SEWAGE PURIFICATION AND DISPOSAL.

(Edwin H. Wilkinson, Engineer for Drainage, Hobart.)

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The subject of the disposal and the purification of sewage is one that has of late years received the close attention of the greatest scientists. More especially is this the case in the United Kingdom. It will be my endeavour this evening to describe a few of the various methods adopted for purifying the sewage, and the agencies whereby this state is brought about, together with various methods of disposal in use in various parts of the world. For much of the information contained in this paper (for which I claim no originality) I am indebted to the work by Mr. Dibdin on the purification of sewage and water. A very great deal of useful matter was also obtained from a recent "Report on the Latest Methods in use in the United Kingdom and elsewhere," by Mr. J. Davis, M. Inst. C.E., who was until lately Engineer-in-Chief for Sewerage Construction in New South Wales.

In the bacterial disposal of sewage, as carried out at many places, we assist nature in carrying out her work without offence and without danger to us. When an animal dies and remains unburied in the fields, Nature's scavengers, in the form of bacteria, soon make themselves evident, and in a comparatively short time entirely dispose of the carcase.

In order to more forcibly impress upon you this bacterial life, which plays such an important part in the purification of sewage, I ask your permission to be allowed to quote from some of the remarks of Mr. W. J. Dibdin, late Chemist to the London County Council.

Firstly, sewage consists of animal substances, largely composed of fibrine, gelatine, chondrine, albumen, etc.; and, secondly, vegetable substances, such as starch and woody fibre (cellulose), gummy matters, with tannin, etc. The decomposition takes place by the active organisms, "aerobic," as they were called by Pasteur in contradistinction to the anaerobic organisms. As their name implies, the first-named live only in the presence of air, whilst the latter live in the absence of air. When air is freely present the aerobic organisms destroy the organic matters in an inoffensive manner.

According to Dibdin, the nitrogen of the gelatine, etc., is resolved with either the production of ammonia and the oxides of nitrogen, or possibly set free as 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, etc., are formed as a result.

It will be understood that the substances mentioned are intended to represent only types of compounds actually present in such a heterogeneous mixture as that which we are considering.

In the process known as combustion, or burning, the organic matters combine with oxygen, but the same action is brought about by the life processes of animals.

In the case of the higher animals, when the food is taken into the stomach, it there undergoes the process of digestion, and a portion is absorbed into the system, where, by the action of the blood, it is eventually oxidised as it rushes through the lungs, in which it is freely exposed to the air taken in by the breath. Thus is kept up a slow process of oxidation, marvellous in its character and action. It matters not whether it is meat and bread eaten by human beings; grass, etc., by horses or fowls; or a mixture of these things by microbes or by the direct action of fire; the final result is precisely the same, viz., combustion, fast or slow, as the case may be. But in bringing about this result we must not neglect to ensure an ample supply of oxygen, otherwise we shall have foul gases formed, such as sulphuretted hydrogen, and so create a nuisance.

Here we must further consider the action of the minute organisms already referred to as "bacteria," or "microbes."

These are minute living bodies, some of which are ever present in various forms in or on every substance known; and whenever the circumstances are favourable they bring about the destruction of the organic matters simply by living on them. In reference to their general character that while at first they were thought to belong to the animal kingdom, it is now generally accepted that they are plants. With reference to the size of the bacteria, it is, indeed, difficult to describe them in popular language. They vary in length from one-five thousandth to one-twenty-five thousandth of an inch. When viewed under the most powerful microscopes they appear to be a little larger than dots of ink on paper. "If," say Pearman and Moore in their work on "Applied Bacteriology," "we could view an average human being, under an equal degree of magnification, he would appear to be about four miles in height."

In a volume equal to the 66th part of a grain, Bujivid estimated no less than eight thousand millions of microbes.

With reference to the incredible rapidity with which the bacteria multiply under conditions favourable to their growth and development, Cohn writes as follows:—"Let us assume that a microbe divides into two within an hour, then again into eight in the third hour, and so on. The number of microbes thus produced in 24 hours would exceed 16½ millions; in two days they would increase to 47 trillions: and in a week the number expressing them would be made up of 51 figures. After 24 hours the descendants from a single bacillus would weigh 1-2666lb.; after two days over a pound; after three days, 7,366 tons. It is quite unnecessary to state that these figures are purely theoretical, and could only be attained if there were no impediments to such rapid increase."

