevent the stagnation of the filtrate.

A manhole rises vertically from the centre of the bed, having a diameter of 6 feet and a height of 10 feet 6 inches, formed of open brickwork.

The clinker was between 3 inches and 1 inch, except around the manhole and the extreme circumference, where a layer of very coarse clinker is placed.

Effluent obtained from the No. 1 open septic tank was pumped by means of a pulsometer to the Whittaker rotating sprinkler, and by it distributed in a shower over the whole surface.

The bed was started on March 9th, 1899, at the rate suggested by Mr. Whittaker, of 100,000 gallons per 24 hours, *i.e.*, at the rate of 3,000,000 gallons per acre per 24 hours. The first filtrates were exceedingly bright and clear, due no doubt to the suspended solids being at first retained by the bed, but the filtrate gradually became turbid. As the turbidity increased the analyses also gave worse results, *e.g.*: The average of the analyses on March 9th and 12th, 1899, was ·15 Alb. NH_3 and ·97 oxygen absorbed. As solids began to work out of the filter the results became worse, until on March 28th the analyses, including the solids in suspension, gave ·246 Alb. NH_3, and 1·66 Oxygen absorbed.

Surface clogging.

On March 24th the top layer of the filter was covered with a deposit of iron, and the bed began to show signs of surface clogging, pools of water being formed upon it. On April 4th, 1899, the number of pools had increased so that the sewage began to run down the centre manhole and the sides. The flow was therefore reduced to 33,000 gallons per day, in order to see if this reduced quantity could be taken in. No improvement arising, two of the four arms of the sprinkler were stopped in order to make the sprinkling more intermittent. But still the effluent gathered in pools on the surface, though the reduced work given to the filter gave improved results, on April 9th ·102 Alb. NH_3 and ·337 Oxygen absorbed. WHITTAKER BEDS.

The bed was now allowed to rest from April 13th to April 17th, 1899. This rest allowed the surface to drain dry, but did not prevent the liquid pooling upon the surface on re-starting the bed. The filtrate obtained on the 17th was very good, containing ·77 Nitrogen as Nitrates, but from that date decreased in quality until May 8th, 1899, when it contained ·26 Alb. NH_3 and ·775 Oxygen absorbed, whilst only a trace of nitrates were present. Bed resting.

This falling-off in the results was due to the surface being covered with an abundant gelatinous mycelium-like growth (Pylobolus), which prevented the effective æration of the filter. Surface clogged with a growth.

On May 8th the surface was removed to a depth of one foot in order to expose a new surface, it having been noticed that the growth did not extend to more than a few inches. On re-starting on May 9th, 1899, the filtrates were very clear and good, and continued so until May 18th, when, owing to the surface again clogging, the results again became unsatisfactory, *e.g.*, Alb. NH_3 = ·19; Oxygen absorbed = ·842. Surface removed.

On May 20th, 1899, the bed was stopped and allowed to rest until May 24th. This rest only produced a slight improvement in the filtrate and very little alteration to the surface clogging. Beds resting.

Mr. Whittaker's idea was that heating of the sewage as it goes upon the bed was not only valuable at all times, but absolutely essential in cold weather, and that it was within Injection of Steam.

WHITTAKER BEDS.

practicable limits of cost, because he claimed to require a greatly reduced area of filter, with heated sewage. The condensed steam of the pulsometer, mixing with the sewage increased its temperature, and at Mr. Whittaker's desire steam was in addition directly injected. It was found that this increased the temperature of the septic effluent from 59° at which it left the tank, to 72·5. It was considered quite too costly to do this on a large scale, and as the growth on the surface of the bed appeared to be promoted by the heated effluent, the use of injected steam was discontinued, and it was found that by the pulsometer alone, the heat of the septic effluent put on the bed was raised from 59° to 67°—about 8 degrees. This is not necessary during the warmer months; but with an unroofed open bed, worked on the continuous principle, there may be difficulty in winter weather.

Effects of rest.

On May 30th the process was stopped, and the bed allowed to rest until June 13th, 1899, when it was re-started at a rate of 50,000 gallons (*i.e.*, 1,500,000 gallons per acre) per 24 hours. The filtrates first obtained were very clear and good (Alb. NH_3 = ·08; oxygen absorbed = ·344), whilst a large amount of nitrates had been produced during this rest, as was evinced by the fact that the average sample for June 14th contained 3·5 grains per gallon of nitrogen as nitrates. The surface of the bed remained perfectly free from clogging until June 18th, and on June 26th, 1899, it became necessary to fork the surface. It was noticeable that this forking, by opening out the surface, and the better aeration of the bed, caused better filtrates to be produced. This improvement continued until the surface of the bed again became clogged. It was therefore evident that for the production of good effluents it was necessary to keep the surface open.

Surface covered with Coarse Coke.

