THE BIOLOGICAL PURIFICATION OF SEWAGE.

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A partial recognition that natural purification of organic matter was due to living organisms was arrived at early in last century, when Cagniard de la Tour discovered that yeast was a living plant, and Schwamm demonstrated that putrefaction was due to something in the air which heat could not destroy, and that meat would not putrify in calcined air.

Pasteur proved that fermentation and putrefaction did not take place in the absence of living organisms, which he divided into ærobic, or thriving in the presence of oxygen, and anærobic, or growing without it.

Frankland, in 1872, had pointed out that "a filter must not be considered as merely a mechanical contrivance, the process carried on being also chemical."

In 1872 the Berlin Sewerage Commission reported that sewage matter was converted into nitrates, not by a simple molecular process, but by organisms present in natural sewage and soil.

Dr. Sorby, in 1883, remarked on the very large proportion of the detritus of fæces which was lost in the river owing to the action of "countless thousands of living creatures."

Duprè, in 1884, stated that "the consumption of oxygen from the dissolved air of a natural water is due to the presence of growing organisms, and that in the complete absence of such organisms little or no oxygen would be thus consumed."

In May, 1886, Duprè "proposed to cultivate the low organisms on a larger scale, and to discharge them with the sewage effluent into the river (Thames), as the power these lower organisms had was remarkable."

At Bolton, in 1887, Duprè said: "Whatever scheme may be adopted, except destruction of the sewage material by fire, the agents to which the ultimate destruction of sewage is due are living organisms (not necessarily micro-organisms), either vegetable or animal."

The earliest modern initiation of the bactterial treatment of sewage appears to be due to Dr. Alexander Mueller. He "took out a patent in which he endeavoured to utilise the micro-organic life in sewage for the purpose of purification, and which was actually in operation at one time to purify the effluent of some works for the manufacture of sugar from beetroot."

About the same time, January, 1882, the "Mouras Automatic Scavenger" was thus described in France: "This mysterious contrivance, which has been used for twenty years, consists of a closed vault with a water seal, which rapidly transforms all the exrcrementitious matter which it receives, into a homogeneous fluid, only slightly turbid, and holding all the solid matters in suspension in the form of scarcely visible filaments."

In January, 1887, Mr. Dibdin, in a paper on "Sewage Precipitation," read at the Institution of Civil Engineers, said: "Very alkaline effluents, such as those produced by the use of lime in excessive quantities are very liable to putrify, instead of becoming purified by oxidising organisms."

In November, 1887, the Massachusetts State Board of Health began their well-known experiments on the purification of sewage by chemical precipitation and by filter beds. In their report of 1890 the process was compared to a combustion, and was found to be most rapid in the summer months.

In 1891 the Main Drainage Committee of the London County Council authorised a series of experiments at Barking Outfall. These were carried out with most successful results.

The credit for applying on a practical scale the knowledge of bacteriologists, that certain organisms had the power of liquifying organic matters, belongs to Scott-Moncrieff, who, in 1891, liquified the sewage from a househould of ten persons by means of a continuous upward flow tank filled with coarse flints.

In 1894 the Sutton experiments were carried out, screaned sewage being successfully treated by double contact beds.

In 1896 the Exeter Septic Tank system was put into operation by Mr. Cameron, the City Surveyor. He treated a flow of about 50,000 gallons of sewage daily in a closed tank, using crude sewage without any screening, but passed it through a grit chamber. The effluent was treated in five contact beds. A set of automatic gear on the tilting bucket principle, devised by Mr. Cameron, regulated the cycle of filling, resting full, emptying, and standing empty.

At Leeds, in 1898, experiments with the Sutton method were carried on. Here crude, screened, and partially settled sewages were used in open and closed septic tanks, followed by treatment in various kinds of contact beds and continuous filters.

At Manchester, in 1898, three experts were appointed to advise upon the whole question of sewage purification. They used both open and closed septic tanks and various kinds of contact beds and continuous filters.

Meanwhile municipal authorities in Great Britain have put down experimental works, covering a great variety of processes, with a view of arriving at a satisfactory conclusion as to the best method of dealing with the sewage of their respective districts.

The purification of sewage by chemical treatment or by land filtration is dropping into disuse, while the bacterial method is fast becoming the factor for dealing with the difficulty.

