The rise & progress of aerobic methods of sewage disposal : being notes of a lecture delivered before the Association of Managers of Sewage Disposal Works at the Royal Sanitary Institute on March 18th, 1911 / by W.J. Dibdin.

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BY

W. J. DIBDIN, F.I.C., F.C.S., &c.

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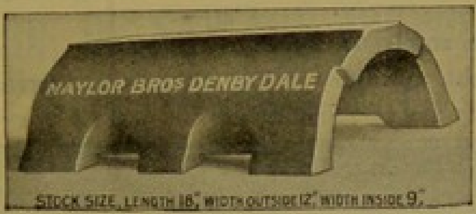
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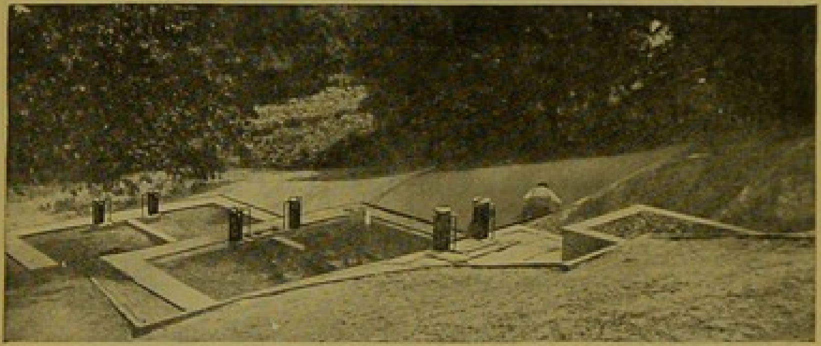


THE RISE AND PROGRESS OF AEROBIC METHODS OF SEWAGE DISPOSAL.

By W. J. DIBDIN, F.I.C., F.C.S., &c., Past President.

IN order to gain a clear idea of the work to be accomplished in effecting the inoffensive or "aerobic" destruction of the waste organic debris of a community, let us first consider the nature and extent of the work to be done. These waste

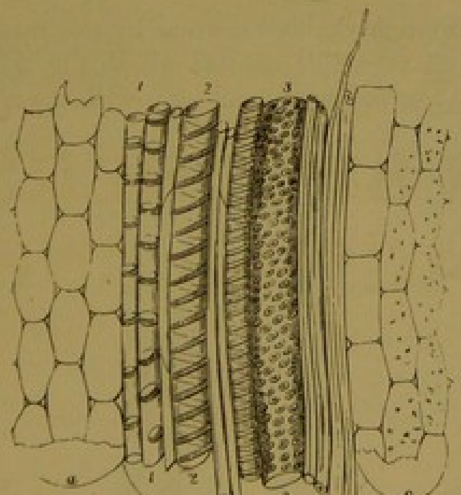


FIG. 1.—Longitudinal Section of Stem of Italian Reed; *a*, Cells of the Pith. *b*, Fibro-vascular Bundle, containing 1, Annular Ducts; 2, Spiral Ducts; 3, Pitted Ducts with Woody Fibre. *c*, Cells.

A 2

matters necessarily belong to either the vegetable or animal kingdom, and in either case are of a complex character.

Fig. 1 shows a fragment of vegetable tissue which fairly represents the remarkable variation in the intricate cellular structure of all vegetable debris; whilst Fig 2 indicates only the superficial surface of animal skin with the nerve ramifications, apart from the general cellular structure of the muscles, tendons, fat cells, &c. Fig 3 shows the elastic nature of striated muscular fibre.

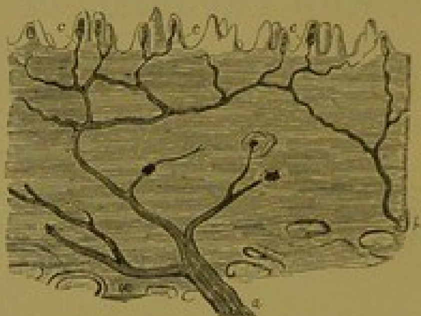


Fig. 2.—Vertical Section of Skin of Finger, showing the Branches of the Cutaneous Nerves.

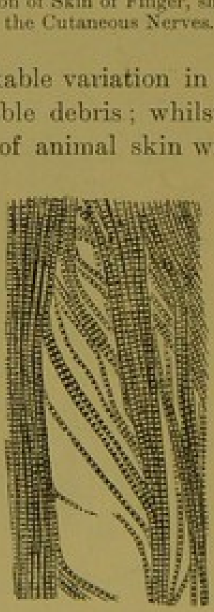


Fig. 3.—Striated Muscular Fibre, separating into Fibrillæ.

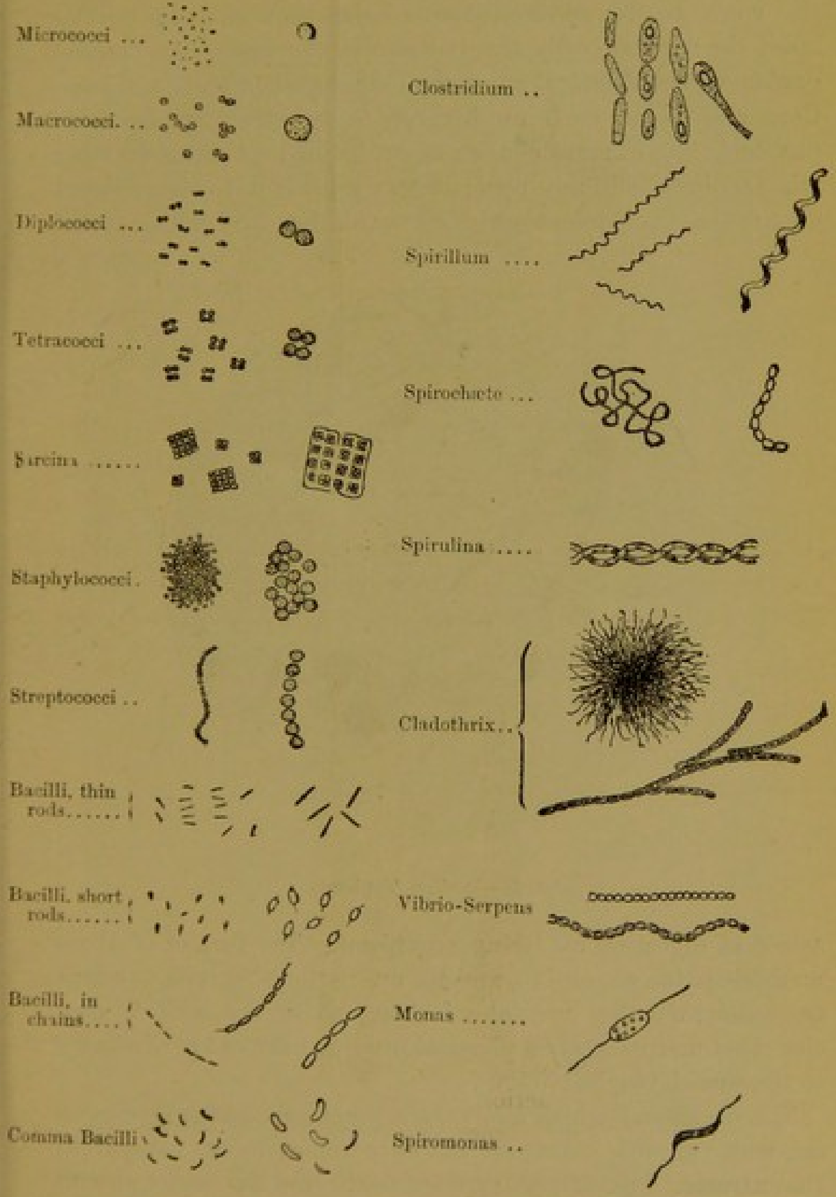


Fig. 4.—Types of Bacteria.

From these elementary illustrations it will be seen that the work to be accomplished consists not only in pulling apart the separate cells, &c., but also in the molecular disintegration of the chemical substances employed in their composition, and is of such an involved character that no mere physical state of rest or inaction on inclined or other surfaces will facilitate it in any way; but we must look to either direct destruction by violent chemical oxidation fire, &c., or to the action of digestion by living organisms. The former of these methods is too expensive, and we are perforce driven to adopt the latter, whether we intend doing so or not, as it is now clear that many so-called physical processes are but preliminary to the final biological action.

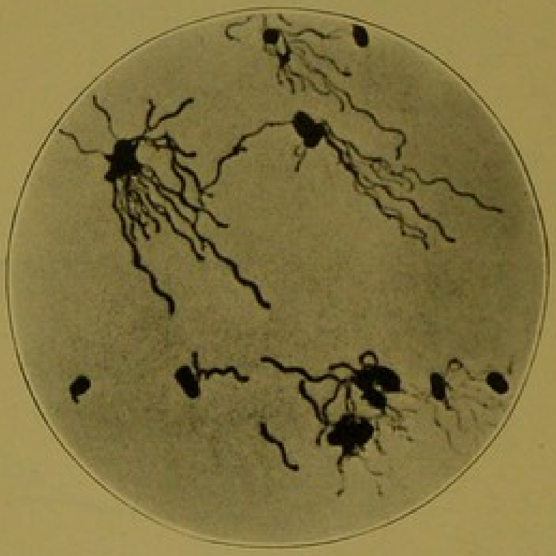


FIG. 5.—Bacillus Typhosus.

The organisms which exert their beneficent action by digesting waste organic debris are not only numerous but variable in the extreme. Fig. 4 shows types of bacteria of the more common varieties, many of which are more complex in their nature than was formerly supposed. Fig. 5, for instance, shows the baccillus typhosus with numerous whip-like processes or "flagellæ" magnified about 5000 diameters.

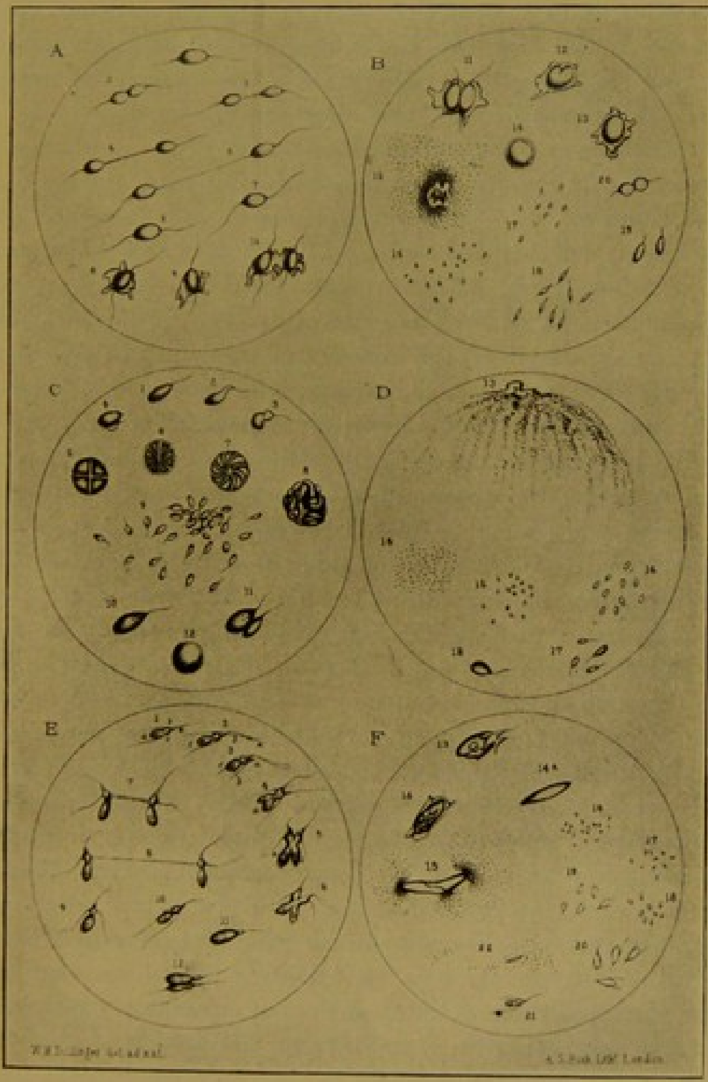


Fig. 6.—Life Histories of Saprophytes.

Next to the bacteria we may place the monadina represented in Fig. 6, showing the late Dr. Dallinger's beautiful illustration of the life history of these minute organisms, their method of propagation, &c.

The life history of Saprophytes is described by the late Dr. Dallinger in "The Microscope and its Revelations" (Carpenter), from which the following short description of the plate—Fig. 6—is extracted by the kind permission of Messrs. J. and A. Churchill, who have also kindly lent the blocks of Figs. 1, 2, 3, and 9:—"The simplest of these organisms is represented in Fig. $6A_1$. As it is with the entire group, all is subservient to rapidity of multiplication, and there are two methods in which this is effected. The first and commonest is by fission. Fig. $6A_1$ represents the normal form of the organism. It has a long diameter of about $\frac{1}{5000}$th of an inch. In a certain stage of its history, as it swims freely, there suddenly appears a constriction across its body, as in Fig. $6A_2$. This is at once accompanied by an apparent effort of the opposite flagella to pull against each other; the consequence is a very rapid stretching of a neck of sarcode between two halves of the body, as at Fig. $6A_3$. This becomes longer, as at 4, and attains the length of two flagella, as at 5, when the two dividing halves approach and mutually dart from each other, snapping the connecting fibre of sarcode in the middle, so that two perfect forms are set free, as in 6 and 7. This in the course of two or three minutes is once more begun and carried on in each half successively, so that there is increase of the form by this means in rapid geometric ratio.

"But this is an exhaustive process vitally, for after a period varying from eight to ten days there always appear in the unaltered and unchanged field of observation normal forms, with a remarkable diffluent or amœba-like envelope, as seen in Figs. 6, 8, and 9. These sometimes swim and sometimes creep amœba-like by pseudopodia; but directly the different sarcode of one touches that of another they at once melt together, as in Fig. $6A_{10}$. This leads to the rapid approach of the oval bodies of the two organisms, as in Fig. $6B_{11}$, resulting in their fusion, as in Figs. $6B_{12}$, $_{13}$, $_{14}$, and a still condition of the sac ($_{14}$) for a period of not less than six hours, when it bursts, as seen in $_{15}$, pouring out an immense host of exquisitely minute spores, as shown in 15. These are opaque or semi-opaque, but by observation upon them at a temperature of 65 deg. to 70 deg. Fah. they in the course of thirty minutes become transparent, elongate as in 16 and 17, and, continuing to grow, assume the conditions and sizes represented in 18 and 19, and we are able to trace them through all their changes of growth from the spore into the adult condition, as at 20, until they entered upon and passed through the self-division into two described and figured in Fig. 6A."

Fig. 6 (Figs. C, D, E, F) represent similar life processes in other forms of this class of Saprophytes, and, with the foregoing, clearly indicate the enormous rapidity with which these organisms develop under favourable conditions.

"One of the most important researches thus ably prosecuted by Messrs. Dallinger and Drysdale has reference to the temperatures respectively endurable by the adult or developed forms of these monads, and by their reproductive germs A large number of experiments upon the several forms now described indubitably led to the conclusion that all the *adult* forms, as well as those which had reached a stage of development in which they can be distinguished from the respective granules, are utterly destroyed by a temperature of 150 deg. Fah. But, on the other hand, the reproductive granules emitted from the cysts that originate in 'conjunction' were found capable of sustaining a *fluid* heat of 220 deg., and a dry heat of about 30 deg. more, those of the *cercomonad* surviving exposure to a dry heat of 300 deg. Fah. This is a fact of the highest interest in its bearing on the question of 'spontaneous generation' or abiogenesis, since it shows that germs capable of surviving dessication may be everywhere diffused through the air, and may, on account of their extreme minuteness (as they certainly do not exceed $\frac{1}{200000}$th of an inch in diameter) altogether escape the most careful scrutiny and the most thorough cleansing processes, while (2) their extraordinary power of resisting heat will prevent these germs from being killed either by boiling or by dry heating up to even 300 deg. Fah."

