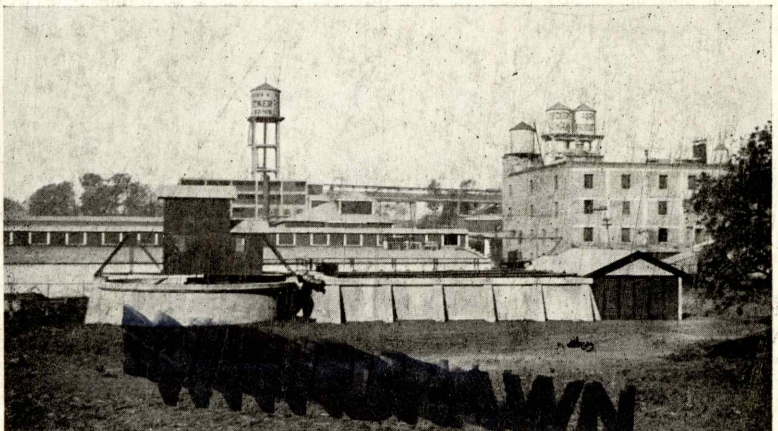
IOWA STATE COLLEGE
OF AGRICULTURE AND MECHANIC ARTS
OFFICIAL PUBLICATION

Vol. XXI | May 14, 1923 | No. 41

SEWAGE TREATMENT

Papers presented at the Fourth Conference on Sewage Treatment, Ames, Iowa, October 11, 12 and 13, 1922.



BULLETIN 57

ENGINEERING EXTENSION DEPARTMENT

IOWA STATE COLLEGE

AMES, IOWA

Published weekly by Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa. Entered as Second-class matter, and accepted for mailing at special rate of postage provided for in Section 429, P. L. & R., Act August 24, 1912, authorized April 12, 1920.

LIST OF CONTENTS

1.—The Relation of the State Board of Health to Iowa Sewage-Treatment Plants
By Hans V. Pedersen.............................Page 5

2.—The Relationship of Sewage Disposal to Water Purification
By J. J. Hinman.................................Page 7

3.—Sewage Treatment and Its Relation to Public Health
By Earle L. Waterman............................Page 10

4.—Methods of Sewage Disposal
By Rolland S. Wallis............................Page 15

5.—The Role of Bacteria in Sewage Purification
By Max Levine...................................Page 19

6.—The Activated-Sludge Process for Sewage Disposal
By Edward Bartow................................Page 25

Conferences on sewage treatment are held annually at Iowa State College under the auspices of the Engineering Extension Department. These meetings are of practical value to municipal officials and others directly or indirectly responsible for the operation of sewage-treatment plants.

This publication contains six papers of a general character which were presented at the 1922 conference. The balance of the program consisted of practical talks on treatment-plant construction and operation (illustrated by lantern slides and blackboard sketches), demonstrations and discussions of the problems encountered in the care and operation of such plants. Considerable time was devoted to the consideration of the individual problems of those in attendance.

THE RELATION OF THE STATE BOARD OF HEALTH TO IOWA SEWAGE-TREATMENT PLANTS

By Hans V. Pedersen, Sanitary and Civil Engineer, Iowa State Board of Health, Des Moines, Iowa

There is no very clear conception general over the state as to just what relation the Iowa State Board of Health has to the sewage-treatment plants of the state. Some folks seem to have the idea that the State Board of Health is a sort of policeman going around the state with a big stick looking for opportunities to pounce down on someone and make them do something unnecessary. They seem to have a feeling of resentment even when they are not quite certain what they are talking about.

Some folks can see no relation at all between the State Board of Health and the sewage-treatment plants of the state, and believe that any work done along this line is money spent foolishly. Others have the idea that the State Board of Health is all powerful and something to be afraid of and avoided, while still others look at the State Board of Health as a big joke. In a few words, I wish to set forth the true relation between the State Board of Health and the sewage-treatment plants of the state.

The present code of Iowa states that it is the duty of the State Board of Health to make such rules, regulations and sanitary investigations as it may from time to time find necessary for the preservation and improvement of the public health. Now, if it is the duty of the State Board of Health to preserve and improve the health of the public, the next thing is to point out just how or why a sewage treatment plant has anything to do with the health of the public.

It is conceded that the public water supply of a community is one of the most important factors in public health. Someone has said that more sickness and deaths during the history of the world have been caused by impure water supplies than from any other cause. Whether or not this be true, it is a fact that there is much sickness caused by impure water.

One of the chief causes of impure or unsafe water supplies is due to the fact that surface pollution is in some manner finding its way into the water. If it were not for this so-called surface pollution, most of our water supplies would be safe; and if it were not for the waste matter of the human race there would be little surface pollution. Everywhere man goes he produces more or less waste material; and everything of an organic nature that is thrown out on the ground, hauled to dumps or discharged into streams tends to decay, to become foul and to afford a rendezvous for many kinds of bacteria. Of the various kinds of waste matter human excreta is the most dangerous, as it naturally carries many intestinal disease germs. If surface water is contaminated by seepage from privies or cesspools and that contaminated surface water finds its way into a water supply, then such a water supply is unsafe due to the fact that it may at any time contain dangerous disease germs.

The one great sanitary problem, then, is how to dispose of all dangerous waste material in such a way as to reduce the possibility that rats and flies and other agencies may spread the disease germs which it contains, and, insofar as is possible, to allow no chance of its getting into the public water supply. How best to dispose properly of its human waste material is a problem that every community must solve. The waste material commonly known as house sewage is disposed of most efficiently by the use of the modern sewer system and the sewage-treatment plant. Here we take all the waste water from the kitchen sink, the bath tub, the lavatory and the stool and discharge it through a system of pipes to a place outside the town, where we proceed to reduce the sewage solids to a non-putrescible state. The modern sewer system and sewage-treatment plant are most important factors in removing community wastes. A good sewerage system is regarded by the State Board of Health as being a public utility most beneficial to the public health. That is why the State Board wants to see as many sewage-treatment plants in the state as there are cities and towns. The better we succeed in disposing properly of all the waste material of the state, the more safe our water supplies will be. The more we neglect this important phase of community living, the more unsafe our water supplies will become and the greater our risk of contracting waterborne diseases.

But, important as it is to have a modern sewage-treatment plant installed, it is not enough for a community just to spend their good money in building one. After the plant is constructed it is just as important to see that it properly does the work for which it was built. No sewage-treatment plant will work long if neglected and, as it is very important to have a plant working satisfactorily all the time, the State Board of Health wishes to learn from time to time just how each and every plant is operating. If the Board is to be a real guardian of the public health, it is its duty to insist that all plants be kept working properly. It is for this reason that the engineer of the Board is instructed, insofar as is possible, to keep in touch with all the plants and to offer assistance to any community that is having trouble in getting their plant to do the work expected of it.

The State Board does not wish to force its services on a community. It merely wishes to instruct the men, who are responsible for the plant, how to operate it, and to urge hasty action whenever a plant is found that is not working properly. In fact, the Board only wants to do its duty in protecting the health of the community by urging proper disposal of the wastes that tend to interfere with its health and welfare.

You can readily see, however, that it would not be a good policy to wait until a plant has become entirely useless before assistance is called in. How much better would it be to catch the difficulties in time to make the necessary corrections, and then to perform the certain duties necessary to good operation before the plant is put entirely out of commission. It is therefore thought advisable that regular inspections be made at least once a year to see how each plant is working, and to urge that certain work be done at the right time. This, of course, is an ideal arrangement but so far it has been impossible to carry it out because of lack of assistance in the State Board of Health. Because of this lack, and because of the impossibility of getting in touch with all the plants, these sewage-treatment conferences have been held yearly for the purpose of instructing anyone interested in keeping up their community sewage-treatment plants. During this conference many good things will be brought out, and you are all urged to ask questions regardless of how trivial they may seem—and to keep asking questions until you have found out just what you want to know. After taking in this conference, you are urged to go home and put some of the things you have learned into practice. Then, if you get into difficulty, remember that the State Board of Health is a friend ready to come out and help you if requested to do so.

