Original Articles.

THE BIOLOGICAL DISPOSAL OF SEWAGE.

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In the following paper it has been the aim of the writer to present a sketch of the subject at the same time comprehensive and concise. With this view he has been constrained to lay down somewhat dogmatically perhaps the principles which he himself is most in favour of.

To have given more than a brief description even of these would have swelled the text to twice its present bulk and have rendered it less acceptable to the reader. It is possible also that greater diffuseness might have weakened the impressions it has been desired to convey.

The author must plead excuse for occasional repetition of the same words and expressions, a tautological blemish, which, in the process of an exact description, is both necessary and unavoidable.

Should the publication of this sketch be the means of giving the subject of Biological Disposal of Sewage more publicity and at the same time prove suggestive, the writer's object will have been attained.

It is proposed to deal with the subject under two headings;

1. Under this heading a description of the principle of the biological disposal of sewage will be given, together with a general outline of its applicability.
2. Attention will be drawn to both the desirability and practicability of its introduction, under certain conditions, into India.

The difficulty of an universal application of this system on a large scale being recognised, especially in places where the water-supply is from wells; the practicability of introducing separate small installations suitable for the use of municipal, cantonment, regimental, hospital and jail latrines is suggested.

I. It should be borne in mind that in the biological disposal of sewage the process is effected naturally by the alternate and combined action of chiefly anaërobic and aërobic organisms, whose normal element is sewage, and whose function in economics is sewage disposal.

Their numbers may be said to vary from 1,000,000 to 12,000,000 per c. c. of crude sewage.

The process will be described in three stages, *viz.*—

A.—Liquefaction.—In a septic tank, open or closed.

B.—Liquefaction and Nitrification.—By upward or downward passage of the liquefied sewage, through contact beds, followed by a period of rest therein.

C.—Nitrification and Oxidation.—By continuous downward filtration through open filter beds.

A Liquefaction is effected chiefly through the agency of anaërobic organisms, as an example of which, may be mentioned the various forms of "Clostridium" and the "Bacillus Amylobacter." Liquefaction appears to be directly accomplished by the products of these organisms, by the action of a class of soluble nitrogenous compounds known as "Enzymes." The hydrolytic action of these bodies may be compared to that effected by diastase pepsin and trypsin, during the process of digestion.

Scott-Moncrieff's experiment (1891), whereby the purification of sewage was aimed at by upward filtration, through contact beds of stone, appears to have been the first step towards the solution of this problem of disposal of sewage by natural means.

The liquefaction effected was chiefly through the agency of anaërobic organisms with the production probably of some ammoniacal compounds.

The necessity of liquefaction as an initial step in the natural disposal of sewage will be better understood by a reference to the three stages tabulated above, and if it be pointed out that the life of contact beds and filters would be considerably shortened and their area of action diminished by the passage of crude sewage into them, it will be obvious that liquefaction, as an initial step in the biological disposal of sewage, is necessitated by the fact that the contact beds are found to become sooner or later clogged by solid organic matter which they are unable to dispose of.

It may be mentioned here that precipitation by chemicals, as by the aluminous sulphate of iron or by lime, is still practised as an initial step in the disposal of sewage in some places; apart from the expense entailed, it is a retrograde step, inhibiting as it does, the natural action of the organisms which it should be our chief aim to cultivate under conditions most favourable to them, and this object can scarcely be attained by subjecting them to a preliminary, to say the least, nauseating dose.

How then is this initial step of liquefaction to be most satisfactorily obtained ?

The answer is by allowing the sewage to rest for a period and in a tank where anaërobic conditions are favourable and where the requisite degree of liquefaction can take place. For efficient working, the tank should be capable of containing 1 to 1½ days' flow. The size, however, may vary, within limits, inversely with the size of the contact beds.

The question as to whether a septic tank should be open, or hermetically closed in, has been the subject of much discussion. It may be said in favour of the former that it is less expensive, and in some respects more under control, and has been found to give results as good as the closed.

It seems to me, however, that in India it would be better, in order to maintain as uniform a temperature as possible, as well as to protect the scum which forms on the surface from heavy rainfall, to have a roof over the tanks or to close them. Against the open tank is the fact that the gases generated are not under control, as in the closed tanks where they can be carried off by pipes and burnt. I have been in the vicinity of open tanks for hours, and though somewhat unpleasant at times, the term "nuisance" could scarcely be applied to them.