Pursuing the range of useful living organisms in order of their size, Fig. 7 shows some of the varieties of the infusoria

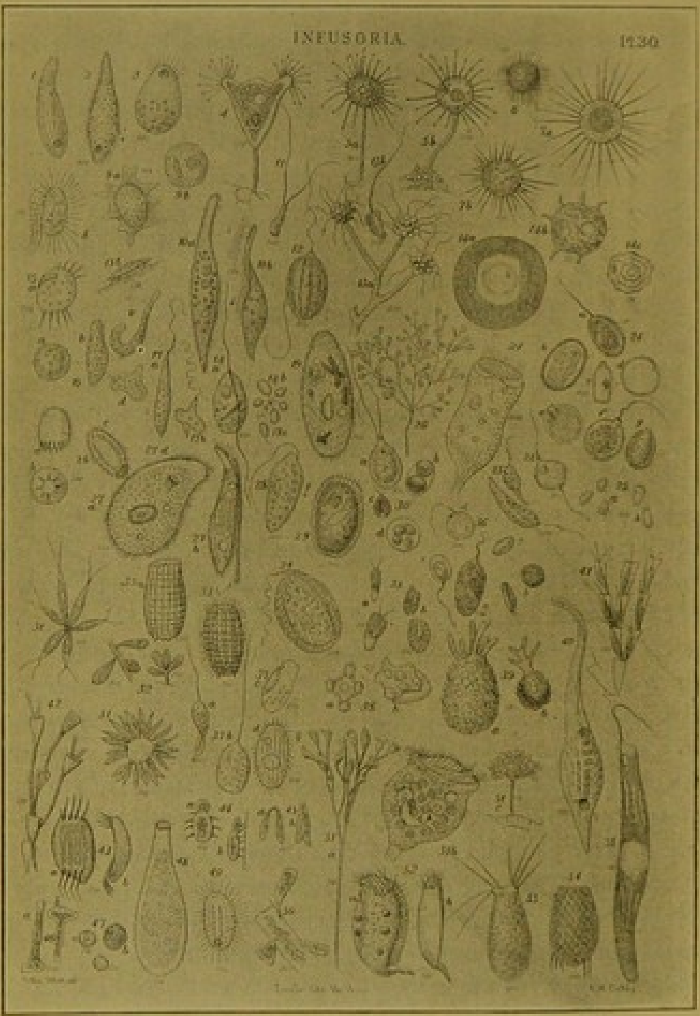


Fig 7.—Infusoria. From Griffith and Henfrey's "Micrographic Dictionary." (By kind permission of Messrs. Gurney and Jackson, Mr. Van Voorst's successors.)

of a higher type, which abound in all waters containing the organic matters which serve as their food.

Fig. 8 illustrates some of the various kinds of microscopic worms, &c., which play an equally active part in the work.

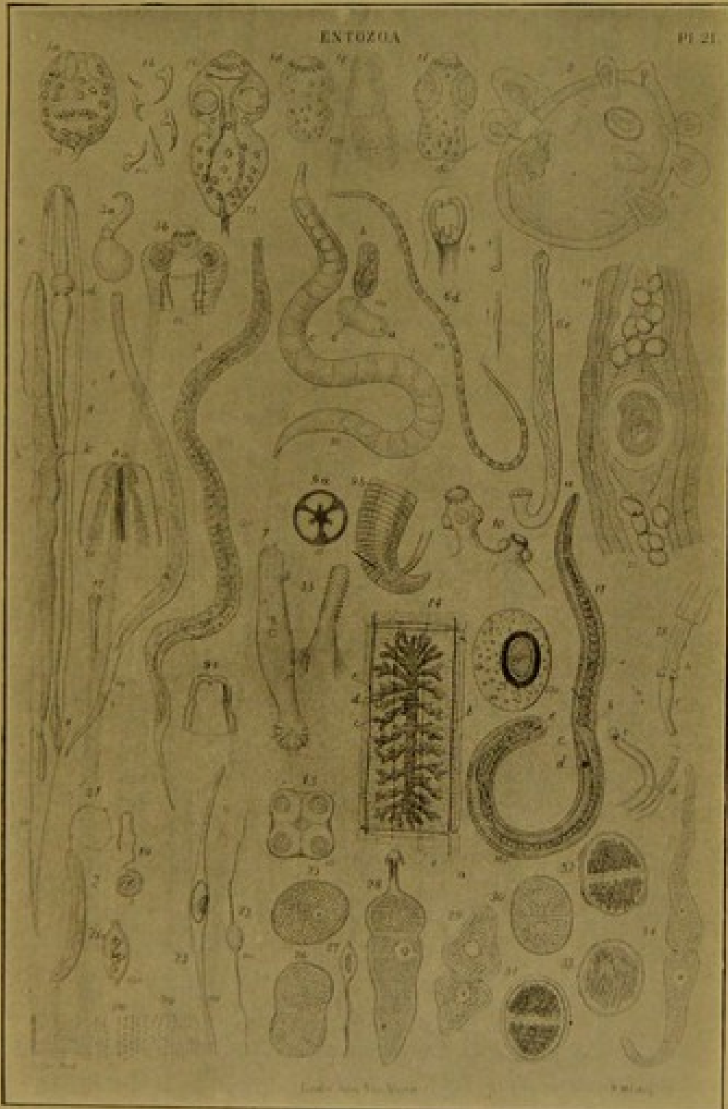


FIG. 8.—Entozoa. From Griffith and Henfrey's "Micrographic Dictionary." (By kind permission of Messrs. Gurney and Jackson, Mr. Van Voorst's successors.)

On the other hand, there are a number of growths of a different kind, having somewhat the character of the *beggiatoa*

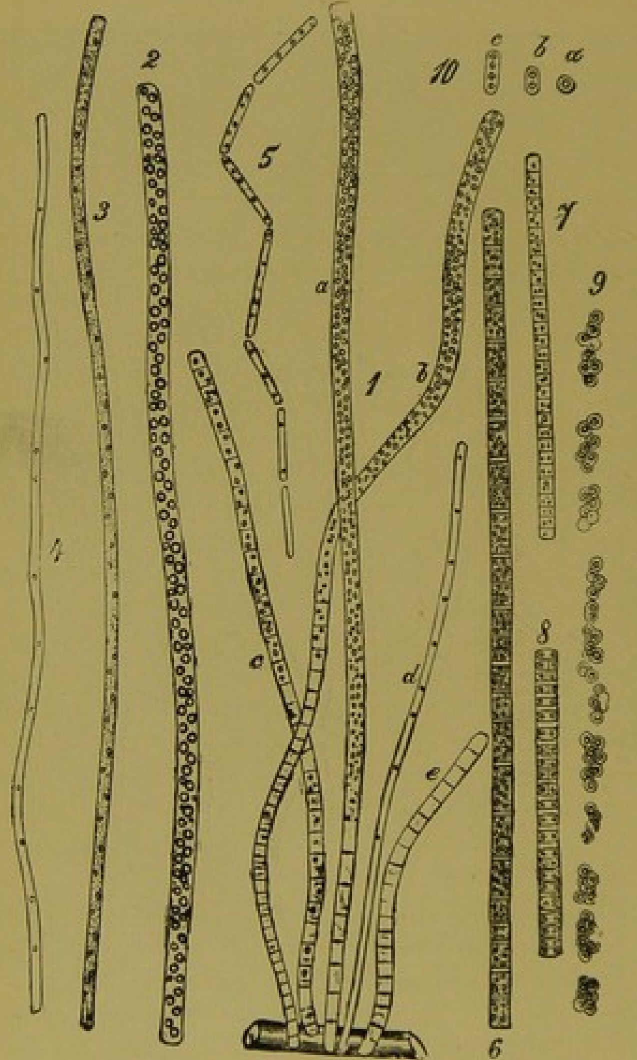


FIG. 9.—Beggiatoa Alba. (From De Bary's "Comparative Morphology of Fungi.")

alba, or "sewage fungus," shown in Fig. 9. In this case the filaments have the well-known grey colour; but in many other kinds of filamentous growths known as confervoideæ the green chlorophyll is present, thereby indicating an ample supply of oxygen.

In the case of rivers, &c., these various organisms are supplemented by others of a larger character, such as the water-fleas, larvæ, worms, &c., and in estuary waters, &c., shrimps, &c. The late Dr. Sorby once described how he fed tame shrimps held in his hand, and observed their manner of feeding on sewage debris.

That these various organisms live and thrive on the food supplied to them in the form of waste organic debris is no new thing. As early as their first discovery in the seventeenth century, Kircher and Leeuwenhoek observed the infusoria and many of the bacteria, and Baker, in 1743, clearly indicated their scavenging properties, but it was not known that their action was the sole cause of the slow destruction of organic matter. Liebig termed their slow oxidation "eremacausis" (*slow-burning*), on the assumption that the action was a direct combination with oxygen, resulting in a brown pulverulent substance known as *humus*. Graham, in 1842, remarked: "The absorption of oxygen by alcohol in its acetification is a true eremacausis; so also is the slow process of nitrification. Eremacausis seems to be entirely prevented when water is excluded, or when the substance is exposed to a temperature of 32 deg. Fah." *Aerobic biological action* is but the precise definition of the *fact* formerly known as *eremacausis*, or slow oxidation, the whole difference being that the modern definition indicates both *fact and cause*, whilst the older denoted the *fact* only.

It is not a little remarkable that the early attempts to employ this method for the artificial purification of sewage were confined to *anaerobic* or putrefactive methods. The *aerobic* process of land treatment belongs more strictly to natural methods, and when suitable land of sufficient area was employed no nuisance was created and all went well; but with the increase of sewage the land became overcharged and anaerobic conditions prevailed.

In 1877 MM. Schlœsing and Muntz showed that nitrification (which Graham said was due to "Eremacausis") of sewage in soils was due to an organised ferment, which was confirmed by Warington, and in 1881 Frank Hatton described before the Chemical Society a brilliant series of experimental demonstrations of the effect of various gases on bacteria in the presence of fresh meat and water, and showed how oxygen was used up, carbonic acid formed, and nitrogen eliminated concurrently with the decomposition of organic bodies.

Warington in 1882, at the Society of Arts, described his idea of a filter bed "having a greater oxidising power than would be possible by an ordinary soil and sub-soil. Such a bed would be made by laying over a system of drain pipes a few feet of soil obtained from the surface (first 6in.) of a good field."

In the following year Dr. Sorby, in his evidence before the Royal Commission on the Discharge of Sewage into the River Thames, remarked: "A very large portion of the detritus of fæces thus manifestly lost in the river is not lost by *decomposition*, but utilised by countless thousands of living creatures. The difference between the results of these two processes will be at once understood when we reflect on what would be the state of London if all the animals consumed as food were left to decompose in the streets."

In 1884 Dr. Duclaux wrote: "Whenever and wherever there is a decomposition of organic matter, whether it be the case of a herb or an oak, of a worm or a whale, the work is exclusively done by infinitely small organisms. They are the important, almost the only, agents of universal hygiene; they clear away more quickly than the dogs of Constantinople or the wild beasts of the desert the remains of all that has had life."

The Royal Commission above referred to adopted these views, but did not clearly differentiate the various functions, and confused matters by referring to "by fermentation and by oxidation," and many experimentalists were thereby misled, thinking that by fermentation was meant *anaerobic* or putrefactive action, to be followed by direct oxidation by immediate chemical combination with the oxygen of the atmosphere—a misconception which has led to much delay in the progress of the science and practice of sewage treatment.

In order to show the precise method, as far as possible, by which solid organic particles are destroyed by the agency of living organisms existing in the presence of air, I have made the series of experiments set out in Table I. (facing page 16), which speak for themselves.

So far we have dealt with the destruction of the organic matters, but it must not be overlooked that this destruction is but a preliminary preparation for the utilisation of the components in the creation of new forms. Green plants can derive their nitrogen in part from ammonium compounds, but more readily from nitrates. The cycle of change through which matter passes from living tissue to inorganic substances, and thence to living tissue again, is illustrated in a diagram, Fig. 10, by Prof. Sedgwick, which indicates the transformation of organic nitrogen in nature.

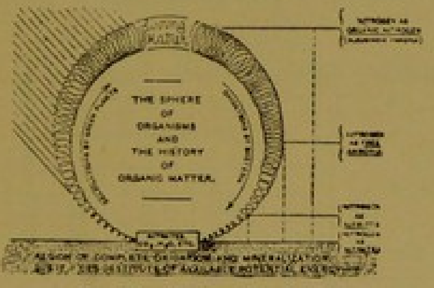


Fig. 10.—Sedgwick's Spiral.

The increasing size and closeness of the spiral on the left-hand side indicates the progressive complexity of organic matter as built up by the chlorophyll bodies of green plants in the sunlight; the other half of the figure denotes the reverse process carried out largely by bacteria.

In nature there are of course many "short circuits," as, for instance, when dead organic matter is used for food and built up again into the living state without being nitrified and acted on thereafter by green plants. The complete cycle however, is as indicated on the diagram. This is more apparent if we consider all living organisms as only so many digesting agents.

Chemical Character of Waste Matters.

The following Table II. shows the chemical composition of the larger number of particles existing in sewage :—

TABLE II.

Substance.	Nitrogen per cent.	Hydrogen per cent.	Oxygen per cent.	Carbon per cent.
Gelatine	18·3	6·6	25·1	50·0
Chondrine	14·4	7·1	29·4	49·1
Albumen	16·0	7.1	22.0	53.0
Cellulose (wood fibre)	—	6.2	49.4	44.4
Starch	—	6.2	49.4	44.4
Fat (Stearic acid)	—	12.7	11.3	76.0

It will be observed that each of these substances already contains oxygen, and the inquiry naturally follows how much more do they need to complete the oxidation of the nitrogen, hydrogen, and carbon? This is best answered by Table III., showing the actual conditions in each case :—

TABLE III.

Pounds of Oxygen Required to Oxidise every 100 lb. of Substance.

Substance.	Oxygen required.				Oxygen already present.	Difference or additional oxygen required for complete oxidation of substance.
	By the nitrogen.	By the hydrogen.	By the carbon.	Total required.		
Gelatine	52·3	52·8	133·3	238·4	25·1	213·3
Chondrine	41·1	56·8	131·0	228·9	29·4	199·5
Albumen	45·7	56·8	141·4	243·9	22·0	221·9
Cellulose (woody fibre)	—	49·6	118·4	168·0	49·4	118·6
Starch	—	49·6	118.4	168·0	49·4	118·6
Fat (Stearic acid)	—	101·6	202·5	304·1	11·3	292·8

The last column shows the excess of oxygen required, beyond that already present in combination, for complete oxidation.

Source of Oxygen.

The next step is to inquire—Where can we obtain the oxygen necessary? In the course of a series of experiments instituted infusoria, and various bacteria.

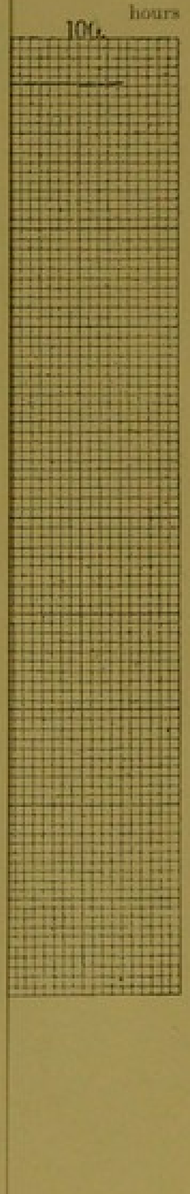
Substance.	First day.	Second day.	Third day.	Fourth day.
Lean of raw beef...	In four hours the red colour had turned to grey.	The beef had sunk into the mud, grey in colour, and swarming with bacilli, spirilla, monadina, &c.	Beef scarcely visible, being now one mass of various organisms.	Meat entirely disappeared.
Cheese...	In four hours the cheese was light grey in colour.	Cheese had sunk into humus, swarming with bacilli of various kinds.	Cheese reduced to a thin layer.	Entirely reduced to a pasty condition.