We would like very much to be able to come around once a year to see how things are going and to offer advice, but as that is impossible at this time we want to offer our services to all those who request it. The State Board of Health wants you to go home and to tell your neighbors and friends in other towns that it is not trying to force anyone to do anything unnecessary, but that it is sincerely trying to protect the health of the people of the state by urging the proper disposal of all waste matter—that it urges proper installation and maintenance of sewage-treatment plants because it realizes that the more plants we have in the state, and the better work they do—the more safe our water supplies will be and the less of preventable diseases we will have to deal with.

THE RELATIONSHIP OF SEWAGE DISPOSAL TO WATER PURIFICATION

By Professor J. J. Hinman, Jr., Chief of Water Laboratory Division, State Board of Health, Iowa City, Iowa

Practically all water supplies, public or private, that are analyzed and found unsafe, are so reported because they are found to have received contamination by sewage, or because they are found to be open to the danger of receiving sewage contamination. Those supplies that are unsafe because of any mineral substances that are found in them are distinctly in the minority.

Now, sewage-like matters may contain a great variety of substances, but the material which concerns us most is the human bowel discharges which it carries. And the reason we are concerned about this material is simply because it is very likely to carry living organisms which have come from cases of disease, or from persons who have recovered from disease. Most of the living organisms which come from the bowels (chiefly bacteria) are relatively harmless, but with them may come some which are definitely known to be the cause of disease. These are the ones which come from persons who are sick with the disease, or from those who have gotten well but continue to give off—either continuously or at intervals—the specific living organisms that cause the trouble.

Organisms that are to be especially feared are the typhoid bacillus and its near relatives—the paratyphoid bacilli, the spirillum of asiatic cholera, the dysentery bacilli, and various animal parasites, either in the free form or as cysts or eggs. In this country, our natural isolation and our excellent marine quarantine protect us in a great measure from asiatic cholera. Many varieties of parasites, including the dysentery organisms, may be brought in by travelers or by immigrants. Typhoid fevers, however, remain our chief concern, because the disease is so widely disseminated, and because we have a large number of individuals who continue to give off the organisms which cause the disease for many years after having recovered from the clinical manifestations. There are also some ill-defined diarrheas which seem to be associated with sewage contamination of water supplies.

The shallow private well is frequently contaminated by sewage-like material. Usually the obvious source is a nearby privy vault or cesspool. The contamination commonly enters near the top of the well, but sometimes, especially in the deeper wells, the sewage-like matters are carried into channels in the rock through which they may be transported for considerable distances.

Sometimes sewage is disposed of by running it into sink-holes or underground passages in the rock, and one never knows when it will show up again in some well. The practice is a most dangerous one.

The most satisfactory means of improving the quality of water in wells which have been found unsafe is to make the top and the upper part of the casing water-tight to keep out surface drainage; and, more important yet, to remove the sources of contamination.

In any community, the installation of sewers is an effective means of removing the contaminating materials, for once a sewer is installed, the use of the old-fashioned privy becomes more rare and should ultimately cease. But, while this is a great help to the community, it frequently means simply the shifting of the burden from the individual citizens to the property owners through whose land the sewage-laden stream passes, and to the other towns farther down the stream. Nuisances may be caused—suits commenced; and endless difficulties follow.

However, the duty which the community up-stream owes to the people and communities down-stream is fairly definitely recognized, and it is understood that the easily-demonstrated nuisance must be cleaned up. It is the desire to prevent nuisances and the wish to avoid lawsuits, consequent upon nuisances, that are usually the motivating impulses behind the installation of any plant to treat sewage so as to partially purify it.

While less evident than the local nuisances just outside the city limits, the water-supply problems of towns situated farther down the water-shed ought to be considered.

There is a great deal of popular misinformation about the self-purification of streams. Many people believe that all streams are in a state of purity seven miles below the outlet of a sewer. Now, it is true that streams do purify themselves to a certain extent, due to the effect of sedimentation, the action of oxygen and countless saprohytic bacteria, the disinfecting power of the sunlight and so on. Agitation in shallows, large diluting volumes, rapidity of current, and a number of other factors determine how far the sewage may easily be detected. But the streams continuously receive other pollution, and certainly no stream in Iowa is safe to drink from unless the water is treated in some way so as to destroy or remove the greater number of the bacteria which it contains.

It is not economical to treat sewage so as to produce a product which is purer than the normal for the water into which it is discharged. Neither is it necessary to carry the refinement of the process beyond the point at which the dilution and the natural purification of the effluent in the stream would leave the water received at the waterworks intake no worse than if only the usual runoff from the land were all that was to be considered. But the exact point at which the treatment is just ample is not a fixed point—nor is it easy to locate.

General practice aims at the production of a sewage effluent which is non-putresible or stable—that is, one which will not cause odors and discoloration. It is easily conceivable that such a standard might not under all cases be satisfactory insofar as the protection of the water supply is concerned, since bacterial reduction is not by any means complete. It is not the smell which causes the greatest concern to the operators of the water plant, although the consumers would, of course, object strenuously to any trace of sewage odor, and rightly, too. The odors may accompany large numbers of bacteria, and these are the things which must be taken care of by the water plant. The bacteria may and do persist in large numbers even after all odor has disappeared.

The point to consider is, will the sewage effluent put too great a demand upon the water-purification plant? Will the load be more than the plant can reasonably be expected to bear?

The International Joint Commission for the Studying of the Pollution of Boundary Waters between the United States and Canada found that a reasonable load for a water-filtration plant was exceeded when more than 50 per cent of the 1/10 c.c. samples of raw water, taken over the period of a year, showed the presence of the bacterium coli group of organisms. Now, there are water plants that have quite successfully treated waters richer in bacterium coli than the standard would allow, i. e., 500 per c.c. Indeed, some treat waters which are about 10 or 12 times as heavy as is stated.

When there is no redress, such water must be treated—at least until a better water can be found. However, the apparatus does not always function properly, the operating conditions change with weather and the stream, and allowance must be made for errors and for breakage. There are plenty of cases on record where insufficient treatment for a comparatively short period of time was followed by serious consequences.

In Iowa most of the streams which receive the direct effluents of sewage plants are small, and the greatest problem is to get the effluent to a stream of sufficient size for adequate dilution without causing nuisance on the way. For this purpose alone, non-putrescibility of the effluent is usually sufficient. At the present time most of the communities purifying river water which has received sewage take the water from streams of some size. The dilution helps them by diminishing the filter load. However, none of the plants have failed to show occasional periods of unsatisfactory service. At such times the actual danger to the community was often a serious matter.

None of our small inland streams should receive any considerable volume of untreated sewage if it is to be used afterwards as a source of water supply. All sewage discharged into the streams from which water supplies are obtained ought to be treated, so as to let the water of the stream at the intake of the water plant come close to the standard set by the International Joint Commission. The fact that the plant can usually take care of the pollution is not sufficient, as it is the exceptional cases which are usually connected with serious sequelae.

SEWAGE TREATMENT AND ITS RELATION TO PUBLIC HEALTH

By Earle L. Waterman, Associate Professor of Sanitary Engineering, State University of Iowa

It is the purpose of this paper to define to some degree and to emphasize the importance of sewage treatment from a public health standpoint. Many people have the idea that a sewage-treatment plant is built for the sole purpose of treating the sewage so that it will not cause a nuisance. This is not surprising, since almost anyone can recognize a nuisance, while it requires a trained sanitarian with adequate laboratory facilities to determine the presence of material dangerous to public health. As a matter of fact, a sewage-treatment plant has two functions, and one hesitates in naming them in the order of their importance to the general welfare. As usually stated, they are—to treat the sewage in such a way that it will not cause a nuisance when finally discharged into some natural drainage channel, and to eliminate or destroy the disease germs which may be present in the untreated sewage. Since the methods by which these results are obtained are more or less the same, it may be well to consider first what is meant by the terms involved in any discussion of the question and to review briefly the history of the art of sewage treatment, noting particularly the developments which have brought it to its present stage.