As the clogging was due to a vegetable growth, which did not penetrate into the bed more than a few inches, it was decided to cover the surface of the bed, after thoroughly forking, with a layer, of one foot in thickness, of exceedingly coarse coke, which it was thought the growth would not choke. This was done on July 10th, 1899. A great improvement in the quality of the filtrates was produced, as shewn by the great increase of nitrates, *e.g.*, on July 8th the nitrogen present as nitrates was ·49, and on July 13th ·756. The filtrate continued to be clear from July 10th to July 30th, but from the latter date, large quantities of brown suspended matters came out from the bed, causing the values obtained from the Alb. NH_3 and oxygen absorbed tests to rise considerably. The Free NH_3, however, remained very low (about ·2), whilst the N as nitrates remained over ·7 grains per gallon, shewing that the aeration of the bed was not being interfered with. The coming through of these solids in suspension in the filtrate was at first very disappointing, and was looked upon as condemning the system. Further experience, however, has shewn that a large part of these solids are irreducible, and, therefore, if they do not come out, but stay behind in the filter, they must necessarily choke it up. They were soon found to be non-putrescible, and to be readily settled.

Surface again clogged.

On October 3rd, 1899, the surface being again clogged, notwithstanding the fact that it consisted of coarse coke, the bed was allowed to rest for 24 hours. This produced no change, and, therefore, from October 4th to October 11th, 1899, the bed was allowed a further rest. This rest not producing any appreciable result, the whole surface was thoroughly forked over.

Flow reduced.

On December 20th, 1899, the flow was further reduced to 250 gallons per square yard, *i.e.*, to 1,250,000 gallons per acre, this being the slowest rate at which the sprinkler could be kept rotating.

Effect of Frost.

During the winter of 1899-1900, there were two severe periods of sharp frost, from December 9th to December 29th, 1899, and from February 2nd to February 15th, 1900. During

WHIT-TAKER BEDS.

both of these periods, although the outside of the bed was covered with icicles, it was found that the purification was not materially affected, because by the action of the pulsometer pump the temperature of the effluent going on to the bed was kept a few degrees above that of the sewage.

Grains per Gallon.	State of Weather.	Septic Tank Effluent.			Filtrate from No. 1 "W." Bed.				Percentage Purification.	
		Free. NH_3.	Alb. NH_3.	Oxygen Ab-sorbed.	Free. NH_3.	Alb. NH_3.	Oxygen Ab-sorbed.	Nitro-gen as Nitrates	In Alb. NH_3.	In Oxygen Ab-sorbed.
Nov. 24th to Dec. 8th, 1899	No Frost	1·47	·383	4·45	·800	·116	·730	·476	69 %	83 %
Dec. 9th to Dec. 29th, ,,	Frost	2·13	·481	4·36	·967	·129	·731	·283	73 %	83 %
Jan. 18th to Feb. 1st, 1900	No Frost	1·60	·463	4·10	·507	·075	·523	·597	83 %	87 %
Feb. 2nd to Feb. 15th, ,,	Frost	1·77	·442	4·46	·718	·111	·688	·731	74 %	84 %

Bed Sludging up.

Towards the beginning of April, 1900, the appearance of the filtrate greatly detoriated. The suspended solids were dark coloured, and the supernatant liquid obtained after settling them out was opalescent, and sometimes threw down a buff-coloured precipitate similar to that from the Contact Bed filtrates. This was caused by the accumulations of solids in the filter preventing the efficient aeration of the bed, and also causing unequal distribution of the liquid throughout the filtering material. This choking up of the interior of the filter caused some of the liquid to run down the outside of the filter, and also down the manhole. The filter was therefore allowed to rest for ten days. On re-starting the filtrate was again good, and remained so until May 1st, when signs of deterioration became apparent at the same time as leakage on the sides. On May 12th the bed was stopped, pending experiments in washing out the bed, which have not yet been carried out, and it is feared that the material which was used for this bed was too fine.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM MARCH 9TH, 1899, TO MAY 8TH, 1900.

WHITTAKER BEDS.

Purification effected.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hrs., 80° F.).	Nitrogen as Nitrates.
Septic Tank Effluents ...	78·4	13·1	1·80	·434	4·02	—
Filtrate—Whittaker Bed, No. 1	69·8	5·6	·688*	·113*	·684*	·548*
Purification effected on Septic Effluent ...	—	57%	61%	73%	83%	—

* Analysis made after rough settlement of suspended solids.

THE FOLLOWING TABLE IS THE AVERAGE OF A NUMBER OF COMPARATIVE ANALYSES MADE UPON THE FILTRATE FROM THE WHITTAKER BED, NO. 1, WITH AND WITHOUT SUSPENDED SOLIDS.

GRAINS PER GALLON.	Albuminoid Ammonia.	Oxygen Absorbed.
Filtrate containing Solids ...	·233	1·40
,, after Settlement of Solids	·105	·610

In view of the fact of the suspended solids being non-putrescent in character, the following analysis may be of interest. The sludge produced by the settlement of the filtrate was washed, and as far as possible freed from the larger living organisms, such as worms, larvæ :—

Analyses of Mud.

Loss on ignition	= 31·3	per cent.
Ferric Oxide...	= 31·3	,,
Silica and matter insoluble in acid	= 18·9	,,
Other mineral matters	= 18·5	,,
	100·0	,,

The filtering material of No. 1 Whittaker bed having been found to be too fine in character, it was decided to build a smaller bed and to fill it with very coarse coke.