Sewage has been described as a complex liquid, consisting of the liquid excretions of the inhabitants; the foul waters from the kitchens containing vegetable and animal matters, bits of fat, and other refuse; the "suds" from the washing of dirty linen, cooking utensils, and the people themselves, holding in solution and suspension soap, fatty acids, and the exudations from the human skin." Such slops left to stand for 24 hours become most foul and offensive.

In the case of water-closet towns, in addition to the above polluting matters, there are the solid excreta from the inhabitants—paper and other matter of a like nature emptied through the closets into the sewers—but there is also a larger amount of clear water."

If kept for a few days the liquid will undergo decomposition through the action of putrefactive bacteria. The albuminous matters will be split up, carbonic acid, marsh gas, and ammoniacal derivatives being evolved. At the same time the liquid turns black from the action of traces of sulphuretted hydrogen found on the infinitesimal quantity of iron generally present in sewage.

Sewage therefore is a thing to be got rid of as soon as possible; so that, where it is possible to discharge it direct into the ocean, in deep water, as at Bondi Outfall, it is the easiest and cheapest method of dealing with it. It has been difficult to induce engineers and the people generally to believe that the manurial value of sewage is so small as not to be worth considering, and much money has been wasted in attempts to turn sewage to account as manure.

Lime precipitation and sludge pressing was the most common form of chemical treatment, but in practice it was a disgusting process.

It is now universally admitted that it is highly desirable to follow Nature's method as closely as possible in destroying the undesirable matter in sewage, and the septic tank method does so by allowing the bacteria contained in the sewage itself to get to work breaking up the suspended solids; whereas the lime precipitation process was the very reverse, for the bacteria were entangled and carried down by the precipitated sludge, and putrefaction was simply delayed until the effect of the lime wore off. Even supposing the effluent were as good, the cost of lime treatment is prohibitive, and the disposal of the sludge is a great nuisance.

By the precipitation process the sewage was clarified, but by the bacterial process the solid matter in the sewage is liquified by fermentative action, and at the same time a very decided reduction in the albuminoid ammonia takes place, and also the oxygen absorbed by the tank effluent is very considerably less than by the crude sewage.

A gallon of water weighs 70,000 grains. An average English town sewage contains about 100 grains of solid matter to the gallon, the remaining 69,900 grains being water. Of the 100 grains solid matter a certain proportion, varying in different towns, at different times of the day, and at different seasons of the year, will consist of organic matter, the average amount being 40 grains.

It is the object of sewage purification to remove, as far as possible, that 40 grains of organic matter, and to as nearly as possible oxidise that which cannot be removed. All the organic and mineral matter in suspension should be removed, and in a good effluent, as much as 80 per cent. of the organic matter in solution will also be oxidised to nitrates.

An average sewage containing 100 grains of solid matter to the gallon will have about 70 grains in solution.

Composition of one gallon of typical average sewage:—

			Parts per 100,000.
1. Solid matter in suspension—			
(*a*) Organic ..	20		
(*b*) Mineral ..	10		
	=	30 grs. per gallon	= 42·8
2. Solid matter in solution—			
(*a*) Organic ..	20		
(*b*) Mineral ..	50		
	=	70 grs, per gallon	= 100
		100 grs. per gallon	= 142·8

Nearly all the solid matter in suspension and a fraction of that in solution can be removed by lime precipitation or other similar process in the form of sludge, the proportion of the total solid matter so removed being about 50 per cent., or the same proportion can be removed by fermentation into gaseous compounds.

The solids in suspension contain about one-third of the organic nitrogen, and one-half the carbonaceous matter of the sewage.

Before describing the means adopted to effect this removal by the fermentative or septic process, it may be well to give some definitions.

Septic Tank.

A septic tank may be described as a vessel generally rectangular in plan, and of comparatively shallow depth, the greatest length being in the direction of sewage flow. The bottom generally slopes slightly towards the inlet end to facilitate the removal of sediment or sludge when necessary. The material used in building the tank is generally brick, slate, or concrete rendered with cement. The tank may be either closed or open. The inlets and outlets must be thoroughly submerged. A septic tank requires no fall, the liquid enters and leaves at the same level.

Contact or Bacteria Beds.