Sewage is the waste matter of a municipality. In a general way it

is the water which has been used for various purposes and thrown away. It is the water which has been distributed throughout the municipality to meet the demands of life and industry. It consists of approximately 998 parts of water, one part organic and one part mineral matter in every 1000 parts. A very large percentage of the water used for domestic, commercial, and public purposes is eventually discharged into the sewers.

These waste waters have a very different character from that which they had before they were used in the ways mentioned. From the household they have received discharges from the human body, grease, soap and mineral matter from sinks, lavatories and bath tubs. The waste waters from industrial establishments are as varied in character as the industries which use water in their processes. Laundries, bakeries, creameries, milk distributing plants, hotels, restaurants, dye works, clothes-cleaning establishments and garages are found in nearly every town or city, and each contributes waste waters of different kinds. There are also many other kinds of industrial wastes which are frequently discharged into the public sewers; but these are not as common as those mentioned above, and are often of such a character as to necessitate special treatment before they can be turned into the sewerage system.

The waste waters from public buildings such as schools, hospitals, comfort stations and public halls may differ somewhat from domestic sewage. The sewage from hospitals will be quite different from that which comes from other sources, for in addition to the material found in domestic sewage it will probably carry disinfecting agents and material used in the care and treatment of hospital patients.

Thus we see that the sewage of a municipality may vary widely in character, coming as it does from so many different sources. Although the amount of matter which has been added to the water (during the time in which it was passing from the water-supply system to the sewer) is relatively small, this added material converts pure water into sewage and makes sewage treatment necessary.

The disposal of sewage in such a manner that it will not cause a nuisance or be capable of causing harm is an art which has been gradually developing since the middle of the nineteenth century. In England the development of public water-supply systems and the increasing use of water closets made it necessary to devise some method of disposing of the waste waters. Sewers provided a means of removing the waste waters from buildings, and the rivers seemed the logical places into which the sewage should be emptied.

As the volume of sewage increased and the ratio of the volume of water in the rivers to the volume of sewage became less, conditions in the streams and along their banks grew worse and worse. Instead of being assets to community life, the rivers became liabilities. The conditions offended both the senses of sight and smell and were logically called nuisances. Some action was necessary.

Since these problems arose before the germ theory of disease was established (1876), the real importance of sewage disposal as a factor in the preservation of health was not recognized. That there was some relation between the disposal of sewage and the spread of disease was thought probable, but could not be proven. It was thought that the odors given off by decaying organic matter were a factor in spreading disease. This belief, of course, was partially responsible for the demand that nuisances caused by sewage be abated.

Various methods, such as sewage farming, land treatment, settling basins and chemical precipitation were used in England for the treatment of sewage before it was discharged into the streams. These methods were successful in reducing some of the nuisance, but were not entirely satisfactory.

The gradual development of knowledge concerning bacteria (particularly their part in changing harmful organic matter into harmless mineral forms) revolutionized the art of sewage treatment. While some of the processes that had been used for treating sewage actually depended on bacterial action for the results obtained, this fact was not known when the processes were developed. Treatment plants had been in operation for at least fifteen years before Pasteur brought out the results of his experiments in bacteriology, the work which really founded the science and gave the world its first definite knowledge of the function of bacteria.

The Massachusetts State Board of Health was the pioneer agency in developing the biological principles which form the basis of the art of sewage treatment as we know it today. Since 1888 the experiments which have been made at the Lawrence, Mass., station have given to engineers a sound basis for the design and successful operation of sewage-treatment plants. The method of intermittent sand-filtration which is used in many Iowa sewage-treatment plants was first developed at the Lawrence station, and was the method adopted for some of the earliest sewage-treatment plants in Massachusetts.

It is not the purpose of this paper to describe the various methods of sewage treatment. The references to the history of the development of the art have been made rather to call attention to the fact that the problem of sewage disposal first received attention because of the nuisances created by discharging relatively large amounts of sewage into natural waterways. Also, to point out that the relation of sewage treatment to public health was not recognized until after the germ theory of disease was established in the early eighties of the last century. The discovery of the fact that specific communicable diseases were caused by specific bacteria shed new light on the problem of sewage disposal.

Briefly stated the germ theory of disease is that the germ of a disease must be taken into the body from the outside before the disease can develop in the body. These germs, or bacteria, do not grow outside of the human body, as a rule. They may live for some time outside of the body, but they do not usually increase in numbers. So it may be said that the germ or bacteria which causes a disease in one person was discharged from the body of another person. Bacteria do not have the power of motion in themselves (that is, they do not travel from one point to another), so they must be carried in or on some medium which does move. In the so-called water-borne diseases like typhoid fever, the bacteria are frequently carried in the water.

The work of disease bacteria is done in cycles. To illustrate, let us suppose that a person drinks some polluted water in which there are typhoid bacilli and that these bacilli develop rapidly in the body. The person then has a case of typhoid fever. During the progress of the disease many of the typhoid bacilli leave the body in the discharges from the kidneys and intestines. Perhaps these discharges are thrown out on to the ground, into a privy, a cess-pool or the sewer. They are carried along with the waste water, and eventually mingle with a larger amount of surface or underground water. The typhoid bacilli do not find conditions outside of the body favorable to their growth. The result is that they die—some very quickly and others after longer exposure to unfavorable conditions. It is possible that some of them may find their way by means of food or water back to a human body. If this occurs, the cycle is complete. The cycle consists of development of the bacteria in one human body, discharge from the body, a period outside the body during which the bacterium either dies or is transmitted to another body—in which event the cycle starts again.

One of the principal functions of public health work is to break cycles of this kind. An important phase of the work of officials who are charged with the duties of protecting the health of the public consists of erecting and maintaining barriers which prevent the spreading of communicable disease. We have just pointed out the fact that the bacteria which are the cause of typhoid fever are discharged from the body in the feces and urine, and for this reason are very likely to be present in the sewage of a municipality.

Perhaps some of you are thinking that since there are no cases of typhoid fever in your community that typhoid bacteria are not present in the sewage and, further, that when there is a case of typhoid fever that the physicians and nurses take great care to disinfect the discharges from the patient before they are emptied into the sewer. Unfortunately, the absence of recognized cases of typhoid fever in a community does not necessarily mean that there are no typhoid organisms being discharged into the sewers. There are frequently cases of the disease which are not immediately recognized as such, and others which perhaps are never diagnosed as typhoid fever. The bacteria which come from these atypical or missed cases have just as much power for further harm as those from recognized cases.

There are also the typhoid carriers to be taken into account in considering the possibility of the presence of typhoid organisms in the sewage. These are people who have had the disease (although there are instances on record of typhoid carriers who have never had a clinical case of typhoid fever) who continue to discharge typhoid fever organisms from their bodies for some time—frequently for years. Usually the discharge of organisms ceases within a few weeks after the patient recovers. It has been estimated that 4 per cent of all recovered cases of typhoid fever continue to discharge typhoid bacilli for some time after convalescence. This means that there is always a possibility that sewage may be a transmitting agent for the germs of typhoid fever, as well as for other intestinal diseases.

The removal of the waste waters of a community through a public sewerage system greatly reduces the danger of the spread of certain diseases (particularly those of the intestinal type) within the community itself. The installation of sewers very often results in a lessening of the typhoid fever incidence. But instead of having many possible sources of infection scattered over the community, with a sewerage system these sources are largely concentrated and the infectious material eventually comes to one point—the sewer outlet or the sewage-treatment plant.

