

SEWAGE TREATMENT.*

BY

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CHAIRMAN AND GENTLEMEN: The subject on which I was asked to speak to you to-night is the treatment of sewage. Since the introduction of water supplies into cities this subject has become an important one in many cities. The water as it passes through the city receives the dirt, dust, and excremental discharges from our houses and, together with rain-water, also the dirt and dust that has accumulated upon the streets, roofs, etc. We have turned the clean water furnished us into dirty water, then called sewage, which is discharged into sewers and reaches the nearest watercourses and, with them, finally the ocean.

As cities grew and the watercourses were small their water frequently became offensive. The heavier matters were deposited in the streams as sludge and putrefied, while the flowing water was deprived of its dissolved oxygen, and both sludge and water became offensive.

It was later found that diseases were caused by certain bacteria which were discharged from our bodies while sick, and entered the sewers and the streams. Sometimes these germs became free and infected the air, or the polluted water was used in such ways that the germs entered human bodies and made them sick. Gradually, therefore, the sewage question became not only one of convenience of city life but one of health.

The first serious troubles were experienced in England, where the communities are crowded and the rivers are small. England had also been the first country to generally introduce modern water supplies into houses. Many of its rivers soon began to get foul and sometimes dangerous to health. Therefore the subject of sewage collection and disposal received most attention and the first satisfactory solutions in England.

To-day we have reached the conclusion in all civilized countries that it is practicable and economical to collect sewage

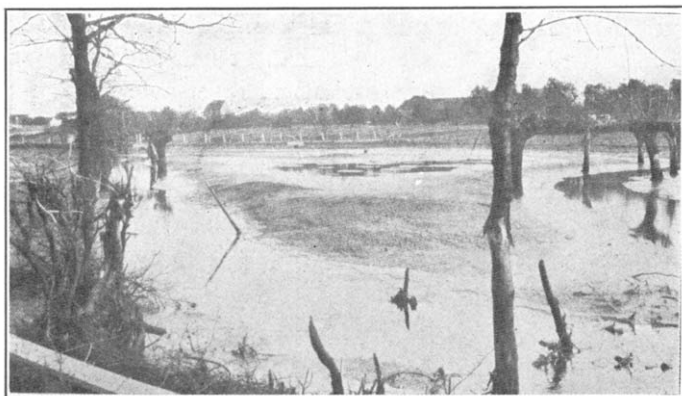
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from houses and cities, and to carry it away underground in sewers, to be delivered either into flowing streams or onto land in such ways that it will neither become a nuisance nor be of any injury to health.

We can now design the house sewers or drains and the receptacles of the waste water in such a way that by cleanliness and proper ventilation we need not have a nuisance in the house nor give disease germs in the sewage an opportunity to enter the same.

We can now design the city sewers in a way so that they can carry the sewage or dirty water from the houses to the out-

FIG. 1.



Poorly-drained land bordering stream in Emscher district of Germany.

falls without causing any nuisance or danger to health on the streets.

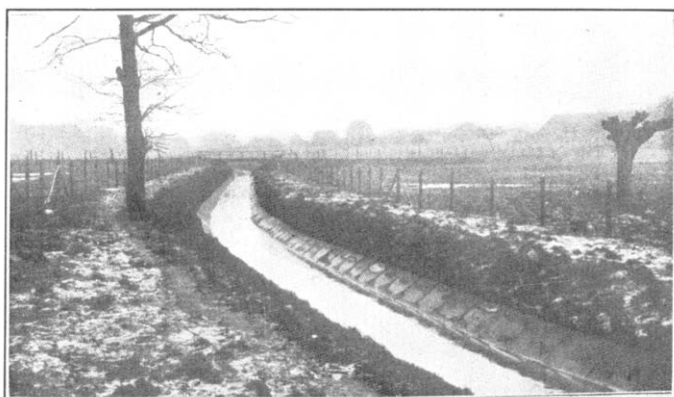
There are many cities, particularly in Europe, where there is no offensive odor within the sewers. In Paris, Hamburg, Wiesbaden, and other cities even visitors regularly inspect them who desire the sensation of passing through these waste-water channels under the streets. I feel satisfied that it is only a question of time when in all cities we shall have our sewerage systems so built and maintained that no more offence will arise from them than we now expect in our bathrooms, water-closets, or kitchens.