On November 2nd, 1908, 7 grammes of raw liver were placed on a layer of the above deposit, laid on the bottom of a 4in. Petri dish, the area being 12in. approximately. The quantity of liver thus treated was equal to the treatment of a sewage 100 times normal strength.

First day (after 24 hours).	Second day.	Third day.	Fourth day.	Eighth day.	Fifteenth day.
Liver had lost colour, odour unpleasant.	Odour offensive.	Very offensive.	Odour decidedly reduced.	Odour had entirely disappeared.	Liver reduced to a very few resistant pieces, which were covered with whitish grey spots consisting of bacillus megatherium. Later, a growth of the mould, mucor caninus, developed.

Note.—This experiment was very drastic. The liver was laid very thickly, with scarcely any room between the pieces, none of which was smaller than $\frac{1}{16}$in. diameter, while many approached $\frac{1}{2}$in.

On November 6th another dish was similarly charged with 1 gramme of beef steak raw, 1 gramme of beef fat, and 1 gramme of cheese. On the sixth day the cheese had entirely disappeared, the beef steak was reduced to a greyish soft mass, and the fat was disintegrated.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hours

some years back in connection with the work of purifying the River Thames, I ascertained that still water, containing no oxygen dissolved therein, will absorb in one hour 10 per cent. of the total possible quantity which it can take at ordinary temperatures and pressures, this total quantity being equal to 1·8 cubic inches per gallon under normal conditions—see Fig. 11. In two hours water will take up 20 per cent. In three hours this quantity will be increased to 26 per cent.; in four hours to 32 per cent.; in five hours to 36 per cent.; in six hours to 40 per cent.; in seven hours to 43 per cent.; and so on, ten hours being required for it to absorb only one-half its total quantity, or 50 per cent. of the 1·8 cubic inches per gallon. If the water is agitated the rate of absorption is far more rapid. As showing the practical bearing of these results upon the water of the River Thames, we may consider their effect on the tidal portion of the river from Teddington to the Nore. The following table shows the average percentage quantity of oxygen dissolved in the water at fifteen different points at and between these places from July, 1893, to March, 1894, as determined by daily analyses at high and low tides at each place during that period:—

TABLE IV.

Average Percentage Quantity of Oxygen Dissolved in the Water of the River Thames from Teddington to the Nore.

(Saturation = 100 per cent. = 2·0 cubic inches per gallon.)

Locality.	High water.	Low water.
Teddington (above lock)	85·0	
Kew	70·3	85·5
Hammersmith	55·7	78·8
Battersea	42·6	67·6
London Bridge	34·5	51·8
Greenwich	24·6	37·4
Blackwall	22·5	34·3
Woolwich	22·2	30·8
Barking Creek	24·2	30·8
Crossness	43·0	41·6
Erith	39·4	29·1
Greenhithe	38·4	25·1
Gravesend	50·7	39·5
The Mucking	83·6	72·0
The Nore	90·1	89·1

From this table it will be seen that the average aeration at high and low water between Teddington and Chiswick is a trifle under 80 per cent. of the total possible quantity. This rapidly decreases until at Woolwich it is only about 26 per cent., when it rises again until it is 90 per cent. at the Nore. In other words, the water as it flows over Teddington Weir is well aerated, and is able to deal with all polluting matters contained in it without suffering any material reduction in aeration, *i.e.*, the rate of absorption from the atmosphere (actual aeration being 85 per cent.) is equal to the rate of consumption by the microbes, &c., feeding on the organic matter.

TABLE V.

Section.	Rate of absorption. Tons per 100 million cubic feet per day.	Tons of oxygen dissolved by the water in section per 24 hours.
Teddington to Chiswick	3·6	4½
Chiswick to St. Paul's Pier	12·7	43
St. Paul's Pier to Deptford	21·4	69
Deptford to Woolwich	43·8	240½
Woolwich to Barking Creek	42·8	105
Barking Creek to Crossness	29·2	131
Crossness to Erith	21·9	126½
Erith to Gravesend	21·9	716
Gravesend to Southend	5·5	949
Total		2384½

Further down the river this process abstracts more oxygen than can be supplied at the former slow rate at the higher degree of aeration, and accordingly the degree of aeration falls, which fall is accompanied by a corresponding increase in the rate of absorption from the atmosphere, as shown by the experiments above quoted. When the rate is again equal to the necessities of the increased number of organisms feeding on the larger quantity of organic impurities, the balance is once more established, and the aeration remains constant at the lower rate.

From these observations it is evident that at Teddington, where the degree of aeration is 80 per cent., the rate of absorption of atmospheric oxygen will be 3·6 tons per 100 million cubic feet of water per day, and as the sectional volume of the river between that point and Chiswick at *high* water may be taken at about 250 million cubic feet, it follows that this reach of water will absorb 9 tons of oxygen in twenty-four hours, or 4½ tons on the assumption that the mean water capacity is one-half of that at high water. In like manner each section of the river may be tabulated as in Table V.

These considerations show the enormous forces at work in purifying our streams and rivers, and constitute the real secret of Nature's method in effecting the destruction of effete matters wherever they may be.

Land Treatment and Contact Beds.

Fig. 12 shows the process which the sewage undergoes in its treatment on clay land with immediate sub-surface drains.

Fig 12.—Diagram A: Land Treatment.

In this case the solids are retained on the surface, and the liquid passes almost immediately to the underdrains with more or less imperfect purification.

Fig. 13 shows the method of treatment on cultivated soil with underdrains at about 18in. below the surface Here the

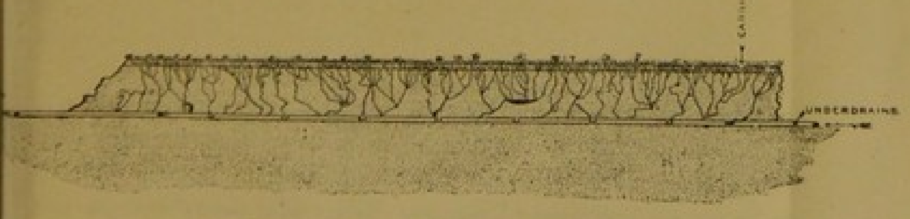


Fig. 13.—Diagram B: Land Treatment.

effect is necessarily greater than in the first instance, in consequence of the greater depth of soil; but undoubtedly the water will find its way more or less directly by channels into the drains, the extent of these fissures and channels determining the quantity of sewage which passes away imperfectly treated.

Fig. 14 shows a similar state of things when the water is put on to a porous or gravelly soil deeply underdrained. For

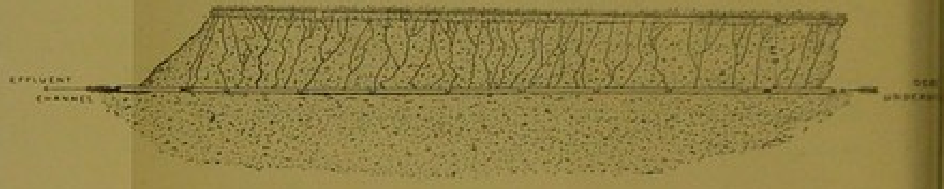


FIG. 14.—Diagram C: Land Treatment.

a while the results will be excellent, but in the course of time channels will be washed out, and through these the effluent escapes.

Fig. 15 shows the arrangement suggested for the more perfect treatment of the sewage by means of the biological

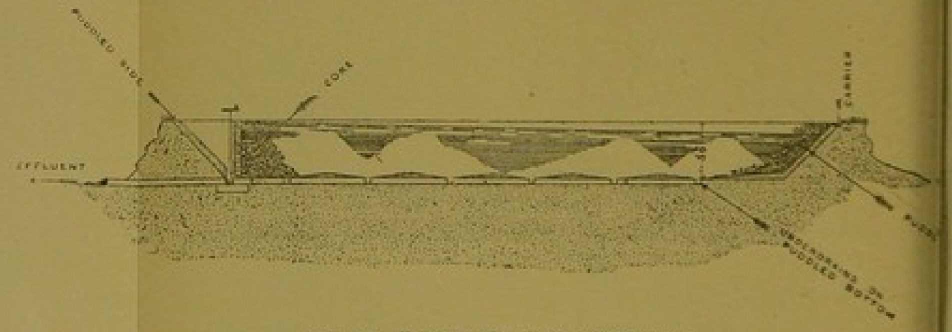


FIG. 15.—Diagram D: Land Treatment.

method. A certain quantity of the land is removed, and the sides and bottom of the "bed" or hollow thus created may be puddled with clay, or concreted if on a porous soil, to make it watertight. Drainage pipes are then laid on the bottom, and the space is filled with some coarse material, such as coke, clinker, broken granite, slates, chalk, burnt ballast, &c. A penstock or sluice is fitted on the outlet drain, in

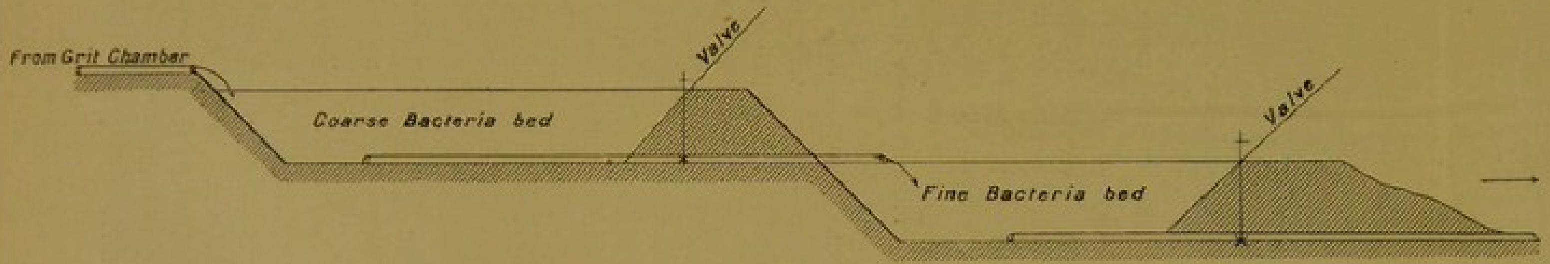


Fig. 16.—Diagram E: Land Treatment.

order to lock the sewage in the bed for a definite time, as already explained. By this means the sewage is brought into contact with each particle of which the bed is composed, instead of being allowed to find its way directly to the underdrains. When a sufficient time has elapsed, the effluent is allowed to escape on to a similar bed at a lower level, but filled with fine materials. Here it undergoes the second "biological" treatment, and is ultimately discharged in a more or less purified condition.

A typical pair of beds is shown in Fig. 16. It will thus be seen that a coarse bed treatment of the crude unsettled sewage is really equivalent to broad irrigation, and that on the fine bed to effluent irrigation, but starting in this case with a better effluent than is usually obtained by means of chemicals; and thus the effluent from broad irrigation on a coarse biological bed is well fitted for the second treatment by effluent irrigation on a fine biological bed.

From these considerations it will be seen that the biological process worked out at Barking Creek and Sutton *is land treatment*, but concentrated, accelerated and controlled, and therefore effective and economical; whilst "land treatment" as generally practised is haphazard, uncertain, and expensive.

The provision of land as a final safeguard may be met most completely by a third fine bacteria bed or a sand filter—in other words, by an area of land properly prepared and drained, and so arranged that all the effluents from the previous beds must pass through it; thus securing triple land treatment, but on an area of land considerably less than that usually employed.

The first example of the application of the system now known as contact is the one-acre bed at the Northern Outfall Works at Barking Creek, on the Thames, which for many years treated one million gallons of effluent from the chemical precipitation process daily. Fig. 17 shows this. The construction was simplicity itself, a triangular plot of marsh land being levelled, and covered with "herring-boned" drainage pipes, two sides being formed by (1) the old wall of the tunnel

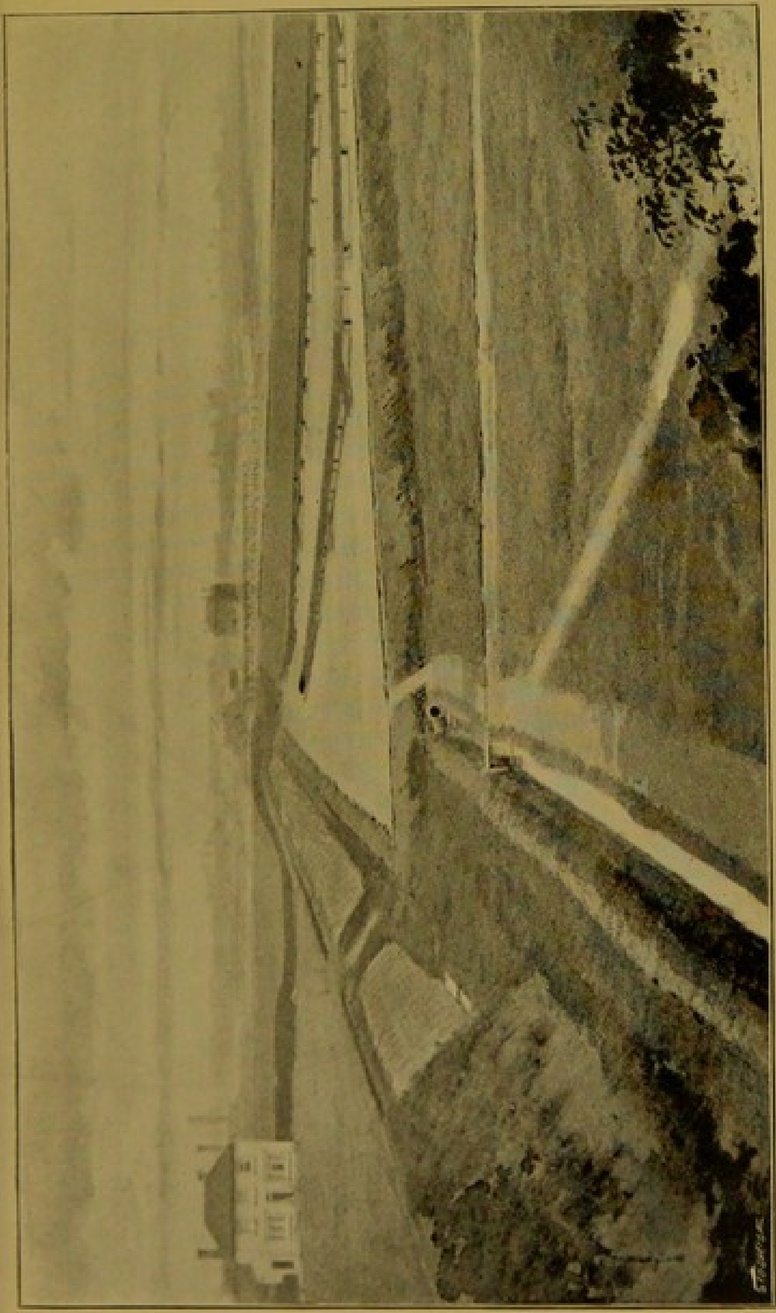


Fig. 17.—One Acre Filter Bed at the Northern Outfall Works, Barking Creek.