B. After the initial stage of liquefaction the process should be continued by the passage of the sewage through contact beds.

Authorities differ somewhat as to whether upward, lateral or downward passage should be adopted. The essential feature, however, is to have a good medium of clinkers, or coke, and clinkers (gravel, coal, may be substituted in cases where the former are not obtainable). The harder the substance the less *débris* will there be, and it is always advisable to wash the medium well, if possible, both before and after placing it in the bed.

It should be noted that though it is a *sine qua non* that the septic tank should be thoroughly well cemented, say with cement from $\frac{1}{2}$ inch to 1 inch in thickness, whereas the contact beds may, if the soil is of clay or very stiff, be merely dug out to the requisite depth; if, however, the soil is loose or loamy the bottom and sides of the bed should be built up with 6 inches—1 ft. of clay and well battered down.

Clinkers, coke, or clinkers and coke, or hard material discarded from rail and steamer engines, &c., should be screened, and in cases in which a downward passage of the sewage is adopted, made to form the medium as follows:—

Top for 1 ft., material which has passed $\frac{1}{2}$ inch mesh, rejected by $\frac{1}{8}''$. Middle for 2 ft., material which has passed 1-inch mesh, rejected by $\frac{1}{2}$ inch. Bottom for 1 ft. material which has passed 3 inches mesh, rejected by 1 inch.

Theoretically, the passage through a contact bed between the septic tank and continuous filters should be attended with good results, as offering the best means of complete liquefaction and of commencing nitrification by aërobic organisms.

It is known that antagonistic organisms do not work well together, one variety overgrowing the other, and it is only fair to suppose that organisms so opposed to each other, as anaërobic and aërobic, would each do their work best where the conditions are favourable, resting or ceasing work when these again became adverse.

It should be here explained that it is usual to fill the contact beds three times daily.

Filling	1 to 2 hours	8 hours.
Remaining full	2 to 3 "	
Emptying	2 "	
Resting empty	2 "	

More frequent or longer periods of rest may sometimes be beneficial.

Theoretically by this intermediate treatment in contact beds anaërobic conditions are to some extent maintained, oxidation and partial nitrification being effected during the filling, emptying, and especially the resting periods allowed to the bed.

Many of the systems in vogue in England stop short at this stage, and consequently unless further purification is effected by a second contact bed, or by land treatment, the effluent produced is not all it might be.

Though the passage through a second contact bed or on to land, owing to further nitrification and oxidation, may be said to be a fairly satisfactory ending, the third stage of purification, whereby the effluent is passed through open filter beds in the manner to be now described, is likely to be attended with the best results.

C. Filtration.—It should be clearly understood that these filters should have no retaining walls, but should be open on all sides. Clinkers or other hard material rejected by a 2-inch mesh may be used and built up as shown in the accompanying diagram. The depth of the filter may be 4 ft. to 6 ft., and the size of the particles used may range from 2 inches to 6 inches; the smaller ones being reserved for the upper layers of the filter.

Great care is necessary to ensure an uniform working of all parts of the filter, and it is obvious that any method, whereby the effluent can be distributed so as to accomplish this, should be, if possible, adopted. Several forms of distributors and sprinklers have been advocated; perhaps the simplest of all, where a fall of 3 ft. or more is available, is by 2-inch iron pipes perforated at intervals of 4 inches with holes $\frac{1}{16}$ inch to $\frac{1}{12}$ inch in diameter. The pipes should be parallel to each other and 4 feet apart. The working, however, is not altogether satisfactory as the holes become clogged, and the streams, unless there is wind, fall constantly in one place. Where money is no object a Stone's Distributor, such as used at Chesterfield, may be adopted and is said to work very satisfactorily.

Among other forms of distributors may be mentioned Stoddart's and Watson's.

The object aimed at and the end obtained by this process of filtration is complete nitrification and oxidation of the remaining organic matter in the contact beds' effluent.