"Fortunately for us," observe Messrs. Pearman and Moore, "various checks, such as lack of food and unfavourable physical conditions, prevent unmanageable multiplications of this description. Naturally the question will at once arise as to what becomes of the dead bodies of those bacteria which succumb in the struggle for existence. A dead bacterium is only so much food for his friend, who evidently considers that all is fish that comes to his net."

The figures given show what a tremendous vital activity micro-organisms or "bacteria" possess, and it may be seen at what speed they can increase in water, milk, broth, yeast, and other suitable and nutrient media. You can realise from the foregoing remarks the enormous force which the sanatarian has at his disposal for the rapid and effectual destruction of waste animal and vegetable matters by the action of the life processes of these minute scavengers, provided that the conditions of their environment are carefully arranged, so as to afford them the freest possible scope.

If any porous material, such as coke breeze, burnt clay, etc., be placed in a vessel or tank, and sewage water admitted thereto, a large proportion of the filth contained therein will adhere to the rough sides of the coke or other material, and the organisms will commence their work by feeding and multiplying so that in a short time the whole surface of each particle of coke or other material which may be employed, will be covered with them. Let the water be drawn off gently, after sufficient time has been allowed for the adherence of the fine particles of matter to the coke. Air will be admitted as the water is lowered, and a fresh impetus will be given to the little workers, who will soon be ready for another supply of food to be given to them in the form of a second quantity of foul water. The organisms at work under circumstances such as these are the ærobic microbes previously described. The anærobic do not depend on the air for their existence, and it is this class that carries on the purification process in what are known as septic tanks. It will be seen these processes may continue indefinitely, and that we can bring about the destruction of objectionable matters completely and economically for as long a time as may be desired.

Such, then, is Nature's method of purification.

The process is termed biological, but it must not be supposed that because this term is used in reference to the treatment of sewage, it is intended to imply that the micro-organisms are provided by the bed itself, and that the sewage does not contain them. The organisms are to be found in all sewage, and they are by the sewage conveyed into the beds, where large surfaces are provided, and on which the bacteria are cultivated.

Having, with these few introductory remarks, given an idea of the great activity of micro-organisms, and of their enormous power in working out purification of sewage, it will perhaps be interesting to hear of what is being done with their assistance in a few of the more important cities of the United Kingdom.

For much of my information on this subject I am indebted to Mr. J. Davis, M.I.C.E., late Engineer-in-Chief of the Sewerage Construction Branch of the Public Works Department of New South Wales, who last year presented his report to the Minister for Public Works on the "Latest Methods in use in the United Kingdom and elsewhere."

In order that we may start at the beginning I shall first deal with Scott-Moncrieff's methods.

It appears that Mr. W. D. Scott-Moncrieff commenced his experiments on a practical scale in 1891. He erected what he called a "cultivation tank," measuring 2ft. 9in. wide, 10ft. long, and 3ft. deep at the deepest end. Excluding the grease by means of a trap, he allowed the entire sewage and waste water from one dwelling house to enter the tank at the lowest end. The sewage passed through a perforated plate, which was fixed about one foot from the bottom of the tank. Underneath this plate the solids were arrested. Above the perforated plate was a layer of flint, through which the liquid portion rose until it reached the level of the outlet drain. The mean depth of the filtering material was 14in., and the space underneath the plate 5 cubic feet.

Mr. Scott-Moncrieff states that the invariable result, where he put down installations of these tanks, based upon an allowance of 3 or 4 cubic feet for each inhabitant served, has been the almost complete liquefaction of the solid matter, and the sludge in every case was a negligible quantity. His next step was to pass the effluent from the cultivation tank through shallow, open earthenware drains filled with coke, but it appears that this treatment had very little effect upon the effluent. However, it was observed that when it passed into an almost stagnant, but bacterially very active, ditch, in the proportion of one to three respectively, the effluent purified what was before a polluted stream. This fact (which to many may be hard to believe) will again be demonstrated further on in this paper, when dealing with experiments carried out with the Manchester sewage.

Using Mr. Scott-Moncrieff's own words, he states that this proves two things:— "First, that the ditch was a very active oxidising agent; and, secondly, that the organic matter coming from the 'cultivation tank' was in a condition highly susceptible to further oxidising changes, and was in a much more unstable molecular condition than the raw sewage, which had seriously polluted the stream when untreated."

He next devised a highly oxidising apparatus consisting of nine wooden boxes (perforated), 7in. deep, and each having an area of 1 square foot, which he placed 2in. apart and above each other. These he filled with coke about the size of beans. In utilising the filtering material for restoring oxygen to the sewage to the fullest extent, he used V-shaped tipping channels, so that the liquid would be evenly distributed.