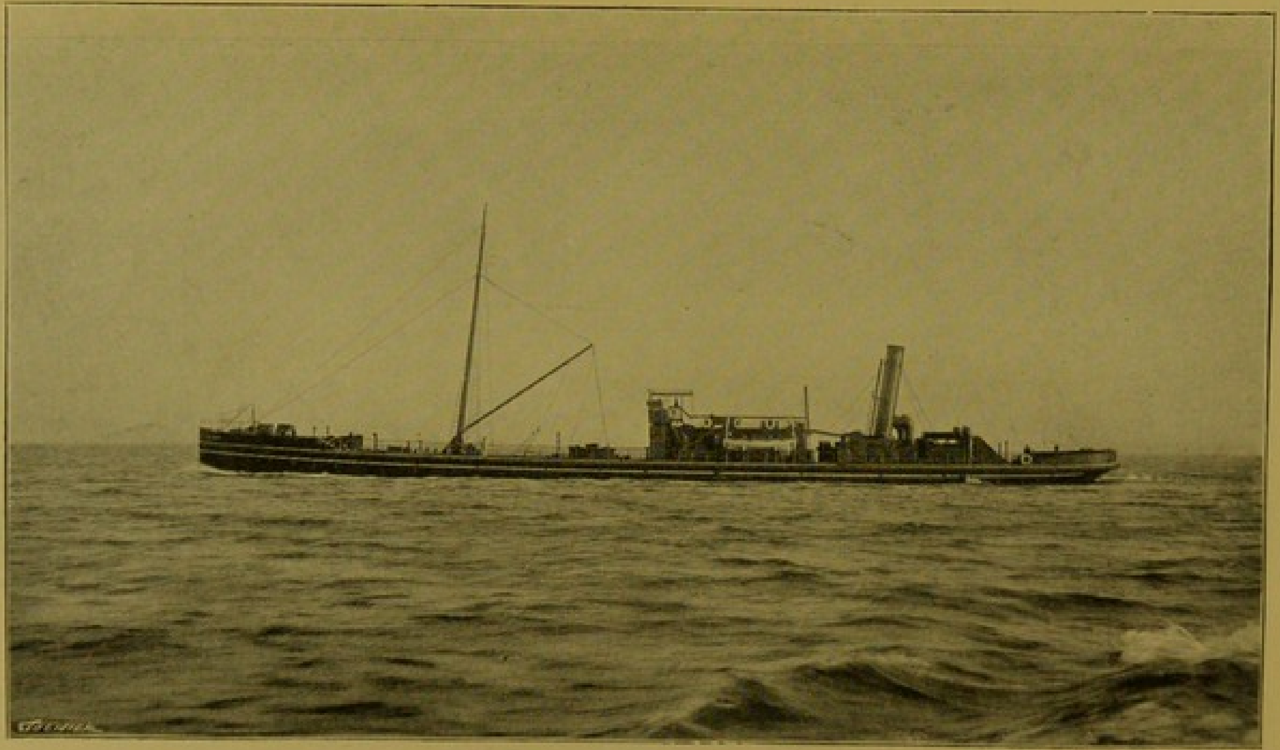


FIG. 18.—Sludge Ship Loaded.

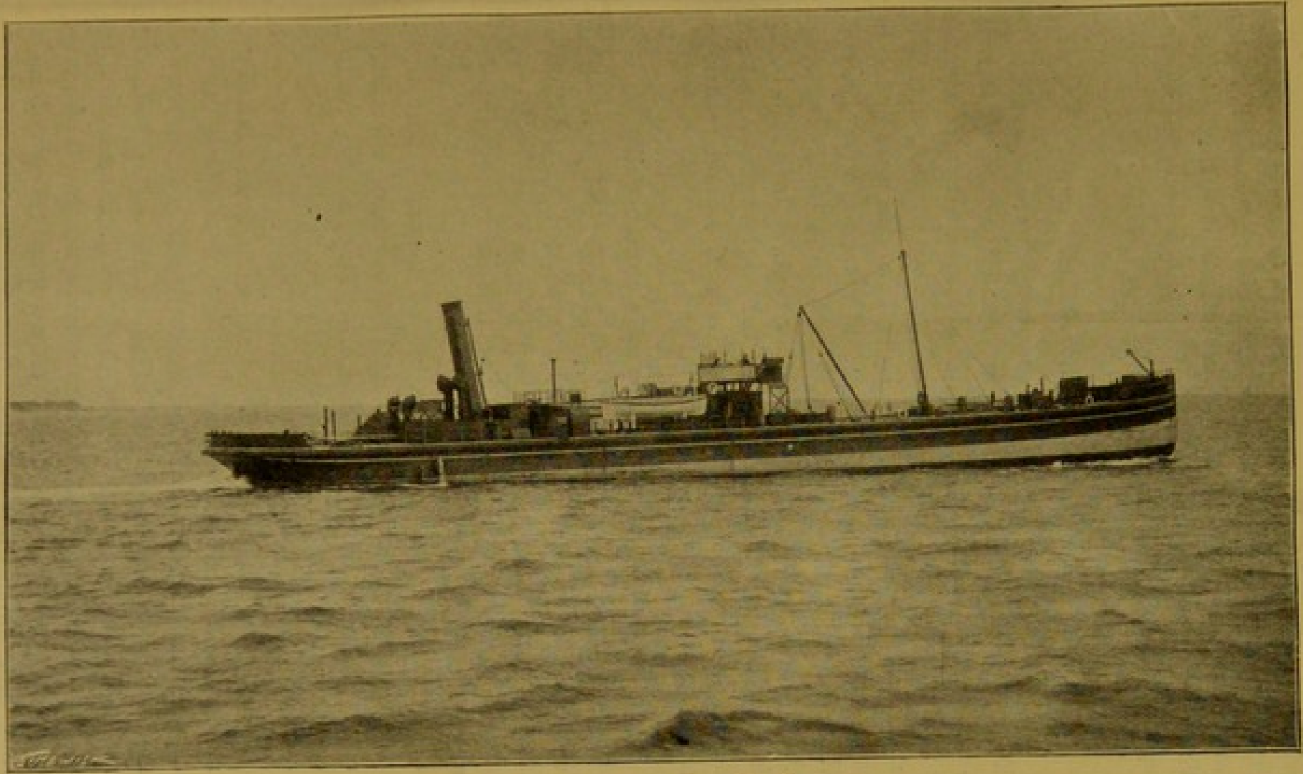


Fig. 19.—Sludge Ship Returning Empty.

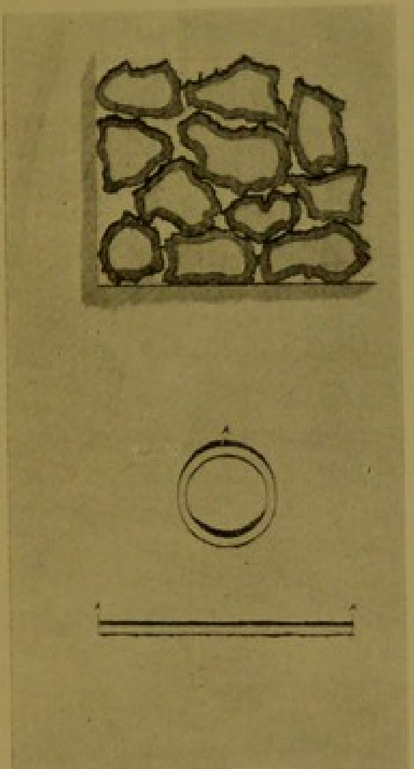
originally constructed to take sewage to the Essex farms (2) the river wall of the River Roding, the third wall being an earthwork dam running from one of the above to the other. The filling material was pan breeze, obtained from the adjoining works of the Gas Light and Coke Company.

Disposal of the Solids.

The solid matters in the London sewage were separated by the use of only 3·7 grains of lime and 1·0 grain of ferrous sulphate per gallon, and the sludge obtained after sedimentation in the precipitating channels was, and is, taken to the estuary of the Thames and discharged into deep water ten to twenty miles below the Nore, where the aerobic organisms of all kinds effectually dispose of it, an average of no less than 50,000 tons of sludge of about 95 per cent. of moisture being discharged weekly. Figs. 18 and 19 show the vessels used for the purpose, one being fully loaded and the other returning empty.

Introduction of the Coarse Contact Beds.

The fact that the fine-grained pan-breeze bed at Barking Creek satisfactorily disposed of the suspended matters in the effluent, which averaged 7·1 grains per gallon, induced me to think that, given proper facilities, the living organisms, if properly cultivated, would do a much larger amount of work, and on the 17th of September, 1896, I ventured to make a suggestion in the visitors' book at the works of the Sutton Urban District Council as follows :—"Why not try putting large ballast in No. 1 Tank and filtering crude sewage through it without chemicals. Bacteria will eat sludge, and save cost of pressing it, &c. Try it." The suggestion was taken up, and the Council turned the tank into the first coarse contact bed, with the result that subsequently the whole of the sewage was thus treated, and all cost of chemicals, &c., saved, and excellent effluents resulted from the secondary treatment in the fine beds. The abominable mixture commonly known as "sludge" was never formed, but only a small residue of inert humus and indigestible residue. The beds worked for about five years, when the humus, &c., gradually filled the pores of the burnt ballast and rendered it necessary to renew the material, the cost of which in comparison with the former expense of chemicals and sludge pressing, was negligible. Unfortunately, in one way, the trouble of refilling was, in view of the then fashionable putrefactive decomposition in tanks, considered as too great, and for a time the aerobic reduction of the solids to humus was looked upon with much doubt.



Section of Coke Bed showing waste space in centre of particles of Coke— and Deposit on surface of Coke.

Section of Pipe with Deposit on upper surfaces of exterior and interior, thus securing double working capacity and surface.

Pipe cut at A and opened out flat, forming a plate.

FIG. 20.—Genesis of the Plate Bacteria Bed.

Having regard to the admitted desirability of avoiding the sludge nuisance, I made further experiments, with a view to preventing the choking of the beds and rendering them selfcleansing, and, consequently, permanent. The final result was that I found that slates or other suitable material capable of forming a series of shelves answered the purpose. The evolution of the idea is fully set out in Fig. 20.

Fig. 21.—Splitting Slates.

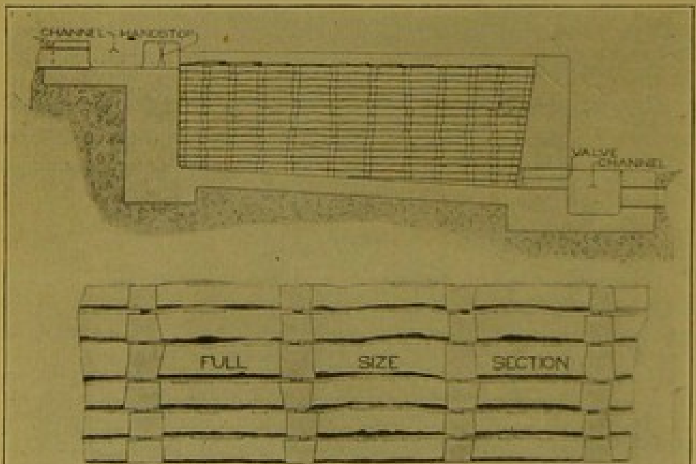


Fig. 22.—Section of Slate Bed.

The dark line on the surface of the plate indicates the layer of "living earth" rapidly formed by the decomposition of the sewage deposit, which layer receives an increment of about one-hundredth of an inch at each filling of the bed with normal sewage. This freshly deposited thin layer is consequently rapidly attacked by the organisms (worms, infusoria, moulds, and bacteria) in the "living earth," and thereby reduced.

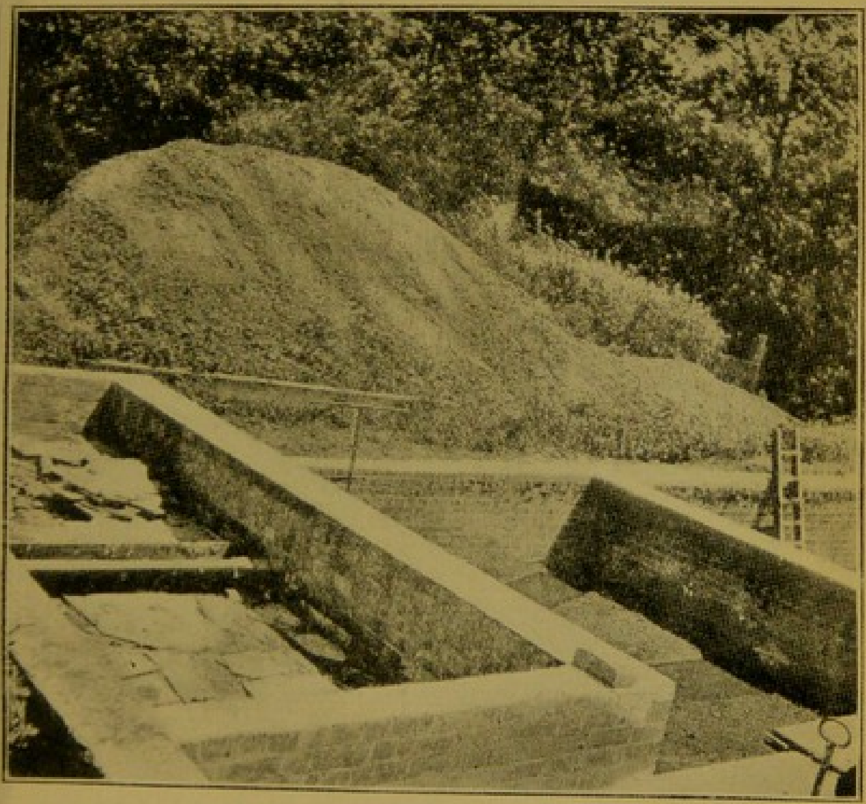


FIG. 23.—Experimental Beds at Devizes.

The distance between the respective shelves of slate is generally two inches, but in certain cases it is advisable to have them only one inch apart. Fig. 21 shows the method of splitting the slate blocks into suitable slabs, which are generally about a quarter of an inch thick, varying with the splitting quality.

Fig. 22 shows the manner in which the slates are placed in position in the beds, the ends being supported on rough slate cubes. The dark lines show the deposit of humus and sewage debris upon them.

Devizes Experimental Slate Beds.

After the preliminary laboratory experiments, a trial bed was erected at the works of the Devizes Corporation. This is

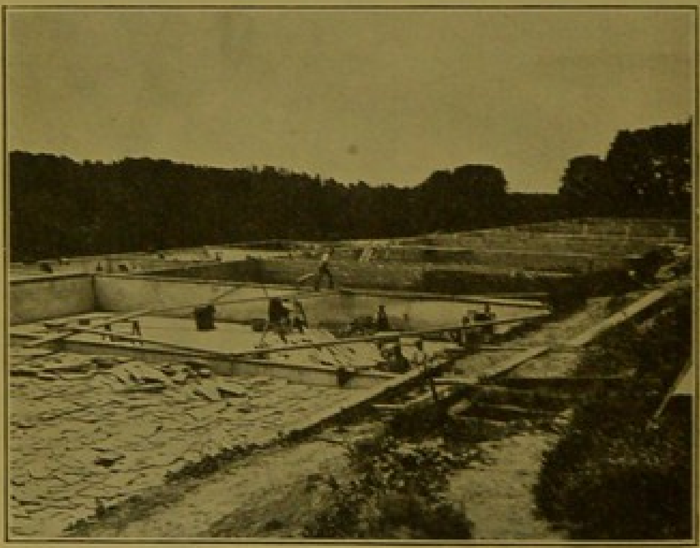


Fig. 24.—Filling Devizes Beds.

shown in Fig. 23. The slate bed is exactly one-half of the size of the secondary fine bed, as the water capacity of the slate bed is double that of the old coarse contact bed, and thus effects a saving of about one-half the constructional cost of the bed and requires only one-half the number of cubic yards of filling material. The success of this system in effecting the inoffensive destruction of the solid matters, and thus avoiding the old-time sludge nuisance with all its expense, &c., decided the Corporation to adopt slate for filling their new series of contact beds. Fig. 24 shows this work being carried out; whilst Fig. 25 shows the beds finished and at work.