Contact or bacteria beds are vessels filled with some filtering medium, such as coke, coal, destructor breeze, clinker, burnt ballast, etc., to a depth of about 4 feet. In shape they are generally rectangular, but any other shape would do as well. They may be built of concrete rendered with cement, or of brickwork, but must be watertight. While being filled with sewage from surface channels, the outlet to tank is kept closed. As the sewage sinks through the filtering medium it displaces the air from the interstices until the beds or filters are full. They are then allowed to stand full for about two hours generally, "in contact" with the filtering medium, and hence the name. As the sewage escapes during emptying, fresh air is drawn into the interstices of the beds again.

The usual cycle of working contact beds is—

1 hour filling.
2 hours standing full.
1 hour emptying.
4 hours standing empty.

The size of filtering material is generally 1in. to ¼in. On the bottom of beds perforated drain pipes are laid to conduct the effluent to the point of discharge.

Percolating continuous or streaming filters are those in which the sewage is as uniformly and continuously spread over the whole surface of the filter as the appliances used will permit.

The filtering medium requires to be hard and durable, but otherwise the nature of the material matters little, as the oxidation is effected by the bacteria in the sewage itself, and not by the filtering medium. The important point is that the material must be quite free from dust. The top layer of 3in. in depth should pass through ½in. mesh, and rest on ¼in. mesh, the remainder of the filter being material which passes through ¾in. mesh and rests on ¼in.

The perforated pipes, which collect the effluent, should be surrounded with material 1in. to 2in. in size.

The depth is generally about 8ft. The shape, in plan, is rectangular, circular, hexagonal or octagonal, the shape varying to suit the particular method of distribution adopted.

As to the material, coal is considered the best for percolating filters. Various other materials are commonly used, such as hard coke, destructor breeze, and clinker, burnt ballast, etc. Even harder materials, such as granite, hard clinker bricks, or gravel, broken to the various gauges, are preferred by many.

The Manchester Commission, appointed in 1898, reported that it is practicable to produce by artificial processes alone sewage effluents which will not putrify, which can be classed as good chemically, and which may be discharged into a stream without fear of creating a nuisance. Stress was also laid on the effluents being judged both from a chemical and from a biological point of view. The artificial processes referred to are classified by them as follows:—

A.—Contact Beds.

1. Closed septic tanks and contact beds.
2. Open septic tanks and contact beds.

3. Chemical treatment, subsidence tanks (where little or no septic action is produced) and contact beds.
4. Subsidence tanks and contact beds.
5. Contact beds alone.

B.—Artificial Filters.

6. Closed septic tanks followed by continuous filtration.
7. Open septic tanks followed by continuous filtration.
8. Chemical treatment, subsidence tanks and continuous filtration.
9. Subsidence tanks followed by continuous filtration.
10. Continuous filtration alone.

Among the conclusions and recommendations made by the three experts forming the Commission are the following:—

"(3) In order that a bacteria contact bed may exercise its full power, it is necessary:—

"(a) That it should be allowed sufficiently frequent and prolonged periods of rest.

"(b) That the sewage applied to it should, as far as possible, be free from suspended matters.

"(c) That the sewage applied to it should be of as uniform a character as possible.

"(4) The above conditions are secured by passing the sewage as it arrives at the works through an adequate system of screens, catch pits, and tanks. Such an arrangement has the further important advantage of leading to the development of those anærobic or septic processes which resolve into gases 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 is a source of so much difficulty and expense, is thus abolished. The above anærobic or septic process is found to take place as effectively in an open tank as in a closed one.

"(5) The capacity of bacterial beds has been found to remain practically constant—about one-third of the tank capacity.

"(6) With regard to the amount of sewage which can be purified by a given bed, our inquiry has shown that each bed may safely receive four fillings in the 24 hours, provided the sewage has undergone the preliminary subsidence and septic preparation in tanks, and that the bed is accorded about one day's rest in every week."

With so many combinations of septic tanks (open or closed), contact beds (single and double), and percolating filters to choose from, it is difficult to arrive at a definite conclusion. I shall therefore quote from the report of Mr. J. M. Smail, M.Inst. C.E., Engineer to the Board of Water Supply and Sewerage, Sydney, on the result of inquiries made by him in Great Britain, Europe, and America. He says: "I have formed the following conclusions:

"(a) That a combination of septic tank and after treatment on bacteria beds fulfils the conditions of modern purification of sewage.

"(b) That, where in the vicinity of dwellings, septic tanks should be covered. This covering need not necessarily take an expensive form—only sufficient to keep down smell and form a local feature.

