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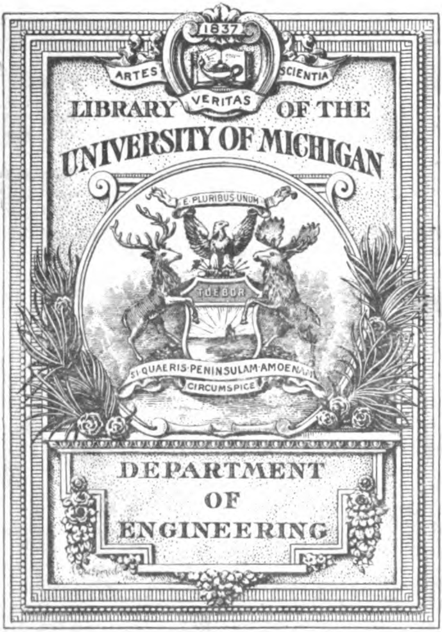

No. 11. THEORY OF ARCHES. By Prof. W. Al[illegible]

No. 1[illegible] ARCHES. By P[illegible]ion, revised and [illegible]

THE TREATMENT

OF

SEPTIC SEWAGE.

BY

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PREFACE.

In the present book, the writer has attempted to give some of the more important developments in the bacterial treatment of sewage, but owing to the limitations of size, none of these can be considered very complete. The work is, in effect, a series of hints, together with indications as to preferable treatment.

It is obvious, that in such a book there is very little original work, and the facts and opinions are necessarily largely drawn from the studies of others. The chief works consulted and to which the author is more or less indebted, are: Sewage and the Bacterial Purification of Sewage, by Rideal; Barwise's Bacterial Purification of Sewage, as well as his earlier book on the Purification of Sewage; Natural and Artificial Sewage Treatment, by Jones & Rœchling; Austin's Report on the Means of Deodorizing and Utilizing the Sewage of Towns; Thudichum's Bacterial Treatment of Sewage; The report of the Royal Commission on Sewage Disposal; Reports of the Rivers' Department of the City of Manchester; Fuller's Composition of Sewage in Relation to Problems of Disposal; Annual Reports of the Superintendent of Sewers of Worcester, Massachusetts; Annual Reports of the Sewerage Commission of Connecticut; Report of the State Sewerage Commission of New Jersey; Waring's Purification of Sewage by Forced Aeration; Reports of the Baltimore Sewerage Commission; Lowcock's Filtration of Sewage; Kinnicutt and Eddy's Action of the Septic Tank on Acid Iron Sewage; and Kinnicutt's Present Status of the Sewage Problem in England; the Reports of the State Board of Health of Massachusetts and the Reports of the New York State Board of Health. More or less use has been made of material in these various books, reports and papers, of which a general acknowledgment is herewith made. In many cases a specific acknowledgment has also been made in the text.

It is hoped that this little book may

serve to clarify the purification of septic sewage. An attempt has been made, so far as possible within the limits of a book of this size, to place this method in its proper relation to other systems of sewage disposal.

G. W. R.

Rochester, N. Y., Nov. 1, 1903.

INTRODUCTION.

SEWAGE disposal has always been a simple enough matter to the non-technical people who mostly control the affairs of municipalities, but to those charged with its administration, it has been, and still continues to be, exceedingly complex. The latter class are conservative in estimates and statements, while the former are positive that they, at any rate, have found the final solution.

When we examine the matter historically, we find that sewage disposal, pendulum like, has swung back and forth between certain extremes. From fifty to sixty years ago, the sewage nuisance had so far forced itself upon public attention, that a considerable number of works were constructed in England, and in the report of Henry Austin, "On the Means of Deodorizing and Utilizing the Sewage of Towns," published in 1857, a general resumé of the subject is given. At that time, chemical precipitation was coming into use and extravagant notions of the value of the manure to be obtained were indulged in. It is unnecessary to state that none of these methods have justified the hopes of their inventors. A large number of patents were taken out for various chemical processes from about 1845 to 1860 or 1870, but the majority of these patents were so impractical as never to go into operation. Indeed, sewage disposal, owing perhaps to its complex nature, is not properly subject to patents. The useful developments thus far have been mostly the work of scientific men, and ordinary inventors have scarcely contributed anything thereto, nor are they likely to, because the complexity of the operations is such as to be beyond them.

THE ORIGIN OF THE SEPTIC TANK.

The separation of the solid matters in suspension by sedimentation, straining or filtration is, however, an interesting process, which was tried in England about 1850, and which, from its developing on lines quite similar to what is now known as the septic process, may be considered a little at length. Mr. Austin describes the works at Cheltenham, England, for what he calls a mechanical process for separating the solid matter of sewage, as follows:

"The building is divided longitudinally, forming below ground two sets of reservoirs or tanks, which are employed alternately. The sewage passes through vertical filters in the upper and lower tanks, whereby the great bulk of the matters in suspension is separated and retained. These filters are 5 feet deep and 2 feet thick, and consist of coarse gravel inclosed within 2-inch perforated boards, these being protected with basket work to prevent clogging.

"The heavier matters of the sewage deposit themselves at the bottom of the tanks, but a large proportion of the solid forms itself into a floating body, and accumulates to about 18 inches thick on the surface. The liquid is conveyed from the angular filters in the upper tanks by a line of pipes in each division.

"A weir, or rather division, in the third or liming tank causes the water, then partially clear, to flow through a channel at each end during its passage, through which a certain proportion of cream of lime mixed on the floor above falls into it, and occasions a further precipitation to take place.

The effluent water then passes through another filter of gravel finer than before, and then through a third, finer still, to the outfall.

"When either reservoir contains a certain amount of solid matter, the flow of sewage is cut off and turned into the other. This takes place about every eight weeks, and the filtering medium of gravel is removed at the same time and washed. The contents of the tanks, which are in a state of 'slush,' are then hoisted in buckets through the trap lids on to the floor above, and wheeled out and mixed with the scavenger's refuse of the town, the ashes, street sweepings, etc. These are brought to the yard, and a kind of embanked reservoir is formed of them immediately outside the building, and as the semi-solid sewage is wheeled into the midst, the dry refuse outside is turned on to it. The liquid is at once absorbed, and after being turned over and thoroughly intermixed, the solid mass is fit for immediate removal and use.

"The ashes and dry refuse of the town are said to be just sufficient for the purpose. They absorb about two-thirds of their bulk of sewage; that is to say, one cubic yard of the ashes, etc., and two-thirds of a cubic yard of the semi-fluid sewage, make only one cubic yard of solid manure."

The foregoing quotation is especially interesting as indicating that Mr. Austin observed an operation in the Cheltenham tank exactly as is now known to exist in a septic tank; that is, the heavier matters deposit themselves at the bottom, while a considerable portion of the solids forms itself into a floating body, accumulating to the thicknsss of about 18 inches on the surface. In view of this fact, it seems fair to say that, in a practical way, Mr. Austin was in reality the discoverer of the septic tank. Nevertheless, the real significance of the septic tank—the fact that the changes going on are biological—was not appreciated by him, as is shown by his calling it a "mechanical process for separating the solid matter of sewage." Nor, indeed, does anyone seem to have appreciated the significance of these tanks, although a number of them were built and operated in England, with such success as is possible for that kind of a tank, but the so-called chemical purification process forged rapidly to the front, and mechanical separation—which we now call septic action—was lost sight of for a number of years, and chemical purification became for a time the leading form in England.

LAND PURIFICATION PROCESSES.

In the mean time land purification processes were, where the proper conditions obtained, slowly gaining ground. These processes have always labored under this disadvantage, that not being in any way subject to patent, they have never had the booming which chemical precipitation and purification by septic action have received, although whether this is so great an advantage may, perhaps, be an open question. At any rate, the progress which such processes have made, while slow, has nevertheless been sure, until we are justified in saying that where proper conditions obtain, broad irrigation and intermittent filtration are, all things considered, the most satisfactory systems yet worked out. As a broad proposition, in consideration of the value of the crops produced, broad irrigation is the cheapest system yet devised. Experiments at Berlin, Paris, Croyden, Doncaster, Birmingham and other places, show that large crops may be produced and be eaten without prejudice to health.

PURIFICATION BY BACTERIAL ACTION.

Let us now consider the recent development of sewage purification by means of bacterial action. This has been a favorite subject for consideration by a number of biologists, scientific writers, etc., for a good many years. The history of the matter will not be gone into at length at this time any further than to point out two or three significant guide posts along the line. Like all other discoveries, its development has been gradual and is the work of many men instead of one.

So far as can be learned, Dr. Alexander Mueller was the first person to clearly appreciate that bacteria were the prime agents in sewage purification. About 1880, Dr. Mueller took out a patent endeavoring to utilize the micro-organisms in sewage for purposes of purification. Works were built under this patent and were in operation for some time, to purify the effluent of a manufacturing establishment for beet sugar. Dr. Mueller says:

"The contents of sewage are chiefly of organic origin, and in consequence of this an active process of decomposition takes place in sewage, through which the organic matters are gradually *dissolved* into mineral matters, or, in short, are mineralized, and thus become fit to serve as food for plants. To the superficial observer this process appears to be a chemical self-reduction; in reality, however, it is chiefly a process of digestion, in which the various, mostly microscopically small, animal and vegetable organisms utilize the organically fixed power for their life purposes.

"The decomposition of sewage in its various stages is characterized by the appearance of enormous numbers of spirilla, then of vibrios (swarming spores) and finally, of moulds. At this stage commences the re-formation of organic substance with the appearance of the chlorophyl-holding protococcus, etc."

In the meantime, in December, 1881, and January, 1882, an account of Mouras' automatic scavenger was published in France. This apparatus consists of a closed vault with a water seal, which it is stated rapidly transformed excrementitious matters into a homogeneous fluid, only slightly turbid, and holding the solid matters in suspension in the form of scarcely visible filaments. The principle upon which the automatic scavenger acts is that animal dejecta contain within themselves all the principles of fermentation necessary to liquefy them. Later observations show that Mouras' view, that animal dejecta contain within themselves the fermentative principle, is fundamentally true, and in this particular Mouras was, with Dr. Mueller, in advance of the scientific workers of that day.

A number of investigators were at work upon the general problem, and in May, 1886, Dr. Dupré, in discussing a paper of Dr. Tidy's, at the Society of Arts of England, proposed to cultivate bacteria on a large scale, discharging them with an effluent into a river where they might be expected to further purify sewage.

DIBDIN'S PAPER BEFORE THE INSTITUTION OF CIVIL ENGINEERS.

In January, 1887, Mr. Dibdin read a paper before the Institution of Civil Engineers, in which he discussed the propriety of using large quantities of lime.

At that time many chemists claimed that lime was especially valuable in sewage purification because it destroyed living organisms, such as bacteria which gives rise to putrefaction, the idea being that if all the organisms could be destroyed that sewage would be rendered innocuous. Mr. Dibdin took the ground that the very essence of sewage purification is not the destruction of bacterial life, but is the resolution of organic matter into other combinations. Hence, it follows that an antiseptic process is the very reverse of the object to be aimed at. That is to say, a septic process is required and hence the name septic sewage applied later on to designate this process.

EXPERIMENTS OF STATE BOARD OF HEALTH OF MASSACHUSETTS.

In November, 1887, the Massachusetts State Board of Health commenced their classical experiments on the purification of water and sewage by filtration. The first two volumes of the reports, published in 1890, laid the foundations of the modern development of bacterial sewage purification processes. The experiments were carried out with an unparalleled wealth of detail, and taken all in all, they are still unapproached by work done elsewhere. The reports have been continued from year to year down to the present time. So far as known to the writer, no criticism of the work of the State Board of Health of Massachusetts has ever been made, except that their experiments were on somewhat too limited a scale to be entirely comparable with practice, nevertheless the general deductions have been confirmed at a very large number of sewage works, both in Europe and America.

SCOTT–MONCRIEFF'S EXPERIMENTS.

An English engineer, W. D. Scott-Moncrieff, constructed experimental works for the bacterial purification of sewage in 1891. He constructed a bacterial tank, in which the old principle of upward filtration was applied, the crude sewage being admitted from below and gradually flowing upwards through a bed of stones. In this way he found that the liquefaction of solids was so effective that the sludge of ten persons was absorbed on nine square yards of land. The space beneath had a capacity of less than five cubic feet and would obviously have filled up except for the liquefying action which had taken place.

DIBDIN'S EXPERIMENTS.

In 1892, Mr. Dibdin began his experiments on filtration through coarse material, such as burnt ballast, coke breeze, gravel, etc., the object being to obtain a high degree of porosity, with power of re-absorbing atmospheric oxygen. In the first series of experiments made, wooden tanks were used with an area of 1/200 of an acre.

In the second series the filter covered an acre of land, the material consisting of three feet of pan breeze with three inches of gravel. These experiments were continued from September, 1892, to November, 1896. Space will not be taken to indicate the results any further than to say that generally the bacterial purification of sewage was considerably advanced thereby.

In the meantime, Mr. Dibdin had also conducted experiments for the Sutton Urban District Council, and in 1896, constructed a bacteria tank for that authority. This tank was fairly satisfactory, and in 1897, the District Council gave orders for a second tank for treating crude sewage. The first tank was filled with raw sewage entirely untreated, except that it had been strained through a screen to intercept the grosser particles. During seventy-six days, sewage was treated at the rate of 773,000 gallons per acre per day, rest period included. In the London experiments one million gallons of the effluent from chemical precipitation were treated on the burnt ballast bed of one acre, as against about 60,000 gallons per acre per day treated through coarse sand, as per the system of the State Board of Health of Massachusetts.

CAMERON'S SEPTIC TANK.

About 1897, Mr. Cameron designed and placed in operation at Exeter, England, a septic tank. This tank is the septic tank as we now understand it. Its features are the reception of sewage without any preliminary treatment, in a covered tank having a capacity equal to anywhere from twelve to twenty-four hours flow of sewage. The cross-sectional area of this tank is large enough to permit the sewage passing very slowly through it, thereby depositing the heavy matters, leaving only the lighter ones to pass forward with the water to the coke breeze filter beds, constructed on the same plan as in the London experiments. A comparison of the plans of Mr. Cameron's tank shows that in the essentials it is quite similar to the tank in use at Cheltenham, England, and also the experimental tank proposed by Mr. Austin in his report of 1857. To appreciate this fact one needs to have Mr. Austin's report before him, together with plans of a Cameron tank.