Fig. 26 shows the storm-water slate beds at the same works.

Following Devizes, other authorities soon adopted the system. At High Wycombe experimental beds have been at work for over five years, and it has been decided to adopt the system for the treatment of the whole of the sewage. At East Dereham, after prolonged trials with a sewage, which at times contains 33 per cent. of steep water from the maltings, the system was adopted, and is now being still further extended.

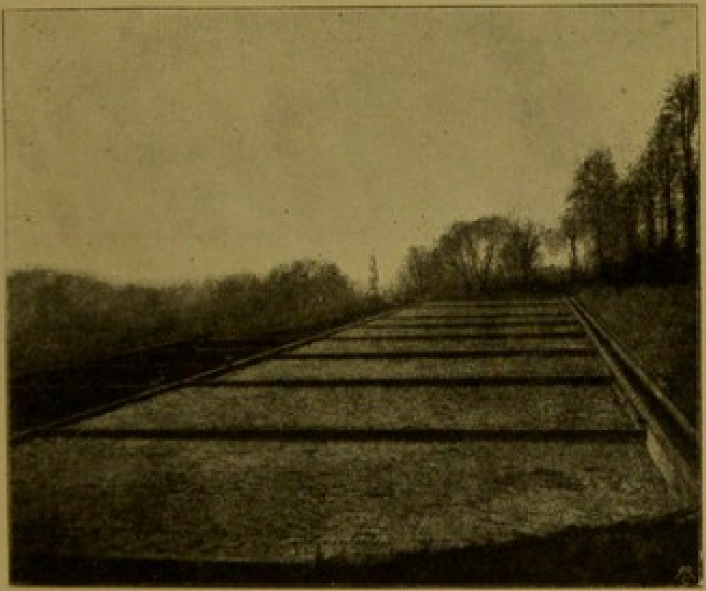


Fig. 25.—Devizes Primary Beds filled with Slate.

The sewage from barracks, particularly artillery, is very exceptional, and in order to ascertain the practicability of treating it on slate beds to avoid the sludge nuisance, the War-office has installed four beds for treating the sewage from the Deepcut and Blackdown Barracks, North Aldershot. Fig. 27 shows these. An extension of the method has subsequently been made to treat the whole of the sewage at the Curragh Camp, Ireland, where there is an average population of 10,000 soldiers and a number of horses. Fig. 28 shows a section of the slates being fitted in the beds.

The effect of climate is often questioned, and in this connection the illustration, Fig. 29, shows the system at work at Gourepore, near Calcutta, whilst various installations are in use in Russia, &c., and the method has now been adopted under the advice of Sir Douglas Fox and Partners and Michell Whitley, M. Inst. C.E., &c., for the treatment of the whole of the sewage of a population of 125,000 at Para, Brazil.

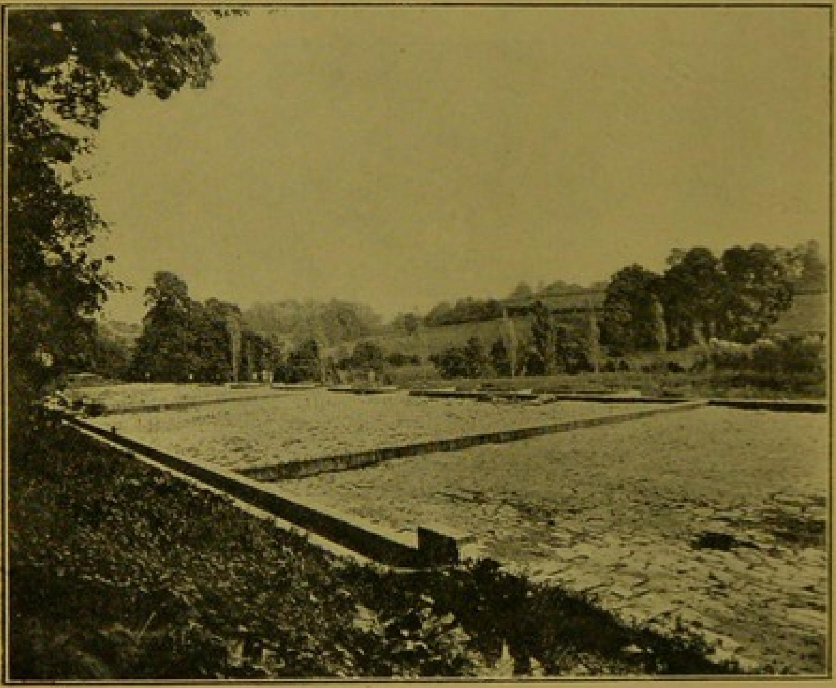


Fig. 26.—Devizes Storm-water Slate Beds.

The possibility of using slate slabs for lining the sides and walls of beds is well shown in Fig. 30, thus making an exceedingly neat and cleanly finish.

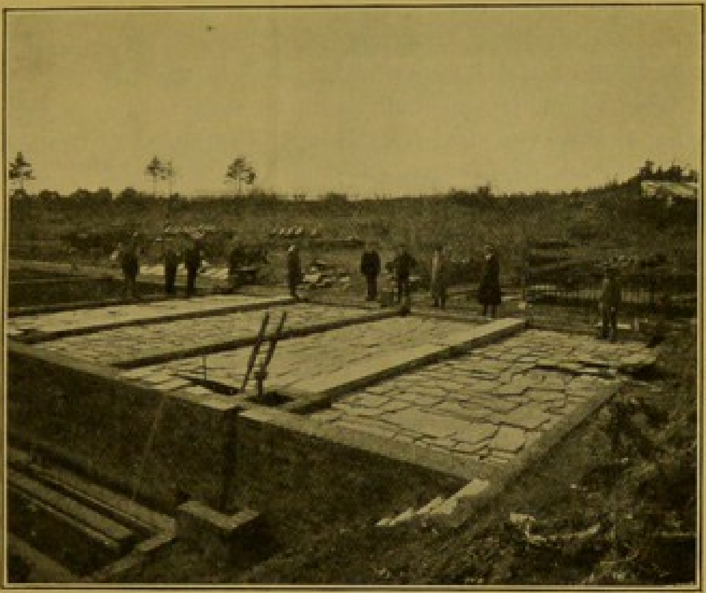


FIG. 27.—Blackdown and Deepcut Barracks.

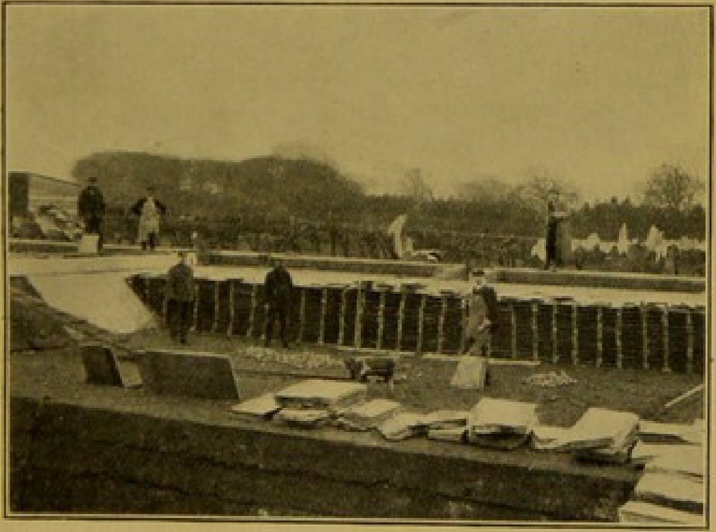


FIG. 28.—Curragh Camp.

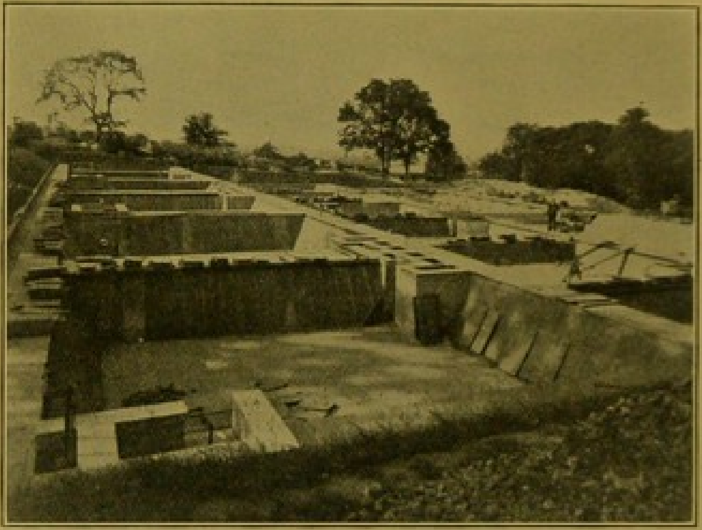


FIG. 31.—Netherne Beds: Slate Construction in Second and Tertiary Beds.

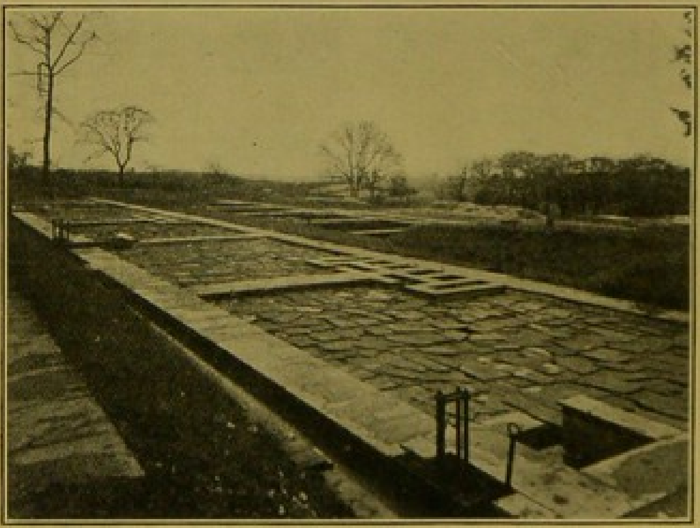


FIG. 32.—Netherne: General View.

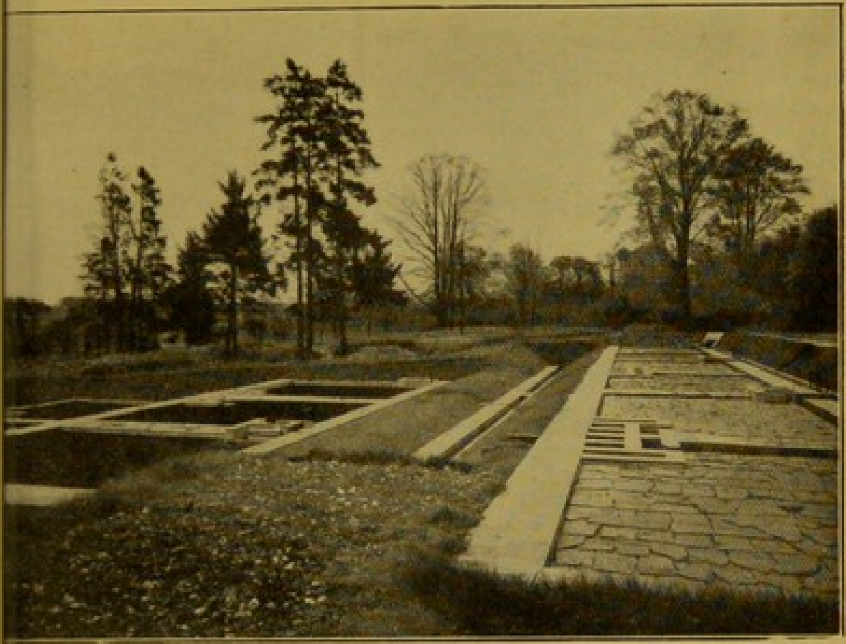


FIG. 33.—Netherne Slate Beds: Laundry Water Chamber on Extreme Right.

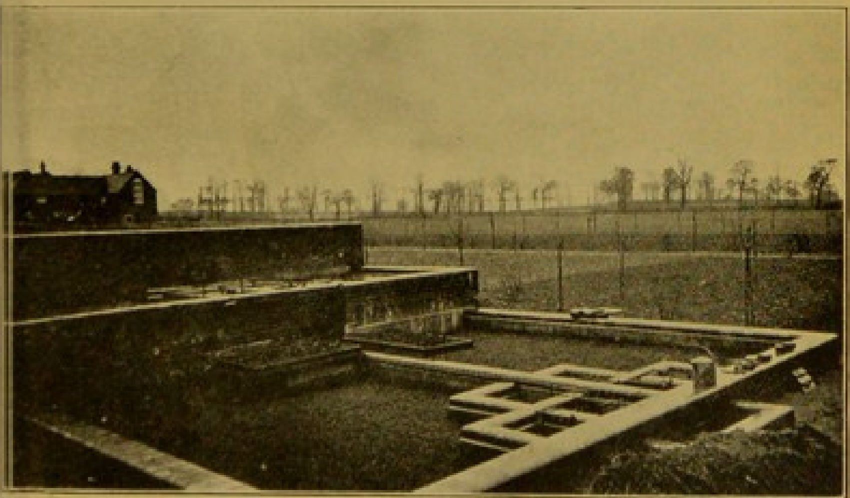


FIG. 34.—Byfleet Cripples' Home: Fine Clinker Beds after Slate Beds.