From a public health standpoint, a public sewerage system which is well planned and well built is one of the most important improvements which any municipality can install. It furnishes a means for the removal of waste waters from the individual homes and makes possible the elimination of probable sources of contamination, such as outside privies and leaching cesspools. Lack of accurate records in regard to the amount of disease and the number of resultant deaths in most Iowa cities and towns makes it impossible to present figures which show actual improvement in public-health conditions as a result of improvements in sewerage methods. However, there are fairly accurate records of this kind in other localities which prove the contention that a public sewerage system is a health asset to a municipality.

But, after collecting the sewage of the city and thus removing dangerous material from the various homes—what are we going to do with it? If it was dangerous to our own community, certainly it is still capable of causing harm to others unless it is disposed of in such a manner that its harmful quality is destroyed. It is not right that a city or town collect its filth and then dump it in the city's back yard. That back yard is very likely to be close to some other municipality's front yard!

Over forty years ago the Massachusetts State Board of Health (after studying problems of this kind) decided "That the principle should be established that each community should dispose of its own filth without allowing it to be a source of offense to others." This is the general principle recognized today. The primary object to be attained by sewage treatment is to produce an effluent which will not cause offensive conditions or be a menace to health. In designing a sewage-treatment plant engineers have three objects in mind:

1. To prevent the waters into which sewage is discharged from becoming offensive to the eye because of floating matter.
2. To prevent such waters from becoming malodorous.
3. To prevent the introduction into the water of germs of disease.

After the plants have been properly designed and built it must be recognized that the responsibility for accomplishing these objects is given to the plant operators. The treatment plant is merely the machine for doing certain things. It is not automatic. It will not operate at its best efficiency without intelligent care. Intelligent care is to the sewage-treatment plant what oil is to a machine. Even though the machine is almost automatic it must have oil if it is to continue

operating satisfactorily. Just so, a sewage-treatment plant must have attention in order that it may produce satisfactory results.

In this discussion of the subject of the Sewage-Treatment Plants and Their Relation to Public Health, I have tried to bring out the following points:

1. The art of sewage treatment was first developed as a result of the nuisances caused by the discharge of untreated sewage into streams.
2. The relation of sewage disposal to public health was not fully recognized until after the discovery of disease bacteria and the germ theory of disease.
3. The fact that sewage probably contains disease organisms most of the time.
4. The importance of sewerage as a protection to public health, and the necessity of considering the health of other communities when disposing of sewage.
5. That one of the objects to be attained by a sewage-treatment plant is to prevent the introduction of disease germs into the water into which the effluent from the plant is to be discharged.
6. That the responsibility for attaining this object and the others for which the sewage-treatment plant is designed falls on the plant operator.

METHODS OF SEWAGE DISPOSAL

By Rolland S. Wallis, Municipal Engineer, Engineering Extension Department, Iowa State College

The purpose of this paper is to present a very brief but a more or less connected discussion of the various methods or processes that may be used in disposing of sewage. While some of the methods to be mentioned are not commonly employed in the relatively small plants in which most of you are primarily interested, it has been thought worth while to try to give you a sort of a summary of the various processes that are available for use under favorable conditions. The processes and the types of apparatus in which you are especially interested will be taken up in detail in the discussions to follow.

Composition of sewage. Sewage has been defined as "the water supply of a town or city after it has been used." Most of the water supply of each properly-sewered district eventually reaches the sewers fouled with various substances, such as soap, vegetable and animal matter, urine and feces. Sometimes these are supplemented by street washings and industrial wastes of various sorts.

While this mineral and organic matter contained in sewage amounts ordinarily to only about one part or volume in one thousand parts, it is this matter that causes us to cast about for some satisfactory way of disposing of sewage. Left to itself much of this solid matter will putrify and create a nuisance in its vicinity, and become a menace to health in various ways.

Sewage disposal and sewage treatment. "Sewage disposal" is a broad term which includes all the methods employed for getting rid of sewage. The term "sewage treatment" includes only such methods of sewage disposal as involve putting the sewage through some artificial process or treatment with a view to effecting sufficient purification so that the resulting liquid may be discharged into small water courses without creating a nuisance or endangering public health.

Dilution method. Where tidal waters, large lakes or streams are available, sewage may be disposed of by what is known as the method of "dilution." This way of getting rid of sewage involves nothing more than dumping the untreated sewage into the water—the dilution and sedimentation being counted on to prevent any appreciable nuisance, and the somewhat involved chemical, bacteriological and biological processes of nature to finally purify (by various changes) the unstable organic matter present.

The dilution method, while the simplest and cheapest, is entirely satisfactory only under certain conditions which rarely apply in Iowa. Most of our larger cities are located on large streams and, as yet, are depending on this method of getting rid of their sewage. In general, they depend on the same streams for their water supply. Just how polluted the water is (due chiefly to the sewage of the towns upstream) depends on various factors, such as the volume and rate of flow, the character of the stream bed, and the conditions as to wind and weather. There are so many variables that it is impossible to state with any certainty that streams purify themselves in flowing any definite distance.

The method of dilution is a crude one. In addition to polluting the local water and ice supply, it discourages or prohibits fish life, frequently makes streams foul and unsuitable for bathing or boating, and is apt to create nuisance conditions along the shores due to the filth left there by wave and current action to putrify and give off odors.

Broad irrigation. Another method by which sewage may be disposed of without artificial treatment is known as "broad irrigation." While in the dilution method the raw sewage is discharged into a body of water, in this method it is discharged intermittently over the surface of certain areas of cultivated land. These areas of land on which the sewage is disposed of are often termed "sewage farms;" and the method is applicable to either raw or settled sewage.

There are so many objections to this plan, which at best is a crude one, that it has seldom been used in this country. While the sewage fertilizes the land and thus assists in the growing of crops, there always exists a danger of spreading water-borne diseases if the sewage comes into contact with the growing crops—especially those that may be used as food without cooking. It is rarely a cheap method, as large areas of open, well-drained soil are necessary. One practical difficulty encountered is that the sewage must be disposed of regardless of crop conditions, and thus too much is often applied to produce ideal growing conditions. A remote location is usually necessary, in order to avoid nuisance due to flies and odors.

Screening. "Screening" is a mechanical method of removing a part of the solid matter from the sewage. The sorts of screens employed vary from coarse screens of steel bars (designed to prevent large floating material from getting to the pumps, into the treatment tanks, or into the body of water for dilution) to fine screens of various sorts so arranged as to remove a large part of the solid matter. This solid matter or "sludge," caught by the latter type of screens, is removed and disposed of by burial or burning—or it may be mixed with garbage to be disposed of by reduction.

Most fine screens are arranged to move continuously so that the solid material that has been collected may be removed by some mechanical means. There are band screens, wing screens, drum screens, disc screens and cage screens—each taking its name from the general shape or arrangement of the screen.

Sedimentation. Much of the solid matter in sewage may be removed by the method of "sedimentation." The relatively heavy particles of mineral matter, carried along in the sewers by a normal rate of flow, will settle out quickly if the velocity of flow is decreased slightly. This rapid sort of sedimentation is sometimes effected in what are known as "grit chambers." These are little more than depressions over which the sewage is caused to flow slowly, so that the sand and other heavy mineral particles will settle out. As this material is not putrescible, it needs no further treatment and may readily be disposed of as filling material somewhere about the plant.

A good deal of the finer solid matter remaining in the sewage will settle out if the sewage is allowed to flow very slowly through a large settling tank. In the "plain sedimentation" process the sewage is periodically diverted from one tank to another so that the settled sludge may be removed before decomposition or septic action has had time to take place. The sludge is then disposed of much as in the case of screenings. Plain sedimentation may be more rapidly effected where certain chemicals are added which cause the finer floating particles of solid matter to be carried down by the larger and heavier flocs of chemical precipitate which settle out much more rapidly. This use of chemicals increases the treatment cost materially—hence, this process is seldom used except where industrial wastes require special treatment.