The septic tank has been experimented upon by the State Board of Health of Massachusetts and a large amount of valuable matter is given in the reports of 1898–1901, inclusive. These experiments, however, are on somewhat too small a scale to be decisive, although probably the main conclusions will be verified by more extended experiments. The most satisfactory experiments carried out in the United States have been made at Worcester, Massachusetts.

As to the success attained in the purification of septic sewage, the results are somewhat contradictory, although under certain conditions, the process may be a material addition to a sewage purification plant, but success can not be depended upon in every case. Apparently, a distinction must be made between fresh, stale, septic, and sewage mixed with refuse manufacturing waste, such as refuse from tanneries, slaughter-houses, acid works, cheese factories, etc. All these different forms of pollution need to be experimented upon before a final general rule can be formulated.

As regards the treatment of fresh sewage, the results indicate that an accumulation of sludge within the septic tank must be expected, amounting to a considerable percentage of that originally present in the sewage on entering the tank. Enthusiastic advocates of bacterial purification have affirmed an entire doing away with the sludge difficulty, but thus far this claim has not been verified. The sludge difficulty still remains, and when sewage works are operated on a large scale, will be the source of considerable trouble in the future, as it has been in the past.

With stale sewage, which has undergone mechanical, chemical and bacterial action while flowing through the sewers, it is possible that the action in the tank will be much more satisfactory than in the previous case. Experiments indicate that a considerable proportion of the organic matter in suspension will be removed either by liquefaction or by changing to gaseous form, and that its effluent can be easily further purified by filtration.

In the case of septic sewage, which has already been subjected to bacterial action, further bacterial processes may not only be unnecessary, but even harmful, because they render sewage difficult to purify by subsequent oxidation.

EXPERIMENTS AT WORCESTER, MASSACHUSETTS.

As to the effect on sewage containing manufacturing wastes, the report of Messrs. Kinnicutt and Eddy, The Action of the Septic Tank on Acid Iron Sewage, is perhaps the most authoritative of any experiments thus far instituted. These gentlemen state that from the slow passage of an acid iron sewage containing an amount of organic matter represented by about one part of albuminoid ammonia in one hundred thousand parts, an amount of iron in solution from five to eight parts and the free acid in terms of sulphuric acid about ten parts in one hundred thousand parts, the following results may be expected:

"(1). That about one-fourth of the total solid matter contained in the sewage will be removed.

"(2). That the effluent from the tank will contain about 20% less soluble matter than the crude sewage, owing to the soluble matter in the sewage being decomposed or changed into soluble substances.

"(3). That the amount of suspended matter removed from the sewage will not greatly exceed 30% unless special precautions are taken to retain in the tank the finely divided iron sulphide formed by the reduction of the soluble iron sulphate in the sewage.

"(4). That the amount of organic matter removed from the sewage, as determined from the albuminoid ammonia, will average from 20% to 25%.

"(5). That of the suspended organic matter, the amount removed will average a little under 50%, and that the amount of soluble organic matter removed will not average much more than 10% of the soluble organic matter in the sewage.

"(6). That of the suspended matter taken out of the sewage in its passage through the tank, from 60% to 70% will remain in the tank and have to be removed; only from 30% to 40% of the arrested suspended matter being changed by the action of the bacteria into soluble or gaseous substances.

"(7). That the amount of sludge that will have to be handled when it is necessary to clean out the tank will not, however, equal 60% to 70% of the weight of the sludge that would be formed from the removal of the same amount of suspended matter in a sedimentation tank, but will not be more than 50% of this amount, owing to the fact that the sludge in a septic tank contains less water than the sludge in a sedimentation tank.

"(8). That with an acid iron sewage containing street washings, the amount of mineral matter in the sludge will be about 50% of the total solid matter in the sludge, and of this mineral matter over one-third will be found to be iron sulphide.

"(9). That decomposition of the sludge, as shown by the evolution of gas, will take place in winter as well as in summer, if the temperature of the sewage in the tank does not fall below 45° F., but the rate of decomposition will be much slower —one-half of what it is in summer.

"(10). That the amount of gas evolved from the septic tank with a sewage similar to Worcester sewage and having about the same range in temperature as Worcester sewage, will average a little over one-half a cubic foot for every hundred gallons of sewage passed through the tank, the rate of flow of the sewage through the tank being eighteen hours. In the warmest months the amount evolved will, however, be about one cubic foot, in the coldest months about one-fourth of a cubic foot.

"(11). That the gas given off from a septic tank with acid iron sewage does not contain hydrogen or sulphide of hydrogen, but is a mixture of marsh gas, carbon dioxide and nitrogen in about the following proportions: Marsh gas, 75% ; carbon dioxide, 6% ; and nitrogen, 19%."*

METHODS OF SEWAGE DISPOSAL.

Where there are large bodies of water, either the sea, or inland lakes, or large rivers, disposal by dilution is a common method. Irrigation and intermittent filtration through sand areas are also common methods. Chemical precipitation, which has been extensively employed in England, where there are two hundred to three hundred plants in operation, is not, at the present time, considered a very satisfactory method, although the size of the stream or body of water, and whether or not it is used as the source of a public water supply, may be properly taken into account. Not only in England, but in this country there are a considerable number of cities and towns which must secure a substantially complete removal of organic

* A considerable portion of the preceding pages is taken from a discussion of Sewage Disposal in Proc. of Am. Soc. C. E., for Sept., 1903, Vol XXIX, No. 7, pp. 832-38.

matter before sewage is discharged into small streams. To remove the suspended matter and a portion of the organic matter from sewage and discharge the effluent into such, is no longer permissible—a higher degree of purification is required.

Finally, in an enumeration of methods of sewage disposal, we come to the biological methods—either the septic tank, followed by filtration through bacteria beds, or treatment on bacteria beds, alone, preceded by a removal of the coarse material, detritus, etc.

Sedimentation, mechanical separation, etc., may also be mentioned, although they can hardly be considered as systems of sewage disposal at the present time.

TEMPERATURE OF SEWAGE.

Experiments of the State Board of Health of Massachusetts, at their Lawrence Experiment Station, show that the temperature of sewage entering septic tank varies from about 39° Fahr. in January, to 74° in July. The winter temperature of the air at Lawrence is an average for

December, January and February, about 27° to 28° F., although for the winter of 1887–8, it was 22.4° F. The mean of January for this year was 15.5° F., which is stated to have been the coldest for twenty years. Table No. 70, on page 305 of Sewage Disposal in the United States, gives full information as to temperature of sewage at Lawrence. This table is included in the chapter On the Temperature of the Air and Natural Soils in Relation to Sewage Purification, etc., to which the reader is referred for an extended discussion.

Many of the micro-organisms, although not all of them, flourish within a small thermometic range—from about 50° F. to 100° F. The Massachusetts experiments showed that organic matter was stored in the filter during the winter and destroyed by nitrification as the temperature rose in the following spring.

In the septic tank there is apparently a small evolution of heat. In the Leeds results, as given by Mr. Dibdin in his evidence before the Royal Commission on

Sewage Disposal, it appears that in winter the temperature of the bacteria bed was 10° higher than that of the atmosphere. In one case, the temperature of the applied sewage was 58°, but on standing in the bed for an hour, it rose to 64°.

In the testimony of H. M. Ward before the Royal Commission on Sewage Disposal, it is stated that there are bacteria which will grow in liquids with temperatures as high as 158° F. In decomposing heaps of manure, the temperature sometimes goes higher than this—but there are certainly bacteria present even at somewhat higher temperatures than 158°.

The testimony of Dr. Rideal was to the effect that bacterial action was more rapid in summer than in winter.

The testimony of Mr. Fowler was to the effect that in the case of the open Manchester septic tanks, ice did not form on the top of the tanks, although snow gathered on the surface of the same.

The following table shows the effect of frost upon bacteria beds, as determined at Leeds, England:

TABLE NO. 1.

Effect of Frost upon Bacteria Beds, at Leeds, England. (Temp. = ° F.)

Date.	State of Weather.	Rough Bed.						Fine Bed.				
		Temperature of Sewage.	Temperature of Atmosphere.	Temperature of Bed Before Filling.	Temperature of Bed When Full.	Temperature of Filtrate.	Temperature of Bed When Empty.	Temperature of Atmosphere.	Temperature of Bed Before Filling.	Temperature of Bed When Full.	Temperature of Filtrate.	Temperature of Bed When Empty.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Fortnight ending Dec. 8, 1899	No Frost	58.9	45.5	56.3	57.2	56.7	55.9	45.5	54.8	54.8	54.6	54.5
Dec. 8-29, 1899	Frost	53.1	31.2	49.4	49.8	49.4	49.2	31.9	47.4	46.1	46.1	46.0

THE DISTINCTION BETWEEN FRESH, STALE AND SEPTIC SEWAGE.

Fresh sewage usually contains free oxygen and nitrogen in the form of nitrites, and nitrates, together with a relatively large proportion of organic matter in suspension.

Stale sewage is sewage in that state when the carbon, through bacterial agency in the presence of free oxygen, is oxidized; nitrogen and hydrogen unite to form ammonia, which uniting with the carbonic acid, forms ammonium carbonate. Under the influence of the mechanical, and bacterial forces acting upon it, the dissolved organic matter is finally exhausted, but up to this point free ammonia increases, while crude organic matter decreases. We designate as stale, sewage from which the free oxygen has just become exhausted and free ammonia increased to the possible maximum by the exhaustion of the oxygen.

After the oxygen is exhausted, the bacteria still continue active and chemical changes go on, breaking up organic matter into simpler forms. While sewage containing free oxygen has not a particularly offensive odor, after the oxygen is exhausted, sewage become very ill-smelling, because of the generation and escape of hydrogen compounds of carbon, sulphur and phosphorous. The result of these changes is to decrease the amount of carbonaceous and nitrogenous matter in the sewage. Sewage in this state is known as septic sewage.

In the 1895 report of the State Board of Health of Massachusetts, it was recognized that in stale sewage the organic matter is finely divided, and hence a much larger percentage of it will enter the pores of a filtering material, and the filter surface will not become so quickly clogged as it will when fresh sewage is applied to a filter.

THE TREATMENT OF SEPTIC SEWAGE.

The treatment of septic sewage may for present purposes be taken to mean not only the treatment necessary to produce septic sewage in the shortest possible time, but also such further treatment as may be necessary in order to purify the sewage, for it should be understood that septic sewage is only slightly purified, as may be sufficiently seen by considering the following tables. This treatment is also called the bacterial treatment or purification of sewage.

TABLE NO. 2.

Average Analyses of Sewage as it enters Septic Tank, at Lawrence Experiment Station. (Parts per 100,000).

Year.	Temp. ° F.	Ammonia.			Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter
		Free.	Albuminoid.				
			Total	In Solution			
1898	—	4.44	0.79	0.47	9.21	4.00	——
1899	58	3.49	0.89	0.26	7.10	5.75	1,922,000
1900	55	4.99	0.98	0.37	10.55	5.72	2,993.400
1901	53	5.54	0.88	0.44	10.62	5.08	3,954,000

Table No. 3.

Average Analysis of Effluent of Septic Tank, at Lawrence Experiment Station. (Parts per 100.000).

Year.	Temp. ° F.	Ammonia.			Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter
		Free.	Albuminoid.				
			Total	In Solution			
1898	57	4.86	0.41	0.32	10.11	2.29	324,500
1899	57	4.03	0.34	0.25	7.00	2.52	577,100
1900	56	4.61	0.39	0.25	9.93	2.85	1,209,500
1901	56	4.90	0.43	0.29	10.40	3.12	671,000

Examining Tables Nos. 2 and 3, it is seen that for the year 1898, there was a slight increase in the free ammonia, with slight decrease of the albuminoid ammonia. The bacteria for that year are not given in the sewage as it enters septic tank, but the effluent still contains about 325,000 bacteria per cubic centimeter. In 1899 there was a slight increase in the free ammonia and a material decrease in the albuminoid ammonia, so that the total albuminoid ammonia impurity is not specially large. The bacteria in the sewage as it entered the septic tank amounted to 1,922,000 per cubic centimeter, and in the effluent from the septic tank, to 577,100 per cubic centimeter. In 1900 there was a slight decrease in the free ammonia as the sewage flowed from the septic tank, with a material decrease in the albuminoid ammonia. Bacteria amounted to 2,993,400 per cubic centimeter as the sewage entered the tank, and to 1,209,500 per cubic centimeter in the effluent from the septic tank.

COMPOSITION OF SEWAGE IN THE UNITED STATES.

According to the State Board of Health of Massachusetts, sewage may be denominated either strong or weak, according to the amount of organic matter in a given volume of sewage. The following are the average yearly analyses of sewage experimented upon at Lawrence, Massachusetts, for the years 1898–1900, as taken from a street sewer in that city.

Table No. 4.

Yearly Average of Analyses of Sewage from a Street Sewer in Lawrence, Massachusetts. (Parts per 100.000.)

Year.	Temp. ° F.	Free Ammonia.	Albuminoid Ammonia			Chlorine.	Nitrogen as		Oxygen Consumed	Bacteria per Cubic Centermeter.
			Total.	In Solution.	In Suspension		Nitrates.	Nitrites.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10	(11)
1898	59	2.60	1.00	0.67	0.34	10.38	0.201	0.0197	7.20	2,076,000
1899	60	3.47	1.02	0.58	0.44	11.90	0.156	0.0185	9.02	2,484,000
1900	61	3.41	0.97	0.56	0.41	11.81	0.141	0.0135	9.25	2,884,000

COMPOSITION OF ENGLISH SEWAGE.

The following table, as given by Mr. Fuller, shows the composition of the sewage of a number of towns in England. The following are some of the main facts in regard to the sewerage of these towns:

Huddersfield.—The average analysis of sewage in this manufacturing city with a population of 100,000, is based upon the mean result of hourly samples collected for twenty-four consecutive hours on five different occasions, averaged with the mean analysis of the sewage from August, 1898, to February, 1900. The sewers are on the combined plan, with 29% of the dry weather flow made up of trade refuse.

Leeds.—This analysis represents sewage from a manufacturing city with a population of 430,000, covering the period from November, 1898, to June, 1900. The sewers are on the combined plan and contain much trade waste—especially iron liquor.

Leicester.—The average analysis from this city of 220,000 population, represents the results from mixed half-hourly samples taken one day a week for a period of one year—from September, 1898, to September, 1899. The sewers are on the combined plan, receiving waste from dye works and wool-scouring establishments.