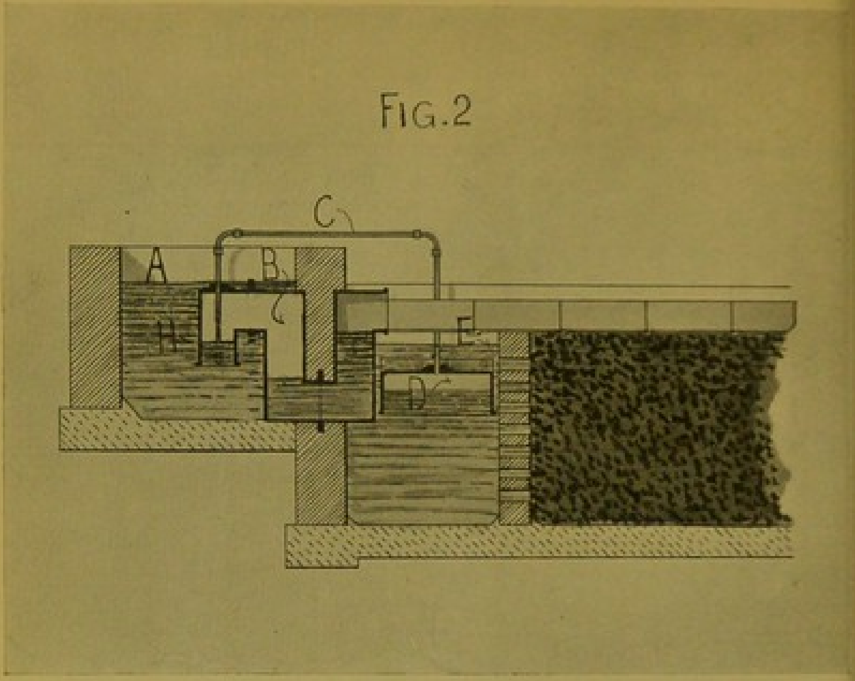


Fig. 35.—Adam's Feed Syphon, Air Trapped

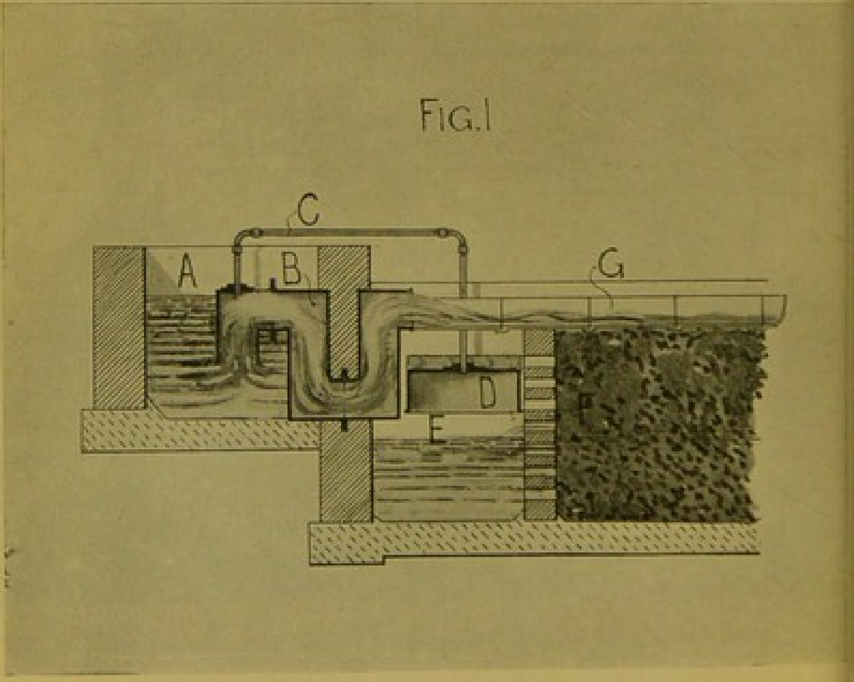


Fig. 36.—Adams' Feed Syphon, Water Passing.

into the water of the lower tank; then when the water rises up the central column the air imprisoned in the dome D is sent back through the air pipe into the trap and creates a pressure which prevents a further passage of water to the bed until the confined air is liberated from within the feed. The latter operation is effected by means of the air transferred from a dome in the adjoining or the last operated bed, the pressure of this air acting upon the water of the trap from which, when the water is blown out, the air from the feed finds exit. Fig. 35 shows a feed under compression. Fig. 36 the feed with the water passing through it. Fig. 37 shows overdraw syphon for timed discharge of bacteria beds. The syphon proper is placed in a chamber which is filled at a given rate through a trap which draws its supply from the bacteria bed. When the syphon starts it not only discharges the contents of the

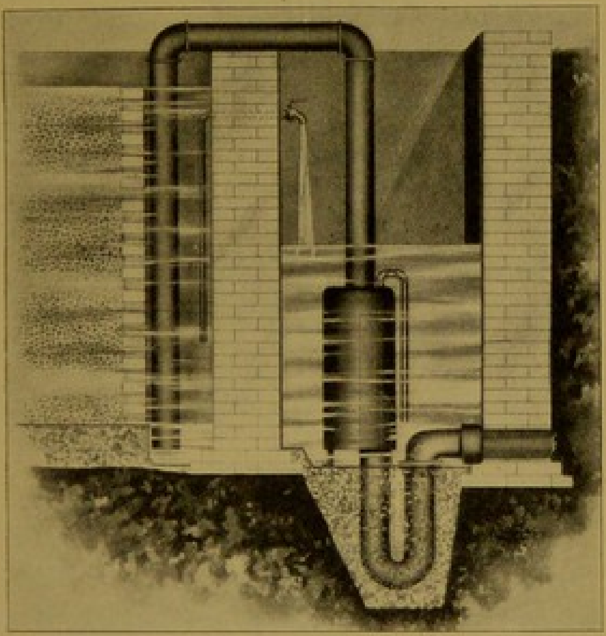


Fig. 37.—Adams' Timed Syphon.

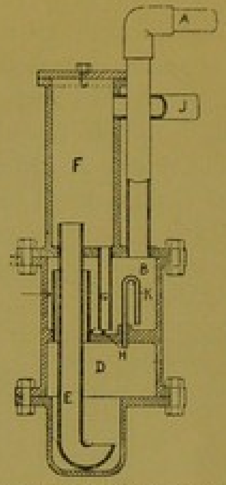


Fig. 38.—Burn Bros.'s "Sequela" Relief Apparatus.

Fig. 39.—Burn Bros.' "Sequela" Alternating Syphon

chamber but also the contents of the bacteria bed to which it is connected by means of the overdraw pipe.

An alternative form to Messrs. Adams' is that of Messrs. Burn Bros. The primary filters are usually supplied with sewage from a collecting or dosing chamber in which two or more discharge syphons are fixed, or they may be filled from a supply channel under certain circumstances. In the former case a syphon discharges immediately the collecting chamber is full. A "Sequela" relief apparatus—Figs. 38 and 39—is attached to each syphon and causes these to discharge alternately or in rotation with unfailing regularity. The relief apparatus, Fig. 38, is divided into three compartments, and depends for its working on the transference of oil, of a special nature, from one compartment D to another compartment B *viâ* compartment F in stages, corresponding with the number of syphons under control, each relief apparatus at the commencement being set a stage in advance of the one next to it. After a syphon has discharged, the oil which has been transferred to the compartment B in the relief apparatus is automatically returned to the compart-

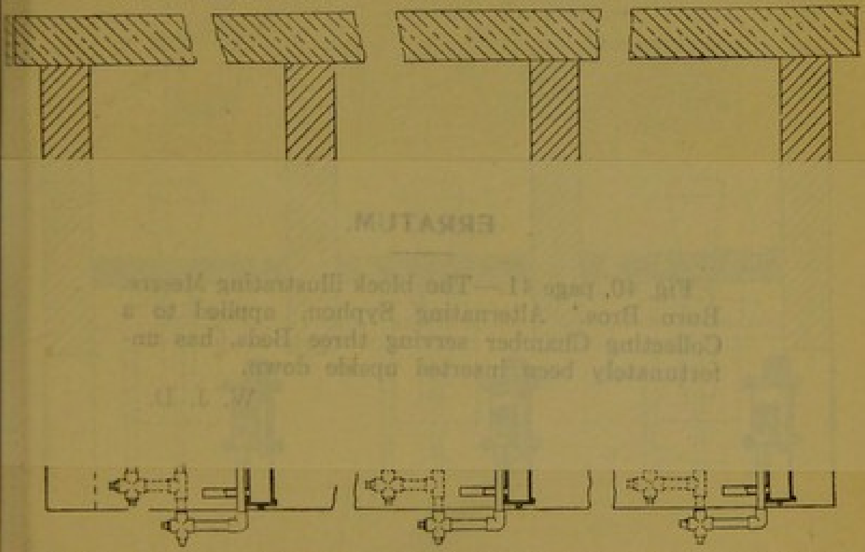


FIG. 40.—Burn Bros.' Alternating Syphons applied to a Collecting Chamber serving three Beds.

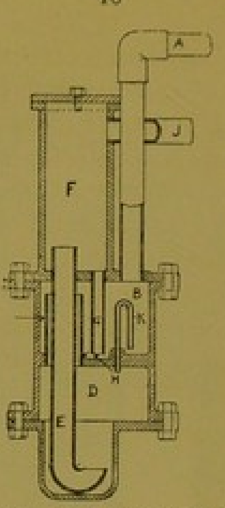


Fig. 38.—Burn Bros.'s "Sequela" Relief Apparatus.

ERRATUM.

Fig. 40, page 41.—The block illustrating Messrs. Burn Bros.' Alternating Syphon, applied to a Collecting Chamber serving three Beds, has unfortunately been inserted upside down.

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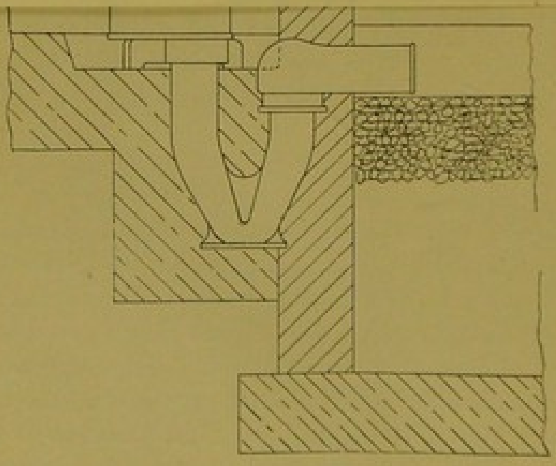

Fig. 39.—Burn Bros.' "Sequela" Alternating Syphon

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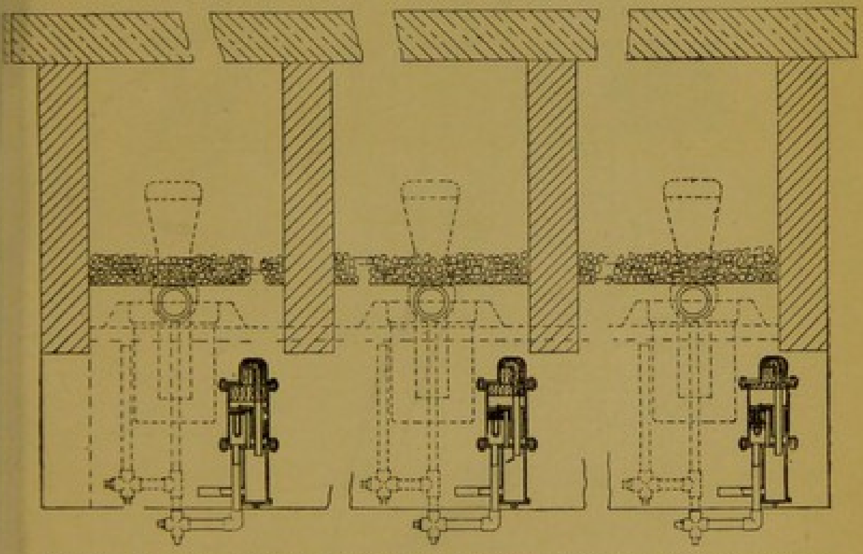

FIG. 40.—Burn Bros.' Alternating Syphons applied to a Collecting Chamber serving three Beds.

ment D, and the apparatus is then ready for another series of operations. Thus, the oil, which is non-evaporative and non-freezing, is used over and over again, and as it does not come in contact with the sewage, it remains quite pure and serviceable for years.

A discharge syphon—Fig. 41—is fixed in each filter, and in order to ensure a proper period of contact of the sewage with the filtering material, each syphon is provided with a "Horometer" relief apparatus—Fig. 42.

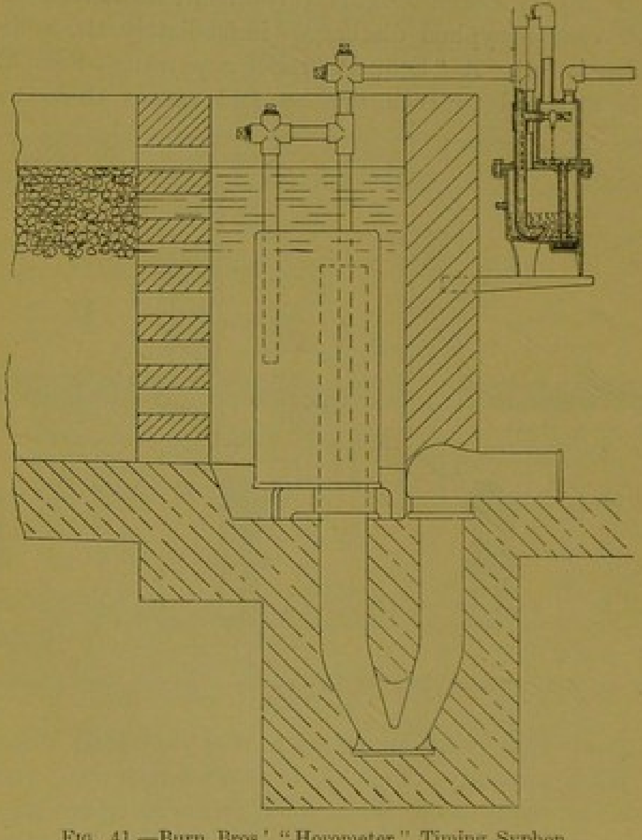

Fig. 41.—Burn Bros.' "Horometer" Timing Syphon.

This apparatus can be set to give a period of contact varying from twenty minutes to twenty-four hours. The "Horometer," like the "Sequela," depends upon the transference of oil from one compartment to another, but in this case only two compartments are necessary, M and P.

As the filter fills the oil is forced, by air pressure, to rise in a vertical pipe from compartment M above the level of a regulating tap, which is set to pass the oil into compartment P in the time determined upon for the contact of the sewage in the filter, and as soon as the necessary quantity of oil has been transferred through the tap the syphon discharges.

After the syphon has discharged, the oil is automatically returned from compartment P to compartment M, and the apparatus is again ready for use.

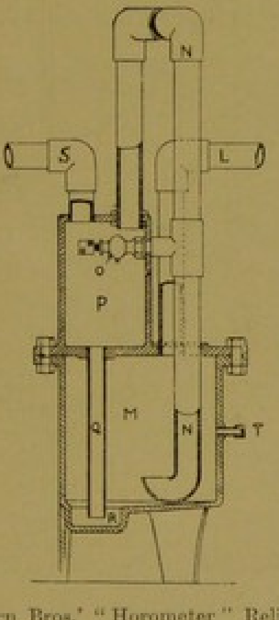

Fig. 42.—Burn Bros.' "Horometer" Relief Apparatus.

No water-tight brick chambers or compartments are required in the filters in connection with the apparatus. It is only necessary to construct a screen in dry brickwork or perforated iron around the syphons to hold up the filtering material.

The question of the use of automatic apparatus is largely one of finance; in other words, will the capitalised working expenses pay for the installation, &c.

Sprinkling or Percolating Filters.

Spray jets are strongly in favour with some, and are largely used, but the space at my disposal in the present notes precludes detailed reference to these, as well as to many excellent forms of distributors by makers other than those mentioned, such as the Candy, Caink, Ham, Baker, &c., my point being merely to indicate these various methods of distribution.

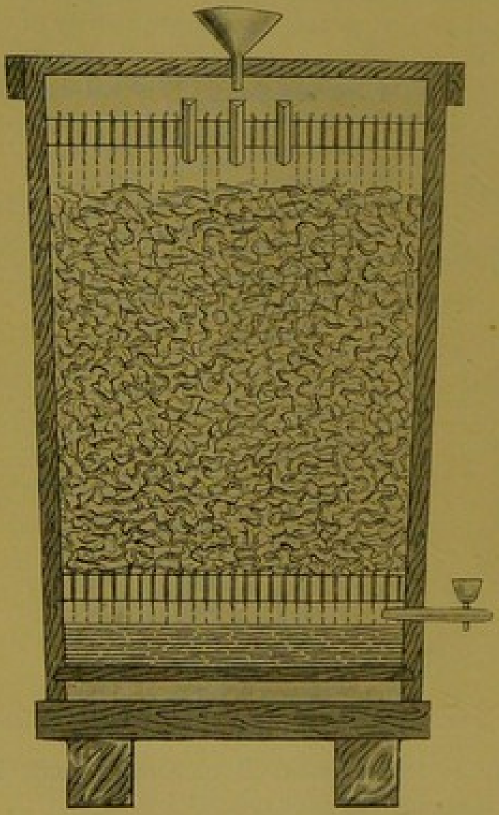

Fig. 43.—Section of Vinegar Vat (after Muspratt, 1860).