Whittaker Bed, No. 2.

WHITTAKER BEDS.

Construction.

The construction of this No. 2 bed was as follows: Rows of semi-circular perforated tiles, having a diameter of 18 inches, are placed edge-to-edge, and raised above a slight inclined plane of concrete by means of small brick columns, so that there is a clear air space between the tiles and the concrete floor. Upon the floor thus constructed is built an octagonal pigeon-holed wall, and the space within this wall is filled in with coarse coke; first, to a depth of one foot above the pipes by coke not less than two inches in diameter, and the rest of the bed is then filled with coke of not less than $1\frac{1}{2}$ inches diameter. Altogether there are nine feet in depth of coke.

The septic tank effluent is distributed over the surface by a Whittaker sprinkler, and the filtrate is collected by a channel running round the concrete floor.

The rate of filtration was 1,000,000 gallons per acre (*i.e.*, 200 gallons per square yard) per 24 hours, working night and day.

The bed was started on September 2nd, 1899. The first filtrates obtained were exceedingly clear but putrescent, shewing that though solids in suspension were being kept back, bacterial action was not yet devoloped. This continued until September 19th, when the filtrate became turbid from the large quantity of suspended solids coming out from the coarse coke; but, nevertheless, nitrates were present, and the filtrates were non-putrescent in character.

Since then the filtrates have remained turbid but non-putrescent, and no change has been made to the bed itself until April 7th, 1900, when the coke upon the surface, which had disintegrated somewhat, was renewed.

Bed choking up.

Work was continued night and day, till towards the middle of May, 1900, the quality of the filtrate obtained deteriorated. This was considered to be due to the accumulation of solid matter in the filter interfering with effective aeration, and also to some extent causing the liquid to be unequally distributed throughout the bed. The surface of the bed was also clogged to a small extent by the usual growth. WHIT-TAKER BEDS.

On May 23rd, 1900, an interesting experiment was made to see if the matter on the surface, and the accumulations within the bed could be washed out. It had often been noticed that if, for any purpose, the arms of the sprinkler were held from rotating, then within a few minutes the filtrate became very turbid, with an excess of solid matter coming out. This was due to sending the whole volume, which, during the rotation of the arms is distributed over the whole surface through only a small part of it, and so increasing tenfold the flow through that part.

This suggested that with a coarse bed like this No. 2, the bed could be washed out; accordingly a three inch hose, with town's water, was turned on one square yard of the bed, and successively over the whole surface. The bulk of the accumulated solids came out in the first three minutes, during which the filtrate was exceedingly turbid; a test tube with ten inches in it settling down three inches of sludge. After the first few minutes the number of solids coming through rapidly diminished. With these washed-out solids came out an immense number of cyclops, larvæ, &c. The sludge was found only slightly putrescent, although it would necessarily contain organic matter in process of transition. No doubt, if the experiment had been made after a rest of one or two days, the sludge would have been as little putrescent as that which comes out in the normal flow. The filtrates obtained immediately after this washing-out experiment were good, but soon afterwards became worse although they remained non-putrescent. These bad filtrates continued to the middle of June when they again improved, the nitrification being exceedingly good, viz., 1·31 grains per gallon of nitrogen as nitrates.

WHITTAKER BEDS.

Effect of Frost.

During the winter of 1899-1900 two periods of keen frost were experienced. Although on both of these occasions the bed was covered with ice, and the semi-circular pipes at the bottom of the bed were filled with large icicles, the purification was not materially interfered with.

Grains per Gallon.	State of Weather.	Septic Tank Effluent.			Filtrate from No. 2 "W." Bed.				Percentage Purification.	
		Free. NH_3.	Alb. NH_3.	Oxygen Absorbed.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed.	Nitrogen as Nitrates.	In Alb. NH_3.	In Oxygen Absorbed.
Nov. 24th to Dec. 8th, 1899	No Frost	1·47	·383	4·45	·659	·077	·623	·658	79·8 %	81·5 %
Dec. 9th to Dec. 29th, ,,	Frost	2·13	·481	4·36	·670	·092	·586	·528	80·8 %	86·5 %
Feb. 2nd to Feb. 14th, 1900	No Frost	1·60	·463	4·10	·228	·056	·442	·823	87·9 %	89·2 %
Feb. 15th to Feb. 25th, ,,	Frost	1·77	·442	4·46	·498	·070	·519	·752	84·1 %	88·3 %

Average of Analyses referring to Period from September 2nd, 1899, to June 30th, 1900.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hrs., 80° F.).	Nitrogen as Nitrates.
Septic Tank Effluent ...	78·1	14·4	1·85	·455	4·18	—
Filtrate—Whittaker's Bed, No. 2	70·7	7·7	·532*	·079	·590*	·669*
Percentage Purification on the Septic Effluent ...	—	46 %	71 %	82 %	85 %	—

* Analysed after the rough settlement of suspended solids taken from October 23rd, 1899, to June 30th, 1900.

The following Table is the Average of a Number of Comparative Analyses made upon the Filtrate from Whittaker Bed, No. 2, with and without Suspended Solids.