"(c) That detritus tanks are absolutely necessary where heavy matters are discharged into the sewers.

"(d) That tanks should be designed to ensure the maximum deposition of suspended solids in sewage when passing through.

"(e) That where favourable ocean discharge cannot be obtained, the 'percolating,' 'continuous,' or 'streaming' filters, combined with covered septic tanks, is the most economical method of sewage disposal where levels will admit, in order to minimise local nuisance.

"(f) That the system can be adopted in country towns where the liquid wastes are discharged into rivers, where water is used for potable purposes, provided secondary percolating filters are provided. This conclusion is on the assumption that levels are favourable to work the distributing apparatus; failing this, double contact beds should be used.

"(g) That the filtering media should be of material which resists disintegration, and be graded so as to give them maximum amount of aeration. Indiscriminate piling of material into a filter bed is simply wasting money in sewage purification.

"(h) That the tank effluent should be distributed over the filtering media in fixed quantities at short intervals. This system admits of the maximum amount of aeration, in the filter.

"(j) That storm water filters are necessary to relieve the daily filters from being overtaxed, and that the Local Government Boards' rule of six times the daily dry weather flow is a reasonable one to observe in this State, all discharge above this quantity being dealt with by storm overflows into the nearest watercourse."

Speaking of open septic tanks, Mr. Smail says: "I did not find one open tank which did not give off a smell even in a quiescent state."

On the question of contact beds versus continuous filters he says: "Good results have been obtained from either, but the balance is in favour of the continuous system, in view of the quantity of tank effluent dealt with per acre in 24 hours, which is in excess of the contact system."

On the same subject, Mr. Davis, Under Secretary for Public Works, and formerly Engineer for Sewerage Construction, in his report, says: "Good results are obtained by both methods, but where the sprinklers can be conveniently introduced, many prefer them, and with these I am disposed to agree."

Whatever combination of septic tanks, contact beds, or percolating filters be adopted, sewage must undergo two changes before it can be purified, viz.:—

1. Liquefaction.
2. Oxidation.

In a purely biological process a detritus tank must be provided to remove the insoluble mineral matter in suspension before the sewage reaches the septic tank, or contact bed, or percolating filter, otherwise there would be rapid silting up and choking. As has already been pointed out, the average sewage contains in suspension 10 grains of insoluble mineral matter per gallon.

It is usual to have detritus tanks side by side, through either of which the sewage may pass; so that before one is full of silt, the other may be brought into use while the first is being emptied.

After passing the detritus tank the sewage should be screened to remove the coarser solids, especially rags, paper, corks, etc., if they can be conveniently got rid of by burning or otherwise. Paper in particular proves very troublesome, especially in the open tanks, because it disintegrates so slowly, and as it floats on the surface it frequently forms a solid mass that hardens in the sun, and scarcely dissolves at all.

From the Manchester conclusions, it follows that before oxidation is attempted, liquefaction in a septic tank should take place, though at Leeds good results were obtained from double contact beds without septic tanks.

When Cameron's closed tank at Exeter was put into operation it was found that a thick, tough scum, 2in. to 6in. thick, formed on the top of the tank, while any sludge that settled was decomposed with the production of carbonic acid gas, marsh gas, hydrogen, and ammonia both free and combined. The resultant mixture was a highly inflammable gas. Below the scum was a zone of fermentation, in which the sewage was mainly clear, but bubbles of gas kept the liquid in a state of quiet admixture. At the bottom of the tank the layer of dark, peaty sludge was so small as not to require removal after a year's working.

It may here be mentioned that at Rookwood a septic tank, 9 feet deep, has at present, after about five years' working, only 4in. or 5in. of peaty sludge at the bottom.

The Manchester experiments showed that the open tank gave rather better results than the closed one, but it seems certain that in Australia septic tanks must be closed for two reasons—

1. The smell given off is at times objectionable.

2. The solids (especially paper) float to the surface, and instead of forming a leathery scum from 2in. to 6in. thick, as described in the Exeter tank, they form a hard cake, which has increased in thickness to a very considerable extent in all the open tanks near Sydney, and especially at North Sydney Outfall.

It may be mentioned that at the latter place, the tanks are about to be covered.