The first contact beds, viz., at Barking Creek, London, and at Sutton, were all worked by hand. Their success soon led to the suggestion to distribute the sewage over the surface of the beds by a system of sprinklers, so that the beds might work continuously, as the spray of the liquid would carry atmospheric air and consequently oxygen into the beds, which the ordinary contact beds obtained when they were emptied. This had been considered in connection with the original Barking Creek bed, but the advantage was not considered to be commensurate with the expense. That the system was not novel in principle may be seen from Fig. **43**, which shows a section of a large vinegar vat as described by Muspratt. The vat is filled with beech shavings, upon which fermented liquor is dripped, thus percolating downwards. The shavings become coated with an organism known as the *mycoderma aceti*, or vinegar plant, which converts the alcohol obtained by the fermentation, or, as Liebeg would have said, by eremacausis, of the malt into acetic acid, the action being one of slow oxidation.

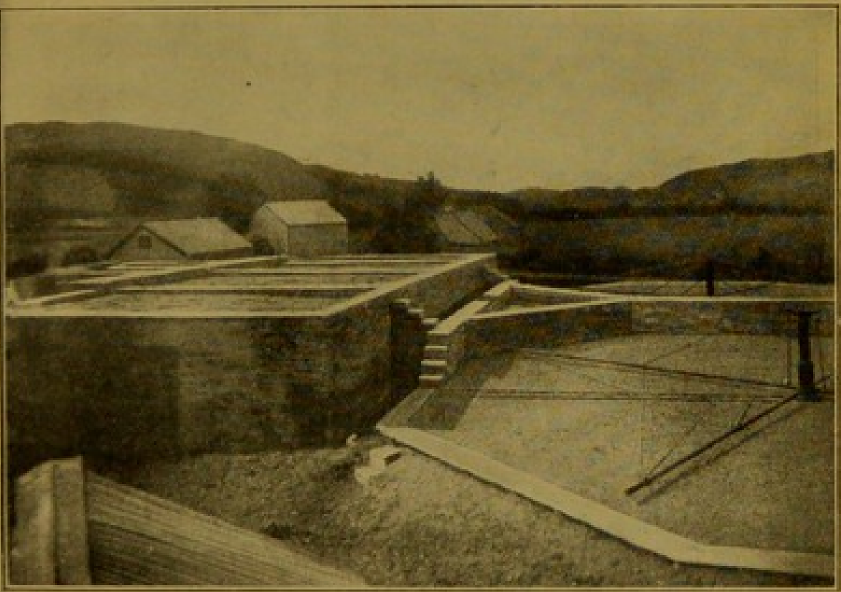

FIG. 44.—Machynlleth Slate Beds and Sprinklers.

Fig. 44 shows this method adapted by Mr. Sidney Lowcock,

M. Inst. C.E., to the secondary treatment of the slate bed effluent from the sewage of Machynlleth, and it is embodied in the schemes for Faversham, Harpenden, and other places.

Illustrations Figs. 44, &c., show various forms of sprinklers and installations with them in use.

Messrs. Birch, Killon and Co.'s Fiddian Automatic Distributor, or Sprinkler—Fig. 45—consists of an elongated water wheel of about 18in. diameter, which not only revolves on its horizontal axis, but travels itself over the surface of a filter by means of wheels fixed on its axle.

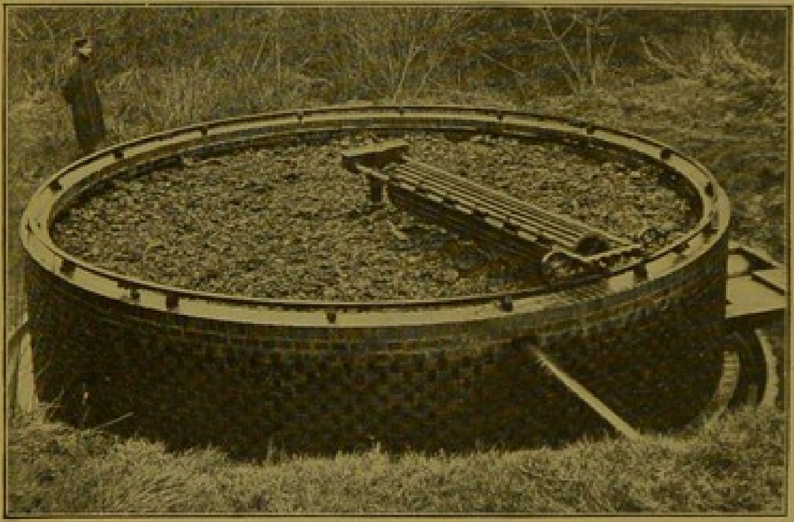

FIG 45.—Fiddian Automatic Distributor for the Netheravon Cavalry School, Salisbury Plain.

It is connected by a pipe to a supply of sewage or tank effluent, and the sewage falling over weirs into the buckets of the wheel spreads itself along the bucket (divided for convenience into sections), and its weight causing rotation of the wheel drum, it falls from the buckets in extremely small doses, sprinkling the filter until it covers the whole surface equally in every part, the weirs being graduated in length on a circular filter to secure this result.

The distributor is used on all kinds of filters. In plan, large ones are usually either circular, as at East Dereham, or rectangular, as at Nuneaton, but small filters are usually circular. The head required to operate the distributor is about 18in. (no dosing or measuring tank being required), and this should be allowed between water level in tank and top of filtering material. No head or force is required to drive the distributor other than the sewage itself.

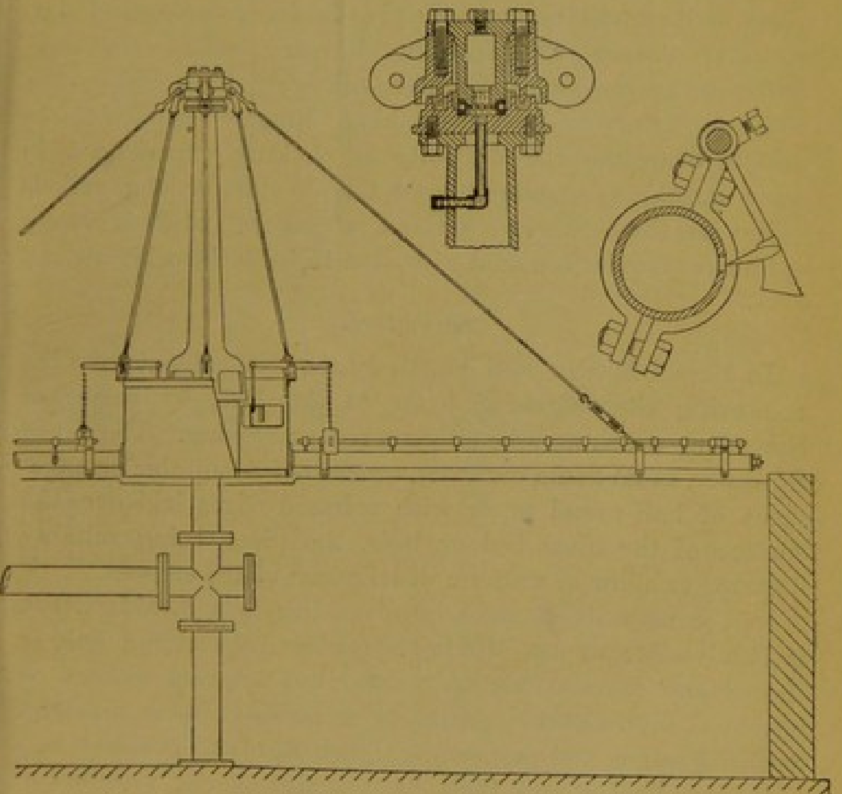

Fig. 46.—Burn Bros.' Rotary Sprinklers.

The Fiddian sprinkler has *no small holes*, the waterway throughout being large and unrestricted, the distributor is always efficient, with little or no attention except for occasional lubrication.

(2) *It distributes any quantity*, with equal efficiency. The smallest dribble will fall into a bucket and accumulate weight

until it revolves the wheel drum, whilst a larger volume will keep the drum rotating over the filter.

(3) It distributes the sewage uniformly and in the *smallest possible doses* over the *whole surface* of the filter with suitable rest intervals, and not merely in spots or lines far apart.

Burn Brothers' Patent Automatic Rotary Sprinkler—Fig. 46—has self-regulating apparatus for dealing with wide variations in flow from one to five, or even six, volumes, and self-cleaning orifices. This sprinkler has no "Seal," as the regulating device prevents the centre tank overflowing and renders this unnecessary. The self-cleaning "Fingers" applied to the orifices overcome the difficulty of choking experienced in some sprinklers, enabling the machine to run for long periods —one to three weeks—without attention, whereas many sprinklers require constant attention to keep the orifices clear.

Spreaders.

In Messrs. Mather and Platt's system the effluent from the measuring chamber is fed on to the beds by means of Spreaders, which may be either fixed or moving. The Fixed Spreader, as its name indicates, consists of a suitable arrangement of half-round pipes with serrated edges laid over the surface of the filter bed or beds, the pipes being suitably disposed to allow of uniform distribution of the effluent.

In the majority of cases, however, this firm considers that it is advisable to use Moving Spreaders, because not only is the effluent more evenly distributed, but a certain amount of beneficial intermittent sprinkling is assured, which aids the bacterial action, and produces a higher degree of purification.

Messrs. Mather and Platt have designed and installed a large number of successfully working Automatic Rotating Spreaders with open-trough arms (Fig. 47), in which the reaction of the liquid issuing in jets from the arms effects the desired rotation, this being aided by the special form of turbine centre used, which assists the reaction of the issuing jets. The open-trough Rotating Spreaders of Messrs. Mather and Platt have been constructed sometimes with two arms, but more frequently with four arms; the area of bed covered ranges from 14ft. diameter to upwards of 200ft. diameter; thirteen electrically driven Rotating Spreaders of 207ft. diameter, in addition to the smaller ones, have recently been constructed for the Huddersfield Corporation, the most important scheme of distribution of sewage by rotating spreaders hitherto put into execution.

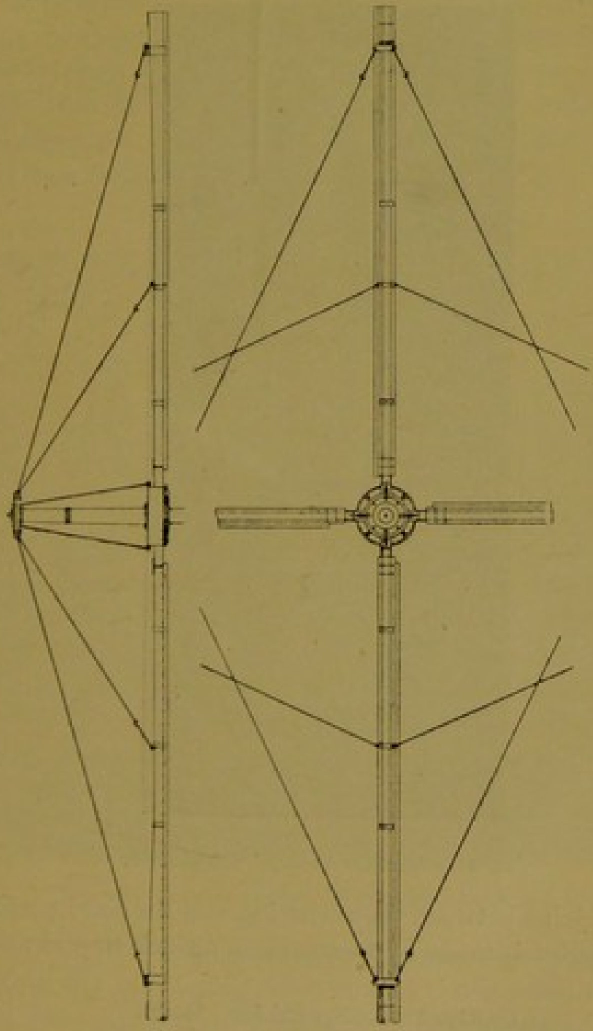

Fig. 47.—Mather and Platt's Automatic Rotating Spreaders.

Figs. 48 and 49 show Messrs. Adams' "Cresset" Distributor, and the crosshead from which the body is hung. These bearings are accessible without dismantling the distributor. The joint between the revolving and the fixed portion of the distributor is made by means of an airlock trap of annular form.

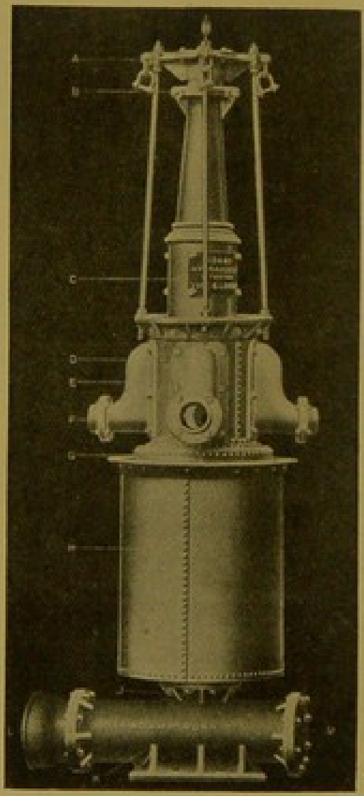

Fig. 48.—Adams' "Cresset" Distributor.

Contact v. Sprinkler Beds.

There have been many discussions as to the relative merits of contact and sprinkler beds, with the net outcome that contact beds have by no means fallen into the disuse some advocates of the alternative method would seem to desire.

For instance, after ten years' experiments, the whole of the sewage of Sheffield is to be treated on a series of 30 acres of contact beds. Again, in the Fourth Appendix to the Fifth Report of the Royal Commission, a report is given on the experiments made by Prof. Percy Frankland and Mr. Silvester on the treatment of the sewage at Oldbury, the summarised result being (p. 469) :—

"(3) That, working at approximately the same rate per cubic yard per day, triple contact filtration gives a better result than triple percolating filtration.

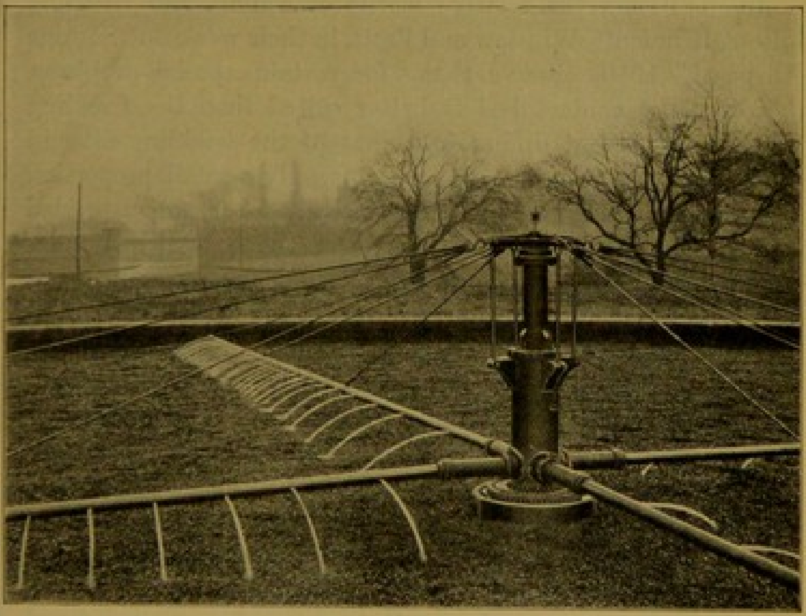

Fig. 49.—View of Central Column and Revolving Body.

". . . it will be seen seen that, except as regards oxidised nitrogen, the percolating filter effluent is distinctly the inferior of the two. As it also contains more sulpho-cyanides than the contact bed effluent, the result may perhaps be looked upon as furnishing further evidence in favour of the theory, first put forward, I believe, by Dr. G. J. Fowler, of Manchester, that, by reason of the much longer time of contact with the filtering material, contact bed filtration is preferable to percolating filtration, where chemical substances which have the power of inhibiting the development of bacterial life (*e.g.*, phenols, as in this case) are present in the sewage to be treated."