In the "septic" or "Cameron" tank, and also the "Imhoff" or "Emscher" tank, the flow of sewage is continuous. The sludge which settles out undergoes a continuous process of decomposition which reduces it in volume and gradually changes it in character so that it can be disposed of periodically with little difficulty and no appreciable nuisance.

Both septic and Imhoff tanks have been widely used in this country, and their construction and operation will be taken up thoroughly later in the program.

Flitration. "Filtration" is a process much employed in sewage treatment. Mechanically speaking, a filter is very similar in action to a screen, though as a rule the filtering process is not employed until the heavier solids are removed by sedimentation or screening. More important than the straining action is the purification affected by the bacteria which exist in the various forms of filter beds.

These filters may be roughly classified as fine filters and coarse filters. Fine filters may include two sorts of soil filtration. Sand filter-beds may be employed (as in many of our Iowa plants), or the natural soil may be used where it is sufficiently open in character and well-drained. If the treated sewage is discharged on the surface of the land we have practically what was described as the "broad irrigation" method of disposing of raw sewage. Sometimes (and especially with small institutional or private plants in densely populated districts) the treated sewage from septic or Imhoff tanks is discharged into a system of distributing tile laid just beneath the surface of the ground. This method is termed "sub-surface irrigation." The construction and operation of the intermittent sand filters mentioned above will be fully described in a later paper.

Coarse filters include sprinkling or trickling filters and contact beds. In each of these the "filter" material is broken stone, far too coarse to result in the actual filtering of the sewage. The purification effected in these filters is due to the action of the bacteria present on the surface of the stone.

The essential difference between sprinkling or trickling filters and contact beds is that the dose of sewage is allowed to trickle through the former after being sprayed over the surface by the sprinkler heads, while in the latter type the dose is held in contact with the stone for a short period of time and then allowed to flow away. The construction and operation of both of these types will be described fully later in the program.

Aeration. The "aeration" process as usually applied may be briefly described as one in which large quantities of air are forced through the sewage in order to oxidize and purify it. An elaboration of this method, known as the "activated-sludge" method, is one of great promise. In this process a certain amount of "activated-sludge" is kept in continuous and intimate contact with the sewage by the agitation produced by the aeration. This process (along with certain mechanical aerating processes) will be described more fully in Professor Bartow's illustrated talk, tomorrow evening.

Disinfection. Various methods of disinfecting sewage have been employed. Of these the cheapest and most widely used is that of adding chemicals—commonly those compounds containing free chlorine. Other methods which have proven efficient experimentally are the "electrolytic" processes and the "ozone" process, but due to their cost and difficulty of operation they have not been put into extensive use. In one electrolytic process the sewage is passed through electrolytic cells between iron plates which serve as electrodes. Lime is usually added and the process followed by sedimentation. In addition to being costly, the ozone process is difficult to handle, as ozone is only slightly soluble in water. While "the primary object of disinfection is usually to reduce to a negligible degree the danger of spreading of disease by pathogenic germs," it is generally considered more practicable to apply a high degree of purification to the water supply rather than to the sewage.

The foregoing very condensed statement briefly summarizes for you the various processes which may be employed in the treatment of sewage. In few cases is any one of these methods depended on to effect the degree of purification desired—usually they are used in combination. Thus, in the septic tank we have a combination of the processes of sedimentation and bacterial decomposition—while the intermittent sand filter (often used to treat the settled sewage coming from the tank) depends on mechanical filtration and another sort of bacterial action. Frequently, also (even in the case of small plants), we find the processes of coarse screening and rapid sedimentation employed in small grit chambers through which the sewage must pass before it reaches the tank.

THE ROLE OF BACTERIA IN SEWAGE PURIFICATION

By Max Levine, Associate Professor of Bacteriology and Bacteriologist, Engineering Experiment Station, Ames, Iowa

The speakers who preceded me have discussed in detail sewage purification plants, their construction and methods of operation. These plants are really factories in which the objectionable raw material, sewage, is transformed into substances which are not offensive. I shall attempt this afternoon to make you better acquainted with the workers within these factories (namely, the bacteria) and how they destroy and transform the undesirable sewage constituents.

In order to adequately appreciate the role of these bacteria in sewage disposal we must understand or know just what we are attempting to do when we are purifying a sewage, and why treatment is necessary at all. What is sewage? What is the nature of the raw material which we present to these bacteria in the tank or trickling filters, etc., for purification? I shall not bore you with details of chemical composition or analysis. The following table gives us some conception of the character of material present in ordinary sewage.

CONSTITUENTS IN SEWAGE (AFTER FULLER)

Constituents	Pounds dry suspended solids per 1,000 population per year
Feces	2,800 lbs.
Toilet and newspapers	1,600 lbs.
Soap and washings	2,200 lbs.
Street washings	1,600 lbs.
Miscellaneous	800 lbs.
Total	90,000 lbs.

For the city of New York it is estimated that for every 1,000 of the population 90,000 pounds of dry suspended matter must be disposed of, but, as only one part in 1,000 pounds of sewage is in the form of dry suspended matter, this means that for every 1,000 of population a sewage flow of ninety million pounds (approximately eleven million gallons) per year must be treated.

Why is it necessary to treat this material? What are the objections to letting this flow away into the nearest stream or dry run?

It was seen from the foregoing that sewage consists of suspended solids in a large volume of water. Consequently if such a mixture is permitted to flow into a slow-moving stream or a dry run these substances in suspension soon settle out, accumulating into unsightly deposits. The first problem in sewage purification is that of separating these unsightly substances to prevent such deposition, and this is usually carried out by interposing a sedimentation or septic tank between the sewage and the stream. Sewage, however, is not merely a mixture of suspended solids in water. There are also present in solution materials of a highly complex chemical nature which, together with the suspended solids, are continually decomposing with the liberation of very objectionable odors. Some method is needed, therefore, to prevent or destroy these offensive odors and compounds.

Sewage, furthermore, is not merely a mixture of solids and liquids of complex chemical composition, but it contains as well a large number of bacteria. In a sense we may regard sewage as a culture medium in which bacteria are rapidly growing at the expense of the solids and liquids present. Considering the nature and the source of the sewage constituents, it must be apparent that intestinal disease-producing bacteria may also be present; and this raises a third problem, the elimination of disease producing micro-organisms.

The problem in sewage purification, then, briefly stated, is as follows: to get rid of solids, prevent development of objectionable odors and destroy harmful bacteria. If you were given a mixture of 90,000 pounds of malodorous material (such as was indicated in the table of the composition of sewage) and were asked to dispose of it without creating a nuisance, a method which would in all probbaility suggest itself to you would be to burn it. That would indeed be a very effective means of disposal, but when it is diluted with one thousand times its volume of water, it could not be so readily burned by the application of a torch. Yet, in the last analysis, it is really only by a kind of burning that the objectionable constituents of sewage may be and are destroyed. This, however, is brought about—not by a flame—but by living plants or bacteria.

What are bacteria? Bacteria are very minute plants. They are so small that they can not be seen with the naked eye, and most of them when magnified one thousand times appear but one-eighth of an inch long and possibly half that in diameter. They are made up of single cells which are of various shapes, falling (for the most part) into the following three types: (1) spheres, which are technically known as cocci, (2) rods, which are spoken of as bacilli, and (3) twisted rods, which the bacteriologist calls spirilli. It has been said that bacteria are very small; many of them are about 1/25,000 of an inch in length and but half of that in width and thickness. You may perhaps get a better conception of the minuteness of these forms if you could imag-

ine them packed herring-like fashion on an area of one square inch. There would be 1,250,000,000 in that area, or if we were to pack a cubic inch full of such bacteria we could squeeze in the tremendous number of 62,500,000,000,000.

