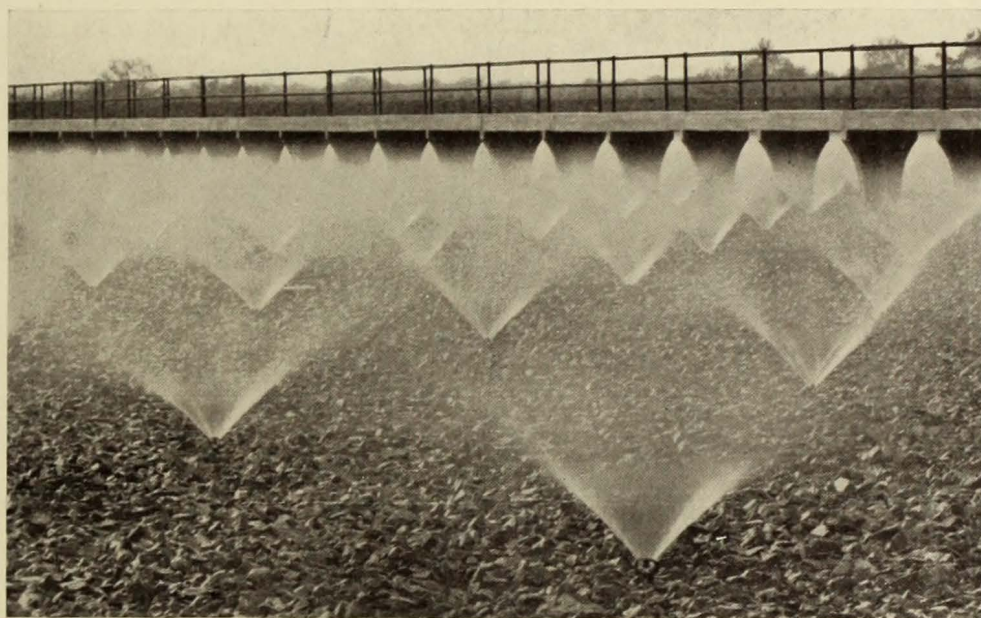


AMERICAN MUSEUM OF NATURAL HISTORY

Protection
OF
River and Harbor Waters from
Municipal Wastes



TRICKLING FILTERS, COLUMBUS, OHIO

By **CHARLES-EDWARD AMORY WINSLOW**

Curator of Public Health

GUIDE LEAFLET NO. 33

APRIL, 1911

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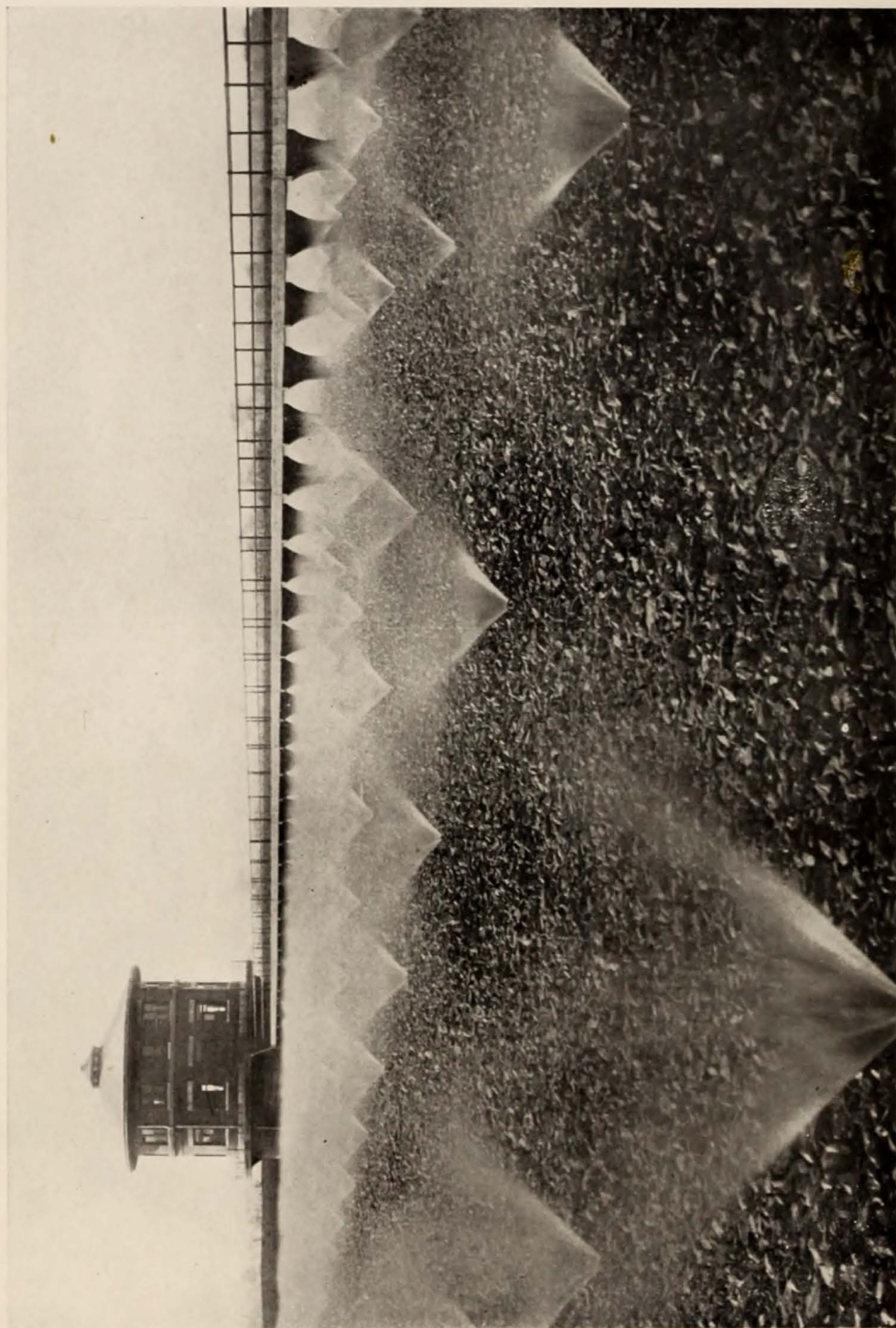
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TRICKLING FILTERS, COLUMBUS, OHIO

By means of fixed sprinkler nozzles, sewage is sprayed evenly over the surface of a bed of coarse stone. This method is at present considered one of the most effective of all devices for sewage purification

Protection of River and Harbor Waters from Municipal Wastes

WITH SPECIAL REFERENCE TO THE CONDITIONS IN
NEW YORK

BY

CHARLES-EDWARD AMORY WINSLOW, M. S.
Curator of Public Health

NEW YORK
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AMERICAN MUSEUM OF NATURAL HISTORY

MARY CYNTHIA DICKERSON, Editor

PROTECTION OF RIVER AND HARBOR WATERS FROM MUNICIPAL WASTES

WITH SPECIAL REFERENCE TO THE CONDITIONS IN NEW YORK

THE PROBLEM OF SEWAGE DISPOSAL

CITY life presents pressing and peculiar biological problems. When a large number of human beings are concentrated upon a small area the fundamental needs of individual life must be met by new means. Special measures must be adopted for getting food from a wide radius into the center where so much of it is to be consumed. The spread of epidemics which always threaten crowded communities must be guarded against; and the waste products which accompany all living processes must be removed.

This last task, the removal of the city's wastes, is one of the most difficult which confronts a modern municipality. From every large city there pours out a river of waste material which pollutes streams, harbors and foreshores, spoiling what should be the chief pleasure spots of the city and damaging property values, if it does not actually threaten human life and health. By the modern methods of sanitary science these liquid wastes can be purified and rendered harmless and it is with such methods of protecting the purity of inland and seaboard waters that a section of the Public Health Exhibit of the American Museum now deals.