London Northern Outfall.—This average analysis refers to a population of about 3,250,000 and is estimated from records obtained at different periods during the past twenty years. Ground water and manufacturing waste do not seem to have been a very important factor. The sewers are on the combined plan.

London Southern Outfall.—This average result is based upon the data for the years 1893–4. These analyses represent a somewhat different sewage than that of the Northern Outfall, due in part to manufacturing refuse, but more particularly to ground water entering the sewer. The sewers are on the combined plan and receive the sewage of 1,675,000 people.

Manchester.—The average analysis of sewage from this manufacturing city with a population of 562,000, is based on hourly samples which were mixed in equal proportion from Monday noon until Friday noon, to give four representative daily samples per week. The data cover the period from May, 1900, to January, 1901. The sewers are on the combined plan, with much trade refuse.

TABLE NO. 5.

Average Analyses of Sewage from English Cities, with Estimated Corresponding Volume per Capita Daily. (Parts per 1,000,000).

City.	Average Daily Flow of Sewage per Capita: U. S. Gallons	Imp. Gallons.	Liters.	Oxygen Consumed: 4 Hours at 80° F.	5 Minutes at 212° F.	Nitrogen as: Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Dissolved Matters: Total.	Mineral.	Organic and Volatile.	Suspended Matters: Total.	Mineral.	Organic and Volatile.	Solids: Total.	Mineral.	Organic and Volatile.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Huddersfield..	108.0	90.0	410.0	99.0	165.0	10.7	6.05	123	715.0	597.0	118.0	346.0	164.0	182.0	1061.0	761.0	300.0
Leeds.........	60.0	50.0	225.0	126.0	210.0	23.6	11.3	—	1070.0	—	—	610.0	240.0	370.0	1680.0	—	—
Leicester......	60.0	50.0	225.0	107.0	180.0	—	14.2	—	1045.0	—	—	635.0	—	—	1680.0	—	—
London North	48.0	40.0	180.0	80.0	133.0	39.0	4.3	132	870.0	565.0	305.0	483.0	228.0	225.0	1353.0	793.0	560.0
London South	60.0	50.0	225.0	67.0	112.0	34.5	4.3	267	1093.0	755.0	338.0	408.0	183.0	225.0	1501.0	938.0	563.0
Manchester...	72.0	60.0	275.0	118.0	197.0	24.0	6.0	170	940.0	470.0	470.0	370.0	200.0	170.0	1310.0	670.0	640.0

QUANTITY OF SEWAGE TO BE PROVIDED FOR.

It is quite common in the United States to provide for one hundred gallons of sewage per capita per day, although the size of the town may be properly taken into account. Broadly, the use of water is greater in large towns than in small, and in some cases, at any rate, seventy or eighty gallons per capita per day will be sufficient. The following three cases may be taken to show the probable quantity at typical public institutions.

(1). At the State Insane Hospital, at Weston, West Virginia, as the result of several days gaging, made in January, 1891, the mean total flow for twenty-four hours was found to be 101,047 gallons. The tributary population at the hospital, including officers, patients, attendants and nurses, was 1,000. In addition to sewage proper, the sewer received some roof water, but at the time of making the gagings there was neither rainfall nor melting snow to contribute from this source. The sewer, however, received the water of condensation from the steam heating apparatus at the hospital, amounting, in the month of January, to about 10,000 gallons per day. Aside from this addition, the results may be taken as representing the normal sewage at the institution. There was little or no leakage from water fixtures. The maximum, amounting to 6,696 gallons per hour, occurred between 9 and 10 A. M., while the minimum of 2,079 gallons per hour occurred between 1 and 2 A. M. Deducting the estimated water of condensation at 10,000 gallons per day, there remains about 91,000 gallons per day of sewage, proper, which for a tributary population of 1,000 amounts to 91 gallons per capita per day.

(2). The main sewer at Long Island State Hospital, at Kings Park, N. Y., was gaged December 10–14 inclusive, 1900, with the result of showing an average flow for twenty-four hours of 338,779 gallons. The total population of the hospital was 3,250, giving an average of 104 gallons per capita per day. This, however, did not in clude the laundry sewer, which was gaged separately, and which gave an average of 92,143 gallons per day, or 28 gallons per capita per day.

(3). The sewers of old colony, Manhattan State Hospital, at Central Islip, N. Y., were gaged December 21–25, inclusive, 1900. The gagings gave a mean flow of 88,193 gallons in twenty-four hours. The tributary population was 1,400, equivalent to 63 gallons per capita per day. The gagings here included flow of laundry sewer, and, therefore, represent the total flow from the hospital.

Taking an average of the mean flows at these three hospitals, it is found to be 95 gallons per capita per day. At Kings Park, however, the use of the water was very lavish, as was it also at the West Virginia Hospital, and indeed, in insane hospitals generally, the sewage flow may be expected to be larger than in other hospitals, insane patients taking every opportunity to allow water to run, by blocking open water closets, fixtures, etc. It is not doubted, therefore, that at Kings

Park, by systematic attention, the use of water could be easily reduced to 80 gallons per capita per day, and the same is also true of the West Virginia Hospital. At Manhattan State Hospital it is already as low as can reasonably be expected. It may be again pointed out that at Kings Park the laundry sewage amounted to 28 gallons per capita per day.

In the case of all these gagings perfectly tight sharp-crested weirs were used, and there is no reason for supposing that the results are not accurate. In every case the sewage was found to fluctuate between a maximum and minimum quite similar to that given in detail for the West Virginia Hospital.

As regards towns, probably for those of only a few thousand inhabitants, 70 to 80 gallons per capita per day is sufficient, while for larger towns, the use of water is somewhat more lavish. In any case, there is no doubt but that it is much greater than necessary.

CHARACTERISTICS OF SEPTIC SEWAGE.

When sewage is drawn from a septic tank it is generally of an exceedingly offensive odor, darker colored than when entering, though usually clearer than sewage before treatment. It contains a smaller amount of nitrogenous organic matter in solution. When sewage enters a septic tank we may consider 40% of the total nitrogenous matter as in suspension, while in the effluent from such a tank there is not much more than 20%. Another advantage is that the suspended matter in the effluent from such a tank is much more finely divided than in fresh sewage. Usually, free ammonia is increased somewhat, while the albuminoid ammonia is decreased, as has already been pointed out in discussing Tables Nos. 2 and 3. Nitrification does not take place in the septic tank, because its activity depends upon another class of bacteria.

The action of the septic tank is to break up complex organic compounds into simpler substances, preparing the sewage for more easy purification by some form of filtration. It is, in effect, a way of aiding the bacteria in either intermittent filtration, double contact beds, or by filtration through percolating filters.

The following, from Kinnicutt and Eddy's Worcester report, gives the more essential points of septic action:

"The breaking down of the complex organic substances is due, directly or indirectly, to the action of anærobic bacteria, and as the result of this action a certain amount of the suspended matter in the sewage is brought into solution and a part of the organic matter changed into water, ammonia, carbon dioxide, nitrogen, marsh gas and hydrogen.

"In the passage of the sewage through a septic tank a large amount of suspended matter settles down to the bottom of the tank and is there acted upon by bacteria and so changed that a part of it is rendered soluble and is carried off in the effluent, while a portion is broken up into gases which escape from the tank.

"The action of the septic tank is therefore twofold, preparing the sewage so that it is more easily acted upon by the ærobic or nitrifying bacteria, and removing, in the form of gas, a certain amount of the organic matter that the crude sewage contains. The changes that take place in the septic tank and the amount of organic matter that has been removed from the sewage, have usually been determined by examination of the crude sewage and effluent; and comparatively little attention has been given to the study of the deposit formed in the tank or to the gases given off by the decomposition of the organic matter.

"The study of the gas evolved and of the deposit formed are, however, of very decided importance, for the only way organic matter, can be removed from the sewage is by precipitation or by being changed into gas; and the determination of the amount and of the composition of the gas formed, give a much better idea of the energy of the bacterial action than can be obtained by the examination of the sewage and the effluent. The effluent from a septic tank is usually considered as the sewage from which a certain amount of organic matter has been removed, while, in fact it is the sewage minus this quantity, but with the addition of liquid compounds derived from the decomposition of the sludge at the bottom of the tank, and of suspended matter thrown up to the surface of the liquid by violent evolutions of gas. It is on this account that the examination of the sewage and effluent do not give the amount of bacterial action that is taking place at any time given within the tank, or the true amount of purification of the sewage that is entering the tank during that period."

ÆROBIC, ANÆROBIC AND FACULTATIVE BACTERIA.

Two general classes of bacteria are recognized—the anærobic, or those acting without the presence of oxygen, and the ærobic, or those requiring oxygen for efficient action. The facultative bacteria are those which may exist either with or without the presence of air. In the septic tank the work is performed by anærobic bacteria, and at the conclusion of septic action the surviving bacteria are largely facultative. A considerable proportion of the bacteria in the effluent are liquefying bacteria.

Experiment shows that ærobic bacteria flourish in the presence of manganese and soda compounds, especially the manganate and nitrate of soda, but anærobic fermentation is prevented when these compounds are present. Aerobic fermentation will not take place in a strong acid sewage. Lime and soap are also detrimental when present in sewage in considerable quantities. In his testimony before the Royal Commission on Sewage Disposal, Mr. Dibdin expressed the opinion that the anærobic bacteria are mischievous—that better results will be obtained by confining sewage purification to the ærobic forms.

BOTH ÆROBIC AND ANÆROBIC BACTERIA EFFICIENT IN THE PURIFICATION OF SEWAGE.

As stated in the foregoing, either ærobic or anærobic bacteria may be utilized for sewage purification, although the method is very different. In order to utilize anærobic bacteria, sewage is confined in a closed tank, while in the utilization of ærobic bacteria, the opposite takes place—that is, sewage is spread over coarse filters of clinker or broken stone, coarse enough to bring every portion of it in contact with the air.

In English works on sewage purification, treatment by anærobic bacteria is called the septic tank system, while a general name for treatment by ærobic bacteria without the use of a septic tank is sometimes denominated the Sutton system or process, due to the fact that works utilizing this method were first constructed at Sutton, England. Moreover, the two processes are usually combined, the liquefaction of the sludge taking place in a septic tank, followed by further treatment through bacteria beds.

LOCATION OF BACTERIA IN THE SEPTIC TANK.

As just seen, according to the theory of the septic tank, the bacteria living in it are those which thrive without the presence of air, or anærobic, and hence cause putrefaction instead of nitrification. Experiments have been made showing that the bacteria in the tank live on the sides, bottom and top of the tank, where organic matter accumulates and where they are found in enormous numbers compared with the numbers found in the liquid passing through the tank. In Scott-Moncrieff's tank, sewage is passed upward through a tank filled with broken stone, the supposition being that this broken stone will afford an extensive foothold and breeding place for the necessary bacteria. The sewage enters at the bottom of the tank, where the sludge accumulates, if it accumulates at all. In such a tank an upward filtration is carried on; the sewage passing upward meets and is acted upon by the bacteria living upon the surfaces of the broken stone.

AS TO THE DIMENSIONS OF A SEPTIC TANK.

So far as there is any definite experience in the matter, a septic tank should have about the following dimensions: From 5 to 10 feet in depth—it ought not to be less than about 5 feet and probably not to exceed 10 feet, although on this latter point the writer does not know of any satisfactory experiments. The width may be two to five times the depth, and the length such that the required quantity will just pass through in a predetermined time. For instance, with 100,000 gallons of sewage per day the tank may be 10 feet deep by 30 to 50 feet wide, two changes per day being assumed. For one change per day the tank should be of double the preceding size. The proper test of dimensions of a septic tank is, however, the relation of velocity of flow through the tank, as discussed in the chapter on Velocity of Flow, etc.

PREPARATION FOR VARIATION IN THE QUANTITY OF SEWAGE.

It will be evident without special discussion, that the flow of sewage through such a tank should be tolerably uniform, varying not very greatly from day to day. Where there are large variations a special arrangement of the tank should be made to take care of such. These arrangements may include (1), either automatic gates which may be lowered, thus reducing the depth and cubic content of the tank; or (2), arrangements by which only part of the tank is used; or both. Where there are great variations the tank may be made in two parts, so arranged that one part may be thrown out of service when the flow is greatly reduced.

LENGTH OF TIME REQUIRED FOR EFFICIENT SEPTIC ACTION.

The experiments of the State Board of Health of Massachusetts indicate that a septic tank should not be filled more than once in twenty-four hours, although some of the experiments made by this Board indicate that for a maximum flow of gas, at least thirty-six hours would be required. Unfortunately, with long flows, the tank capacity becomes so large as to make the septic system an exceedingly expensive method of purification, and accordingly the tendency has been to cut down the tank until a number of tanks have been installed of so small a size in relation to the total quantity of sewage to be passed per day that the sewage is not retained therein more than five or six hours. It is doubtful if under these circumstances the purification attained is very valuable, as the bacteria require some time in which to perform their work. For the present, the writer is disposed to say that the capacity of the tank should be such as to permit of not more than one change in twenty-four hours—that is to say, if the daily sewage flow of a town is 300,000 gallons, then the septic tank must have a capacity of 300,000 gallons.

Many of the experiments made in England indicate from eighteen to twenty-four hours as the proper time for an efficient septic action.

A septic tank also requires from two to four months time before it is in proper action. Hence, sludge should be removed without materially interfering with the liquid portion. The inoculation of a new tank with crust from a mature one will materially assist the second tank to efficient action.

SEPTIC TANK AT EXETER, ENGLAND.

In 1895, Donald Cameron, City Surveyor of Exeter, constructed a sewage purification plant, in which the solid matters of the sewage were destroyed by the action of anærobic bacteria, followed by final purification through the action of ærobic bacteria in clinker filters.

The installation at Exeter consists of a grit chamber, a septic tank and five filter beds, four of which are working constantly, with one held in reserve. The septic tank has a capacity of about 54,000 Imperial gallons, which represents from eighteen to twenty hours flow of the sewage. The grit chamber is formed by building a wall across the tank and is divided into two portions by a wall along the middle line. In these chambers, the grit and road detritus are deposited, the sewage passing into the tank proper containing only traces of suspended mineral matter. The tank proper has a total length of about 58 feet, in which the sewage remains from eighteen to twenty-four hours, according to the volume supplied by the sewer. The tank is constructed of bricks laid in cement and covered with an arch of similar material.