As to the rate of flow through a septic tank, it is generally thought desirable to provide space equal to one day's dry weather flow; but, taking the average number of places visited by Messrs. Davis and Smail, the result is 19 hours' capacity. Probably the higher figure should be adopted, and the tank be of such a shape as to allow a rate of flow not exceeding 8 feet per hour, so as to get rid of the greatest possible proportion of the solids in suspension, in order that the life of contact beds and filters may not be diminished. In many cases the rate is two or three feet per hour only.

In summing up the subject of liquefaction by means of septic tanks, Dr. Barwise says: "Personally, I am in favour of liquefaction being started in a septic tank, the process being finished by means of an anærobic bacteria bed, which is always kept full of sewage. The original form of this bed is one in which upward filtration takes place, but a simpler arrangement consists in lateral filtration through a tank filled with hard material of 1in. to 3in. in size. If the subsoil is clay, to construct a tank on this principle, it is sufficient merely to dig a hole in the ground, and allow the sewage, which has passed through a detritus tank, and some form of septic tank, to percolate laterally through the bed. By placing 6in. to 9in. of coarse clinker above the water-level of the bed, and covering with a little soil, good crops of rye grass may be grown. Beds constructed on this principle have been tried on a large scale by Dr. Richards at Chesterfield, with the result that the albumenoid ammonia was reduced on the average from ·72 to ·38 parts per 100,000, and on the Burton Farm from ·5 to ·25 per 100,000."

He further adds: "The septic tank should hold about one day's dry weather flow, except when an anærobic bed is also employed, in which case half a day's dry weather flow will suffice."

Oxidation.

After the solid matter in suspension has been liquefied by bacterial agency in the septic tank, or anærobic bacteria bed, or both, the organic matter in solution has to be oxidised. This is done either in contact beds or in artificial filters. Dibdin introduced the contact beds, using an 8-hour cycle—1 filling, 2 standing full, 1 emptying, 4 resting.

Various ingenious devices have been adopted for automatically working the cycle of changes in contact beds.

At Exeter, Cameron's gear consisted of tilting buckets filled by overflows from the contact beds.

In New South Wales, at Chatswood, the main principle is that a float in one contact bed operates, by means of a lever, the discharging valve in another.

At Rookwood the overflow from a bed when filled, fills a bucket attached to two shafts by levers. The falling of the bucket shuts off the supply to its own bed, opens the discharging valve of a second bed, and opens the inlet valve to a third.

At Mosman, after a bed is filled it remains full till a slow overflow from the bed itself has filled a bucket. The fall of the bucket opens the discharging valve of the bed, and the emptying of this bed draws off the water from the actuating bucket of the next bed, allowing it to rise, thus closing the discharge valve and opening the admission valve so that the next bed begins to fill.

With percolating filters the first system consisted of applying sewage for eight hours, and giving the filters 16 hours' rest for aeration; then by means of the automatic flushing tank the cycle of work was reduced to about twenty minutes; then by the use of tipplers to a few minutes; then at Chesterfield the period was reduced to 10 seconds by using a Shone ejector to force the tank effluent through perforated pipes, and finally the continuous or percolating filters came into use.

The only difficulty in connection with the latter is to secure uniform distribution, and to effect this various methods have been tried, as for instance—

(a) Fixed pipes with numerous small perforations.

(b) Revolving sprinklers like those used for watering gardens.

(c) Stoddart's perforated iron and many others.

The point to be aimed at, whatever system is adopted, is to bring the sewage into contact with the filtering medium in the thinnest films in the presence of abundance of air, so that the oxidising germs may work with the greatest activity.

As to the relative merits of contact beds and percolating filters, Dr. Barwise makes the following summary:—

Relative Merits of Contact Beds and Artificial Filters.

Contact Beds.	Continuous Filters.
Advantages of Contact Beds.	
1. There is no necessity for carefully distributing the sewage.	The sewage must be distributed by stationary or revolving perforated pipes, or other means.
2. The filter material need not be carefully graded, 1 in. to 2 in. diameter giving average results.	To obtain the best results, material must be free from dust, and be from $\frac{1}{4}$ in. to $\frac{3}{4}$ in. diameter.
Advantages of Percolating Filters.	
1. Contact beds must be constructed with watertight walls which must necessarily be expensive.	Percolating filters cost less, as retaining walls of any kind are not necessary, in fact, are harmful.
2. Double contact beds are required to approach the same result as one percolating filter.	Percolating filters give the best results.
3. The area supplied to a contact bed is only equal to the volume of sewage treated, therefore oxidation is limited.	The air supplied to intermittent percolating filters may be more than five times the volume of sewage treated, therefore more highly oxidized effluents are obtainable.
4. The sewage owing to being stagnant in the contact bed, has a greater tendency to plug it up.	The filter does not deteriorate, the only plugging which takes place is on the surface.
5. Double contact beds require one square yard for every 112 gallons.	Continuous filters may purify over 500 gallons per square yard, when there is ample time.