City sewage is a far less offensive substance than might be imagined. To the sight it is simply a grayish liquid with fine flocculent suspended matter in it; to the smell it is inoffensive when fresh, having only a faint musty odor. Analysis shows that the average American sewage contains less than one part in a thousand of solid matter, the rest being water. Of the solid matter half is of mineral nature, so that only a residuum of perhaps four-hundredths of one per cent of organic matter requires especial treatment. It is the vast volume of the sewage stream however, which makes the problem such a serious one. For example, there is now discharged into New York harbor about 500 million gallons of sewage a day. This amount of liquid if concentrated in one place, would fill East River under the Brooklyn Bridge for a distance of one-fifth of a mile. Even four-hundredths of one per cent

of this immense mass of liquid amounts to 800 tons; and this is approximately the amount of organic matter discharged into New York Harbor every day.

The organic matter in sewage, which is the principal source of embarrassment in its disposal, is made up for the most part of imperfectly oxidized unstable molecules which may undergo one or the other of two different series of changes. First, it may decompose or putrefy in the absence of oxygen, with the production of offensive gaseous compounds. Or secondly, under the influence of oxygen it may undergo another process — that of nitrification, a slow burning or combustion which converts the organic matter into nitrates or other mineral substances, without the production of foul odors and in a wholly innocuous way.

Where sewage is discharged without due precautions into the nearest watercourse, the first sort of change is likely to result. If the volume of the sewage in relation to the stream be small, there may be enough oxygen present to care for the organic matter. If, on the other hand, the volume of sewage exceeds the purifying capacity of the stream (which may be taken as about one part of sewage in fifty parts of water) the whole process changes: instead of self-purification, there is putrefaction. Decomposable organic matter accumulates on the bottom and the whole stream or pond is turned into a fermenting pool, the odor from which may produce a serious nuisance for considerable distances from its banks. Conditions like these now exist within the limits of Greater New York in such places as the estuaries of the Gowanus Canal and Newtown Creek.

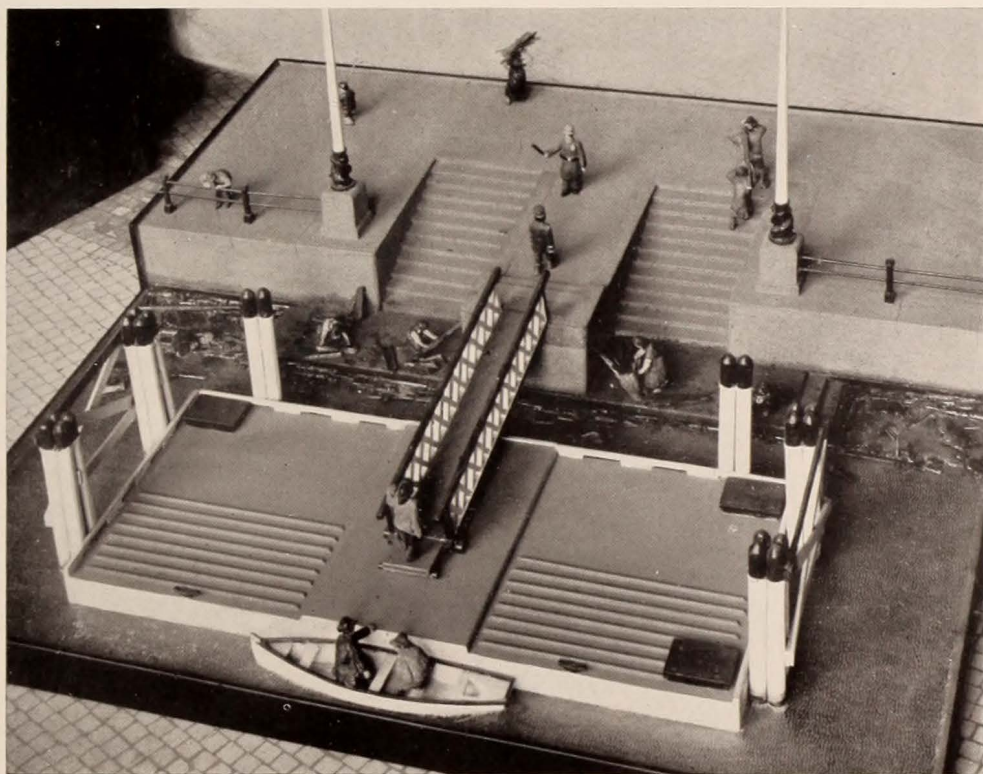
CONDITIONS IN NEW YORK HARBOR

New York is more fortunate than most cities in its insular position and in the large bodies of water which wash its shores. Even here however, the present methods of disposal by the haphazard discharge of some sewers at the piers or bulkhead lines is manifestly unsatisfactory. So far as the harbor waters as a whole are concerned, it must be noted that the amount of diluting water available is much less than would at first sight appear. The hourly variations are great. Over 3000 million cubic feet of water pass through the Narrows in a single hour at the maximum period of flood.¹ The total ebb at this point is 12,213 million cubic feet; but the