Grains per Gallon.	Albuminoid NH_3.	Oxygen Absorbed.
Filtrate, containing Solids	·183	1·27
,, after Settlement of Solids ...	·069	·523

GENERAL OBSERVATIONS ON CONTINUOUS FILTRATION.

OBSERVATIONS ON FILTRATION.

These experiments in continuous filtration by spreading sewage like rain upon a surface of coarse coke, well ærated at the bottom and sides, were interesting and important, and shewed that in so short a time as the fifteen minutes required to pass through the bed, remarkable changes took place. It is true, that to the eye the filtrate looks anything but satisfactory, but on holding it up to the light in a glass tube, the turbidity is seen to be due, not to discolouration of the liquid but to the presence of suspended solids, which soon settle down, leaving the liquid clear above. These solids are found to be absolutely non-putrescent, and about half of them being ferric oxide and silica are not further reducible by bacterial action, and if they do not come out must choke the bed. They involve, after filtration, a settling tank, the sludge from which would for Leeds septic effluent, with an average of 13 grains suspended solids, be equivalent to six tons of sludge per million gallons. It dries readily without giving rise to any nuisance. The final filtrate, taking results over the whole period of working No. 2 Bed, give on analysis ·079 per gallon of albuminoid ammonia, and ·59 per gallon of oxygen absorbed. This means a purification by the filtration of about 83 per cent. on the septic effluent put on to the bed, and a total purification by the septic tank and the filter of 92 per cent. on the crude sewage.

Washing out Accumulations.

It is not suggested as practicable, that continuous filters can be washed out by turning on a hose or town's water, nor is it desirable to so far wash out the bed as to wash out the bacterial life. The washing-out would be conveniently and automatically accomplished by increased flow during rain. Thus, if the normal flow of one million gallons per acre gave good results, and while bringing out solids in suspension which must be afterwards settled, yet left behind some accumulation, this would be washed out as soon as the flow increased. Increasing the flow to three volumes will not damage the filter, though, no doubt, during such increased flow the degree of purification would not be so good.

The Whittaker sprinkler was not found very efficient, and required frequent attention and cleaning of the holes. There is room for much improvement in distributors.

It is proposed to try an experiment with continuous filtration on a coarse bed, well roofed in to conserve the heat in the sewage. The artificial heating, proposed by Mr. Whittaker, it is feared, will prove too costly on a large scale.

Continuous Filtration of Crude Sewage.

In previous pages we have dealt with the double contact filtration of crude, screened, and settled sewage, and also with the continuous and contact filtration of septic effluent.

It was desired to investigate the possibilities of dealing by continuous filtration with more or less crude sewage. For this purpose three small experimental beds were used, which had been constructed for use as triple contact beds, but had not been put to work for that purpose. These beds were a little over 12 feet square, and had an area of 17 square yards, and a depth of four feet. The first of these was filled with the coarsest coke available, the second with coke to about 1 inch and 1½ inches in size, and the third with small coke about five-eighths inch. The distribution was by tipping troughs, and the sewage used was the crude sewage after passage through three screens, the smallest of which was 37 per inch. The first of these screens, which had one-eighth inch mesh, kept back small pieces of paper, matches, &c., and the second and third screens kept back most of the fibre, but all the finely divided solids in suspension passed on to the beds. The keeping back of matter by the screens, although it greatly facilitated the work, did not remove any important proportion of the solids in suspension, the matters removed being those which usually do not come into the analysis: as paper, matches, fibre, &c.

FILTRATION OF CRUDE SEWAGE.

The first filtrates from the fine bed were very clear, the suspended matter being at first entirely kept back by the coke, but after a few weeks these solids began to work through, and the filtrate became somewhat turbid, though giving fair analytical results when the solids had been settled. Trouble, however, arose in two directions, first by the development of a growth in the upper part of the coarse bed, and secondly by the pooling of the sewage on the surface of the finest bed.

It was soon found impracticable to go on dealing with crude sewage over fine coke, even after passing over beds Nos. 1 and 2 filled with coarse coke.

These experiments were therefore stopped, the material taken out of No. 2 and 3 Beds, which were then refilled with very coarse coke, 1½ inch and upwards. When this was done semi-circular perforated drain pipes, nine inches in diameter, were placed in the bottom of each bed, thus reducing the coke depth in each case, but securing more effective æration.

For the tipping troughs on No. 1 Bed a Candy sprinkler was substituted. This sprinkler has two arms and works intermittently, sewage passing for one minute, followed by three minutes' rest. This intermittence, in sprinkling, was in some respects a disadvantage in connection with such coarse material, for the sewage passed through the beds in rushes. On the other hand the intermittence probably proved useful in improving the æration of the first bed.

FILTRATION OF CRUDE SEWAGE.

This second experiment was started on March 26th, 1900, at a rate of flow of 750,000 gallons per acre, that is 150 gallons per square yard per day.

It will be understood, therefore, that this continuous filtration was over three beds of the coarsest coke: the first three feet six inches, and the second and third about two feet six inches each in depth; and no doubt it would have been much better to have had this eight feet six inches of coke all in one column, with a single distributor.