When the sewage from the house gets into the sewer it consists of liquids and solids. At first nearly all of the matter which is liable to become offensive is in solid form. The sewage can

be strained when leaving a house, and the liquid on standing will rarely, if ever, become foul, because whatever little dissolved organic matter it may contain is oxidized by the large quantities of dissolved oxygen. As the sewage runs on the solid matter is more and more dissolved. After a mile or two, and generally at the outfalls, we find that about one-half of the waste organic matter is in solution. After flowing many miles a still larger part is dissolved.

It is important to realize this last fact, because the question of sewage disposal and treatment is very much dependent upon

FIG. 2.



Land bordering stream in Emscher district of Germany after improvement of stream channel.

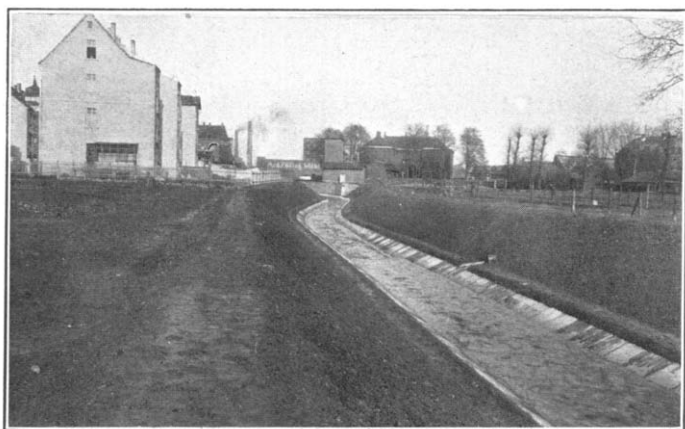
the physical condition of the sewage and whether there is much organic matter in solution or not.

The nuisance resulting from sewage is caused by the gradual exhaustion by this matter of the oxygen dissolved in the water. Organic matter as it decomposes first consumes oxygen, and when the latter is all gone an entire change takes place in the process, and hydrogen is then consumed. The first process we call oxidation, and it is entirely inoffensive. The other process we call putrefaction, and it is quite offensive. It is the condition which we have tried to prevent and can now prevent, knowing better than formerly the conditions under which it occurs.

Both oxidation and putrefaction are accomplished by the action of bacteria, which fact, as it concerns sewage, has been

known only for the last thirty or forty years. Since the discovery of bacterial action in converting dead organic into mineral matter we utilize two classes of bacteria for this purpose. One class is that of the aërobic bacteria which cause oxidation in the presence of oxygen; the other class is that of the anaërobic bacteria which live in the absence of oxygen. We are concerned, however, with two orders of anaërobic bacteria. One produces putrefactive or offensive conditions, the other does not. This fact has been applied to sewage treatment only within a few years. The latter kind are not putrefactive; they decompose the

FIG. 3.



Open sewer in Emscher district of Germany.

sewage without oxidation and yet do it in an entirely inoffensive way. Offensiveness is caused by the production of bad-smelling gases, of which the principal one is sulphuretted hydrogen. We can now prevent the development of sulphur bacteria, which produce this gas, by creating conditions which allow other bacteria to develop which produce marsh gas and carbon dioxide, neither of which is offensive. In the modern methods of sewage treatment we therefore endeavor to utilize the aërobic bacteria, and, of the anaërobic bacteria, chiefly those which produce marsh gas and carbon dioxide. This practice constitutes the greatest progress we have made in sewage treatment during the last few years.