The effluent flows from the tank by means of a pipe, the inlet of which is below the water level in the tank. It then enters a horizontal trough, closed at both ends, so that the water escapes over the sides in a very thin layer, upon the ærobic beds. Four of these beds are filled with furnace clinker and one with coke breeze. They each have an area of 80 square yards and are 5 feet deep. By means of an automatic apparatus the filling, standing full, emptying, and resting empty for æration are regulated. One filter is filled at a time. It stands full while the next is filling, after which it is discharged and remains empty while the third and fourth are filling.

CHARARCTER OF THE EFFLUENT FROM SEPTIC TANK AND BACTERIA BEDS.

The effluent produced by the septic tank followed by filtration through double contact beds, is comparatively clear and colorless and fairly inodorous, provided the septic tank and beds are properly constructed. It does not putrefy on standing and contains appreciable quantities of nitrates. It can be discharged into a stream, containing nothing injurious to fish life. Nevertheless, it is not fit for drinking water, but should it be necessary to discharge it into a stream which is the source of a water supply for a municipality, it may be further purified by passing through additional bactaria beds, in which way it is possible to absolutely purify the water, although it can not be concealed that the double, or in some cases triple filtration necessary to produce this result will be very expensive.

THE NATURE OF THE PROCESS IN THE SEPTIC TANK.

The process taking place in a septic tank is both mechanical and biological. Experiment shows that sedimentation is effected, provided the rate of flow of sewage does not exceed 3 feet per minute. The flow in a septic tank is very much less than this—usually not more than a few feet per hour. Hence, it follows that the suspended solids will be mostly precipitated before traveling very far from the inlet end of the tank. As these solids fall to the floor of the tank they become subject to the action of bacteria, which in time render them soluble. As bacterial action proceeds the settled particles become buoyant, owing to the entangling of gases generated during the process, and rising to the top of the tank, form a thick leathery scum. This scum is in a high state of bacterial activity—liquefaction progressing freely. The matter which finally falls back to the bottom is a black, inoffensive mass of small bulk as compared with the original suspended solids from which it was derived.

This leathery scum forms easily and makes an almost impermeable covering, beneath and on the under side of which, the micro-organisms thrive under anærobic conditions even when the tank is not roofed.

PERMANENCY OF BACTERIAL OR CONTACT FILTERS.

Bacterial or contact filters are constructed of coarse material and the entire depth is brought into contact with the sewage applied each day. The name, bacterial filter, is misleading as an intermittent sand filter is as truly a bacterial filter as filters of coarse material—the only difference is that material is fine in one case and coarse in the other. Contact filter is considered a more suitable term. The material of these filters may be either coal, coke, broken stone or cinders—although broken stone and coke are considered to be the best.

The question of the permanency of these filters is one of importance from whatever point of view it may be looked at. As to whether the open spaces—the interstices—will become filled with mineral and organic matter so that the filtering material will require removal and washing, if the filter is to be continued in operation, is a question of practical moment. The following examples from the Report of the State Board of Health of Massachusetts, at their Lawrance Experiment Station, are pertinent.

The contact filter, containing 4½ feet in depth of ashes and cinder, first in use in November, 1896, had become so badly clogged by December, 1898, that it was thrown out of service.

Another contact filter was placed in operation in September, 1897, and contained five feet in depth of cinder freed from fine material. This filter was in good working condition in January, 1900, operating at the rate of approximately 560,000 gallons per acre per day, and producing as satisfactory an effluent as can be expected from a contact filter. At the end of two years the interstices of this filter had decreased 12%, or from 55% to 43%, but since that time there has been little or no decrease.

Another contact filter has been in operation for over two years at the average rate of 666,000 gallons per acre per day. This filter has operated quite similarly to that previously described. It is filled with coke, but there is no tendency to disintegration observable in the coke in this filter. Quite similar results have been obtained with two other filters.

In the 1901 Report, it is stated that one of the foregoing filters at the end of four years has lost 35% of its open spaces, on which account the rate was reduced to 520,000 gallons per day. Up to October, 1901, this filter had been filled but once daily, but upon November 15, the filter was filled in three applications, allowed to stand full one hour and then drained, five hours being allowed for draining, after which it was filled and drained again, thus increasing the rate to 1,000,000 gallons per acre per day. The average rate of filtration of this filter for the year 1901 was 577,900 gallons per acre per day, but in the month of April of that year, the rate was only 290,000 gallons per acre per day.

Judging from the operation of the foregoing contact filters, so far as one can learn from the time they have been in operation, there first takes place a rapid decrease of 12% to 15%, which is due to the settling and breaking down of the material of the beds, after which the decrease is slower, but so far as can be seen, after five or six years, these filters will require the removal of the filtering material and rewashing. When they are again put in operation there will be required a little time to bring them into proper bacterial condition. But if such filters are rested for sufficient periods and efficient means for removing the mineral matter taken, they may be continued in service for eight or ten years.

Probably, the chief question is as to the loss of capacity of a contact bed through the growth of organisms and the deposit of the ashes of organic substances. It has been shown that if material of a contact bed be examined when in active condition, every piece is found covered with a slimy growth. Under the microscope, this slime is found to be composed of bacteria and zoöglea. The action of the bed depends upon the quality and amount of this material—the greater the amount, the greater the efficiency—but if the limit is passed, the liquid capacity is diminished and the water will not drain away. As to whether the growth of organisms can be so regulated that the bed can do its proper work, and at the same time not lose its capacity for liquid, is not yet settled.

QUANTITY OF SEWAGE WHICH CAN BE TREATED BY BACTERIA BEDS.

No universal rule can be laid down as to the quantity of sewage which can be treated in bacteria beds. The English Local Government Board insist that a bed should be used but once daily, and fixes the water capacity at one-quarter of the gross content. Probably, the object in demanding this capacity is to enable a portion of the storm water to be dealt with the same as ordinary sewage. It is claimed that bacteria beds may be filled twice daily and that in some cases, at any rate, they work better than if filled but once. There is, however, a disadvantage in too frequent working, because the water capacity becomes diminished, with the result that less and less sewage can be treated each time.

Taking 25% water capacity and depth of bed of 4 feet, and emptying twice a day, 800,000 U.S. gallons of sewage per acre can be treated per day. Or, with one filling, one-half this quantity can be treated. With greater depth an additional quantity can be treated, but there is a limit to the depth of the bed—probably, it ought not to exceed 7 to 8 feet. With percolating filters, quantities as high as 2,000,000 gallons per acre per day are claimed, and in some cases, experiments in England indicate as high a rate as 4,000,000 to 5,000,000 Imperial gallons per day, but whether this rate can be maintained for any length of time, is not yet setlted. For present purposes we may say that 300,000 to 500,-'000 gallons per acre per day may be treated on primary beds, 4 feet deep, and from 800,000 to 1,000,000 gallons per acre per day on secondary beds, 3 feet deep, and 2,000,000 gallons on percolating filters. These figures are, however, very general, and for a broader view the reader is referred to various extensive publications treating this division of the subject.

THE NUMBER OF BACTERIA IN CRUDE SEWAGE.

Crude sewage contains at least one million bacteria per cubic centimeter, and frequently more than ten million. A very large proportion are capable of growing at blood heat. The following are some of the common forms:

Bacillus coli communis.—This form is apt to be present to the extent of at least 100,000 per cubic centimeter. It is an intestinal bacterium, which may possibly be pathogenic. Its presence must be regarded as of importance, because (1), it serves as an index of the possible presence of other and more objectionable forms; (2), certain strains are distinctly pathogenic in the case of the lower animals; and (3), there is ground for believing that *Bacillus coli* may play a role in the causation of human disease.

Bacillus enteritidis sporogenes.—The number of spores of this form in crude sewage may amount to 100 per cubic centimeter. This bacterium is extremely virulent to guinea pigs, and there is evidence that it has been related to epidemics of acute diarrhœa in the human subject.

Streptococci.—The number of *Streptococci* in crude sewage may be taken at 1,000 per cubic centimeter. These are delicate micro-organisms, readily losing their vitality and dying. They are present in the intestinal discharge of animals, but are seemingly absent from large amounts of pure water and from virgin soils, but can be readily demonstrated in soils and waters recently polluted with excremental matters.

There are numerous other forms present in sewage, but the preceding are for present purposes the more important.

The inoculation of animals with even as small a quantity as 1/1000 of a cubic centimeter of crude sewage frequently results in death.

THE NUMBER OF BACTERIA IN SEWAGE EFFLUENTS.

The effluents from septic tanks, contact beds, percolating filters, etc., contain an enormous number of bacteria. From 200,000 to 400,000 per cubic centimeter is not uncommon. Frequently, the bacteria are practically as numerous as in the raw sewage.

The different kinds of bacteria and their relative abundance, appear to be very much the same in effluents as in crude sewage. As regards undesirable bacteria, the effluents frequently contain nearly as many

Bacillus coli, *Bacillus enteritidis sporogenes* and *Streptococci* as crude sewage. No definite proof has been furnished that the effluents from bacteria beds are more safe in their possible relation to disease than is crude sewage. Indeed, the available evidence tends to show that they must be regarded as nearly, if not quite, as dangerous to health as raw sewage. Moreover, the inoculation of animals with effluents from bacteria beds goes to show that they are nearly as pathogenic as crude sewage.

It is possible, when the land is of the proper quality, with land treatment, to secure remarkably good bacteriological results. In intermittent filtration through coarse sand it is not specially difficult to secure a reduction of the original bacteria in the crude sewage of over 99%. Broadly, the treatment of sewage on land must be considered more satisfactory, from a bacteriological point of view, than its treatment by the septic tank, followed by filtration through bacterial or contact beds.

The effluents from chemical processes are not sufficiently purified to permit of their discharge into a water supply with out further treatment.

AS TO THE PURIFICATION OF CONCENTRATED SEWAGE.

The State Board of Health of Massachusetts placed in operation in September, 1899, a septic tank to receive the sludge from settled sewage, the idea being that in places where the volume of sewage was large and the expense of septic tanks for treatment of the entire volume prohibitive, the sludge collected at the bottom of ordinary settling tanks could be flushed into a small septic tank and there partially destroyed by anærobic bacteria. During the winter of 1899–00, there was a constant accumulation of sediment in the tank, until in the middle of May, 1900, over 60% of the tank was filled with a dense sludge. Sewage of the character of that in Table No. 6 was continued to be applied, but the accumulated organic matter decreased, until on January 1, 1901, the sediment occupied only 8% of the tank capacity. We may assume that the right conditions for the desired bacterial action did not occur until the summer of 1900, as there was no further accumulation during the winter of 1901. The following tables show the average yearly composition of this concentrated sewage as it enters the septic tank and of the effluent from such tank:

TABLE NO. 6.

Average Yearly Composition of Concentrated Sewage as it enters Septic Tank. (Parts per 100,000).

Year.	Temp. ° F.	Free Ammonia.	Albuminoid Ammonia. Total.	In Solution	In Suspension.	Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1900	57	4.43	2.52	0.29	2.23	10.41	13.02	8,104,000
1901	55	4.84	4.04	0.33	3.71	11.08	18.11	8,667,000

TABLE No. 7.

Average Yearly Composition of th Effluent from Septic Tank receiving Concentrated Sewage. (Parts per 100,000).

Year.	Temp. ° F.	Free Ammonia.	Albuminoid Ammonia. Total.	Albuminoid Ammonia. In Solution.	Albuminoid Ammonia. In Suspension.	Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1900	55	5.90	0.55	0.27	0.28	9.72	3.85	1,182,400
1901	54	9.74	1.10	0.31	0.79	11.52	6.75	720,600

This brings us to the consideration of what seems to be an important point in the septic tank—that the more concentrated the sewage is, the more satisfactory will be the resolution into simpler forms.

TRANSFORMATION OF CELLULOSE, ETC.

One of the most useful functions of the septic tank is hydrolosis and the transformation into gases of the cellulose in sewage, such as paper, rags and other refuse matter, vegetable matter, etc. On October 4, 1900, a considerable quantity of newspaper, cotton and woolen cloth was placed in the septic tank of the State Board of Health at Lawrence, Massachusetts. This material was contained in wire baskets. On December 31, the cloth and paper were still intact, but so rotton they fell to pieces when touched. The same substances, upon the surface of a filter would have remained, without much change, for a longer period. It is stated that the action of the tank is such as to destroy, in a few months, either rubber or leather boots, but so far as can be learned, there are no adequate experiments verifying this statement.

COMPOSITION OF SEPTIC TANK SLUDGE.

The composition of sludge will depend upon the composition of the sewage, as to whether storm water enters the sewers and how thoroughly the sewage is screened before entering tank, etc. The following analyses of the sludge from the septic tank at Worcester give an idea of its composition:

TABLE No. 8.

Composition of the Sludge at Worcester.

Date.	Specific Gravity.	Per Cent.	
		Solids.	Water.
January 4, 1901...	1,039	8.73	91.27
May 7, 1901.....	1,041	9.70	90.30
October 22, 1901..	1,043	9.93	90.07

Rather singularly, chemical analyses of the sludge forming in septic tanks, etc., do not seem to have been made by the English investigators.

COMPOSITION OF SEPTIC TANK CRUST.

The following tabulation is an analysis of a sample of the crust, taken from the closed septic tank at Worcester, in February, 1901

	Per Cent.
Silica, SiO_2..........................	12.62
Iron sulphide, FeS...............	8.93
Iron, Fe (not united to sulphur)	1.61
Sulphur, S, not as sulphide....	0.00

	Per Cent.
Alumina, Al_2O_3	12.62
Lime, CaO	4.23
Carbon, C	41.83
Hydrogen, H	6.51
Nitrogen, N	5.20

Formerly, it was believed that the crust was a necessary part of septic action, but this view has been recently modified. In many cases no permanent crust is formed, but only a light scum over parts of the tank, from whence it is inferred that a crust is not a necessity, but merely an incident in the liquefaction of the solids taking place in the tank. The open septic tank at Worcester is at times completely covered with a crust, while at other times only a small proportion is covered. The formation, non-formation and disappearance of the crust are phenomena for which there is as yet no adequate explanation.

ACTION OF THE SEPTIC TANK ON ACID IRON SEWERAGE.

The foregoing results at Worcester, Massachusetts, have been obtained by experimenting on tne ordinary acid iron sewerage of that city, as it reaches the sewage purification works. These experiments were begun in the autumn of 1900, and have since continued. The septic tank used was a discarded iron pressure tank, 14 feet long and 5 feet in diameter. The inlet tube was 2½ inches in diameter and bent at a right-angle after it entered the tank and extended down about one foot below the level of the sewage. The outlet tube of the same diameter, at the opposite end of the tank, also extended one foot below the level of the sewage. The sewage was four feet deep in the tank, there being an air space at the top of one foot. These experiments show, as has already been pointed out in an earlier chapter, that the purification effected by a septic tank in the case of an acid iron sewage is not very great.