¹ Data in regard to conditions in New York Harbor are quoted from the *Report of the Metropolitan Sewerage Commission*, 1910.

total flood is 11,030, so that the net outflow is proportionately small. In the Hudson River the ebb is 6,910 million cubic feet and the flood 5,740 million. In the East River the figures are respectively 4,068 million and 3,968 million cubic feet and in the Harlem River 176 million and 153 million. The result is that most of the sewage oscillates back and forth instead of passing promptly out to sea.

The general effect of this pollution is manifest in the reduced oxygen content of the harbor. The East River above Hell Gate contains on the



Gathering driftwood from the polluted waters about the steps of the Battery. Photograph from a model in the American Museum

flood tide 92 per cent and on the ebb tide 80 per cent of the oxygen necessary for saturation. Below Hell Gate the values fall to 69 per cent on the flood and 60 per cent on the ebb. In the Hudson River above Spuyten Duyvil there is about 84 per cent of the oxygen necessary for saturation, on both tides; below Spuyten Duyvil the figure falls to 76 per cent on the flood and 66 per cent on the ebb. Samples taken from the eastern end of the Harlem show on the average only 43 per cent of the oxygen necessary for saturation on the flood tide and only 27 per cent on the ebb. The upper East River

and the upper Hudson are in general in fair condition; the lower sections of these rivers adjoining Manhattan Island are considerably polluted; and the Harlem River is grossly polluted. In the immediate vicinity of sewer outlets the conditions which exist are distinctly offensive to the senses.

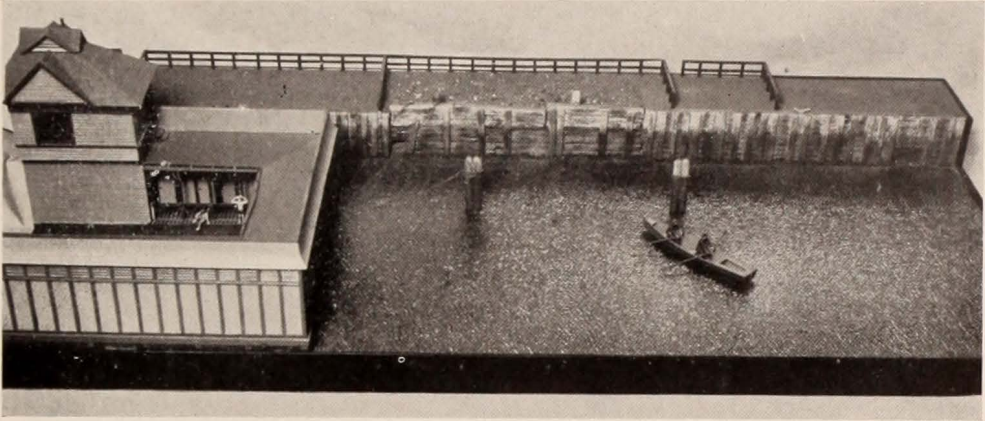
Besides these conditions of local nuisance, there are real dangers to health involved in the present method of disposal of New York sewage. The wastes from a city always contain the germs of such infectious diseases as typhoid fever, and those who come in contact with water into which such wastes are discharged are liable to contract the diseases in question. More or less contact is inevitable with the waters immediately surrounding the shores and docks. Thus at the steps in Battery Park and all about the