We can now say that the entire process of sewage collection

and disposal, from start to finish, can be conducted inoffensively. We do not hesitate, as we did less than fifty years ago, to have a bathroom next to our bed- or living-room. The kitchen sink has less odors than formerly. Street sewers in many cities are no longer offensive.

We have not yet advanced as far as this in all street sewers, particularly in our country, because they are not all properly built nor cleaned. The suspended matter carried by the sewage is frequently retained either by deposit or by the roughness of the sewer lining or by eddies formed, where the flow is not

FIG. 4.

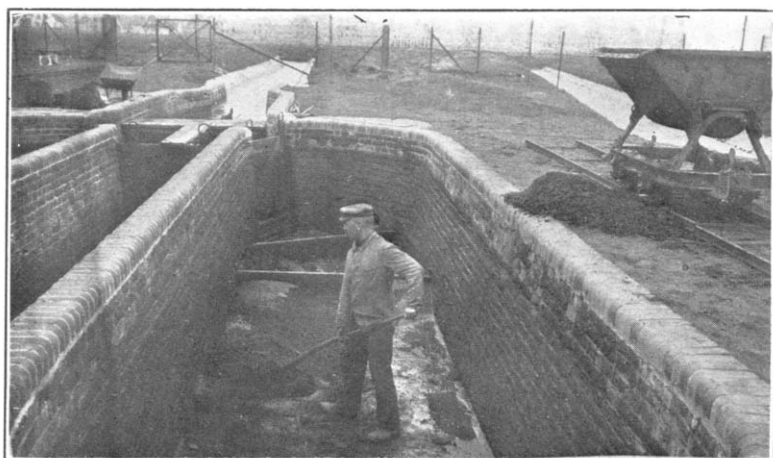


Sewage screen.

regular. In such cases where the retention is more than a day the dissolved oxygen becomes exhausted and putrefaction begins. To prevent this retention the sewage must have a steady and regular flow and rapid velocities, and the interior surface against which the sewage flows must be as smooth as practicable. All the progress in city sewerage that has been made in the last fifty years has been along these lines, so that as a result thereof the sewage not only is devoid of odors in the sewer but is delivered at the outfall with a remnant of dissolved oxygen and without putrefaction. In fairly good sized towns properly sewered and where the sewers are kept clean I have never observed at the outlet anything worse than a stale odor.

To get this result we should also have proper means of flushing the sewers, and also of well ventilating them so that they contain fresh air at all times. The oxygen of the air replenishes what is being exhausted by decomposing matter in the water and by the temporarily stranded matter along the sides. In Europe it is customary to flush the smaller sewers once or twice a week, the larger ones once or twice a month. In our country we do not yet flush the sewers as much as we should, and in most cities the flushing is left to the rain-water which enters occasionally. Rain-water flushing may prevent serious deposits, but it will not pre-

FIG. 5.



Grit chamber during cleaning.

vent temporary deposits which produce the objectionable odors. Small sewers are flushed by automatic flush tanks, which generally keep the smaller sewers in a better condition than the larger ones.

Flushing and ventilating not only prevent nuisance but also help to remove disease germs. Ventilation either tends to desiccate them or to scatter them by dilution to points where they are likely to perish. Flushing carries them away to the outfall. A large number of pathogenic bacteria connected with typhoid fever and diarrhoeal diseases are doubtless contained in sewers. Yet careful inquiries made in Europe and here have not resulted in the discovery of a single case of typhoid fever or

dysentery which could be directly traced to sewer air where sewers had been kept clean and fresh.

Sewers were first introduced for the purpose of carrying away rain-water. It was only a second thought to carry away also the waste water from the houses through the introduction of the so-called water-carriage system of sewage removal. The method of uniting the sewage and rain-water in the same channel has caused what is known as the combined system of sewerage.