PURIFICATION EFFECTED BY SEPTIC ACTION.

In order to show the purification which may be effected by a septic tank under varying circumstances, the following tabulation is given, showing the results obtained at Worcester, Massachusetts, compared with those obtained at Exeter, Manchester and Leeds, England.

PER CENT. REMOVED.

	Total.	Soluble.	Suspended.
Worcester	22.25	20.67	25.57
Exeter	23.81	—2.576	56.01
Manchester	27.22	15.45	57.06
Leeds	34.61	12.05	70.37

The following table shows the average results at Worcester, Massachusetts, from October, 1900, to December, 1901, inclusive:

TABLE No. 9.

Average Purification at Worcester.

(Parts per 100,000)

Temperature ° F.		Gas	Total Solids.			Solids in Solution.			Solids in Suspension.		
Sewage.	Effluent.	Cubic ft. per day.	Sewage.	Effluent.	Per cent. removed	Sewage.	Effluent.	Per cent removed.	Sewage.	Effluent.	Per cent. removed.
58.57	58.41	7.28	74.6	58.0	22.25	50.54	40.09	20.67	24.06	17.90	25.57

THE AMOUNT OF SLUDGE CONVERTED INTO SOLUBLE OR GASEOUS SUBSTANCES.

The amount of sludge converted into soluble or gaseous substances, varies greatly at different places. Thus, at Exeter and at Leeds, as given by Dibdin and Harrison, about 70% was converted, while at Manchester, Fowler reports 40%. At Pawtucket, R. I., 47% was converted, but at Worcester, Massachusetts, according to Messrs. Kinnicutt and Eddy, only 28% was converted.

At the Manhattan State Hospital, at Central Islip, N. Y., there is a septic tank receiving the entire day's flow of sewage which has been in use fourteen years. Sludge is removed twice a year. During a visit to the hospital in July, 1901, the writer saw the sludge removed from this tank, which receives on an average over 88,000 U. S. gallons of sewage per day. This is equal to the sewage of 1400 population at 63 gallons per capita per day. There was a scum eight to ten inches thick on top and the total sludge amounted to about two cubic yards, or to four cubic yards per year. The sewage of the hospital is purely domestic.

At Manchester, England, from one-half to two-thirds of the sludge is removed by the action of the septic tank. Even at this reduction, there still remains 60,000 to 80,000 tons of sludge to be cared for per year.

Hence, from the foregoing, it seems clear that with an acid iron sewage like that at Worcester, Massachusetts, a more frequent clearing out of the sludge from a septic tank will be required than with ordinary domestic sewage.

VARIATION OF RATE OF FLOW IN COMPARISON WITH THE VARIATION IN AMOUNT OF THE DIFFERENT CONSTITUENTS.

In his paper, the Composition of Sewage in Relation to Problems of Disposal, Mr. Fuller calls attention to the wide variation, both in the quality and in quantity at different hours of the day. In order to fully illustrate its significance, the following table is given, as taken from Mr.

Fuller's paper. This table shows the percentages which the volume of flow and the amount of the principal constituents of sewage at different hours of the day are of the average quantities.

TABLE NO. 10.

Comparison of the Percentages which the Flow of Sewage and the Amount of its Different Constituents at Different Hours are of the Averages for the day.

Hour.	Rate of Flow.	Residue on Evaporation			Nitrogen as		Oxygen Consumed.	Chlorine.
		Total.	Dissolved.	Suspended.	Free Ammonia.	Albuminoid Ammonia.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9-10 A. M.	124	143	126	180	150	180	158	99
11-12 "	116	160	159	162	157	155	167	114
1-2 P. M.	123	129	131	125	107	107	110	127
3-4 "	116	142	114	204	113	141	141	120
5-6 "	107	123	137	93	116	99	92	217
7-8 "	103	97	105	79	141	117	110	116
9-10 "	92	67	76	49	84	66	85	75
11-12 "	85	84	76	101	98	87	99	77
1-2 A. M.	74	35	43	16	35	31	22	53
3-4 "	70	28	39	6	8	15	16	38
5-6 "	77	32	44	8	16	14	19	38
7-8 "	114	69	74	59	101	87	82	61

ACCUMULATION OF SLUDGE IN A SEPTIC TANK.

The septic tank at present in use at the Lawrence Experiment Station of the State Board of Board of Health of Massachusetts consists of an air tight wooden box divided by two partitions into three equal compartments. Floating partitions prevent passage from one compartment to another of the scum on the surface of the sewage. The following table shows the percentage of the total capacity of this tank, filled with sediment, at different dates:

TABLE No. 11.

Percentage of Capacity of Septic Tank Filled with Sediment.

1900	January 1 per cent.	May 24 per cent.	October 4 per cent.	December 31 per cent.
Inlet compartment	22	22	19	33
Middle compartment	—	33	14	22
Outlet compartment	11	11	10	11

From January 1 to April 12, the sewage averaged seventeen hours in passing through this tank. From April 16 to April 30, it was twenty-one hours. From May 1 to December 31, it was sixteen hours. At the end of the year there was one-half inch of floating matter on the top of the sewage in the inlet compartment but not enough to be measured in the other compartments of the tank.

The following data from Worcester, Massachusetts, show the accumulation of sludge in the tank from July 9, 1900, the time it was first placed in operation, to October 16, 1902.

On October 29, 1901, the depth was 16¼ inches, equalling 16.14 cubic feet. The density was 1.043 and the amount of water it contained equalled 90.03%.

On October 16, 1902, the depth of sludge was 23 inches, equalling 96.99 cubic feet. The density was 1.047 and the amount of water it contained equalled 88.57%.

UNIFORM FLOW IN SEPTIC TANK.

The arrangements of a septic tank should be such as to insure uniformity of flow throughout its whole extent. If the arrangements are not properly made, sewage is likely to flow through the tank in a comparatively narrow stream and with greater velocity than if the flow were uniform throughout the cross-section.

In order to insure uniformity of flow, the pipes leading into the tank may be made to dip below the surface and metallic distributers placed across the tank every ten or fifteen feet. The first scum board should project a few inches above the highest line of flow, but with a space of at least two and one-half feet between its lower edge and the bottom of the tank, while the second scum board should be set with its upper edge a foot and a half below the surface and with its lower edge fifteen or eighteen inches above the bottom of the tank. At the far end of the tank, sewage should flow out in a shallow stream over some kind of a weir.

GAS EVOLVED FROM A SEPTIC TANK.

During the year 1900, the quantity of gas passing away from the septic tank at Lawrence, Massachusetts, was measured, with the following results:

TABLE NO. 12.

Quantity of Gas from a Septic Tank.

1900	Temperature ° F. Air.	Temperature ° F. Sewage.	Gallons of Gas per each 100 Gallons of Sewage Passing through Tank.
10 measurements, between April 21 and May 1, inclusive	54	51	4.6
14 measurements, between May 2 and May 22, inclusive	55	52	6.3
22 measurements, between July 10 and July 20, inclusive	80	74	8.4
Measurements During Month of October	65	65	4.5

The foregoing figures apply to the conditions at the Lawrence Experiment Station. Measurements made during the night, when the flow of sewage was less under control, and a smaller volume passing per hour than in the daytime, showed that a volume of gas equal to 13 gallons for each 100 gallons of sewage, was evolved. As an average for sewage of the composition of that at Lawrence, we may say that probably four to five gallons of gas per 100 gallons of sewage, may be expected. This gas represents in effect the purification effected by a septic tank, although it is proper to point out that the action is quite pronounced in the direction of causing the sewage to be more amenable to treatment by either intermittent filtration, bacterial filters, or on what are now called contact beds. It is also marked in the reduction of the sludge although the amount of reduction varies greatly with different sewages. In some cases, the sludge is entirely removed, as for instance at Lawrence, where for four years no sludge has been taken from the septic tank. On the other hand, with different qualities of sewage, large quantities are removed. As a general average, it may perhaps be safe to say that 50% of the total sludge in the sewage will be taken care of by a septic tank, though it should be understood that this figure is very general, the reduction varying from 90% to 25 to 30%. From 30% to 40% of the sludge flows away in the effluent to be cared for on the contact beds, or on whatever additional purification is provided.

Thus far, there does not seem to be any way to determine beforehand just what reduction in the quantity of sludge will take place in the tank—apparently, each case must be studied by itself, although for a purely domestic sewage, entirely free from manufacturing wastes, we may say that from 70% to 90% of the sludge will disappear, and in a few cases, the sludge has entirely disappeared, but at least one-third flows away in the effluent.

At Worcester Massachusetts, where a different quality of sewage has been experimented upon, the following quantities of gas have been given off. The amount of sewage passing through the tank in this case was 2,350 gallons in twenty-four hours, while at Lawrence only 250 gallons per day passed.

Table No. 13.

Yearly Average of Gas Evolved at Worcester, Massachusetts.

Year.	Mean Temperature.		Cubic feet of gas per day.	Gas in gallons per 100 gallons of sewage.
	Sewage.	Effluent.		
(1)	(2)	(3)	(4)	(5)
1901	58.08	57.78	7.37	2.408
1902	55.88	55.27	12.62	3.939

In the year 1902, considerable more gas was evolved than in 1901, 3.939 gallons of gas per 100 gallons of sewage being given off. In commenting on this, Messrs. Kinnicutt and Eddy say that the low results in 1901 are believed to be due chiefly to the high acidity of the sewage, and experiments made in the laboratory confirm the statement that when sewage has a much greater acidity than is represented by twenty parts of free sulphuric acid in one hundred thousand parts, it is practically germicidal.

Moreover, the results in 1900 show that

the quantity of gas is directly dependent upon the temperature and that about twice as much gas is evolved in warm as in cold months. This fact apparently indicates that the purification affected by the septic tank will be considerably more effective in warm weather than in cold weather. In the month of July, 1901, 7.7 gallons of gas per 100 gallons of sewage were evolved, while in December of that year, 0.57 of a gallon of gas per 100 gallons of sewage was evolved.

COMPOSITION OF THE GAS EVOLVED.

The following tabulation shows the average composition for the year, 1902, of the gas evolved at Worcester, Massachusetts:

Carbon Dioxide, CO_2.	Oxygen, O.	Absorbed by Cuprous Chloride, Ca_2Cl_2.	Methan, CH_4.	Nitrogen, N.	Hydrogen, H.
5.90	0.76	0.50	75.18	17.40	0.26

SHOULD SEPTIC TANKS BE COVERED?

When the septic tank first came into use, it was considered necessary that it be closed tightly in order to secure efficient action, excluding both air and light. The following table, from the Manchester reports, shows that there is no particular advantage in a tightly closed septic tank.

TABLE No. 14.

Comparative Analyses of the Effluents from Closed and Open Septic Tanks.

Week Ending	Effluent from Open Septic Tank.	Effluent from Closed Septic Tank.
	Grains per Gallon.	Grains per Gallon.
July 12, 1899	0.25	0.30
" 19, "	0.22	0.31
" 26, "	0.24	0.35
Aug. 2, "	0.21	0.32
" 9, "	0.23	0.31
" 16, "	0.22	0.27
" 23, "	0.19	0.30
" 30, "	0.22	0.34
Sept. 6, "	0.21	0.25
" 13, "	0.25	0.305
Average	0.22	0.301

Similar experiments have been made by the State Board of Health of Massachusetts, with the following results:

TABLE No. 15.

Average Analyses of Sewage Entering and Effluents from Open and Closed Septic Tanks. (Parts per 100,000.)

	Ammonia.				Chlorine.	Oxygen Consumed.	Bacteria per Cubic Centimeter.
	Free.	Albuminoid. Total.	Albuminoid. In Solution.	Albuminoid. In Suspension.			
(1)	(2)	(3)	(4)	(5)	(5)	(7)	(8)
Sewage entering tank.	3.26	0.62	--	0.62	7.32	4.32	—
Effluent of open tank.	3.92	0.35	0.28	0.07	7.68	2.54	424,000
Effluent of closed tank.	3.88	0.34	0.25	0.09	7,46	2.42	443,C00

As the result of these experiments, open septic tanks have been tried in many places, and provided that care is taken to properly submerge inlets and outlets, and to have the tanks constructed with efficient scum boards, the solids are liquefied as thoroughly as in a closed tank.

THE NECESSITY FOR DETRITUS TANKS.

Analyses show that even in very pure waters there is a small amount of suspended mineral matter, which when the proper conditions obtain, may be expected to settle to the bottom as sediment. In a septic tank, a portion of the organic matter settles to the bottom, carrying with it a considerable part of the suspended mineral matter. It is evident then, without special discussion, that in the course of time a septic tank would fill up with insoluble mineral matter. In order to prevent this, the sewage should be passed through a detritus tank, which is merely a small tank with a screen at the far end, from which this mineral matter may be removed by a scraping tool. Or the tank may be made in duplicate, so that one tank may be thrown out of use and cleaned, while the other is in use.

THE ROYAL COMMISSION ON SEWAGE DISPOSAL.

In May, 1898, Queen Victoria issued a Commission to report (1), What method * * of treating and disposing of sewage * * * * may be adopted * with due regard for existing law, for the protection of public health and for the economical and efficient discharge of the duties of the local authorities; (2), If more than one method may be adopted, by what rules in relation to the nature and volume of sewage, or the population to be served, or other varying circumstances or requirements, should the proper method of treatment and disposal to be adopted be determined. This Commission was also empowered to make any recommendations which may be deemed desirable in reference to the treatment and disposal of sewage. The Commission are investigating the bacterial purification of sewage in all its phases and its report already fills five volumes, with others to be issued. In their Interim Report, published in 1901, it is stated that the following classification will serve to show the nature of the artificial processes:

"Closed septic tank and contact beds.

"Open septic tank and contact beds.

"*Chemical treatment, subsidence tanks and contact beds.

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* The expression "subsidence tanks" is intended to denote tanks which are used in such way that little or no "septic" action is produced.

"Subsidence tanks and contact beds.

"Contact beds alone.

"Closed septic tank followed by continuous filtration.

"Open septic tank followed by continuous filtration.

"Chemical treatment, subsidence tanks and continuous filtration.

"Subsidence tanks followed by continuous filtration.

"Continuous filtration alone."