You may well ask how these organisms which are so small can be of any significance. The answer is that what they lack in size they make up in number. They have a rather simple and peculiar, but a very rapid method of multiplication. When a bacterium is ready to propagate, it will grow to maximum size and split in two, forming two individuals. Each of these will repeat this process of splitting, thus causing a very rapid increase in number. If we begin with a single organism and assume that this organism will divide once an hour we will find that at the end of one day its progeny will amount to the tremendous figure of 17,000,000. This will readily be seen from the accompanying table.

Number of Generations or Divisions	Bacterial Population	Number of Generations or Divisions	Bacterial Population
0	1	13	8,192
1	2	14	16,384
2	4	15	32,768
3	8	16	65,536
4	16	17	131,072
5	32	18	262,144
6	64	19	524,288
7	128	20	1,048,576
8	256	21	2,097,152
9	512	22	4,194,304
10	1,024	23	8,388,608
11	2,048	24	16,777,216
12	4,096		

Now, as a matter of fact, many of the bacteria in sewage will subdivide in as short a time as 20 minutes, so that the presence of tremendous numbers (if they find favorable conditions for growth) is not surprising, and it compensates for the diminutive size of the individuals. In sewage there are frequently 250,000 of these bacteria per drop, and as many as 10 million per drop have been observed in some sewages.

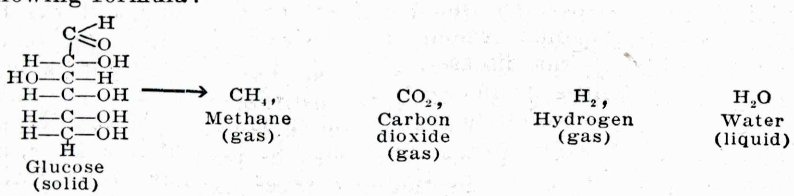
From the point of view of the sewage operator, bacteria may be divided into two groups: (1) the beneficial or desirable and (2) the harmful or objectionable. Among the desirable bacteria we include those types which are not disease-producing, but which are capable of bringing about changes in the sewage constituents so as to prevent a nuisance. These forms are always present in sewage. Among the undesirable or objectionable forms which may be present in sewage, are the disease-producing types, particularly those capable of producing intestinal disease, such as typhoid, dysentery and cholera. The sewage operator must necessarily deal with both of these types, and it is the aim of sewage plants to create favorable conditions for the growth and activities of the beneficial, harmless forms, and at the same time create conditions which would be unfavorable and destructive to the disease-producing bacteria.

One of the characteristics of bacteria (as of all living matter) is the indispensibility of oxygen. Some bacteria must have air, in which oxygen is present as a gas combined with other elements. Air consists of approximately 21 per cent oxygen and 79 per cent nitrogen, not in combination, but separate and distinct from each other in the form of gases. Bacteria which must have air or free oxygen are spoken of as **aerobic.**

Other bacteria will not grow in the presence of free oxygen. They must have oxygen for growth, as that is a requirement of all living things, but they prefer to take their oxygen from substances in which it is combined with other elements. Such bacteria are spoken of as **anaerobic,** meaning that they do not require or desire air. In sewage purification both the **anaerobic** and **aerobic** bacteria are utilized to bring about the desired changes; the former in the septic tanks, the latter in the filters. We shall discuss first the **anaerobic** bacteria, with respect to their action on the sewage constituents.

The role of anaerobic bacteria. It has already been pointed out that one of the difficulties which would arise if raw sewage were dumped into a slow-moving stream is the accumulation of suspended matter into unsightly and objectionable deposits. A settling, usually in a septic tank, is interposed to prevent this type of nuisance. The first changes which take place in a septic tank are the settling out of the substances heavier than water (forming a sludge, and the rising to the surface of the greasy, oily, and light materials as a scum. Within the tank the conditions are evidently such as to prevent the presence of air, so that the **anaerobic** bacteria find most favorable conditions for growth. Now, since all bacteria must have oxygen, and as in the septic tank this exists only in combination with other elements (no air or free oxygen being present), the bacteria find it necessary to break up the sewage compounds to get at the oxygen. The situation may be illustrated by the following example.

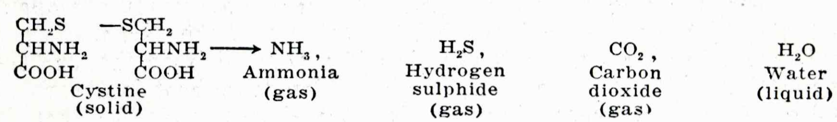
If we were presented with food in a glass container which was kept sealed we would eventually break this container, shattering it to bits, perhaps, to get at the food. Similarly, the bacteria find it necessary to break up complex compounds in order to obtain the oxygen which they inclose. The chemist tells us that corn sugar or glucose has the following formula:



Showing the complex solid corn-sugar, and the relatively simple liquid and gaseous products into which it is decomposed by bacteria in septic tanks.

It is made up, he says, of carbon (C), hydrogen (H) and oxygen (O), the latter two being gases and arranged as indicated in the formula. You will note that the oxygen is surrounded by other elements. In breaking into the compound to obtain this essential substance the sugar falls to pieces, so to speak, into little bits forming such things as methane (a compound of carbon and hydrogen which has the formula (CH_4)), carbon dioxide (which consists of one part of carbon and two of oxygen, and is therefore written (CO_2), hydrogen gas (H_2), and water (which is made up of two parts of hydrogen and one of oxygen and therefore indicated by the symbol (H_2O)). The bacteria in this case have broken up a solid substance, cane sugar, into gases and water.

If in place of sugar you take a substance like egg or hair, one of the important constituents is cystine, which may be represented by the following formula:



Showing transformation of cystine (a solid constituent of eggs, hair, etc.) into simple gaseous and liquid products, by bacterial action in septic tanks.

It consists of carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and sulphur (S). The bacteria will decompose such a compound with the liberation of methane (CH_4), ammonia (NH_3), hydrogen sulfide (H_2S), water (H_2O), etc. The point is that the bacteria have taken solid substances, like sugar, egg, and hair, and in their attempt to extract the oxygen which these solids contain have broken them down into gases and liquids. If you will look at the formulae for sugar and egg constituent and then at those of the decomposition products (water, ammonia, carbon dioxide, etc.), it must be evident that complex solid substances have been broken down into simpler ones which are gases and liquids. This, then, is the characteristic action taking place in septic tanks. The sludge is digested or liquified through the action of these **anaerobic** bacteria. Looking at the products of digestion we find such substances as hydrogen sulfide (H_2S) and ammonia (NH_3). These compounds have very objectionable odors, particularly the former, which has the characteristic odor of decomposing eggs. The effluent from a septic tank is not a purified sewage. It will foul a stream if introduced in sufficient quantities. If we look at the substances, hydrogen sulfide (H_2S) and sulphuric acid (H_2SO_4), it is apparent that the differences between these two substances is that the latter has four parts of oxygen added to it. The hydrogen sulfide has a very objectionable odor, while the sulphuric acid has none. The loss of odor was brought about by the addition of oxygen which we therefore speak of as oxidation. Oxidation is nothing more nor less than a kind of burning process.

The role of aerobic bacteria. This brings us to a consideration of the action of the **aerobic** bacteria in the purification of sewage. To prevent a nuisance sewage must be oxidized or burned. For burning, as is well known, air must be provided. If a stack of wood or a piece of coal is burned in a furnace, what actually happens is a union of oxygen of the air with the wood or coal through the agency of flame or heat. The fuel is oxidized. In burning sewage a union of oxygen of the air with the objectionable sewage constituents is brought about through the agency of bacteria. The furnace in which this latter change takes place is the filter. In the filter conditions are just the reverse of what they were in the septic tank. The filters are well aerated. When a dose of sewage is thrown upon them the anaerobic bacteria, which had been thriving in the septic tank, find unfavorable conditions, and will not function. The **aerobic** bacteria, on the other hand, find favorable conditions and will thrive. We have on the filter the oxygen, sewage constituents, and bacteria brought in intimate contact. The bacteria bring about a combination of the oxygen and organic matter of the sewage, thus preventing a nuisance.