The sewage took only a quarter of an hour to pass through the three beds, and the first results were very unsatisfactory with a total purification of about 50 % only. The filtrates gradually improved until in about three weeks the bed had got into condition, but shortly after this, solids began to work through, and made the filtrates turbid. This was the same result which had been noticed on the Whittaker beds; that the solids in suspension were at first kept back, but gradually worked their way down through the filter until they began to come out with the effluent. These solids were found, however, on coming out, to be different in character to what they were on going in. They settled more readily, and were very slightly putrescible.

When these solids had been settled from the final filtrate, good analytical results were obtained, namely: ·099 Alb. NH_3 and ·667 oxygen absorbed per gallon.

This result, in view of the short time taken by the sewage in passing over this very coarse coke, was certainly remarkable, but it will be seen that the process would require to be followed by a settling tank. The solids so settled would probably be found similar in character to those experimented with in the case of the Whittaker bed, and give rise to no nuisance in the drying of the sludge.

The growth on the top of No. 1 bed has not up to the present caused any inconvenience.

The following table gives the average of the analyses since the starting of the experiment, and including the early bad filtrates. It will be seen that these analyses, although including the solids in suspension, shew a purification of 71 per cent. on the crude sewage measured by the Alb. NH_3, and 78 per cent. measured by the oxygen absorbed, but recent analyses made from the settled filtrate shew a purification of 90 per cent. as measured by the Alb. NH_3, and 92 per cent. as measured by oxygen absorbed, and nitrates ·3.

FILTRATION OF CRUDE SEWAGE.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM MARCH 26TH, TO JUNE 30TH, 1900. ANALYSES ARE INCLUSIVE OF ALL SUSPENDED SOLIDS.

Purification effected.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed.	Nitrogen as Nitrates.
Sewage	123·2	44·2	2·36	1·04	8·90	—
Filtrate from 1st Bed ...	87·6	19·2	1·58	·599	4·37	—
,, 2nd ,, ...	74·0	7·9	1·15	·430	2·78	—
,, 3rd ,, ...	71·7	7·7	·828	·297	1·93	.141
Percentage Purification ...	—	82 %	64 %	71 %	78 %	—

It was noticed that the solids in suspension coming out with the filtrate were very irregular in quantity, as if they were washed out in occasional rushes.

This interesting experiment has not been carried on long enough to enable any definite conclusions to be come to, but, so far as it goes, it shews that it would be possible, after screening off the coarser solids and the fibre, to deal with crude sewage by continuous filtration over very coarse material in such a way as to bring out the undigested solids, and to guarantee that the beds would not choke up. From the irregularity in the amount of solids coming out, it is evident that by increasing the flow the beds can be readily washed out.

FILTRATION OF CRUDE SEWAGE.

No doubt with a somewhat increased depth of coke, and improved construction, the solids coming out could be obtained in an entirely non-putrescent condition.

As evidences of the æration obtained in this process, it may be mentioned that on the wet surface of the third bed green confervoid growths have recently appeared.

One curious thing was noticed, that when the sewage put upon the beds was very considerably darkened by dye, the colour was completely taken out in the final filtrate, and indeed the greater part of the colour had disappeared from the filtrate in the first bed.

The experiment is being continued, and is thought to be sufficiently promising to make it worth while to make a new "Leeds" bed on these lines in one column with twelve feet of coke, with other modifications.

Ducat Filter.

An experiment has recently been started in the continuous filtration of crude sewage on a filter constructed on lines suggested by Colonel Ducat, of London. This filter has an area of $\frac{1}{100}$th of an acre, 48·4 square yards, and a depth of 10 feet. The material used being clinker three-eighths inch to five-eighths inch. The sides of the bed are built, not of brick, but of drain pipes, 12 inches long and $5\frac{1}{4}$ inches external diameter. This construction secures the complete exposure of the sides of the filter to the air. Outside this perforated wall is a second wall, distant from it about three feet, and built of solid brickwork for the purpose of keeping in the heat, and it carries a roof covered with thatch. The bottom of the bed has six perforated brick channels connected with the outer air, through which pass cast iron hot water pipes connected with an external boiler, intended to supply artificial heat during cold weather. The crude sewage was raised to the level of the bed by means of a Tangye pump, and passed through a three-sixteenths inch screen and a small grit chamber. The distribution of the sewage was by means of tipping troughs. This construction is prohibitively costly.

DUCAT FILTER.

The bed was started on March 29th, 1900, working alternate hours for 10 hours, and resting for fourteen, the rate of flow, while working, being 200 gallons per square yard. The filtrate on April 6th was exceedingly clear and bright, suspended solids being retained in the bed. On April 14th the bed was worked for 10 hours continuously, with 14 hours' rest. This change immediately caused the filtrate to become opalescent, but after a day's working it again cleared. On April 16th the surface shewed signs of choking, and small pools began to form. On April 26th the whole surface was practically covered with stagnant sewage; the filtrate steadily deteriorated, and at the same time a grey filamentous growth began to appear in one outlet basin, very similar in character to that found on the surface of the Whittaker Beds.

The unsatisfactory character of the effluent led on April 27th to reducing the work to alternate hours work for 10 hours, with 14 hours' complete rest. The change produced no alteration for the better, and on April 30th, 1900, the process was temporarily stopped.