In recent years it has frequently been found more economical to carry the dirty water or sewage away by a separate system of pipes, and the rain-water by another system. An economy results from the fact that in building up town areas we are generally more concerned at first in removing the dirty house water in pipes than the street water, and are willing to let the latter run off on the surface so long as no trouble is caused thereby. When the latter becomes objectionable, then it often happens that much shorter drains are required, because the rain-water is comparatively clean and can be discharged into any near brook, while the sewage must be carried farther away and perhaps must be treated. Sometimes a city has both systems, as, for instance, your own city of Philadelphia, where the combined system is used for the largest part, but where in the suburbs there are sections where the separate system has been preferred as being less expensive.

The separate system is generally preferred where the sewage must be treated in some way, and where it must be pumped. Should there be a large amount of rain-water mixed with the sewage, the treatment and the pumping become expensive.

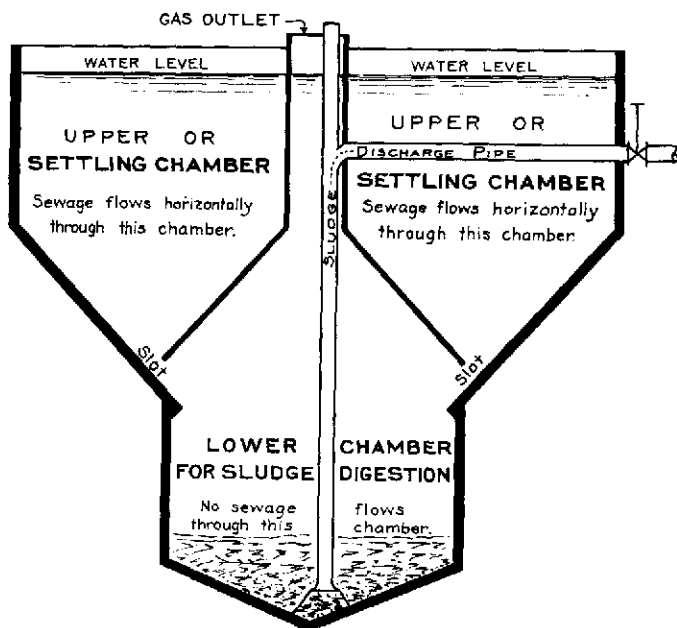
The question has frequently been raised as to whether or not the first flow of the rain-water, which generally carries manure and dust from the streets of a city and a great many bacteria deposited upon the street surface, should be carried into the sewers or kept separate in the storm-water drains. Dr. William Dunbar, of Hamburg, very carefully determined the condition of the street water at the beginning and at the end of a storm. He found that at the beginning the water was as foul as the sewage in the sewers. It is very desirable, therefore, if it can be practically done, that in the case of a separate system the first wash from the streets be taken into the sewers, so that it can be treated with the sewage. This expedient is followed in some

cities in Europe, and I think that in the future it will be followed more frequently in our country than heretofore.

Another most important part of a city sewerage system is the final disposal of the sewage. This should be accomplished in a manner so that it will not be harmful nor unpleasant. We should, therefore, soon determine upon a place of final discharge and a method of treatment to which it should be subjected.

Such a treatment may be complex. We have to consider

FIG. 6.



Vertical section through Imhoff tank at right angles to the direction of sewage flow.

disease germs on account of the danger to health, and the putrefying matter so far as a nuisance is concerned. We have further to distinguish between the most economical ways to prevent both of these troubles.

One part of the sewage is solid matter in suspension, and the other part is liquid matter together with fine suspended matter which will not readily settle out but remains in the liquid and causes it to be more or less turbid.