The action taking place on the sewage filter is strikingly analogous to that taking place in a furnace. In the case of the furnace, when coal or wood is burned, a union of air and coal is initiated through the application of heat. As a result of this union more heat is generated and gases such as carbon dioxide (CO_2) are given off. If the draft in the furnace is closed, thus reducing or eliminating the air supply, then heat production is reduced (as are also the products of combustion) and the furnace soon goes out. In sewage purification the filter functions as the furnace and the sewage constitutes the fuel. When well constructed, air present in the filter combines with the sewage through the action of bacteria (which corresponds to the heat in the case of the furnace), and this results in the production of more bacteria and various products of combustion—such as carbon dioxide (CO_2). It is, therefore, very essential for good combustion that the filters be well aerated exactly as it is indispensable to have a good draft for combustion in a furnace. To throw too much sewage on a filter will have the same effect as throwing too much or too compact fuel in a stove and shutting off the draft. When the filter clogs, it can not work efficiently because it can not get the air.

In conclusion, it may be said that in a septic tank the sewage constituents are broken into small pieces, in which form they are more readily burned or oxidized on the filters. The septic tank may be likened to an ax or a pick which is applied to fuel to reduce it to convenient furnace size. The filters function as the furnace. The whole process of sewage disposal is one of adequate combustion or burning of the sewage constituents through the action of bacteria. The septic tank must be so constructed as to provide the best possible conditions for growth of anaerobes, while the filters must be so designed and operated as to give a most abundant supply of air to the aerobic bacteria growing upon them.

THE ACTIVATED SLUDGE PROCESS FOR SEWAGE DISPOSAL

By Edward Bartow, Professor and Head of Department of Chemistry, State University of Iowa

Methods of sewage disposal are of two types: Those which require anaerobic bacteria and those which require aerobic bacteria. In the anaerobic class are methods of tank treatment, including the cesspool, septic tank, the Imhoff tank, the Dortmund tank and other methods where air is excluded.

Aerobic methods include dilution in large bodies of water, broad irrigation, sand filtration, contact beds, sprinkling filters and the more recently developed activated sludge.

The aerobic methods, as a rule, give the most satisfactory results, though combinations of anaerobic and aerobic have proven satisfactory. For example, many American cities, including Columbus, Ohio; Pittsburgh, Massachusetts; Plainfield, New Jersey; and Mason City, Iowa, use this combination. Ames, Iowa, is at the present time (1922) constructing a sewage-disposal system of this type.

In America, tanks followed by sprinkling filters using nozzles are the most popular combination for the mixed aerobic anaerobic methods. At Birmingham, England, where nozzles have been used for many years, a new installation contains mechanical distributors which travel back and forth over rectangular beds and siphon the sewage (which has been treated in tanks) from open troughs to the moving distributors. Broad irrigation has been used for many years in Berlin, Paris, London, and other European cities; but because of the large land areas required by broad irrigation, and because of the odors and comparatively large areas required for the combination tanks and sprinkling filters, more rapid, more intensive and complete methods have been sought.

The activated-sludge process has been the result of a combination of studies in England and America. In 1912, at the Massachusetts State Board of Health, Clark passed sewage into tanks in which were developed, on shelves or baffles, what he called green growths. These growths, according to Clark, had the power of removing organic matter from sewage and of purifying the sewage very rapidly. About the same time Black and Phelps, at Brooklyn, N. Y., passed sewage through tanks containing numerous shelves and in which the sewage met air blown in through perforated pipes in the bottom of the tank. Both of these types of aerators for sewage disposal had purifying action and improved the character of the sewage treated.

In 1912, Fowler of Manchester, England, visited America and saw the experiments being carried on at Lawrence, Mass., by Clark. Fowler and Numford had been attempting to develop a specific type of bacteria which would more rapidly liquify or purify sewage. As a result of his visit to Lawrence he suggested to Ardern and Lockett that they attempt to develop growths from the sewage itself. The first experiments were made in bottles of gallon capacity. A sludge was developed, after a number of weeks, which had the power of changing the form of nitrogen from ammonia to nitrate with great rapidity, leaving a liquid which was perfectly stable. The results were so encouraging that a series of experiments were tried with barrels and, later, with a tank of twenty thousand gallons capacity, operating on the fill and draw system.

It was my privilege to see the barrels in operation and to see the tank of twenty thousand gallons capacity in the latter part of August, 1914. The process was so successful that the city of Manchester constructed a tank of about 500,000 gallons capacity at their Withington works and, later, one of 750,000 gallons capacity at the Davy Hulm works. To date about thirty plants either have been constructed or are contemplated in England.

Upon returning to this country with F. W. Mohlman, the experiments in bottles were repeated and a small tank designed in which it was possible to develop a sludge and purify domestic sewage from the city of Champaign within a few hours. This experimental plant was followed by a series of three concrete tanks four feet square. These were later followed by a tank of 75,000 gallons capacity made from the old Champaign septic tank. During this period T. Chalkley Hatton of Milwaukee made experiments, first on a small scale and then in a plant designed to handle 1,000,000 gallons of sewage per day. E. H. Sands of Houston, Texas, planned and built two plants, one of 6,000,000 and one of 12,000,000 gallons capacity. These plants have been of the same general type. The sewage enters at one end of a long tank, where it is mixed with sludge that has been collected from a settling tank. In passing through the tank it is stirred and aerated with air which is blown into the bottom through porous plates or diffusers. In the United States these have been almost exclusively filtros plates. In England a porous tile made by Messrs. Jones and Atwood or later by the firm, Activated Sludge Limited, the successors of Jones and Atwood, is used. After passing through the aeration tank the mixed sewage and sludge enters the settling tank, having either a bottom sloping to an outlet from which the sludge could be pumped to the entrance to the aeration tank, or having a collecting mechanism consisting of radial arms to which are attached plows and which would carry the sludge to a central well, from whence it could be pumped to the beginning of the aeration tank.

The features of the process which have delayed its development are the cost of compressed air and the satisfactory drying of the sludge. Attempts have been made to decrease the cost of the air by using an intermittent flow, by so arranging the bottom that the minimum amount of air required for stirring may be used, and by methods of mechanical aeration.

The intermittent use of air has been tried in England, but without great success. Activated Sludge Limited, the English company which claims ownership of the English and American patents on the process,

have devised a scheme at Manchester, England, in which diffuser plates are placed along one side of a long tank in such a manner that circular currents are set up. The liquid is kept saturated with sufficient air to support bacterial life, and the current is great enough to keep the sludge in suspension and prevent putrefaction. A comparative test made on the waste from a starch factory at Argo, Illinois, indicates a saving of at least 25 per cent of air by this arrangement.

The most successful system of mechanical aeration has been devised by Haworth, superintendent of the sewage-disposal works at Sheffield, England. He first used a box in which was installed a cylindrical mechanism which revolved at the surface of the liquid, partially submerged. The liquid was kept agitated by the mechanism and sufficient air carried into the liquid to support the bacterial life. Haworth's next scheme was by the use of a vertical shaft around which paddles, revolving, keep the liquid in motion through a long series of tanks. This was followed by the construction of a plant intended to handle 1,000,000 gallons of sewage per day, consisting of a long series of tanks four feet wide and four feet deep, with paddle wheels at intervals to carry the sewage and sludge at a sufficient rate to keep the sludge in suspension. This plant has been in operation for nearly two years with satisfaction. It is claimed that it will operate at a cost of twenty horse-power per 1,000,000 gallons for the other process stirred with air. With the approval of the British Board of Health, plans have been made for the construction at Sheffield of a plant of 15,000,000 Imperial gallons capacity. The first unit of two and one-half million gallons capacity will be in operation by March, and will be installed on the site of the contact beds which have become inadequate for the disposal of Sheffield sewage. The process in use at Sheffield has been imitated by the engineers of the city of Paris, France, for an experimental plant of 1,500,000 gallons capacity. The French engineers gave careful consideration to all processes and have constructed the mechanical aeration of the Haworth type. When I saw the plant in August of this year it had been in operation about six weeks and was furnishing, without odor, a clear stable effluent, much to the delight of the French engineers. John Watson at Birmingham, England, after preliminary tests, has determined to use the Haworth type of mechanical filtration. It is his plan to partially purify sewage by activated sludge, and to finish the process by passing the effluent from the activated-sludge plant to the sprinkling filter beds which have been in operation for many years.