It was found that practically all of the suspended matters had been arrested upon the surface, and, by preventing the efficient æration of the filter, had produced the bad filtrates.

During the whole of this period the bed was warmed by means of the hot water apparatus, the temperature of the filtrate being about 10° F. higher than that of the sewage.

The filter, when giving the best results, produced a purification of 90 per cent. in albuminoid ammonia, and

DUCAT FILTER.

93 per cent. in oxygen absorbed upon the sewage sent on to the bed. The nitrogen present as nitrates in the filtrates also reached ·56 grains per gallon.

Purification effected.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM MARCH 29TH TO APRIL 30TH, 1900.

GRAINS PER GALLON	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hrs., 80° F.).	Nitrogen as Nitrates.
Sewage	129·7	53·7	2·88	1·09	7·98	—
Filtrate	71·6	Nil.	1·00	·122	·711	·313
Percentage Purification ...	—	—	65 %	88 %	91 %	—

It was thought that the chief cause of the clogging was due to wool fibre passing the screen and so getting on to the bed. To obviate this the sewage, before going on to the bed, was now sent through a three-sixteenth inch screen, and then through a layer of the bed material one inch in thickness. Before re-starting, the choked surface was removed to a depth of two inches and replaced by new material.

The bed was re-started on June 13th, 1900, filtering at the rate of 200 gallons per square yard for alternate hours for 10 hours, followed by 14 hours' rest. The filtrate at first was opalescent, but this totally disappeared by June 15th, leaving the filtrate exceedingly clear and bright.

On June 20th the bed began to work continuously for 10, and rest 14 hours. This increased amount of work caused the filtrate to become opalescent, but this had cleared off again by June 22nd. The filtrate remained clear until June 24th, when the filter was put to work continuously throughout the 24 hours. The opalescence again cleared off, leaving the filtrate very bright and clear. Green growth also began to appear in the basin.

During this period the hot water pipes were not used. The temperature of the filtrate was on the average about 4° F. lower than that of the sewage. The *best* results obtained were as follows:— DUCAT FILTER.

AVERAGE OF ANALYSES REFERRING TO PERIOD FROM JUNE 13TH TO JULY 7TH, 1900.

Purification effected.

GRAINS PER GALLON.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hrs., 80° F.).	Nitrogen as Nitrates.
Sewage	127·9	59·4	2·79	1·07	9·90	—
Filtrate	69·0	Tr.	·165	·043	·241	·848
Percentage Purification ...	—	100 %	94 %	96 %	97 %	—

But at the date of this report, after less than a month's work, signs are again appearing that the surface is becoming choked, and the filtrates are rapidly falling off in quality.

It seems quite unlikely that the crude sewage of Leeds can be dealt with on such fine material, but the experiment is being continued, and further light will no doubt be thrown upon it.

CONCLUDING NOTES.

Readers are referred:—

For General Observations on Intermittent Filtration (Contact beds, to page 58 et seq).

For General Observations on Septic Tanks, to page 81 et seq.

For General Observations on Continuous Filtration, to page 95 et seq.

For Recent Experiments in Continuous Filtration of Crude Sewage, to page 96 et seq.

It is only necessary here to add that all the experiments in biological treatment shewed the remarkable purifying effects

CON-CLUDING NOTES.

of bacterial oxidation, and that it was more rapid in dealing with dissolved impurities than with solids in suspension, many of which are but slowly reduced.

Double Contact beds gave good results with crude sewage, and excellent results with partially settled sewage or with septic effluent.

Single Contact beds are insufficient for dealing with crude sewage, but give fair results with settled sewage or with septic effluent.

The real difficulty with contact beds is to maintain capacity. No doubt the loss of capacity is due partly to degradation and consolidation of the material of the beds; but even if material can be found of even size, and not liable to break up, and even if the bulk of solids in suspension is first settled, the choking up of the beds would be likely to arise sooner or later. The hope that accumulations would be dissolved by rest has not been fulfilled at Leeds. The beds, however, digest a large part of the suspended solids put upon them (see page 108), but only by working them at the rate of one filling per 24 hours, could the continued life of the rough bed be secured, and even then the ultimate choking seems inevitable, owing to retention in the beds of matters which have reached an irreducible condition.

It is proposed, before finally abandoning contact beds for the treatment of Leeds sewage, to try experiments with beds so constructed that they will pass out undigested matters with the effluent; non-putrescible matters which will be afterwards settled.

The continuous filtration of sewage or septic effluent on fine beds, although giving very good early results, would appear to be impracticable on account of the rapid choking of the beds. On the other hand, *continuous filtration over very* *coarse material*, of septic effluent, and even of sewage has given interesting and remarkable results, if the solids in suspension, which come out in the effluent, are settled after filtration. These solids are non-putrescible, can be readily settled, and the drying does not give rise to evil odours. It would seem that the coming through of these solids, which for the most part are not further reducible, and largely mineral, ensures the permanence of the coarse continuous beds.

CON-CLUDING NOTES.