Installations have been carried out on this plan in several places, notably at Birmingham, at Chelmsford, and at Caterham, under the sanction and authority of the War Department. At the latter place there is exceedingly strong sewage from the barracks, which accommodate 1,200 persons.

Dr. Rideal, who was asked by the War Department to report on the efficiency of the installation at Caterham, states the results are satisfactory, and that "the process has been successful in destroying completely four-fifths of the total organic matter present in raw sewage."

Septic Tanks.

Under the septic tank system the largest installation as yet carried out is at Barrhead, where the works are designed to serve a population of 10,000, and to purify a maximum flow of sewage and storm water of 400,000 gallons per day.

The works consist of two grit chambers, four septic tanks, and eight bacteria beds, all of which are built with concrete. The sewerage main discharges into the grit chambers, from which the sewage passes, without screening, into the septic tank.

When the septic tank system was first introduced it was thought that it was necessary to exclude all light and air. It is now found by experience that the results obtained from raw sewage are the same whether the tanks in which the anærobic microbes are active, is covered or open. This may be due, perhaps, to the coating of hard scum which is formed in the tank, and which would tend to exclude the light and air.

There may be cases, however, where, for various reasons, it would be advisable to cover the tanks. For all practical purposes it is settled beyond dispute that the open is as efficient as the closed tank.

Manchester Sewerage.

To prevent the pollution of the Manchester Ship Canal, in 1896 proceedings were instituted against the Corporation at the County Police Court, and an order made calling upon the Council to do what was necessary within 12 months. This period has had to be extended, as it was found impossible to make the necessary experiments to enable a conclusion to be arrived at in the time given.

Eventually a scheme was prepared for conveying the effluent from Davyhulme to the tidal River Mersey at Randall's sluices. When this scheme was referred to a poll of the ratepayers it was rejected by a large majority. Messrs. Latham, Frankland, and Perkins, experts, who were called in to advise the Council upon the question, supported the ratepayers in their decision.

The Council thereupon decided to appoint the three experts already named to advise them and report on the whole question of sewage purification and disposal.

Up to this time no adequate experience had been gained in the use of bacteria beds with sewage diluted with trade refuse.

Upon getting to work the experts named confined their attention to the three methods which had been already before the Council:—

1. Treatment by land.

2. Conveying the effluent into the tidal portion of the river.

3. Bacterial treatment.

Regarding the question of land treatment, they agreed with the committee in rejecting it; firstly, on account "of the great initial cost of land, drainage, conduits, laying out, etc.;" secondly, "of the obvious difficulty of obtaining a sufficient area;" and, thirdly, "of the general unsuitability of the land in and around Davyhulme." With respect to this, they instanced the case of Birmingham, which is now feeling the formidable dimensions of its sewage farm to such an extent that other and more compact modes of dealing with the sewage are being undertaken.

The extension of the sewer to Randall's sluices was condemned from an engineering point of view.

Under their direction, certain beds were constructed at Davyhulme, and experiments were made with them. The filtering medium used in the upper bed was clinker, 3in. to 1in. gauge; and in the lower bed 1in. to ¼in. gauge. Two other beds of similar size, and a fifth, much smaller, were afterwards added, but the clinkers used were of much smaller mesh, as it was found that the coarser filters allowed sludge to get into the body of the bed, and so into the drains below. The material used in the third, fourth, and fifth beds varied from ¾in. to ⅛in. mesh.

Settled sewage was first used, the beds being filled once each day for the first week, and twice a day for four weeks. The beds, having acquired a high degree of efficiency at the end of this period, were filled three times a day for a further term.

As the application of settled sewage was attended with such satisfactory results, it was decided to apply raw sewage on the same lines. For the first month the raw sewage was applied once each day, and the settled sewage twice. This having proved satisfactory the raw sewage alone was applied three times a day, and was continued for nearly two months, when four fillings per day were tried. After the first week the rough bed showed signs of clogging, and settled was therefore resorted to. The experiments with these beds have extended over a period of two years. The effluent from septic tanks was, instead of settled sewage, ultimately passed through the beds. The capacity of the beds was at first rapidly reduced, but when the solids in suspension from the raw sewage had previously been removed, by bacterial action in the septic tank, and the beds had got fairly to work, they maintained a capacity of one-third of the capacity of the bed without filtering material. When a bed fell below this proportion a short period of rest would be the means of restoring it. The larger beds were constructed to contain 10,000 gallons before the clinkers were put in, and when working their capacity was 3,333 gallons.