Another scheme for mechanical aeration has been devised by Joshua Bolton, of Bury, England. Mr. Bolton has used settling tanks of the old Bury system. In the center of tanks about twenty-four feet in diameter he has built wells of sheet iron three and one-half feet in diameter, extending nearly to the bottom of the tank. At the upper part of these wells he has placed a flange extending from a few inches below the surface of the water to a few inches above. Vanes are fastened to a vertical shaft revolving in the flange and carry water from the surface of the tank and throw it in a spray over the surface of the water in the tank outside of the well. Near the circumference of the tank is suspended a baffle which prevents the spray from being thrown to the outside of the tank, directs the mixed sludge and sewage towards the bottom and allows the clarified effluent to flow up on the outside into the outlet trough. In one tank a sloping bottom carries the settling sludge under the central well. In another a slow-moving mechanism, consisting of radial arms with plows, carries the sludge beneath the central well. Preliminary tests with this mechanism have been so satisfactory that the British Board of Health has authorized the construction of a larger plant. It is claimed that the cost of operation may be reduced to fourteen horse-power per 1,000,000 gallons, compared with the twenty horse-power claimed for the Haworth process and the thirty-five estimated for the diffuser process.

In the United States large plants using the diffuser scheme have been constructed at Houston, Texas, and in Chicago, Illinois, at the Maywood plant, and are being constructed at Milwaukee, Wisconsin, and Indianapolis, Indiana, and have been authorized for Chicago, Illinois, north side. Smaller plants are in operation at various points. At Mason City, Iowa, a plant has been installed for the treatment of waste from a packing house (see frontispiece). I designed the plant to take care of the waste when one thousand hogs per day were being slaughtered. The plant consists of rectangular tanks containing aerators and a circular tank with a Door clarifier to allow the sludge to settle and from which it can be returned to the aeration tank. When not overloaded this plant has operated successfully and the sludge has been dried and used in the by-products department.

No use has as yet been made in the United States of the mechanical principle. The mechanical device used at Sheffield would require much larger land areas than would be required for the diffuser process, and the cost of land might in some places prevent the use of the mechanical process.

The second difficulty mentioned above, the de-watering and drying of the sludge, has been an object of investigation both in England and in the United States. Where the plants are running on an experimental basis at Manchester, the excess sludge is allowed to pass into the tanks or on to the drying beds used in the main process. At Worcester considerable land areas are covered with the sludge. Since the sludge contains from 98½ to 99½ per cent of moisture, and since it settles slowly and dries with difficulty, the disposal of sludge is a very serious problem. Centrifugal machines will reduce the moisture to approximately 90 per cent. The ordinary plate and frame filter-press will reduce the moisture to 79 or 82 per cent in the summer time. Experiments in the winter have often failed, unless the sludge has been warmed and treated with sulphuric acid or with alum. The best results have been obtained when the sludge has been warmed to a temperature of 150° F., and treated with sufficient acid or alum to cause the flocculent material to coagulate into larger masses. The best results obtained in America have been with an Oliver or American filter. These filters give a layer of sludge a little less than one-fourth inch

thick, which will dry easily in the open air. The pressed cakes from a plate and frame press are one to one and one-half inches thick and when placed in the dryer are dried on the outside into an impervious layer which holds the remaining moisture inside. The rotary direct-heat dryers have been used for drying at Houston, Texas, without success. It is claimed that the experimental dryer at Milwaukee is satisfactory, and the Sanitary District of Chicago has installed a rotary dryer in its Maywood plant. The Maywood plant is about ready to operate and we will have some information concerning its operation in the near future.

An indirect-heat dryer manufactured by the Bayley Manufacturing Company has been used experimentally. The pressed cake used was too thick for satisfactory operation, and it is my belief that with the material obtained by the Oliver or American filter satisfactory results can be obtained with this apparatus.

The dried sludge obtained in the activated-sludge process contains from four to eight per cent nitrogen. This sludge has been tested by the approved methods for analyzing nitrogen and has been shown to be valuable as a fertilizer. It has also been tested by Lipmann in California, who states that the nitrogen is of the same grade as tankage for fertilizing purposes. With Mohlman, and later with Hatfield, I have made pot cultures on wheat and garden cultures on vegetables, and have shown that the nitrogen is in a form available to support plant life. Calculations from the pot cultures of wheat show a yield of nine bushels per acre when no fertilizer is used, and thirty-six bushels per acre when the pots were fertilized by activated sludge. These experiments have been repeated by Nasmith at Guelph, and our results corroborated. Russell and Richards, at the Tothamsted experiment station in England, have shown that the activated sludge is valuable as a fertilizer. I visited Sir John Russell during the past summer, and was told that he had no doubt of the fertilizing value of the sludge. The next step was for the engineers to find a satisfactory method for drying the sludge. He would then use it in large scale demonstration tests to show its value to the farmers of England. The workmen at the Sheffield sewage-disposal plant have used activated sludge in fertilizing their gardens. These workmen took all the prizes for which they could compete at the Manchester garden exposition. They took the district prizes and the general prizes, twenty-seven in all.

Usually it is necessary to place grit chambers and screens in the purification plant ahead of the activated-sludge plant. Screens of any kind can be used, but we have had some experience with the Dorrco screen at the experiment station at Urbana, Illinois. The sewage enters a tank in which a cylindrical screen revolves at such a rate that screened sewage on the inside of the screen is drawn above the level of the un-screened sewage outside and flows out through the screen, automatically cleaning the screen. Screens of this type have been successfully used in the screening of tannery waste.

It has also occurred to me that the effluent from the activated-sludge plants might be used to form fish ponds. Fish ponds have been in operation at Strassburg, France, for about ten years. The effluent from settling tanks mixed with two or three times its volume of river water will support fish life. The activated sludge effluent is so much better that it should be satisfactory without dilution.

In what I have said in this lecture I have shown you that it is possible to purify sewage by the activated-sludge process, using either air diffusers or a mechanical system of aeration. I have told you that there are engineers and others who have sufficient faith in the process to have attempted it for large installations in the United States and in Europe.

I have shown you that the sludge has definite fertilizing value, and the use of the method, therefore, would be to conserve large amounts of material which are now either wasted in the streams or decomposed and lost through the use of anaerobic biological processes. There merely remains to be discovered the best method for obtaining the air necessary for the bacterial life, and the best and most practical method for drying the sludge.

THE COLLEGE

The Iowa State College of Agriculture and Mechanic Arts conducts work along five major lines:

AGRICULTURE
ENGINEERING
HOME ECONOMICS
INDUSTRIAL SCIENCE
VETERINARY MEDICINE

The Graduate College conducts advanced research and instruction in all these five lines.

Four, five and six-year collegiate courses are offered in different divisions of the College. Non-collegiate courses are offered in agriculture, home economics and trades and industries. Summer sessions include graduate, collegiate and non-collegiate work. Short courses are offered in the winter.

Extension courses are conducted at various points throughout the state.

Research work is conducted in the Agricultural and Engineering Experiment Stations and in the Veterinary Research Laboratory.

Special announcements of different branches of the work are supplied, free of charge, on application. The general bulletins will be sent on request.

Address, The Registrar,
IOWA STATE COLLEGE,
Ames, Iowa