It has been found practicable, for long periods, to work coarse continuous beds 10 feet deep, at the rate of 200 gallons per square yard, or one million gallons per acre per day for septic effluent. At this rate, results giving over 90 per cent. purification are obtained, after settlement of solids coming out in the filtrate, and, although, at this rate some of the solids are retained in the filter and there accumulate, they can be washed out by the increased flow which naturally arises with storm dilution. This possibility of dealing with storm waters is an important feature of the system.

It would seem practicable to deal on such beds even with crude sewage (previously strained through several screens), but in this case a depth of 12 feet of material would be required for Leeds sewage, which is not very strong. These latter experiments have not been carried on long enough to draw from them any definite conclusions.

With continuous beds the chief difficulty will be that of distribution, the ideal being an equal rain of sewage over the whole surface, and difficult of accomplishment on a large scale.

The experiments will be continued, and it is proposed, in constructing new experimental "Leeds" beds, to avoid artificial heating of the sewage, which it is feared will prove too costly, and to so construct the beds that they may, as

CON-CLUDING NOTES.

far as possible, conserve the heat of the sewage, which, even in winter, is always many degrees over freezing point. No doubt this question of retaining the heat of the sewage is one of the difficulties of continuous filtration. There is very little loss of heat in contact beds.

Experiments are proposed to secure a material of even size and form, and not liable to become broken up, and this is not less necessary for the permanent life of the continuous than of the intermittent filters.

Neither the continuous nor the intermittent systems of filtration give rise to any evil odours.

Both give excellent results on chemical analysis, and effluents which improve and do not deteriorate on keeping. From the bacteriological point of view, however, all the filtrates contain a greatly larger number of bacteria than the standard of numbers allowed for drinking waters. This objection is not very material, as it is quite impracticable, in the treatment of sewage, to require transformation into a liquid of potable quality. Indeed, the presence of bacteria in the filtrate may be looked upon as an active element of further purification, and it is only to be remembered that the presence of a large number of beneficent bacteria is always accompanied in sewage by a proportion of pathogenic species. Where filtrates proceed from fever hospital sewage for instance, or where filtrates pass to streams which are used for drinking purposes, some process of final sterilization, with a view to the extinction of pathogenic germs, may be desirable ; but in the case of Leeds, where the purified sewage passes into a stream which will scarcely at any time be brought to safe drinkable condition, the presence of considerable numbers of bacteria in the final flow cannot be considered as an objectionable feature.

This is necessarily an interim report, and no doubt, as the experiments are continued, fresh light will be thrown on this interesting and important subject. CONCLUDING NOTES.

The Corporation of Leeds has just purchased a large estate of 1,890 acres for purposes of sewage disposal, and several years will be required before the great volume of the sewage of the City and its dilutions can be conveyed to it.

There will, therefore, be time to continue the experiments, and to settle, with certainty, the best method of treatment for the local conditions.

T. WALTER HARDING, M.I.M.E.,
Chairman.

T. HEWSON, M.I.C.E.,
City Engineer.

W. H. HARRISON, M.Sc.,
Chemist to the Committee.

ADDENDUM.

It is difficult to get at any reliable estimate of the sludge digested by the beds.

Taking No. 1 rough bed, the total volume dealt with, from October, 1897, to October, 1899, was 38 million gallons, and if the average of suspended solids kept back by the bed is taken at 33 grains, then 178,000 lbs. of dry solids, or 1,780,000 lbs. of sludge (90 per cent. water), has been left on that bed, or, at 10 lbs. per gallon, 178,000 gallons. As the final accumulation in the bed was 56,000 gallons, it would seem that this bed had digested 68 per cent.

The quantity is no doubt less, as the sludge left on the bed contains only 85 per cent. water. On the other hand, the reduction of capacity is partly due to breaking up of the material of the bed, and some matters at first in solution are thrown into suspension and retained. As a rough estimate, 60 to 70 per cent may be taken as a fair approximation of the sludge digested by this bed.

TABLE

SHEWING THE VARIATIONS IN CAPACITY

OF

CONTACT BEDS.

(OVER.)

TABLE SHEWING THE VARIATIONS IN

No. 1, ROUGH CONTACT BED.

Capacity before putting in Coke .. .. = 174,800 Galls.
Original Water Capacity after putting in the Coke .. .. = 83,300

	Galls.	
1897. Oct. 1st ...	83,300	Crude Sewage (3 fillings).
Nov. 1st ...	74,000	,,
Dec. 1st ...	64,000	,,
1898. Jan. 1st ...	57,100	,,
Feb. 1st ...	45,400 Bed rested 14 days	,,
Feb. 18th ...	55,900	Lime Effluent.
Mar. 1st ...	53,000	Screened Sewage (3 fillings).
Apr. 1st ...	45,000	,,
Apr. 27th ...	40,000 Bed rested 7 days	,,
May 5th ...	45,800	(2 fillings).
June 16th ...	43,200 Bed rested 38 days	,,
July 28th ...	56,500	,,
Sept. 1st ...	42,000 Bed dug over	,,
Oct. 1st ...	46,500	Half-settled Sewage (2 fillings).
Nov. 1st ...	44,000 Bed rested 14 days	,,
Dec. 1st ...	45,000	(3 fillings).
1899. Jan. 1st ...	36,000	,,
Feb. 1st ...	31,800	,, Resting on Sundays.
Mar. 1st ...	29,000	Crude Sewage do. (3 fillings).
Apr. 1st ...	25,000	Resting Wednesdays and Sundays.
May 6th ...	22,700	Resting alternate days (*i.e.*, 1½ fillings per day)
June 3rd ...	23,400	,,
July 1st ...	25,600	(1 filling every day)
Aug. 1st ...	26,800	,,
Sept. 9th ...	27,300	,,
Oct. 7th ...	26,900	,,