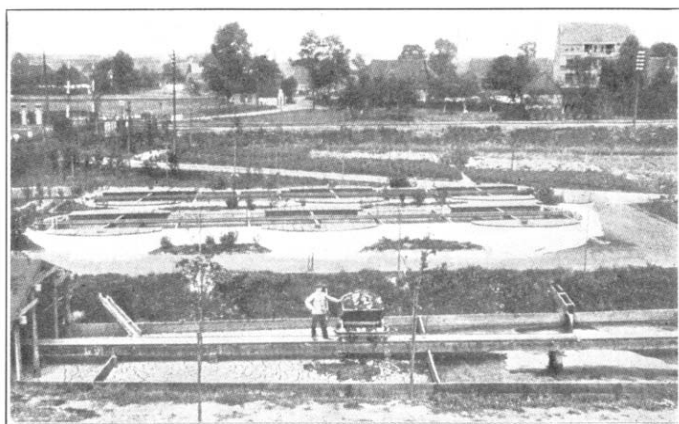
For the purpose of any subsequent treatment it is best to divide

the sewage into these two parts, because the treatment of the solids demands an entirely different process from that of the liquids.

The first thing to be done, therefore, when sewage is to receive any treatment, is to allow the suspended matter to be held back and separated from the liquid matter, so far as this is practicable.

The collection of the solid matter is accomplished by screens and by sedimentation. Many sewers, when they discharge into rivers, have screens near their outfalls causing the larger matters to be retained, taken out, and separately disposed of. Sometimes

FIG. 7.



Imhoff tanks and sludge-drying beds at Recklinghausen, Germany, population 30,000. Note proximity of dwellings.

this matter is pressed, squeezing out much of the liquid, and the remaining matter is either buried or burned.

Where screening is not adopted there is no way of keeping out the floating matter, except by retaining the sewage in large basins in which the floating matter gathers at the top and from where it can be removed at the surface. The retention of the sewage also causes the heavier matters to deposit.

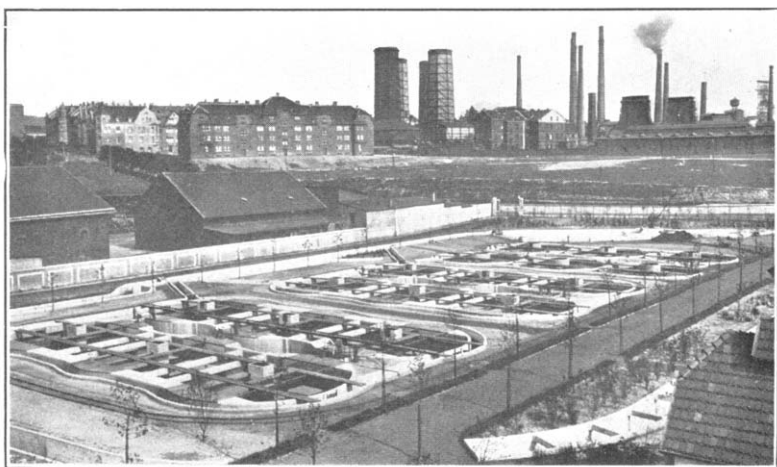
When the oxygen in the sewage is exhausted the deposited matter or sludge begins to putrefy, and the evolution of gases causes the entire mass of sewage and sludge to become putrescent or septic and emit strong odors. Many studies have been made

and perhaps a hundred patents have been taken out relating to the treatment of this sludge so that the results would be acceptable both from the standpoint of cost and nuisance.

The most common treatment has been to put the sludge upon fields, where it was dried, ploughed in, or covered with lime, etc. It has also been pressed, mixed with strong fertilizers or pulverized and used as manure.

In order to have a more complete removal of the suspended matter from the sewage, lime was added to the water. The resultant sludge, increased in quantity, was then usually dumped or pressed into solid cakes, for use as fertilizer.

FIG. 8.



Imhoff tanks at Essen, Germany, population 180,000. Note proximity of dwellings.

All the processes of treating sludge were, however, not very satisfactory because of the resulting stench. Yet they had to be recommended as the best known expedients, and on account of the offensive odor it was necessary to locate the treatment works far away from the inhabited parts of the cities. Only a few years ago the city of Baltimore bought a strip of land about 1000 feet wide outside of its works in order to obviate any nuisance.