The first conclusion of this Commission is as follows:

"We doubt if any land is entirely useless, but in the case of stiff clay and peat lands, the power to purify sewage seems to depend on the depth of the top soil.

"There are, of course, numerous gradations in the depths of top soil which are met with in nature, and it is not easy to draw the line between lands which contain a sufficient depth to justify their use, and lands which do not.

"We are, however, forced to conclude that peat and stiff clay lands are generally unsuitable for the purification of sewage, that their use for this purpose is always attended with difficulty, and that where the depth of top soil is very small, say six inches or less, the area of such lands which would be required for efficient purification would in cer-

tain cases be so great as to render land treatment impracticable."

The second conclusion is:

"After carefully considering, however, the whole of the evidence, together with the results of our own work, we are satisfied that it is practicable to produce by artificial processes alone either from sewage, or from certain mixtures of sewage and trade refuse, such, for example, as are met with at Leeds and Manchester, effluents which will not putrefy, which would be classed as good according to ordinary chemical standards, and which might be discharged into a stream without fear of creating a nuisance.

"We think, therefore, that there are cases in which the Local Government Board would be justified in modifying, under proper safeguards, the present rule as regards the application of sewage to land.

"No general rule as to what these safeguards should be can be laid down at present, and indeed it will probably always be necessary that each case should be considered on its own merits."

The third conclusion of the Commission is:

"We consider it of the utmost importance that the simplest possible means should be provided for adequately protecting all our rivers, and we are further of opinion that it will be desirable, prob-

ably for some time to come, that scientific experiments should be carried on in order to ascertain all the real dangers of pollution, against which they should be protected.

"In the present state of knowledge, and especially of bacteriology, it is difficult to estimate these dangers with any accuracy, and it seems quite possible that they should be either exaggerated or undervalued according to the predisposition of those who have to deal with them. An authority, guided by medical considerations, might not unnaturally be inclined to insist on a degree of purity which may ultimately prove in certain cases to be uncalled for, while another authority, with its mind fixed upon economy, might shrink from taking essential precautions.

"It is, perhaps, scarcely for us to say what arrangements should be made, but we are of the opinion that the general protection of our rivers is a matter of such grave concern as to demand the creation of a separate commission, or a new department of the Local Government Board, which shall be a Supreme Rivers Authority, dealing with matters relating to rivers and their purification, and which, when appeal is made to them, shall have power to take action in cases where the local authorities have failed to do so."

OXIDATION OF STERILE SEWAGE.

In the second report of the Royal Commission on Sewage Disposal, there is a paper on The Oxidation of Sterile Sewage, the object of the experiments being to determine whether or not, when sterile sewage is exposed in thin films to the air, any change takes place. The conclusion is that the oxidation of sewage containing no bacteria is very slow, or that the chemical oxidation due to oxygen in the atmosphere is inappreciable.

DESCRIPTION OF THE WORKS AT BARRHEAD.

Sewage disposal works designed for a population of 10,000 people, contributing a dry weather flow of sewage and storm water of 400,000 Imperial gallons per day, with provisions for dealing with larger exceptional quantities, have been constructed at Barrhead, Scotland. They consist of two grit chambers, four septic tanks and eight aerating bacterial filters, all built of concrete. Each septic tank is 100 feet long, 18 feet wide, and 7 feet deep, roofed by concrete arches on steel joists with brick piers.

The dry weather capacity is 312,000 Imperial gallons, but in periods of storm, allowance is made for a rise of eighteen inches, which gives an additional capacity of 70,000 Imperial gallons. Each filter is 55 feet by 54 feet in area, with 4 feet depth of clinker. The total filtering area is 2,640 square yards. The practical working of these filters is as follows:

The effluent from the septic tank is supplied to one filter at a time and distributed over the surface by a system of stoneware distributing channels. The discharge channel is closed, so that the interstices of each filter become filled with the septic tank effluent. This effluent remains in the filter for one and one-half hours, during which time the dissolved impurities are oxidized by the bacteria attached to the filtering medium. The discharge valve is then opened, whereupon the filtered effluent escapes, drawing down a supply of air into the interstices of the filter.

The filter is then left to drain and aerate, while the other filters are filled in turn, after which the first filter is again filled. The opening and closing of admission and discharge valves is automatic, being effected by the overflow of a small quantity of the effluent.

THE WORKS AT SUTTON, ENGLAND.

In the works at Sutton, the sewage first passes through a sieve which removes large pieces of floating matter, which would otherwise be retained on the top of the bed instead of penetrating it, and, therefore, obviates any danger of clogging the surface. In the case of a town sewered on the combined principle, provision should be made for intercepting the detritus from roads, which otherwise would enter the beds, steadily diminishing their capacity, as well as preventing free æration. For ordinary sewage no other preliminary treatment is necessary.

The screened sewage is then passed into a coarse grained bacteria bed consisting of a tank, either built or formed by excavating the ground, filled with coke, burnt ballast, broken brick or clinker or other suitable material, which will pass through a 3-inch ring, and from which all the finer part has been removed. Material of the size of walnuts has been found satisfactory. This bed is provided with means for preventing the sewage from always entering at the same place. It is also underdrained with agricultural drain pipes, laid with open joints. It is provided with the necessary inlet and outlet valves.

The sewage flows into such a bed until the water level has nearly reached that of the bed material. The inlet valve is then closed and the bed allowed to stand during two hours, the sewage in the meantime being turned upon an empty bed. If too long a time is allowed, there is danger of anærobic bacteria developing at the expense of the ærobic. During this period the suspended matters are deposited and liquefied. The organic matter in solution is also attacked and considerably oxidized. The bed is then emptied upon another filled with finer grained material and another resting period allowed. In this second bed any suspended solids that may have escaped the coarse bed are arrested, either liquefied or rendered soluble, and oxidized, while the purification of the dissolved matter proceeds a stage further. In case a high degree of purity is essential, as when the effluent goes into a town water supply, a third treatment on another bed may be given, the material of the bed being again finer than before. Usually, for the third bed, coarse sand is used.

The work of a bacteria bed is not finished when the effluent has been dis charged. The sludge still remains of which only a portion will have been liquefied while the bed was full. As the water is withdrawn air follows into the bed, filling the interstices, and furnishing the ærobic bacteria with conditions necessary for ærobic reproduction—that is, they have food, moisture, oxygen, darkness and an equable temperature. The deposited organic matters are rapidly attacked and in a short time the bed is ready for another charge.

THE LIQUEFACTION OF SLUDGE.

As stated in an early chapter, the credit for applying practically the knowledge that certain organisms have the power of liquefying organic matters is, by general consent, awarded to Scott-Moncrieff, who, in 1891, liquefied the sewage from a household of ten persons. In testimony before the Royal Commission on Sewage Disposal, he states that the building of a new house afforded the opportunity for making experiments upon a practical scale. He had long been convinced that nature was capable of dealing with the waste products from man and animals, and that supplementing her methods would enable one to deal with special problems of sewage disposal without the necessity of using chemicals. He states that he had been impressed with the rapid liquefaction of the organic waste products in long lengths of sewers.

In the experimental installation at Ashtead, Moncrieff constructed a bacterial tank, into which the crude sewage was admitted from below, gradually passing upward over the surface of a bed of stones. After trying various materials, he found that flints were the best, because they were stable and did not change after placing. In this experimental plant the liquefaction of the solids was so effective that the entire sludge of ten persons was absorbed on nine square yards of land, causing no distinction between the soil and that surrounding. This action had continued for seven years. The space beneath the undergrating of the tank had less capacity than five cubic feet, and would obviously have soon filled up but for the liquefying action taking place.

The author of this system states that he found it necessary to keep back all grease, in a properly constructed grease-trap, because grease interfered with the operation by mechanically arresting the whole process. The organisms seemed quite incapable of carrying on their work in a greasy medium.

Later on, with the object of obtaining an oxidized effluent, the tanks were duplicated and used alternately, with periods of aeration and rest. These tanks gave a clear effluent, but without nitrification, but that the liquid was ready for oxidation was proven by passing the effluent into a small brook, the water of which became clearer below the discharge than above it.

Afterwards, Scott-Moncrieff constructed a tank with trays and air spaces, which performed the operation of successfully oxidizing sewage, and for a description of which reference may be made to any good, recent work on sewage disposal. Volume II of Evidence before the Royal Commission on Sewage Disposal, may also be consulted for the views of Scott-Moncrieff himself.

REDUCTION IN THE NUMBER OF BACTERIA IN A BIOLOGICAL EFFLUENT BY MEANS OF FILTRATION.

The Royal Commission on Sewage Disposal caused experiments to be made on this point, with the following results:

The experiments consisted in passing, at a definite rate, a biological effluent of known bacterial impurity, through four feet of sand, and in daily analyzing the filtrate and in noting the reduction both in the total number of bacteria and in *Bacillus coli communis* and in *Bacillus enteritidis sporogenes.* The experiments were subsequently extended to ascertain whether if *Bacillus prodigiosus* and *Bacillus pyocyaneus* were placed in the biological effluents supplying the filters, they would appear in the filtrate, and, if so, how soon after filtration this would occur, and also when they would disappear again. Experiments were made with the *Bacillus typhosus* in a similar manner. The following are the general conclusions of the Commission:

"When an effluent containing upon an average 800,000 bacteria per cubic centimeter and 10,000 *Bacillus coli* per cubic centimeter is passed through a depth of four feet of soil at a slow rate (viz., between 10 and 4 liters per 12 hours), there is a very great reduction ln the total number and in the *Bacillus coli*, and the chance of a very pathogenic bacterium like the *Bacillus typhosus* appearing in the filtrate must be exceedingly small.

"When it is remembered that normally the *Ba-*

cillus typhosus is not present in the excreta of all cases of typhoid, whilst *Bacillus coli* is always present in the faeces, and that the proportion of typhoid cases to the total number of the population is not large, that typhoid excreta are usually disinfected, and that it has not been shown that favorable conditions exist in sewage for the multiplication of the typhoid bacillus, it appears evident that land or other method of efficient filtration must totally remove this organism from a Dibdin effluent, did it happen to be present.

"In the experiments, the *Bacillus typhosus* was mixed with the effluent flowing on to the filters in far larger proportion than would ever occur in nature, and yet it could not be found in the filtrate."

FILTRATION BY PERCOLATING FILTERS.

The first experiments on continuous filtration, or, preferably, by percolating filters were those of Lowcock in 1892, and Col. George E. Waring in 1894. In the Lowcock experiments, it was attempted to purify crude sewage by forcing air into a gravel or broken stone filter. They were not successful. Percolating filters, as used in England, do not generally attempt to treat crude sewage, but only sewage that has first been acted upon by anærobic bacteria. They depend for efficiency of operation on openness of construction and the applying of the partially purified sewage in the form of spray.

Perhaps the most interesting experiment on percolating filters is the plant recently completed at Salford, England. At this plant the sewage of a city of 250,000 inhabitants, with a dry weather flow of sewage of over 8,000,000 Imperial gallons per day, is to be treated by this method. The sewage is first treated chemically, after which the clarified sewage is run through roughing filters filled with gravel, at the rate of 400 gallons per square yard per day, the rate to be increased up to 16,000,000 gallons in stormy weather. From the roughing filters it is delivered to an ærated bed, 500 bed long, 510 feet wide and 10 feet deep, filled with fine cinder.

After passing through various pipes, the detail of which is not interesting here, the sewage is run out upon the cinder bed through ¼-inch sprays. This bed is thoroughly underdrained with a special form of tile which insures air circulation beneath the filter. There is enough head on the spray pipes to cause the liquid to spout out to a height of five to eight feet, falling like rain upon the surface of the filter.

This plant is undoubtedly very expensive, and it remains to be seen whether the treatment will be successful. This method is probably capable of treating larger quantities of clarified sewage on a given area than any other bacterial process. It has the further advantage that the accumulation of solid matter in the interspaces will only reduce the volume of liquid which can be treated when the amount of solid matter becomes so great as to interfere with the free passage of the liquid.

This method of treatment is also called intermittent continuous filtration, but a preferable name seems to be filtration by percolation, or by intermittent percolating filters. This method of sewage purification has been developed by Colonel Ducat, Whittaker and Bryant and Mr. F. W. Stoddard. All these filters differ from each other in some degree, but are alike in this—that they are appliances for mingling as large a proportion as possible of oxygen with the sewage. Mr. Lowcock and Colonel Waring attempted the same thing in 1892 and 1894. The limit of space in this book makes it impossible to describe these filters in detail, and the reader is referred to the larger works on Sewage Disposal for complete descriptions.

THE INVESTIGATION OF THE RIVER SEVERN.

The Royal Commission on Sewage Disposal made a very elaborate investigation of the River Severn. This river presented great advantages for an investigation of the biological flora because of the following reasons:

"(1). It is a typical example of a river used for drinking and domestic purposes, and for fishing.

"(2). Its volume and velocity can be readly determined.

"(3). It is exceedingly tortuous and therefore comparatively long distances by the river were represented by short distances in a straight line, rendering points of observation within easy reach of one another.

"(4). It received the whole of the sewage of the town of Shrewsbury."

Some of the practical questions investigated were as follows:

"(1). What happened to the intestinal bacteria when they passed into the river?

"(2). How far down the river were they carried and what was the evidence of multiplication?

"(3). Did they accumulate and multiply in the mud of the river?

"(4). At what distance below the source of the pollution was it safe to drink the water?

"(5). What was the simplest and most rapid means of detecting intestinal bacterial pollution in the river?

"(6). What, if any, is the effect of the seasons upon the bacteria of the River Severn?"

The following are the conclusions as to the study of the River Severn, which extended from November, 1899, to February 1901:

"(1). That the *Bacillus coli* is a most reliable test of pollution.

"(2). That the *Bacillus coli* is normally absent in one cubic centimeter quantities of water taken from the Vyrnwy watershed of the River Severn.

"(3). That when the *Bacillus coli* is present in a small stream, contamination from houses can be traced.

"(4). That small land drains are comparatively free from *Bacillus coli.*

"(5). That the small streams running into the Severn often contain considerable quantities of the *Bacillus coli* due to contamination from proximity to houses.

"(6). That the sewage of Shrewsbury causes a very great increase in the number of *Bacillus coli* in the river, and that sixteen miles lower down the effect of pollution can still be detected by the number of *Bacillus coli* present.

"(7). That there is no evidence of the multiplication of the *Bacillus coli* in the river water.