As the filter is only at work during the period the contact beds are discharging their contents, it is advisable to have two or three contact beds working alternately, which, if filled and emptied thrice daily, would necessitate the filter being used for from 12 to 18 hours out of the 24. Continuous working for months on end does not appear to injuriously affect the filter, nor do short periods of rest appear to be harmful. By an automatic gear the alternate discharge of the effluent from the contact beds into the filter could be easily arranged.

In the above description it will be seen that in the process of purification the three stages described merge into one another to a variable extent.

A reference to the accompanying diagram should furnish some idea of the plant required.

It is not within the scope of this article to state what a satisfactory effluent is. The question is an extremely difficult one, and depends rather on the variety of organisms in it than on the numbers, *e.g.*, the presence of very few typhoid or cholera organisms per cc. in an effluent would be a very undesirable state of affairs, whereas the presence of 100,000 comparative harmless organisms, whether liquefiers or not, would not necessarily condemn an effluent. It is satisfactory, and indeed almost imperative, to have periodically the opinion of a bacteriologist on the character of the effluent, especially where this flows into a stream which may be used for *drinking* purposes.

Where the effluent flows into water which is not used for drinking purposes, the usual chemical tests for organic matter and nitrites might in some cases be allowed to suffice. In no instance should the fact that a clean, bright effluent, which does not putrify, is produced, delude one into supposing that it can be carelessly dealt with. It must, however, be borne in mind that the character of an effluent often improves, and a sample from a ripe filter, say one which had been working six months, might give better results than if a sample be taken before the expiration of this period.

I have recently had an opportunity, through the kindness of Mr. Henry Crookes in allowing me to use his laboratory, of making a bacteriological examination of an effluent. The sewage had been passed through a closed septic tank and contact beds only, with what result the following examination, though imperfect, will give some idea;—3 gelatine plates at 20°C, dilutions 10, 100 and 1,000, showed an average of 59,700 organisms to the cc. with a very large proportion of liquefiers; 2 agar plates, dilutions 100 and 1,000 incubated for six days at 20°C. gave an average of 112,800 organisms per cc.

The organisms on two agar plates, dilutions 100 and 1,000, were, after 24 hours' incubation at 37°C uncountable, owing to the surface being overgrown.

A large amount of gas was generated. The following bacteria were demonstrated:

B. Coli, Proteus vulgaris, B. Enteritides, the latter by the anaërobic milk test.

B. Fluorescius Liq., Prodigeosus, Pink Yeast, and a few moulds were also present.

The effluent was very fairly clean, "pearl type" being read through it at a depth of 6 inches.

No putrefactive changes had occured at the end of a week and no bubbles remained 3—4 seconds after shaking.

II. It must be pointed out that only the broad outlines of sewage disposal are being treated on in this article; the subject is full of detail, and it cannot be too strongly urged that all points connected with both the sanitary and engineering sides of the question should receive the careful attention of those into whose hands the responsibility for erecting an installation is placed.

It should be mentioned that no patent rights are attached to the system described. In some cases, particularly where the fall obtainable does not allow of the working by gravitation, it would be necessary to introduce some artificial means of obtaining this; no insuperable difficulty is likely to arise which the ingenuity of our engineers could not overcome. Small separate chambers, interposed between the septic tank and contact beds and filters, will allow of these being emptied by syphons, and the emptying and filling might be automatically arranged.

When a constant daily supply of water from 3 to 20 gallons or more per head and a good fall, say 10 ft., 12 ft., is obtainable, the bacteriological disposal of sewage, in many of our large cantonments and Indian cities, and especially in our hill stations, should be quite feasible.

When the water is distributed by pipes, or even open channels, sufficient of this might be diverted to allow of a water carriage system of sewage being adopted, and of its being disposed of by tank, contact beds, and subsequent treatment by filters or land.

Again, wherever irrigation is practised, there should be little difficulty in diverting and utilising some of this water, sufficient for flushing purposes, and for diluting and carrying the sewage to its destination.

In places where the supply is not capable of general distribution—and we are confronted by a difficulty, the converse of that often met with in England, *i.e.*, the want of a constant and sufficient water-supply; it is still desirable that some such system as the one described for the natural purification of sewage should be carried out as far as possible.

In such cases installations might be made to form part and parcel of latrines, and could be erected at a comparatively small cost to meet the necessary requirements of hospital, jail, cantonments and other latrines used by communities.