About eight years ago a German engineer erected some experimental plants at Essen, modelled after the experience gained at the sewage fields near Hampton, England, where Dr. Travis had been making some promising studies. The Essen experi-

ments, undertaken by Dr. Imhoff, resulted in the discovery of a means of securing a collection and a treatment of the sewage sludge that was not offensive.

This process is now known as that of the Imhoff tank treatment. Varying the process from that used at Hampton, by preventing any circulation in that part of the tank where the sludge is deposited and where it ferments, Dr. Imhoff has succeeded in establishing a decomposition confined to the biological action of such classes of bacteria which develop substantially only marsh gas and carbon dioxide gas, neither of which has an odor.

It is known that if no fresh sewage flows over decomposing

FIG. 9.



Sludge dump for dry sludge after removal from drying beds.

sludge, to supply it with miscellaneous sewage bacteria, the controlling bacteria in the sludge are confined substantially to but two classes; namely, those producing the two inoffensive gases just mentioned.

The Imhoff tank consists of practically two tanks, one over the other. Through the upper one the sewage flows with a velocity reduced so much that its suspended matter will settle. It requires a passage through the tank of from $1\frac{1}{2}$ to $2\frac{1}{2}$ hours. This matter is allowed to slip through a slot into a lower chamber in such a way that no possibility exists for any solid matters to rise and again mix with the fresh sewage passing by in the upper tank. There are special shafts provided for the ascent of

any fat or light matter, which should rise with gas bubbles from the lower chamber, and to form a scum in the shaft, to be removed when necessary. This scum is usually small in amount and could be readily removed if it becomes excessive. It has no objectionable odor in any of the existing plants (see Fig. 6).

The accumulating sludge in the lower tank, when it has become ripe and the existing sulphur bacteria have been practically exterminated, has no odor. This can be found by extracting some of it from different depths. According to the character of the sewage, it requires about three to five months to be de-

FIG. 10.



Dried sludge from Imhoff tanks sold to farmers for fertilizer.

composed sufficiently so that it will not become putrescent when again exposed to the air. The decomposed sludge is withdrawn from the bottom of the tank automatically, and, being deprived of its slimy, putrescible matter, it is friable and porous, looking very much like garden soil, to which it is very similar. The latter has been formed from the leaves and branches without putrefaction and with the evolution of the same inoffensive gases, such as marsh gas and carbon dioxide, which produces the decomposition in the Imhoff tanks. It rapidly drains out its superfluous water, and dries in well-drained beds within a week sufficiently to be spaded and removed.

There are over 100 plants in operation in Germany and this

country, and reports indicate that in none of them which are properly operated does the sludge have an offensive odor. In our country the largest plant is in Atlanta, Ga., and there is one at Holmesburg, Philadelphia, below the Torresdale Water Filtration Plant.

It is gratifying, therefore, that we have now a means of treating the sludge so that it will not be offensive, and we believe that by the same process the disease germs contained in the sludge will have perished by the time it is extracted and dried.

Before sewage reaches the tanks it is advisable, particularly where the sewage contains street wash, to take out any gravel or sand (*i.e.*, grit). This deposition is secured in a special small chamber where the velocity of the sewage is reduced to about 12 inches in a second. This reduction will cause the grit to deposit and the rest of the suspended matter, which contains the foul matter, to pass on to the settling chambers. In these tanks the velocity is much more reduced, generally to about one-tenth inch per second. This comparatively quiescent state causes the deposition of practically all of the foul suspended matter which forms the bulk of the sludge. We use the term "settleable" matter because there is not deposited the fine suspended matter which may cause putrefaction and which must be treated together with the dissolved organic matter.