"(8). That the *Bacillus coli* is present in considerable numbers in the mud of the Severn in the polluted area, and that this mud may be the means of keeping up and extending pollution, but that there is no evidence of the multiplication of the *Bacillus coli* in the mud.

"(9). That there is comparison between total numbers of the bacteria and the *Bacillus coli*, but the relative proportion of the numbers of the latter to the former is small.

"(10). That differences occur between the number of *Bacilli coli* in superficial and deep samples, and samples taken near the banks and in stagnant bays, and that therefore cross-section samples should always be taken.

"(11). That sedimentation and side adhesion to the banks of the solids in suspension take place, and that at places in the bed of the river, anærobic fermentation occurs, whilst along the banks, especially in the wind and water line, ærobic bacteria actively help to destroy the organic matter.

"(12). That certain places in the river are very deep, and that these act as catch pits, that the stream in these places is sluggish, and that sedimentation is favored.

"(13). That in the destruction of organic matter, whether solid or in solution, whilst the bacteria take the greatest share, help is also rendered by the protozoa and higher forms of animal life, by the sewage fungi, the chlorophyll containing protophytes, and the river plants.

"(14). That the *Sphaerotilus natans* is a test of sewage pollution, and that it is a purifier of sewage.

"(15). That there is no evidence to show that pathogenic bacteria multiply in either the water or mud of the river.

"(16). That seasonal variations in the number of bacteria occur, but taking the *Bacillus coli* as the test for pollution, that the number of this organism is dependent upon the numbers present in the sewage entering the river, and that when the river is swollen and muddy the number is small, owing to increased dilution, and that when the river is low the number is large, owing to the lesser degree of dilution which the sewage undergoes when it enters the river.

"(17). That the effect of dilution of the river upon the sewage of Shrewsbury is most marked. That the average maximum number of *Bacillus coli* in the river is only 600 per cubic centimeter, which is much less than in an average Dibdin effluent, whilst a short distance below pollution the number decreases very considerably.

"(18). That there is a relationship between chemical and biological analyses.

"(19). That the River Severn is a good example of a river which it would be difficult to class either as a potable or non-potable stream.

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"(20). That what has been described in this report upon the effects of allowing crude sewage to enter the River Severn is also applicable to biological effluents. Crude sewage is an example of the worst form of pollution, the effluents from biological methods of treatment examples of a lesser degree of contamination, because the solids in suspension in the latter are far less in amount and are in a fine state of division, and the number of the *Bacillus coli* is smaller."

THE LONGLIVITY OF BACILLUS TYPHOSUS IN SEWAGE AND SEPTIC EFFLUENTS.

The Royal Commission on Sewage Disposal having shown that the final effluent from the various biological methods of sewage treatment very often contain the *Bacillus coli* in large numbers, the question naturally occurs whether, if the *Bacillus typhosus* found its way into bacterial beds, it would survive and passing into the effluent, constitute a danger. This matter was reported upon by Dr. Alfred MacConkey, who calls attention to the fact that the *Bacillus coli* tends to die out both in the earth and sand composing filters and in the water and mud of the River Severn. Once outside of the alimentary tract, the *Bacillus coli* is not in the most suitable environment for its multiplication and the innumerable coarser bacteria of purification in their rapid multiplication, use up the food materials and produce products, which in all probability, result in injury to the more sensitive *Bacillus coli.* If in this struggle for existence, the *Bacillus coli* is outdistanced by the coarser bacteria and soon perishes, there is still more reason why the bacillus of typhoid should not long survive outside the alimentary tract. The reason for supposing this is that it has been shown that the *Bacillus typhi adominalis* is much more sensative than the *Bacillus coli* to certain reagents, and that even the slight acid reaction of the potato retards its growth, while the *Bacillus coli* grows luxuriantly.

Some of the more interesting conclusions of this study are as follows:

(1). In the case of crude sewage inoculated with *Bacillus typhosus*, it may be concluded that the organism will die out rapidly. The same thing is also true of partially sterilized crude sewage.

(2). In an open septic tank effluent, inoculated with *Bacillus typhosus*, in the first experiment the organism was recovered after fifteen days, but not after ten days in the second experiment. This medium is more favorable to the *Bacillus typhosus* than an untreated open septic tank effluent.

(3). In the effluent from a Dibdin bed, partially sterilized, the *Bacillus typhosus* is capable of surviving as long as in an open septic tank effluent, having been recovered at the end of fifteen days.

(4). In either a partially sterilized or untreated Cameron effluent, the *Bacillus typhosus* appears to die out more quickly than in the other fluids used. In the case of a partially sterilized Cameron effluent, there were 8,000,000 *Bacilli typhosus* per cubic centimeter at the commencement of the experiment, but these had decreased to less than 3,000 per cubic centimeter in six days and to less than 30 per cubic centimeter in ten days. In the case of a Cameron effluent, untreated, the number of *Bacilli typhosus*, at the beginning of the experiment, was 12,000,000 per cubic centimeter, and none were recovered at the end of six days.

(5). As a final conclusion, it may be stated that the fluids experimented with are inimicable to the growth of the *Bacillus typhosus* and if these bacilli find their way into a bacteriological system of treatment, they meet with conditions hostile to their multiplication.

THE SEWAGE FUNGUS AND ZOOGLEA MASSES.

The sewage fungus has been long recognized as an indicator of sewage contamination. It was studied by the Royal Commission on Sewage Disposal in the Atcham Brook, in the River Alt and at Dewsbury, Leeds and Birmingham.

The fungus is a gelatinous, cottonwool-like and wavy white and reddish growth, which is found in shallow water, on stones, lining drain pipes, attached to water plants and debris. It has also been found in a urinal. Quantities are often seen in the streams of sewage farms and in small brooks and drains found in the vicinity of houses and villages in the country. At Dewsbury it was seen in the mouth of the main effluent from the sewage farm, where in a bright effluent, the tufts of fungus were long and rusty, owing to a deposit of oxide of iron. This form of fungus was identified as *Leptomitus lacteus*. At Birmingham it was encountered in great quantities in the stream receiving the effluent from the sewage farm. In the Atcham Brook the growth was white and the tufts wavy and very gelatinous, and the brook was completely choked by it. A bacteriological examination showed that this stream contained 19,000 *Bacilli coli* per cubic centimeter. It was found that within a short distance a sewer from the Atcham workhouse was connected with the brook. The variety of fungus found in Atcham Brook was *Sphaerotilus natans*.

Although classed under the head of sewage fungus there are certain distinct growths which may be placed among the highly developed forms of bacteria. There are also various bacteria zooglea masses, which may assume a branching appearance like a sewage fungus. The appearance of typical fungus is sometimes caused by extensive growths of a protozoon, the *Carchesium lachmanni*.

In crude undiluted sewage a skin-like growth may form at the sides of the conduit in contact with the air, or at those points where the crude sewage passes over a lip. This growth consists of club-shaped zooglea masses of bacilli and from observations at Leeds there appears evidence that the zooglea masses tend to form sulphur from the dissolved sulphureted hydrogen. Green algæ may also develop in sewage polluted water, and when they do so, they may, with sewage fungus and bacteria, play a direct part in purifying polluted water.*

FLORA OF THE RIVER SEVERN AND THE SHARE IT TAKES IN PURIFICATION.

In the report of the Royal Commission on Sewage Disposal, it is remarked that the relationship of plant life to the purification of streams is a matter of practical interest, and that accordingly a survey of the plants growing in the River Severn and along its banks, has been made in order to ascertain the share they take in cleansing the river.

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* See On the Fresh Water Algæ and their Relation to the Purity of Public Water Supplies Trans. Am. Soc. C. E., Vol. XXI, p. 483, (1889).

Along the wind and water line there is a zone covered with *Euglena*, *Oscillatoricæ* and *Closterium*, together, when the water is polluted, with other protophytes. The polluted mud also harbors much animal life, *Nais* being abundant. This worm has reddened the mud of the Thames and it is abundant in Dibdin effluents. It swarms on *Leptomitus* and *Sphaerotilus*.

The submerged banks support in the deeper parts, *Potamogeton perfoliatus*, *Potamogeton natans*, *Zostera*, *Myriophyllum verticillatum* and *Ranunculus aquatica*, and in the shallower parts, the Sedges, Alisma, water Grasses and Willows. The services which these aquatic plants render a polluted river are very great. After passing through a mass of them, the water is appreciably brighter and cleaner, and it is only necessary to vigorously disturb a patch in order to give the water the muddy appearance which it has in flood time.

The aquatic plants give off great quantities of oxygen in the presence of sunlight. Hence, the quantity produced by the masses of water *Ranunculus* in the River Severn must be large. These will probably materially assist in neutralizing the harmful fermentations which take place in the more highly polluted parts of the river. Microscopical examination of the matter adhering to aquatic plants reveals the presence of numerous protophytes, protozoa and bacteria.

It is a very fortunate feature that in summer time, when the dilution is less, and when putrefaction is much more active, the harmful effects of bacterial activity are neutralized by the growth of these aquatic plants. But in the River Severn, at any rate, this action, while important, is not complete.

ANTHRAX IN THE SEWAGE OF YEOVIL, ENGLAND.

The Royal Commission on Sewage Disposal have given, in their second report, an account of the presence of anthrax in the sewage of the town of Yeovil, England. As this is an exceedingly interesting case, we will refer to some of the more interesting points.

An experimental septic tank and coke beds was installed at Yeovil, where the sewage has the reputation of being excessively foul, due to the large proportion of trade refuse present in it. This trade refuse is derived from twelve hide factories, together with three breweries. Samples of the septic tank liquid were collected on March 22, 1901, which were found to yield cultures of pure anthrax. The inoculation of guinea pigs resulted in their deaths on the sixth and seventh days. In the second experiment only two cubic centimeters were injected.

Sludge from the septic tank was collected on the same date, and guinea pigs inoculated, who died on the third and fourth days. Examination showed that their blood was teaming with the *Bacillus anthrax*.

On April 12, 1901, a sample of coke in one of the coarse beds was taken up from a depth of about one and one-half feet and placed in a wide-mouthed stoppered bottle. Thirty-six cubic centimeters of sterile water were added and the bottle vigorously shaken. The first two experiments were negative, but in the third experiment one cubic centimeter was used to inoculate subcutaneously a guinea pig. The animal died on the fourth day and *Bacillus anthrax* was found present in the blood and organs.

Samples of the coke in one of the fine beds was also collected at the same time, and, after placing it in a wide-mouthed stoppered bottle, sixty-two cubic centimeters of sterile water were added. One cubic centimeter of the surface liquid was injected subcutaneously into a guinea pig, which died on the second day. Its blood and organs were found to contain the *Bacillus anthrax.* The *Bacillus anthrax* was also found in the mud and banks of the River Yeo and Yeo Brook.

As the result of these experiments the Yeovil authorities have made preparation for a final treatment on land.

THE SUBCUTANEOUS INOCULATION OF ANIMALS WITH CRUDE SEWAGE AND WITH EFFLUENTS.

During 1898 and 1899, Dr. A. C. Houston carried out a research on the subcutaneous inoculation of animals with crude sewage and with effluents. The following is a brief summary of some of the results, as abstracted from the report of the Royal Commission on Sewage Disposal:

(1). The subcutaneous injection of crude sewage frequently produced death in from twenty-four to seventy-two hours. Sometimes the effluent from coke contact beds was found to be more pathogenic than raw sewage, but usually a larger dose of effluent than of crude sewage was required to produce a fatal effect.

(2). If the injection of crude sewage or effluent is not followed by fatal results within the first few days, the animal may occasionally die after a lapse of some weeks from pseudo-tuberculosis.

(3). When the animal dies rapidly, virulent microbes may readily be isolated from the blood or tissues of the animal.

(4). If the crude sewage or effluent be previously heated to 100° C. for one hour, large doses may be injected without producing a fatal result.

(5). If the crude sewage or effluent has been previously heated to 80° C. for ten minutes, a pathogenic effect may still be produced, but a larger dose is required than when the liquid has not been heated.

(6). If the crude sewage or effluent be filtered through a sterilized Pasteur filter, very large doses fail to produce a pathogenic effect.

It may, therefore, be concluded that sewage must always be regarded as a liquid potentially dangerous to health, and that sewage effluents, which resemble sewage in their biological composition, must be considered harmful.

THE PERCENTAGE OF VOIDS IN BROKEN STONES.

Experiments as to the voids in broken stone may be found recorded at pages 336–7 in a report dated April 1, 1894, in Appendix E of the Report of the State Engineer and Surveyor of New York for that year.

Four qualities of stone were experimented upon—Genesee shale, a limestone from Ridge quarry, and a Portage sandstone from Portage and Nunda. There is very little difference in the quality of these two latter stones.

Genesee shale gave as a mean of five determinations, the voids at 38.3%, but, when packed in a box with a tamping iron, the mean was 31.6%.

The stone from Ridge quarry was a hard, compact limestone. The mean of five trials, slightly shaken, was 46.2%, and the mean of five trials with stone packed, was 38.6%.

The mean of five trials of the Portage stone, slightly shaken, was 43.3%, while the mean of five trials of Portage stone packed, was 37.4%. The stone from the quarries at Nunda gave very nearly the same results as those at Portage.

These stones were all hand-broken to pass through a two-inch ring, and were free from dust and fine chips.

Coke, as used in filters, has probably a larger percentage of voids than broken stone, but experimental evidence on this point is not at hand.

VELOCITY OF FLOW IN A SEPTIC TANK.

The size of the installation will depend upon the velocity of flow through the septic tank, and velocity of flow, therefore, is directly related to the initial cost. The following tabulation shows the velocities in the Manchester and Leeds experiments:

Town.	Length.	Width.	Depth.		Contents.
	Feet.	Feet.	Ft.	In.	Imp. Gallons.
Manchester tanks	300	100	6	0	1,125,000
Leeds "	100	60	7	7	250,000

If we assume that each tank is to be filled once in twenty-four hours we obtain, at Manchester, a velocity of 2.5 inches per minute, and at Leeds of 0.84 inch per minute. This means that in the Manchester experiments the velocity would have been three times as great as in the Leeds experiments. It is clear, therefore, that if the composition of the sewage of the two towns was identical, the results in the removal of suspended matters could not have been identical. We may conclude, therefore, that the velocity to be employed in a septic tank should not be expressed by the length of time the sewage remains in the tank, but should preferably be expressed by some linear measurement in a stated time, as in inches per minute. Without discussing why, we may say that the depth and breadth of the tank should be such that the flow of sewage through it should not exceed one inch per minute. The following table shows the rate of flow, as well as the deposition of the suspended matters in the septic tanks as used at Exeter, Manchester and Leeds. This table shows a very large proportion of reduction of the sludge in septic sewage is due to the sludge flowing away in the effluents. This is a very important point. In examining the septic sewage disposal plants at Plainfield, New Jersey; Liberty, New York; Rockingham County, New Hampshire Poor-farm, and a private plant at Milton, Massachusetts, in the fall of 1902, this fact was markedly brought out. In all these plants, a large quantity of sludge was passing away in the effluent. At Plainfield and Liberty, this was true even in the final effluent from double filtration through contact beds.