The desirability of excluding all forms of antiseptics and deodorants cannot be too strongly urged. Their utility at any time, except in skilled hands, is more than doubtful.

To overcome any unpleasant odour the extra flushing necessitated should be a great advantage, ensuring as it would a certain dilution.

I read that in experiments carried on in an installation in Calcutta erected on the Exeter Septic Tank system, as little as half gallon per head was found to suffice for its satisfactory working. Conditions are in a warm climate undoubtedly favourable for rapid liquefaction and subsequent nitrification, especially where an uniform and favourable degree of temperature can be maintained. A greater degree of dilution, I think, would be attended with better results, and if two to three gallons of fluid per head were obtainable, the daily output from the tank might be passed into the contact beds without diminishing their capacity to any appreciable extent.

In the present state of our knowledge, are we justified in continuing the system of trenching, now so much in vogue in India, where another and one vastly more satisfactory, from a sanitary point of view, can be successfully introduced?

Every installation, no matter how small, would be a step towards improved sanitation. It is only necessary here to mention two of the many dangers and disadvantages attending the use of trenching grounds, *viz.*, the probability of contamination of water-supplies from trenching grounds, during the rains, particularly a heavy shower of rain, either by surface drainage, or by leakage through cracks in the soil, rat and worm holes, &c. And (2) to the fact, that it can *scarcely be desirable, as is sometimes done, to build on these old trenching grounds*, even after a considerable lapse of time. Dr. Houston has found that garden soil treated with fæces, even after a lapse of six months may contain 26,780,000 micro-organisms per gramme of soil. Practically all the installations on a large scale now in England deal with, in addition to fæcal matter, refuse from breweries, soap works, and the residue from factories, &c., and in some cases, the drainage from roads the dilutions varying from 10 to 100, or, even more in rainy weather. As a result, one of the chief difficulties in disposal of sewage in England is to deal with the excess of fluid, more especially during rainy weather. Of the solids, other than the dejecta, which have to be got rid of, such articles as corks, fats, and *débris* of various kinds, offer the chief difficulty.

Now in most Indian towns and cantonments our sanitary system deals separately—

(1) With fæcal accumulation and urine.

(2) The refuse from cook-sheds, compounds and road sweepings.

Even incinerators which satisfactorily consume both the above are not all they might be, owing to the draining away of urine with some proportion of fæces, and the consequent contamination of the drainage areas in the vicinity of the latrines.

Of the other forms of sewage disposal, few, I think, can be said to be entirely satisfactory, when this is effected by the application of crude fæcal matter to the soil. In places where a constant and uniform water-supply by pipes or irrigation is *not* possible, the desirability of introducing some ready means of sewage disposal to meet various requirements should at least receive the attention of those responsible for the sanitation.

In conclusion, it may be observed that sewage effluents are exceedingly rich in nitrogenous bodies held in solution, and that the value of these as manure is very high.

In many instances an installation might be arranged so as to allow of land irrigation, and the application of a well purified effluent to the soil might safely by permitted.

The almost universal prejudice against cultivation of areas treated with raw sewage would not be so prevalent, if, as in these cases, a clear fluid possessing high manurial qualities could be offered.

MALARIA: AS SEEN IN THE ANDAMANS PENAL SETTLEMENT.

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OUR hospital figures substantiate this theory. Well-cleared established stations like Aberdeen, Haddo and Phœnix Bay are less malarial than out-stations like Goplakabang, but even in the healthy stations it is the men doing hard out-door work that furnish the bulk of the malarial cases. True, it is these men that have the most inducement to come to hospital; but latterly all our malaria cases have been examined microscopically and I have yet to find a malingerer who is competent to produce pigmented crescents at will, or to arrange for a suitable increase in his large mononuclear leucocytes. It appears to me that the convict may at times derive his fever from the bite of an infected mosquito, but that he may also have a relapse from a previous attack through exposure, overwork or some cause lowering his vitality. Again, while a healthy well-nourished man may only suffer slightly from fever after an infected bite, it is obvious that a weakly, chilled, tired man whose powers of resistance are much lowered would, in all probability, suffer to a much greater or more serious extent.