"It will be seen that on the whole, the advantage rests with percolating filters, which not only give better effluents, and do not become so readily plugged; but, owing to there being no necessity for expensive brick retaining walls, are less costly."

There are, however, cases in which contact beds may be preferred. It may be the case where the subsoil is so stiff a clay that the beds may be made watertight without any retaining walls, also where there is very little fall.

Dr. Barwise further says that, taking four feet as the usual depth of a contact bed, sewage which has previously been liquefied in a septic tank may be applied at the rate of 225 gallons per square yard per day, provided that automatic apparatus is adopted.

This is based on the assumption that the liquid capacity of a a bed is one-third of the total, and that the bed receives three fillings in 24 hours.

The Manchester report goes further, and states that four fillings, or 300 gallons per square yard, may be applied if each bed is accorded about one day's rest in every week.

At Exeter there are five beds, four being in use at any one time, while one is always resting.

It is probable that the difficulty of uniform distribution over a continuous filter is greater in practice than is generally admitted, that the plugging of the surface is a very serious difficulty, and that uniform distribution through the filter is never attained, but the tank effluent probably follows regular channels after the filter has been in use for some time.

The following statement was prepared by Mr. Watson, Engineer to the Birmingham Drainage Board:—

Table showing the quantity of sewage purified by means of percolation bacteria beds at various places in 24 hours per acre of bed, with average percentage of purification of crude sewage.

Name of Town or District.	Time Beds were at Work.	Depth of Bed.	Quantity of Sewage treated per 24 Hours.	Average Percentage of Purification.	
				Oxygen Consumed.	Albumenoid Ammonia.
	Years.	Feet.	Gallons.	Per Cent.	Per Cent.
Leeds	3½	9	1,000,000	95	90
Accrington ..	3	8 to 9	1,936,000	90	91·3
Birmingham ..	½	5	1,000,000	86·3	88·4
Hyde	3	9	2,178.000	85·7	90
York	1	6·5	2.129,000	84·5	90
Rochdale	2½	9	1,936,000	84	84·2
Averages ..	2¼	8	1,700,000	88°/o	89°/o

Table showing average annual percentage of purification on crude sewage, based on oxygen absorbed test, obtained by typical processes of sewage purification at various places in England:—

Process.	Town.	Percentage of Purification.	
Septic Tanks and Land	Birmingham ..	90	
Septic Tanks and Single Contact Beds ..	Birmingham ..	80	73%
	Croydon ..	63·8	
	Manchester ..	75	
Septic Tanks and Double Contact Beds ..	Leeds ..	95	84%
	Sheffield ..	87 to 90	
	Burnley ..	87	
	Blackburn ..	75 to 80	
	Carlisle ..	71	
Septic Tanks and Percolation Beds ..	Leeds ..	95	88%
	Accrington ..	90	
	Birmingham ..	86·9	
	Hyde ..	85·7	
	York ..	84·5	
	Rochdale ..	84	
Chemical Precipitation and Percolation Beds, 5 feet deep.	Salford ..	82	
Chemical Precipitation and Percolation Beds, 8 feet deep.	Salford ..	95	

These tables show that for an average period of $2\frac{1}{4}$ years these percolating filters have been treating 1,700,000 gallons per acre per 24 hours, the average depth of filter being eight feet, with an average purification of 88 per cent. and 89 per cent. over crude sewage by oxygen consumed and albumenoid ammonia respectively.

Allowing for period of rest and four fillings, 24 gallons per square yard must be taken as the limit for sludge contact beds, or, say, 1,200,000 gallons per 24 hours per acre; on the other hand, the average depth of bed is four feet as against eight feet of filter. With double contact beds the quantity would only be half as great.

The results show that septic tanks and single contact beds show purification of 73 per cent. as against 84 per cent. for septic tanks and double contact beds, and 88 per cent. for septic tanks and percolation filters, while the one case of septic tanks and land filtration shows 90 per cent.