Table No. 16

Septic Tank Experiments Showing Rate of Flow and Deposition of Suspended Matters.

No.	Name of Town.	Rate of Flow.		Suspended Matters in Sewage.			
		Length of Sojourn of Sewage in Tank In Days.	Velocity of Flow per Minute in Inches.	Per cent. Remaining in Tank.	Per cent. Destroyed and Liquefied in Tank.	Per cent. Leaving Tank in Effluents.	Total per cent.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Exeter.	1.0	0.52	17	39	44	100
2	Manchester.	0.44	5.58	41	22	37	100
3	"	0.56	4.44	23	33	44	100
4	Leeds.	0.5	1.68 }	—	—	—	—
5	"	1.0	0.84 }	average say	28	—	—
6	"	2.0	0.42 }	—	—	—	—

COST OF SEPTIC TANKS, CONTACT BEDS, &C.

Only very general figures as to the cost of installing biological systems of sewage disposal can be given. The following may be of interest:

The cost of septic tank and single filtration through a contact bed for seventy-five people, at Rochester, N. Y., the filtration being at the rate of twenty-four gallons per square foot of area per day, was about $2,000. It is proper to say that this plant was built by day's labor in the winter, and under more favorable circumstances would not have cost to exceed $1,400 to $1,500.

A septic tank of capacity of about 53,000 gallons, for Cuba Village, New York, and designed to care for the sewage, alone, by septic tank treatment purely, of 1500 people, will not cost to exceed $3,400.

According to the 21st Annual Report of the State Board of Health of New York, for 1900, the sewage disposal of Canajoharie, N. Y., if constructed with septic tank and special filter bed, will cost $13,000, with an annual cost for maintainance and operation of $3.000. Capitalizing $3,000 at 5%, we have $60,000. Adding this to the $13,000, we have $73.000, which represents the total cost of the sewage disposal at this place. If, however, dilution is used during the months of heavy rainfall, and septic tank treatment only in months of light rainfall, we have, as the first cost of the works, $6,567, to which may be added for interest, depreciation and operation, say $800 per year, which at 5%, has a capitalized value of $16,000. Adding this to the $6,567, we have $22,567, which represents the total cost of the sewage disposal if dilution is used part of the year. The population of Canajoharie was 2,101 in 1900.

According to the testimony of Mr. Cameron, before the Royal Commission on Sewage Disposal, the installation at Exeter, England, cost $2.15 per capita and $40 per one thousand gallons treated per day. This was on the basis of a population of 47,000, with a maxium dry weather flow to be dealt with of 2,500,000 Imperial gallons per day. These figures only include the works, such as building of tank and filters, grit chambers, the buildings and pen-stalks and valves required for regulating the flow.

The installation at Barrhead is designed for a population of 10,000 and a maximum quantity of sewage of 400,000 Imperial gallons per day. This works out to about $59 per one thousand gallons treated. Generally the smaller the installation the greater the cost.

In illustration of this, at Walingford, the estimate for a population of 3,000, dealing with 90,000 gallons per day, is about $93 per one thousand gallons treated.

At Warley, with a population of 500, and with 20,000 gallons as the maximum quantity to be dealt with per day, the first cost is $119 per one thousand gallons treated. The maintenance cost in this case is 0.66 of a cent per one thousand gallons treated per day.

At St. Budeaux, with a population of 500, and with a flow of sewage of 15,000 Imperial gallons per twenty-four hours, the first cost comes to about $113 per one thousand gallons and the maintenance cost to 0.8 of a cent per one thousand gallons treated.

As to the cost of the material for filter beds, etc., coke at Rochester, N. Y., costs $4 per cubic yard, but in England, judging from the testimony of Mr. Stracham, it will not cost more than about $2 per cubic yard. Clinker, it is stated, cost $1.50 per cubic yard. These figures of cost are, of course, very general, and are understood as general indications only.

PATENTS ON THE SEPTIC TANK.

Extensive patents have been taken out by Cameron, Commin and Martin, of Exeter, England, on the process and apparatus for treating septic sewage. The American patent is No. 634,423, dated October 3, 1899. Cameron and Commin have also secured patent on apparatus for automatically controlling the delivery of the sewage, of which the American patent is No. 634,424, also dated October 3, 1899. These gentlemen have established an office in Chicago, Illinois, and it is understood have installed a number of sewage disposal plants in different parts of the country.

Patents have also been obtained by Garryt D. Mitchell. His patent is for a combined septic tank and bacterial purification bed, and is No. 580,793, dated April 13, 1897. There are a number of other patents, but the foregoing are the more important.

AUTOMATIC ARRANGEMENTS FOR DISCHARGING CONTACT BEDS.

Automatic arrangements for discharging contact beds have been very thoroughly developed in England, where there are in common use for this purpose, ordinary siphons, Adams' automatic siphon, Cameron's automatic gear, and Mather and Platt's automatic valve. A number of appliances have also been developed in this country, but the English designs are, generally speaking, in advance of ours. Automatic siphons for this purpose can be obtained from The Pacific Flushtank Company of Chicago, and Cameron's automatic gear can be obtained from their agent at Chicago.

The automatic siphon, coming into action as soon as a bed is filled, is the simplest arrangement, but the objections to its use are that the organisms require to remain in contact with the filtering medium for a couple of hours. This disadvantage is, however, obviated by the use of Adams' automatic arrangement, whereby the sewage rising in one contact bed compresses air in a dome, cuts off the sewage from this bed and applies it to another. This apparatus can be used for keeping sewage in a contact bed as long as desired.

The automatic alternating gear devised by Cameron, works as follows: The effluent rises in a chamber and lifts a counterpoised bucket, which closes a valve diverting the sewage upon a second filter, at the same time unlocking the first bed.

In the automatic arrangement of Mather and Platt, the outlet of the contact bed is kept closed by the weight of fluid pressing against a valve. When the bed is full the sewage overflows into a tank at the end of the long arm of a lever, and after a certain quantity has passed into the tank, the weight is sufficient to open the valve. Mather and Platt also have an arrangement for feeding beds in regular succession, which consists of a tank in which there is a large float. This tank is filled and emptied by means of a siphon, causing the float to rise and fall. Each fall of the float turns a shaft one-sixth of a revolution. This shaft is armed with cams, which press upon different levers, opening valves supplying different contact beds.

AS TO THE PREFERABLE BACTERIAL PROCESS.

We have seen in the preceding that sewage may be purified either through closed or open septic tanks, followed by single, double or triple treatment in contact beds; or by ordinary chemical treatment, followed by subsidence tanks and contact beds; or by subsidence tanks and contact beds; or by contact beds, alone; or in closed or open septic tanks, followed by filtration through percolating filters, or chemical treatment, subsidence tank and filtration through percolating filters; or by subsidence tank followed by filtration through percolating filters; or by filtration through percolating filters alone; and the question may be appropriately asked, under what circumstances should one process be adopted and when another?

In the septic tank the sewage, after being freed of the coarser particles in detritus tanks, etc., is received in a large chamber, through which the rate of flow should not exceed about one inch per minute. In English towns, where the quantity of sewage does not exceed thirty to forty gallons per capita per day, such a construction can be made quite economically even with this low rate of flow. But in the United States, with from eighty to one hundred gallons per capita per day, the septic tank becomes, for these low rates of flow, quite expensive. The septic tank allows a considerable portion of the sludge to pass away in the effluent, and which again, if the rate of filtration is too high, may clog contact beds to which it is applied.

In contact beds the filtering material need not be very carefully graded and there is no special necessity for a careful distribution of the sewage. Further, contact beds should be constructed with water-tight walls and double contact is necessary in order to secure the same result in purification as with one percolating filter. Double contact beds should be made on the basis of one square yard of material, 4 feet deep for every 130 United States gallons per day of sewage treated. One advantage of the contact beds over the septic tank is that the operations are enough more rapid to permit of two fillings per day, while, as we have seen, the contents of the septic tank should not be changed more than about once per day, but it should be remembered that the content of a contact bed is less than that of a septic tank with the same superficial area.

In percolating filters the sewage should be distributed by stationary or revolving pipes so arranged that the sewage reaches the surface of the bed in the form of spray. The material of such filters should be free from dust and averaging from $\frac{1}{4}$-$\frac{3}{4}$-inch in diameter.

These filters are less expensive than contact beds. The air supply to intermittent percolating filters may be as much as five times the volume of the sewage treated, while in contact beds the air supply is only equal to about the volume of the sewage treated. The effluents from percolating filters are, therefore, more highly oxidized than in the case of contact beds. Percolating filters may purify, under favorable conditions, nearly 600 United States gallons per square yard per day.

In order that the spraying apparatus of percolating filters may work satisfactorily, all the matter in suspension in the sewage should be removed before applying it to such filters.

According to Barwise, the greater the fall available at the outfall, the more should filtration be relied upon. On the other hand, with slight fall, septic tanks and anærobic beds should be made of larger capacity, leaving as little work as possible for shallow filters. The following embodies Barwise's complete answers to the question, as givên in his Bacterial Purification of Sewage:

"(1). In the first place, detritus tanks and screens should under all circumstances be employed.

"(2). Next, it should be borne in mind that the more fall which can be obtained at the outfall works, the simpler the purification plant, the more thorough the process of æration, and the easier the task of obtaining a good effluent. The outfall sewer should therefore be laid with just sufficient fall to make it self-cleansing. No fall should, however, be wasted. For this reason, it is always advisable, whenever it is possible, for the outfall sewer to be brought to the outfall works in an embankment as high above ground as convenient.

"(3). Where there is a large amount of fall at the outfall works, say twenty to thirty feet, the sewage may be purified by multiple filtration without any septic tank, the effluent from the first bed being collected in a tippler or automatic flushing tank, and then distributed over a second bed, and so on over a third, the first bed being a coarse one and the subsequent filters gradually finer. The filters need only consist of heaps of clean clinker, etc., without retaining walls, * * * the distributors being supported above the filter and the sewage being sprayed all over the surface.

"(4). Where there is a moderate fall, a septic tank, say to hold half the daily flow, and a lateral flow bed to hold one-third of a day's flow in conjunction with percolating filters, is a scheme which will utilize a fall of about ten feet to the greatest advantage. When less than ten feet is available the capacity of the liquefying portion of the plant (septic tanks and anærobic beds) should be increased, so as to lessen the work to be done by the filters.

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"(5). When, however, there is extremely little fall, say only four or five feet, the maximum amount of purification that can be effected by the anærobic bacteria should be aimed at. The septic tank itself requires no fall, nor is a fall wanted for an upward-flow filter or a lateral filter. A septic tank should therefore be constructed capable of holding at least a day and a half's flow. The effluent from the septic tank should also be passed through a lateral bed capable of holding half a day's flow. The sewage should be admitted to the lateral bed through a strainer of fine material. * * * The effluent from the lateral bed should then be conducted to a distributing chamber and then either to such a filter as Stoddart's, * * * or by perforated pipes over contact beds, the top layers of which for this purpose should be made of material from one-fourth to half-inch in size, the rest of the bed being of material between one-quarter and three-quarters inch in size. The effluent rising in the effluent chamber should be utilized to work the contact beds in rotation by some such mechanism as Cameron's or Adams'.

"It will be noticed that in this case it is suggested that single contact beds, in conjunction with the septic tank and a lateral bed, are sufficient, but it should be understood that a sufficient area of contact bed must be provided, under these circumstances, to work with two fillings a day, and that the sewage should be uniformly distributed by perforated pipes or a Stoddart distributor over the whole surface of the contact bed. By such a scheme a satisfactory effluent could be produced, although only four or five feet of fall is available at the purification works, and by this means the expense of pumping could be avoided.

"(6). When it is necessary to pump the sewage, advantage should be taken of this fact to apply the sewage intermittently to the filters by starting and stopping the pumps or by working in shifts. To enable this to be done, wherever the engineering aspect of the question permits, the sewage should be allowed to gravitate through the septic tank or anærobic bed, both of which require a slow, continuous movement of the sewage, and it should not be pumped until after it has been screened and liquefied. The motive power used for pumping should be also employed for spraying the sewage and making the intermissions in its application. For this reason, if a Shone's ejector is employed to lift the sewage, it should also be used to spray the sewage over the filter, as is done at Chesterfield.

"(7). Lastly, coarse storm water filters to work at the rate of 500 gallons per superficial yard, must be constructed in every case; 180 yards superficial being provided for every 1,000 inhabitants."

SUMMARY.

The septic tank, although purifying sewage to the extent of 25% to 40%, cannot by itself be used for sewage purification, but it may be used as preliminary to further treatment on contact beds. The number of such beds will depend upon the degree of purification required—for a very high degree there should be three beds, but in many cases, the septic tank, followed by passage through one properly constructed contact bed, will be sufficient.

Sewage may also be purified by passing it upon bacteria beds, without preliminary treatment in a septic tank.

After a preliminary treatment, whereby the solid matters are removed from the sewage, the various forms of percolating filters are efficient methods for final treatment.

The work of the Royal Commission on Sewage Disposal indicates that as a broad proposition, effluents from bacterial methods of treatment are less efficient than effluents from land processes, or at any rate, to make the effluents from bacterial methods equally efficient there must be triple filtration, the final filtration being through coarse sand. The sewage is preferably applied intermittently to such a filter. The experiments of the Commission show that where suitable land is available the land processes are the most efficient systems of sewage disposal yet devised.

In England, where there is a smaller flow of sewage per capita per day than in the United States, a number of bacterial plants have been carried out at less expense than would be possible for land purification processes of an equal degree of purification. But in the United States, with larger quantity and more dilute sewage, for equal purification, land processes are not likely to be as expensive as the bacterial. At any rate, every case needs to be studied on its own merits.

It frequently happens that there is no suitable land to be obtained, in which case, some form of bacterial purification is permissible. As to just which form, circumstances will determine.

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