"These experiments have an important bearing on the recommendations contained in the Commissioners' Third Report. They show that it is practicable to purify sewage containing large quantities of gas liquor, but that special arrangements are required. Some witnesses have stated that the treatment of such sewage was impracticable."

In discussing the relative merits of contact and trickling filters, Kinnicutt, Winslow and Pratt, in their work on "Sewage Disposal," 1910, observe that "for certain special problems, however, the contact bed is better suited than the trickling filter. Its effluent differs from that of the trickling filter in two important respects. It contains only a small proportion of mineral nitrogen and is comparatively free from suspended solids. Another distinct advantage of the contact bed under certain conditions is the low head under which it can be operated. A trickling filter requires at the least 8ft. of head for the bed itself and for the distributing apparatus, while a double contact bed could, if necessary, be crowded into 5ft. Altogether a contact installation lends itself to compact and inconspicuous construction, which is of much practical importance in the design of small plants for institutions or for private houses. The contact bed produces less odour than the trickling filter, and does not breed flies as the trickling filter does. It may therefore safely be installed much nearer to dwellings. Another advantage in the contact system for small disposal plants lies in the fact that it adapts itself more readily to marked irregularities of flow than does the trickling bed."

Biological Activity on Slate Beds.

The account given of the action of a slate bed in effecting the disintegration and destruction of solid matters will show the remarkable power of the method. Some observations as to the number of bacteria in the deposits will be an interesting addition to the facts already related. For the purpose of ascertaining the condition of the deposit I collected samples from the beds treating the sewage of Devizes. Cultures on nutrient gelatine gave the following results :—

TABLE VI.

—	Deposit on top of slates 18in. below surface.	Deposit on under surface of slates 18in. below surface.
Moisture in mud, per cent. ...	75·3	65·7
Colonies developed on nutrient gelatine per gram of wet mud	3,044,000,000	3,167,000,000

With the view of obtaining a further insight into the question, I collected two series of samples of the deposit on the slate biological beds—one from those at Devizes, after they had been at work for fourteen months, and another from those at High Wycombe, after about nine months' work. These two series are of special interest, as those from Devizes are from sewage of an exceptionally foul character, whilst that of High Wycombe is probably one of the weakest in England, and the two series may be taken as fairly representing the extremes in this respect. It must not be overlooked, however, that sewage debris is of about the same general character whether the volume of water is more or less, the strength of the sewage affecting the character of the effluent to a greater extent than that of the deposit.

In each series three samples were collected in such a manner as to follow the variations which had taken place with the increasing age of the deposit, viz. :—Sample No. 1 was carefully scraped from the surface of the deposit, and may be taken as representing the most recently deposited debris, with its adhering bacterial gelatinous film, &c. ; sample No. 2 was collected as nearly as possible at about half-depth ; and sample No. 3 was taken from the under portion next to the slates. It was noticed that in each case large numbers of minute worms, monadina, anguillulæ, and other organisms were present, the worms especially indicating the aerobic conditions which prevailed. The following are the results of the respective examinations:—

TABLE VII.

Sewage Mud from Slate Beds at Devizes, November 13th, 1906.

—	Surface of deposit on slates.	Half-depth of deposit on slates.	Bottom layer of deposit on slates.	Average.
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture...	80·00	80·50	79·70	80·07
Mineral matter	9·05	8·76	8·53	8·78
Organic matter	10·95	10·74	11·77	11·15
	100·00	100·00	100·00	100·00
On dried mud.				
Mineral matter	45·25	45·00	42·00	44·08
Organic matter	54·75	55·00	58·00	55·92
CO	5·8	7·0	4·0	5·6
Ether extract (fat, &c.)	9·62	5·9	7·7	7·41
Organic carbon	20·19	20·09	17·86	19·38
Organic nitrogen	5·98	3·12	3·71	4·30
Ratio N : C	1 : 3·4	1 : 6·4	1 : 4·7	1 : 4·83
Nitrogen on dry organic matter...	10·8	5·65	4·70	7·05
On wet mud.				
Free ammonia	0·028	0·013	0·023	0·021
Albuminoid ammonia ...	0·112	0·135	0·045	0·098
Bacteria, per gram ...	725,000,000	495,000,000	240,000,000	480,000,000

Microscopical Examination.—Large numbers of worms, monadina and other infusoria, anguillulæ, bacteria, both free and in the zooglœa condition, and usual sewage debris.

In each case the deposits were *without offensive odour*, such as would have been evolved from an ordinary sewage sludge. In the bulk the odour was described by Dr. G. J. Fowler and others as slightly resembling that of seaweed. It is most important to notice that when kept for a time in closed bottles an extremely offensive odour was evolved, due to the decomposition of the organisms which freely flourished under normal aerobic conditions. When the deposits were exposed to the air and allowed to "weather," as it is generally termed, the mass became friable and odourless.

I am kindly permitted by Dr. G. J. Fowler, Consulting

Chemist to the Rivers Committee of the Corporation of Manchester, to quote the following results, obtained by him in collaboration with Mr. J. Clifford. In Table IX. are given the results of analyses of material from the Devizes experimental slate beds.

Table VIII.

Sewage Mud from Slate Beds at High Wycombe, September 28th, 1906.

—	Surface of deposit on slates.	Half-depth of deposit on slates.	Bottom layer of deposit on slates.	Average.
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture...	83·68	84·31	84·86	84·28
Mineral matter	7·95	7·75	7·46	7·72
Organic matter	8·37	7·94	7·68	8·00
	100·00	100·00	100·00	100·00
On dried mud.				
Mineral matter	48·66	49·40	49·27	49·11
Organic matter	51·34	50·60	50·73	50·89
CO_2	1·84	3·88	3·24	2·97
Ether extract (fat, &c.)	5·13	7·12	6·89	6·38
Organic carbon	17·31	25·07	23·15	21·88
Organic nitrogen	3·46	4·64	3·73	3·94
Ratio N : C	1 : 5·0	1 : 5·4	1 : 6·2	1 : 5·5
Nitrogen on dried organic matter...	6·6	9·2	7·3	7·7
On wet mud.				
Free ammonia	0·065	0·065	0·060	0·063
Albuminoid ammonia ...	0·270	0·250	0·235	0·252
Bacteria, per gram ...	160,000,000	190,000,000	50,000,000	133,000,000

Microscopical Examination.—Usual sewage debris, with large numbers of small worms, monadina and other infusoria, anguillulæ, bacteria, both free and in the zooglœa condition.

Facilities for carrying out a bacteriological examination of the deposit on the Devizes and High Wycombe beds were kindly furnished by Professor Delepine, the work being done by Dr. Sellers under his supervision. The results are given in the following table, which also gives Dr. Fowler's results of the examination of the same deposit. It is interesting to note the apparent correspondence of the oxidation test with the bacteriological results. This test consisted in passing equal volumes of moist air over known weights of the samples, thence into standard baryta-water, and titrating the residual baryta with oxalic acid.

The production of carbon dioxide increases with the number of bacteria present; but other factors, such as worms, must not be overlooked.

An important point brought out in these investigations is that instead of the few millions of bacteria per gram formerly supposed to be present in a sewage deposit in an active state of fermentation, there is now clear evidence that the number is far greater, and, in conjunction with the enormous number of other and larger organisms, explains their remarkable power to effect the inoffensive decomposition of sewage matters on superposed surfaces under aerobic conditions. Colm estimated that 40,000 millions of bacilli would weigh one grain, or 620,000 millions per cubic centimetre. In the above counts we find 3,167 millions in one case, Table VI.,

Table IX.

Samples of Unweathered and Weathered Deposit from the Experimental Slate Beds at Devizes—Collected July 8th, 1905.

—	Unweathered 1 mm.	Weathered 1 mm.	Unweathered ¼ mm.	Weathered ¼ mm.
	Per cent.	Per cent.	Per cent.	Per cent.
Organic matter	56·5	45·0	57·0	40·1
Carbon in dried substance, 100 deg....	29·10 29·32	17·14 16·86	30·05 30·19	24·21 23·96
Average	29·21	17·00	30·07	24·07
Hydrogen in dried substance 100 deg. ...	4·03 4·13	2·47 2·52	4·26 4·22	2·37 2·52
Average	4·08	2·50	4·24	2·44
Nitrogen in dried substance, 100 deg.... ...	3·80	1·99	3·31	1·83
Carbon on organic matter	51·7	37·7	52·7	60·2
Hydrogen " "	7·2	5·5	7·4	6·1
Nitrogen " "	6·7	4·4	5·8	4·5
Ratio N : C	1 : 7·7	1 : 8·5	1 : 9·0	1 : 13·0

equal to 0·5 per cent. of the total possible, supposing the bacilli to have been packed like sardines in a box!

TABLE X.

Description.	Loss on ignition.	Ether extract.		Oxidation test.
		On dry material.	On loss on ignition.	
Sample scraped from middle layer of deposit on slates. Devizes, November 21st, 1906.	54·52	6·00	11·0	1 gram dry material $= 24 \cdot 6$ c.c. $\frac{N}{10}$ oxalic $= 108 \cdot 4$ mgms. CO_2 $= 198 \cdot 4$ mgms. CO_2 on organic matter
Sample scraped from bottom layer of deposit next slates. Devizes, November 21st, 1906.	43·65	8·75	20·0	1 gram dry material $= 7 \cdot 7$ c.c. $\frac{N}{10}$ oxalic $= 33 \cdot 8$ mgms. CO_2 $= 77 \cdot 4$ mgms. CO_2 on organic matter
Sample taken from drying beds thoroughly weathered. Devizes, November 21st, 1906.	37·09	2·16	5·8	1 gram dry material $= 0 \cdot 1$ c.c. $\frac{N}{10}$ oxalic $= 0 \cdot 044$ mgm. CO_2 $= 1 \cdot 14$ mgms. CO_2 on organic matter

TABLE XI.

—	Bacteria per gram.	Prevailing type.
Devizes: Top layer ...	6,200,000	White, non-liquefying; coli-like; few moulds.
" Middle layer ...	200,000,000	Many moulds; yellow, liquefying; few coli-like.
" Bottom layer...	250,000,000	White, non-liquefying; numerous coli-like; moulds not numerous.
" Thoroughly weathered from drying beds.	4,500,000	White, non-liquefying; many liquefying; moulds numerous.

We may now summarise the present position with regard to the aerobic biological treatment of sewage by the following diagrammatic sketch of the best available systems. It will be observed that anaerobic, evil-smelling and sludge producing methods are excluded from consideration, as these are out of date and do not invite further consideration. They are but a barbaric survival of the past, and inevitably must fall more and more into disuse. If *an*aerobic methods are so good as some few still argue, why not adopt the whole principle for the final treatment of the effluent? Simply because it cannot be done—oxidation *must* be resorted to sooner or later, and we may as well start with it at once and thus avoid all the evils of putrescence.

Water-carried Sewage.

PRIMARY AEROBIC TREATMENT.

- Broad irrigation
  - Ploughing into ground
- Discharge into tidal water
- Artificial aerobic biological treatment

TREATMENT OF SOLIDS.

- Artificial aerobic biological treatment
  - Collection of humus from *slate beds* and weathering to garden soil
  - Retention of humus in *coarse and clinker* bed, which must be cleansed every few years

EFFLUENT OR "SECONDARY" TREATMENT.

- Irrigation
- Discharge into tidal water
- Aerobic treatment on fine contact beds
- Aerobic treatment on percolating beds
  - Coarse material in deep beds
  - Fine material in shallow beds
    - Sedimentation and filtration to collect humus

TERTIARY TREATMENT IF REQUIRED.

- Sand filters
- Irrigation
- Fine contact beds
- Percolating beds

Sedimentation and chemical precipitation which produce anaerobic sludge are, of course, omitted from this scheme. Even if a non-putrescent sludge could be obtained by any reasonable method of chemical precipitation, the system would still be undesirable on the question of cost alone. By abandoning chemical precipitation and sludge pressing at Devizes the annual working expenses were reduced from about £700 per annum to £200, and similar results inevitably follow in all like cases, the practical outcome being that the saving on working expenses paid the interest on capital and repayment of loan, so that the new works were to all intents and purposes a *free gift* to the ratepayers, in addition to the advantage of effectually stopping all nuisance and complaints of every kind.

From the analysis of the weathered humus resulting from the aerobic treatment, it will be seen that it has a high manurial value, and being perfectly inoffensive, is available for immediate use, thus securing the long-desired result of obtaining the maximum fertilising qualities from the solid matters consistent with their economical and inoffensive treatment.

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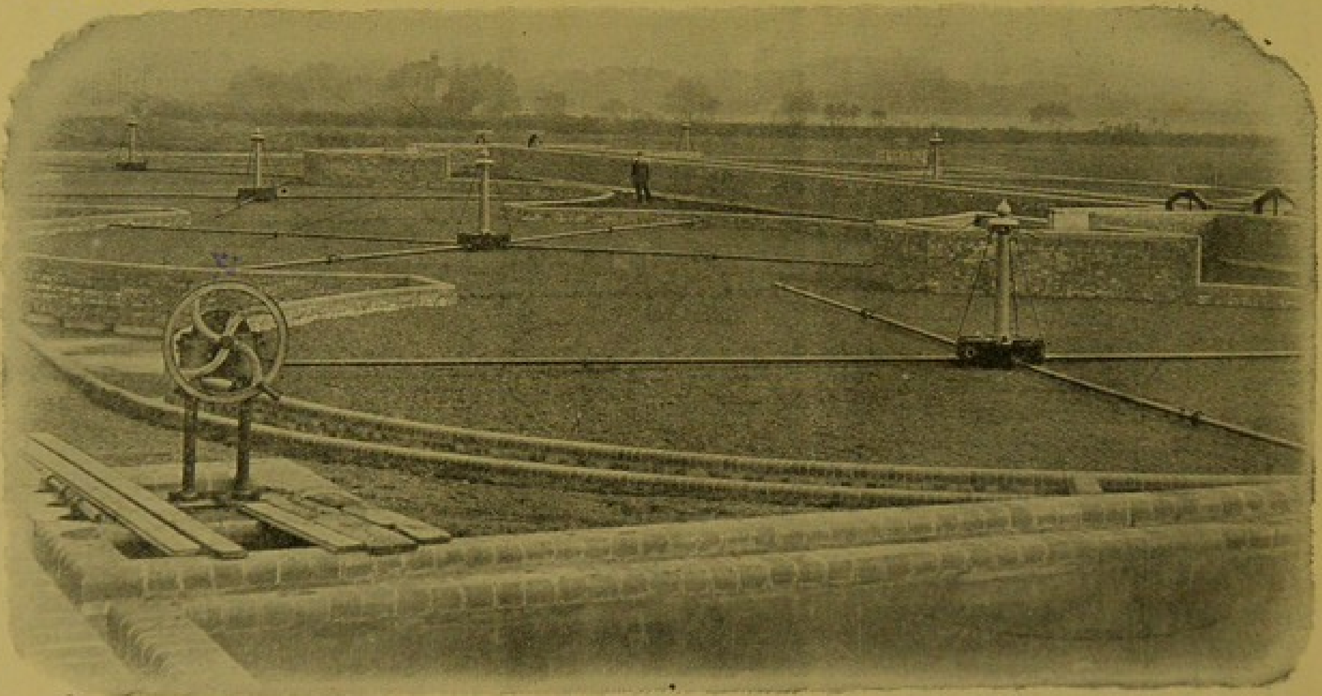

View showing a portion of the Sutton-in-Ashfield Sewage Works where Eight Ham-Baker Revolving Distributors, each 72 feet diameter, are at work controlled by the Ham-Baker Intermittent Valves.

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