Chemical precipitation and percolation beds at Salford show 82 per cent. and 95 per cent. for beds five feet and eight feet respectively.

A typical sewage which has been referred to in the early part of the paper has the following composition evpressed in parts per 100,000:—

Total solids	142
Suspended solids	42
Chlorine	12
Free ammonia	5
Albumenoid ammonia	1

Such a sewage by precipitation or septic tank would have the solids in suspension removed, and in this process the organic ammonia "the index of the organic matter" would be reduced from 1 to perhaps 0·45. The same result would happen if the sewage were passed over the surface of land so as to intercept the solid matter in suspension. The purification which would so far be carried out would be clarification. The sewage would still have the organic matter in solution in it, and whether it is intermittently passed through open soil, such as sand or gravel, or whether it has passed through artificially prepared filters, the change which takes place is the same. It is essential that the sewage should be applied intermittently, so that the air in the interstices of the filtering medium may by this means be periodically received. Unless this takes place the nitrifying organisms cannot oxidize the ammoniacal salts, and convert them first of all into nitrous acid, and finally into nitric acid. When these are formed they immediately replace the carbonic acid in the carbonates of lime, potash, or whatever base the carbonic acid present is combined with, and form nitrates of such bases. The nitrogen in solution therefore passes away in the filtrate as a nitrate, it is not removed. These nitrates are quite harmless; as a rule nitrate of lime is the particular nitrate which is formed.

Parts per 100,000.

	Total Solids.	Solids in Suspension.	Chlorine.	Free Ammonia.	Albumenoid Ammonia.	Oxygen absorbed at 80 F., in 3 minutes.	Oxygen absorbed in 3 minutes, after 7 days incubation.	Putrescibility.	Nitrogen as Nitrates.
Crude Sewage	140	40	12	5·0	1·0	2·5	7·0	4·5	Nil.
After precipitation or Treatment in Septic Tanks ..	105	5	12	6·0	0·5	2·0	3·5	1·5	Nil.
Effluent from Filters	100	Nil.	12	1·5	0 05	0 61	0·61	Nil.	1·5

The above table taken from Barwise on Bacterial Purification of Sewage, shows the changes which an average sewage undergoes.

The standards of purification generally adopted are 1 grain of oxygen absorbed in 4 hrs. and 0·1 grain of albumenoid ammonia. As long as the final effluent shows less than these standards it is considered chemically satisfactory unless it passes into a stream used for drinking purposes. At the same time it must be borne in mind that "the object of purification is primarily the production of an effluent free from putrescibility, and not one in which the chemical ingredients are below some necessarily more or less arbitrary standard."

At Leeds, screening sewage through bars 1 in. apart, was found to remove $2\frac{1}{4}$ c. ft. of solid matter per 53,000 gallons in the day time, and $\frac{1}{2}$ c. ft. for the same volume at night. A regular series of analyses extending over a period of two years gave results shown below, the sewage being screened, then treated in septic tanks and double contact beds.

At Manchester screened sewage was used with septic tanks either open or closed, and single contact beds.

At Exeter the sewage is a weak one; it passes through a detritus tank. It is not screened but is treated just as it comes from the sewers, in closed septic tanks and single contact beds. At North Sydney the sewage is weak, no screening is done, but silt pits or detritus tanks are provided. The sewage is treated in open septic tanks and the effluent filtered through sand beds 5 ft. deep. At Chatswood a silt pit is provided, but owing to the clayey nature of the surface soil it is not found necessary to use it. The sewage is treated in open septic tanks and coke contact beds.

The following table shows the percentage of purification obtained at the above places.

Place.	By Tanks.		By Beds.		Total.	
	Albumenoid Ammonia.	Oxygen Consumed in 4 Hours.	Albumenoid Ammonia.	Oxygen Consumed in 4 Hours.	Albumenoid Ammonia.	Oxygen Consumed in 4 Hours.
Leeds	61	50	26	41	87	91
Manchester	46	33	29	48	75	81
Exeter	45	29	30	53	75	82
North Sydney	32	..	54	..	84	..
Chatswood	26	..	54	..	80	..

In conclusion I have to acknowledge my indebtedness to Dr. Barwise's book "Bacterial Purification of Sewage," also to the reports of Messrs. Davis and Smail, and to a paper by Mr. Bran of the Victorian Railway Department, for nearly all the information given in this paper.