N.B.—The increase of Capacity from July 1st, 1899, is more apparent than real, as with only 1 filling per day the Bed would have a longer time to drain.

No. 3, ROUGH CONTACT BED.

Capacity before putting in Coke .. .. = 102,094 Galls.
Original Water Capacity after putting in the Coke .. .. = 51,800

	Galls.	
1898. Nov. 21st ...	51,800	Partially Settled Sewage (3 fillings). Rested on Sundays.
Dec. 5th ...	46,600	,,
189€. Jan. 2nd ...	38,100	,,
Feb. 1st ...	34,500	,,
Feb. 13th ...	30,400	Grit Settled Sewage (3 fillings). Rest on Sundays.
Mar. 1st ...	28,500	,,
Mar. 27th ...	23,600 Rested 18 days.	,,
Apr. 18th ...	28,600	,,
May 2nd ...	21,700 Surface removed.	,, Beds rest alternate weeks.
May 31st ...	24,900	,,
June 28th ...	22,500	,, Resting alternate days (3 fillings).
Aug. 1st ...	25,000	,,
Sept. 1st ...	25,000	,,
Oct. 1st ...	24,500	,,
Nov. 1st ...	21,200	,,
Dec. 1st ...	21,700	,,
1900. Jan. 1st ...	18,000	,,
Mar. 10th ...	14,700 Rested 16 days and Surface cleaned.	,,
Mar. 26th ...	21,200	,,
Apr. 1st ...	21,000	,,
May 1st ...	18,500	,,
June 1st ...	18,000	,,
July 1st ...	18,200	,,

N.B.—The increase of Capacity from July 1st, 1899, is more apparent than real, as with only 1 filling per day the Bed would have a longer time to drain.

No. 5,

Capacity before
Original Water in the Coke

1899. Feb. 28th ...
Mar. 14th ...
Apr. 1st ..
May 9th ...
June 1st ...
July 5th ...
Aug. 2nd ...
Aug. 16th ...
Sept. 13th ...
Oct. 24th ...
Nov. 22nd ...
1900. Mar. 9th ...
Apr. 6th ...
May 4th ...
June 1st ...
June 22nd .
July 20th ...

CAPACITY OF CONTACT BEDS.

…OUGH CONTACT BED.

…utting in Coke .. = 102,094 Galls.
…apacity after putting … } = 53,100

Galls.	Grit Settled Sewage. Rest on Sundays.
53,100	
46,600	,,
42,000	,,
32,500	(2 fillings per day). 4 hours contact.
30,500	,,
29,400	(2 fillings per day). 2 hours contact.
29,400	,,
29,900	(2 fillings per day). 4 hours contact.
28,300 Rested 25 days.	,,
30,800	,,
25,400	,,
27,600	(3 fillings per day). 2 hours contact.
23,000	,,
18,100	,,
13,200 …sted 20 days and …urface cleaned.	,,
20,500	,,
16,600	,,

No. 7, SINGLE CONTACT BED.

Capacity before putting in Coke = Galls.
Original Water Capacity after putting in the Coke .. } = 55,700

1899.	Galls.	
Mar. 24th …	55,700	Lime Effluent.
Apr. 21st …	50,308	,,
May 5th …	48,600	,,
June 2nd …	43,600	,,
July 1st …	38,000	,,
Aug. 1st …	33,000	,,
Sept. 1st …	28,500	,,
Oct. 20th …	21,600 Bed rested and turned over.	,,
1900. Jan. 3rd …	53,500	,,
Feb. 2nd …	50,300	,,
Mar. 1st …	46,000	,,
Apr. 1st …	41,000	,,
May 1st …	36,500	,,
June 1st …	31,000	,,
July 5th …	25,600	,,

No. 8, SINGLE CONTACT BED.

Capacity before putting in Coke = Galls.
Original Water Capacity after putting in the Coke .. } = 29,500

1899.	Galls.	
Mar. 23rd …	29,500	Septic Tank Effluent.
Apr. 6th …	29,800	,,
May 4th …	27,100	,,
June 2nd …	23,000	,,
July 1st …	18,500	,,
Aug. 1st …	16,000	,,
Sept. 21st …	10,700 Bed rested and turned over.	,,
Nov. 10th …	26,900	,,
Dec. 1st …	24,500	
1900. Jan. 1st …	19,500	
Feb. 1st …	17,000	
Mar. 1st …	16,000	
Apr. 1st ..	13,500	
May 4th …	12,200	
June 1st …	9,800	
July 1st …	11,000	