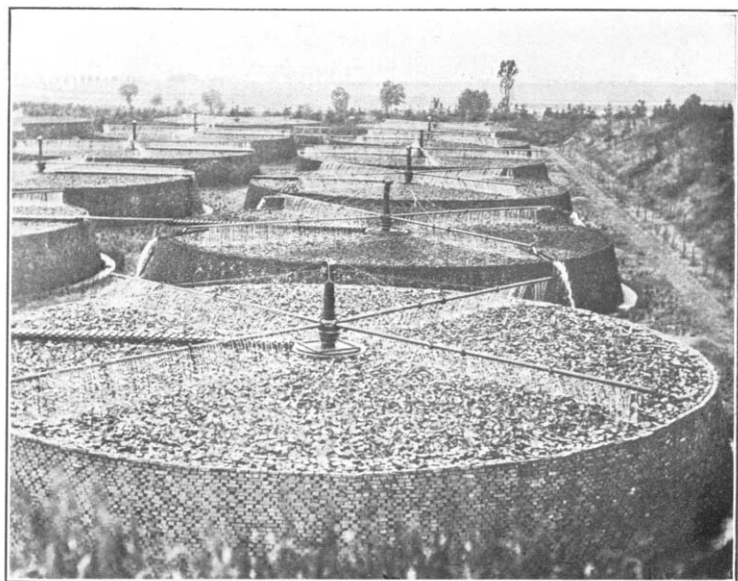
In order to increase the quantity of settleable sludge, experience has shown that by adding a precipitant to the sewage a large percentage of this fine matter and even some of the dissolved matter can be coagulated and also settle into the lower tank. In the latter case the effluent sewage is much clearer, but the size of the lower tank must be correspondingly increased on account of the added sludge and precipitant. It is, of course, a question to be determined in each case as to whether or not it is necessary or wise to add a chemical precipitant.

You have all heard of the septic tank. This was first used under this name in the city of Exeter, England, and it was found that in a single basin where the sewage was retained at least 8 hours most of the suspended matter was deposited on the bottom and underwent putrefaction. It was allowed to remain in the tank until fairly well rotted out, which generally took at least a year.

This was a process of putrefaction which produced chiefly

sulphuretted hydrogen, and, therefore, not only the liquid but also the putrefying sludge sent up bubbles of offensive gas. Notwithstanding this fact, septic tanks have been very extensively used on account of their relative economy as compared to other processes, and it was even heralded as the long-expected final solution of the sludge question. A good deal of the sludge disappeared, so that in a few cases but 10 per cent. of the original quantity was left; in most cases the record is from 25 to 50

FIG. 11.



Revolving sprinkling filters at Wilmersdorf, Germany.

per cent. The reduction in the quantity of sludge handling was the chief attraction of this process.

On account of the odor septic tanks were isolated and kept far away from inhabited sections of a city. In the city of Saratoga, N. Y., there is a well-devised system of sewers and of sewage treatment, with possibly the best instalment of a septic tank in this country. The odor from the tank, however, is very strong. In one of the suburbs of Berlin (namely, Wilmersdorf) septic tanks are also used with very similar results. The odor from the tanks was found to be perceptible over a mile away.

We cannot place much reliance on the figures given as to the reduction of the sludge, because so much depends upon the amount of water contained therein. If we have originally 95 per cent. of water in the sludge and reduce the same to 90 per cent. we have diminished the quantity of sludge practically one-half. This fact makes it necessary, when comparing quantities of sludge, to compare also their percentages of water.

The sludge of the septic tank is of a different character from that of the Imhoff tank. It is not as thoroughly decomposed, generally retains a large amount of fine and slimy matter with a

FIG. 12.



Sprinkling filter at Atlanta, Ga.

large amount of water, and after withdrawal does not become spadeable sometimes for several months.