This question is admirably worked out by Attilio Caccini of Rome, in a series of articles published in the *Journal of Tropical Medicine* for May and June 1902.

THE BIOLOGICAL DISPOSAL OF SEWAGE.

By Capt. E. C. MACLEOD, I.M.S.

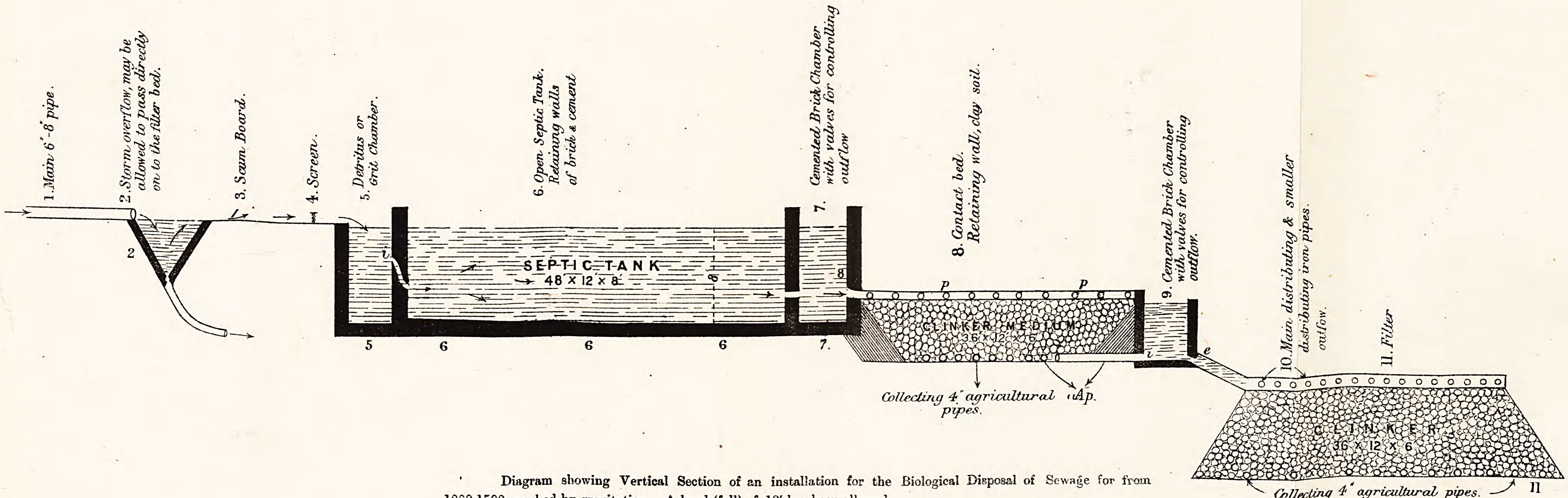

Diagram showing **Vertical Section** of an installation for the Biological Disposal of Sewage for from 1000-1500, worked by gravitation. **A head (fall) of 12′ has been allowed.**

The depth 8′ in the case of the Septic Tank refers to the big Sewage level, and in the case of the contact beds and filter to the depth of Clinker.

Description.

1. Main 6″—8″ pipe.
2. Storm overflow, may be allowed to pass on to the filter bed.
3. Scum board.
4. Screen.
   The main pipe ends at 2 and its place is taken by an open drain to—
5. Detritus or Grit Chamber, 6′ × 4′ × 8′ *deep.*
6. Septic Tank—retaining wall, brick and cement, 48′ × 12′ × 8′ *deep.*

Note.—Entrance into Septic Tank well below Sewage level.

7. Cemented Brick Chamber, 6′ × 4′ × 8′, with valve at e to regulate outflow into distributing pipe p.
8. Contact bed containing Clinkers, shows method of collecting effluent by 4″ agricultural pipes Ap. Retaining walls of clay, 36′ × 12′ × 4′ *deep.*
9. Cemented Brick Chamber, 4′ × 6′ × 4′, with inlet at i, and egress with valve for controlling outlet at e.
10. Pipe or open channel leading into distributing pipes, large and small (Fall 3′).
11. Filter, Clinkers, no retaining walls, shows distributing and collecting pipes.