The beds were treating the effluent from the septic tank at the rate of 600,000gal. per acre, with a resultant degree of purification of 0.5 grains per gallon oxygen absorption in 4 hours; and 0.04 grains per gallon of albumenoid ammonia. The limits of impurity adopted by the Mersey and Irwell joint committee (the authority which has the responsibility of the conservation of the rivers in question) is 1 grain and .1 grain respectively.

In their report the experts say: "The results of the treatment of the open septic tank effluents . . . . . have, from the first, surpassed our most sanguine expectation."

It has been found, with the use of the effluent from either open or closed septic tanks, one contact with a bacteria bed has been sufficient to secure adequate purification.

At the end of 1898 an experimental installation of the septic system was got to work. After it had been working about nine months to try its powers of dissolving solids, garbage was tipped into the tank. After 279 barrow-loads were put in, it was decided to cease. The tank was constructed in size sufficient to hold half a day's supply of sewage. If it had been used as a precipitating tank, at the end of fourteen months the quantity of sludge produced would have been about 12,000 tons, but, upon being emptied, it was found to contain 4,000 tons of sludge, and the garbage had been wholly dissolved. The greater portion of this residue was inorganic matter; the proportions were 60 per cent. inorganic and 40 per cent. organic. A large proportion of the inorganic matter, if not the whole, is recognised to consist principally of silt from the street surfaces, and silt pits are being specially constructed to intercept it before the sewage reaches the septic tank. The rapid rate at which the sewage was passed through the tank may account for the comparatively large amount of organic matter, 1,333 tons. Notwithstanding this, it is a very great attainment to have succeeded in destroying two-thirds of the solid matter, and that, too, when passing the sewage through the tanks twice as fast as is usual in other places. Experiments made at other places show that the most perfect bacterial action is obtained by allowing the contact to be twenty-four hours. A closed septic tank was treating sewage during the whole time the sewage was passing through the open septic tank, and samples of the effluent, taken under similar conditions, show that the results for all practical purposes may be regarded as the same.

The sludge which is not retained in the septic tank passes away in a highly-divided condition in suspension, and by gasification.

From samples of the effluent taken from

the maximum flow the results show that the suspended matter varies from 11.6 to 4.9 grains per gallon.

Exhaustive experiments have been made to determine the effect the effluent from the bacteria beds would have upon the waters of the Manchester Ship Canal. Average samples of the filtrates were taken from the bacteria beds in operation on 132 days. A similar quantity of water was taken from the Ship Canal, and the two were mixed. The Ship Canal water, except in a few cases, when it had been diluted by heavy falls of rain, was putrescible to a high degree, but when mixed with an equal quantity of the filtrate, the mixtures in 117 cases were non-putrefactive. This shows clearly that the organic impurities of the Canal water had been oxidised at the expense of the nitrates in the filtrate, and thus vastly improved. It also bears out the fact demonstrated by Mr. Scott-Moncrieff, and already alluded to.

Of several the following were among the conclusions and recommendations made to the Council by the three experts:—

1. That the bacterial system is the system best adapted for purification of the sewage of Manchester.

2. That any doubts which may have arisen in the first instance as to its suitability . . . . have . . . . been entirely banished. The results obtained have altogether exceeded our expectations.

3. . . . . by passing the sewage as it arrives at the works through an adequate system of screens, etc., the further important advantage is gained, whereby those anærobic or septic processes are developed, and which resolve into gaseous and soluble products the organic suspended matter present in the sewage. A large proportion of the sewage sludge which otherwise accumulates, and the disposal of which causes so much trouble and expense, is thereby abolished. The above anærobic or septic process is found to take place as effectively in an open tank as in a closed one.

It has been demonstrated that the septic tank can effectually dispose of between 40 and 60 per cent. of the suspended matter present in the sewage. A kind of digestive process goes on whereby much of the insoluble suspended organic matter, especially that of animal origin, is liquefied or dissolved. This is probably entirely due to the action of those living organisms previously alluded to, by whose vital processes some ferment or ferments are produced which digest these substances. Vegetable fibre is more resistant, and is but little affected. In alluding to this phase of the subject, Dr. Thresh, in a recent paper, says:—"What is wanted is the discovery of some organism capable of being cultivated and utilised, which possesses the special power of digesting vegetable fibre." In the same paper he mentions a visit he paid to the old sewage works at Buxton, where he found the settling tank almost full of deposited matter. Using his own words, he states that "a few days later some kind of fermentation had set in, and the fluid was effervescing vigorously and in a very short time practically the whole of the solid matter had been dissolved and carried away."