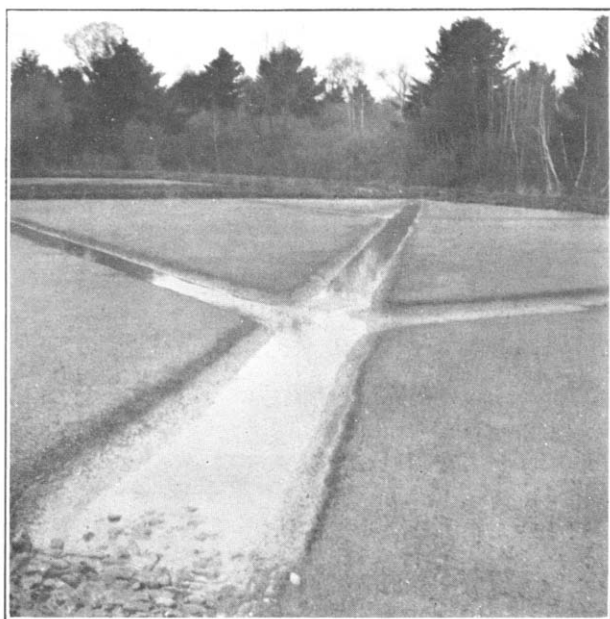
The last subject to be mentioned is the treatment of the liquids after they have been freed from the settleable suspended matter by passing through the tanks. There are still generally left a substantial amount of fine suspended particles and a large amount of dissolved organic matter. The oxygen contained in the water is rapidly extracted.

If the sewage is discharged into a running stream, and if there is enough oxygen in it to oxidize its organic matter, a decomposition of the organic matter will take place in the water. This method of oxidation in running streams is a practicable and legitimate means of oxidizing liquid sewage. It is just as rational

as an oxidation on land. We are, therefore, not justified in seeking the entire exclusion of all sewage from rivers where they can be utilized for oxidation, both economically and without offence.

We must not forget, however, that nuisance is not the only question to be considered. We must prevent also all objection due to the injury of fish and shell fish and to a possible danger from bathing, and in no case can such water, which has received sewage, be used for drinking purposes, unless it is first purified.

FIG. 13.



Intermittent sand filter for sewage at Stockbridge, Mass., showing distributing channels.

We must also not forget that river water may be polluted as much from the natural land washings and city washings during a rain storm as from liquid sewage.

Nearly all of the large cities of the world dispose of their sewage by river dilution. In some cases this process is not properly carried out: the solid matter of sewage is admitted in too large proportions, and sludge remains in the rivers by sedimentation. Sometimes, also, more liquid sewage is discharged than can be properly oxidized by the water. Yet, after the floating

matter and sludge have been removed, before sewage is discharged into a river, and if the river contains enough oxygen, there can be no objection to utilizing nature's means of purifying organic waste matter in this very economical way.

If there is no river, or if the river is not large enough to promptly dilute the amount of sewage in question, and if there is trouble anticipated regarding fish life, then it is necessary to purify some and often all of the sewage on land.

There are many processes of such purification on land which have been tried, particularly in England. It will not be necessary to mention them all, because most of them have been abandoned. To-day there are really but two processes in use: a treatment by coarse-grained filters and a treatment by sand filtration.

The coarse-grained filters are built of material from the size of a walnut to the size of a fist, and of depths varying from 5 to 10 feet. The sewage is delivered upon the top in various ways. In all cases it must be sprinkled either from stationary or movable jets, because otherwise the large pores of the bed would let it rapidly run through. The sewage percolates through the bed by slowly flowing on the surfaces of the grains from one to the other until it reaches the bottom. Upon these grains or stones is a slimy coating which harbors myriads of bacteria. These take from the passing sewage the organic matter which is in solution and convert it into inoffensive and inert matter. While the water may be quite putrescible when sprinkled on, it leaves the filter, if this is properly devised, without putrescibility; *i.e.*, in a condition so that it will not become foul.

The process of sand filtration is virtually the same as just described. The grains are much smaller and, therefore, the liquid can flow directly upon the bed for distribution instead of being sprinkled. The speed of percolation is much slower and, therefore, the purification is greater. Bacteria do the converting in both cases.

Both coarse- and fine-grained beds are underdrained to allow of a free discharge of the effluent, and both should have a free circulation of air between the grains to supply the oxygen which is necessary to convert organic matter.

(A large number of lantern slides were then shown upon a screen and explained. A few of them are here reproduced with brief explanations.)