At Leeds, where the Corporation are carrying out extensive experiments with the bacterial purification of their sewage, the oldest of their septic tanks had been working over fifteen months. Three-quarters of the solids in suspension were left therein, and no sludge had been removed, yet after inspection it was found that the tank contained no more sludge than it did six months earlier. Such a condition showed that there had unquestionably been an enormous consumption of sludge in the tank by septic processes.

Before concluding this paper a reference to the Liernur system of sewerage might prove of interest. The town or city to be served is divided into districts, according to circumstances, and in a centrally situated position a closed receiver is provided for each district, into which the fæcal matter is drawn by vacuum. There are cast iron pipes laid along the streets, and so situated as to enable house connections to be conveniently made. These pipes convey the sewage to the district receivers. From the central station the vacuum there formed is conveyed to the district receiver, and the influence of this causes the sewage to flow by suction to the receiver. The district receivers are in turn emptied by applying the vacuum to the main receiver at the central station. Briefly then, the Liernur system consists of ordinary street sewers (4in.) connected to a main sewer (10 to 12in.), without any openings. At one end, by the house, is a patent syphoned box. At the outfall works is a steel plate cylinder, in which a vacuum is created, say once a day. The result is, the sewage remaining in the boxes and sewers is carried off to the works at six times the speed of water-carried sewage, the air flush being depended upon to cleanse the pipes thoroughly.

From information supplied by the English representatives of the system, and also by their engineer, Mr. Theodore Rennert, M. Inst. C.E., there are three installations at work; one at Amsterdam, one at Trouville-sur-Mer, and the other at a gold mine in Johannesburg.

It is understood that at Amsterdam it was the intention of the designers only to evaporate the fæcal matter, but this has been found impracticable. It is now customary to use a small quantity of water for flushing purposes—about 1 gallon per person. The house slops at Amsterdam are not taken into the sewerage system, but are discharged into the various canals that intersect the city.

According to Mr. D. I. Sanches the engineer in charge of the works, the total population of Amsterdam is about 500,000, and of these about one-fifth, or 100,000, are served by the Liernur system. The street pipes are now laid to an uniform grade from the upper end to the district receivers, and with ordinary junctions, as it was found that the vertical junctions, with right-angled bends, which were originally designed, readily got stopped.

The average number of persons connected with a district receiver (of which there are 50) is 2,000. The greater portion of the closets are of the special Liernur kind.

The mode of treating the sewage devised by Liernur has been entirely abandoned. The expense of drying the sewage was so great, even without the household slops, and with only the small quantity of water used as a flush, that it was found necessary to discontinue the method.

The sewage, as soon as convenient, after its arrival at the works, is precipitated by means of lime, and the supernatant liquor and the sludge are boiled separately for the purpose of throwing off the ammonia. This is sold, and a fair revenue is derived. The supernatant water is thereupon discharged without further treatment into the canal, and the sludge is mixed with house rubbish and removed in barges as manure.

Such a process is wholly objectionable. Thousands of gallons of sewage are stored in large, open tanks, waiting for a number of days to be treated. Another source of no inconsiderable nuisance is the method of mixing the sludge (previously deprived of its ammonia) with the house refuse. In cases where the town to be served is flat some mechanical means of raising and removing the sewage is necessary, and it becomes apparent that each case therefore must be taken on its merits. However desirable it may appear to evaporate the moisture and produce the powder manure, the question of cost would make the method prohibitive. With the knowledge we now possess as to the bacterial action, which can be so readily engaged in resolving sewage into its elements, there is certainly no necessity to resort to evaporation as a means of disposal.

Coming to Hobart the author said that within the next few months the citizens would be asked to say whether or not a scheme for the drainage of the city on modern sanitary principles was desirable. Many were averse to allowing crude sewage to empty itself into the harbour, on the grounds of pollution, but, at the present time the foul slop waters from the houses were allowed to discharge into the street channels, whence they found their way into the natural water-courses, and so on to the waters of the Derwent estuary. From the configuration of the city and its environs, and from an engineering point of view, the natural place for discharging the sewage was at Macquarie Point, where there was deep water, enhanced by an ample tidal flush. With the expenditure of a few thousand pounds, over and above the sum required for a complete system of sewerage, the sewage of Hobart could be rendered quite innocuous, and purified to such an extent that the waters of the harbour would always retain their present standard of purity. It could readily be accepted as a fact, from the knowledge we now possessed of bacterial action, that, by passing all the solid matters through septic tanks before they entered the harbour, the liquefaction of the sewage could be assured, and the pollution of the estuary reduced to a negligible quantity.