CLAM DIGGING NEAR SEWER OUTLET, JAMAICA BAY

Shellfish procured from this and similar localities are sold in the city's markets and are occasionally responsible for cases of typhoid fever. Photograph of a model in the American Museum

city, driftwood and other floating objects are picked out and carried by the poor to their homes. All these objects have been exposed to dangerous pollution and may carry the germs of disease. In Jamaica Bay and elsewhere near New York, clams and other shellfish are taken in the neighborhood of public and private sewers. Some processes of cookery destroy the germs of typhoid but others do not. The amount of disease now caused in this way is probably not large but the danger exists. The most serious of these sanitary problems is that due to bathing in the polluted waters. Free floating bathing establishments are maintained by the City at various points along the water front, often in the near vicinity of

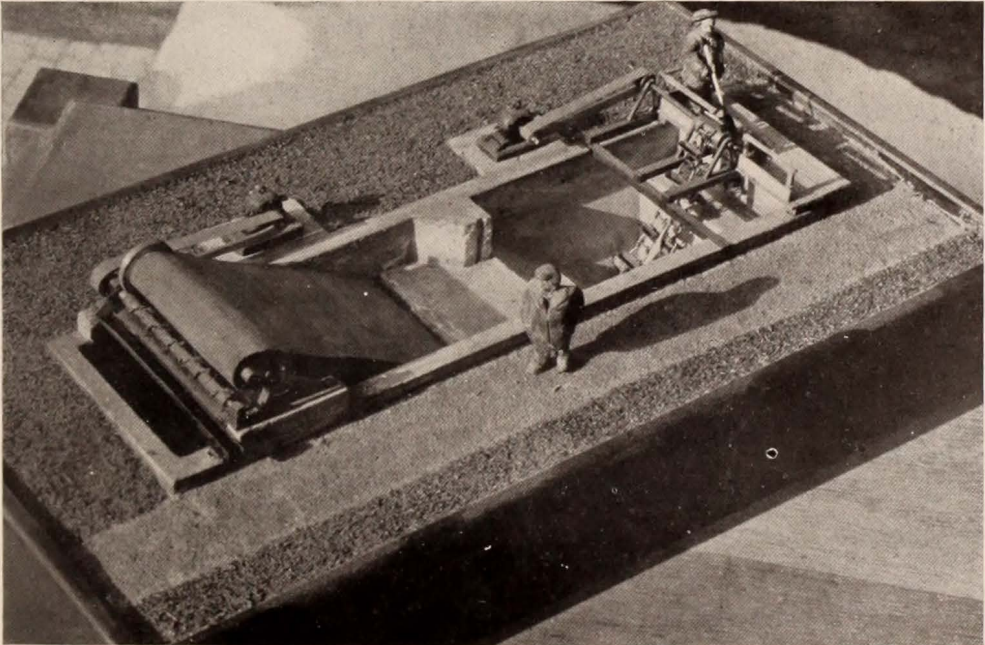


A MUNICIPAL BATHING-PLACE

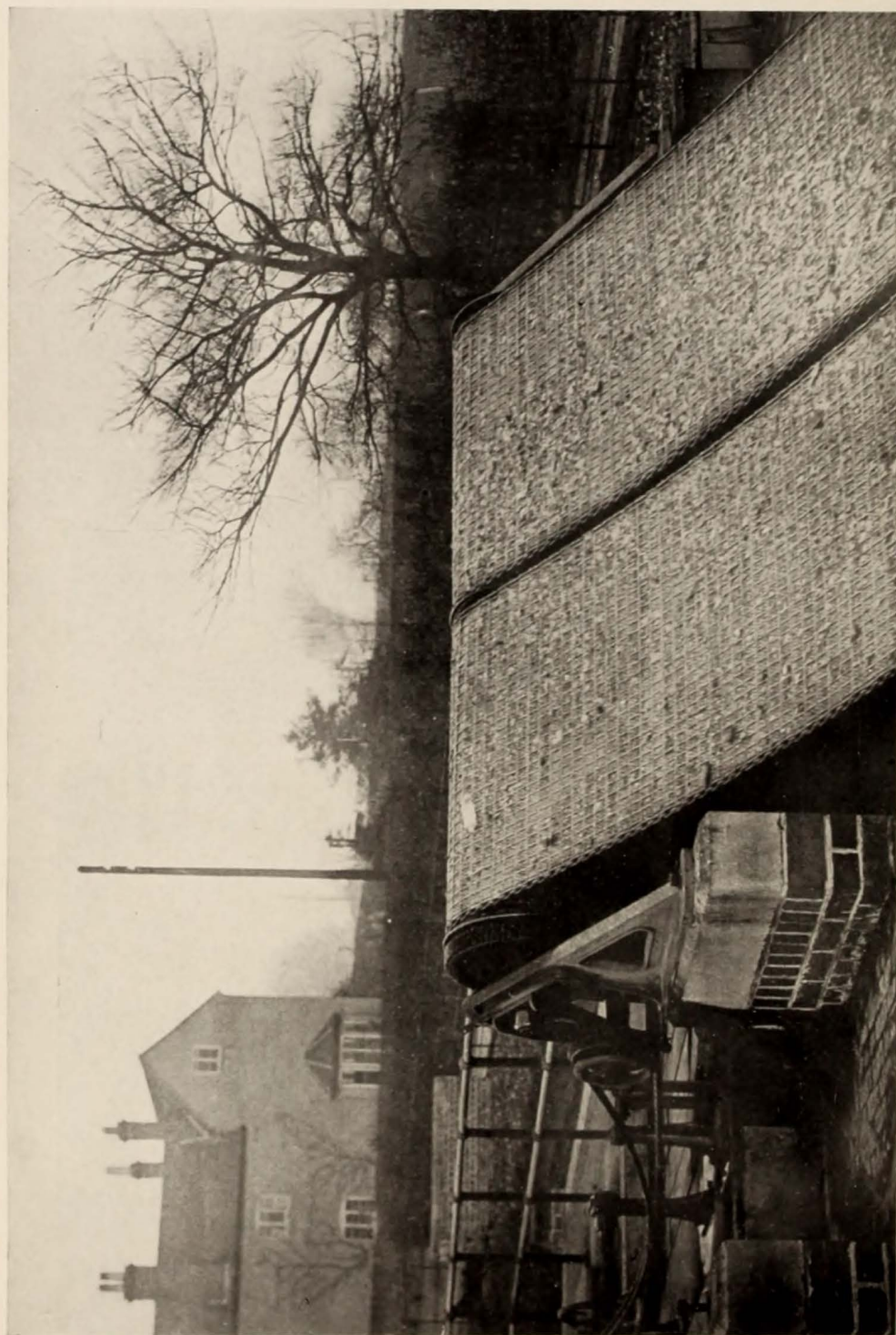
Free floating baths at various places along the waterfront are placed in close proximity to sewer outlets, thus menacing the lives of many who frequent these baths during the summer months. Photograph of a model in the American Museum

sewer outlets. It cannot be doubted that such conditions furnish excellent opportunities for infection of various sorts.

The safe and inoffensive disposal of the wastes of a large city is a difficult but by no means an insuperable task. It involves one or more of three main processes, according to local conditions — namely, the elimination of



Fine mesh revolving screen and detritus tank for removing suspended solids from sewage. Photograph of a model in the American Museum



Courtesy of J. D. Watson

FINE MESH REVOLVING SCREEN AT BIRMINGHAM, ENGLAND

These screens constantly revolve so that a fresh surface is always ready for use

suspended solids, the oxidation of unstable organic compounds and the destruction of pathogenic bacteria.

SCREENING OF SEWAGE

The first problem in almost every case is the elimination of the coarser floating particles by some form of straining or screening. Sometimes this is accomplished roughly by the use of coarse bar screens with bars half an inch or an inch apart. In England and Germany finer screens of wire cloth with meshes as close as a tenth or even a twenty-fifth of an inch have been used. Such screens are frequently arranged to revolve like an endless belt, so that a fresh area is constantly brought into action and the accumulated screenings are carried upward and automatically brushed off into a trough.

Where it is necessary to remove a larger proportion of suspended solids than can be held back by screening, sedimentation is the next process called into play. Screening alone is sufficient for all practical purposes in some cases, so in others screening and sedimentation will produce an effluent pure enough to be discharged into adjoining waters. As a preliminary to the processes used for final purification, sedimentation almost always plays a part.

SEDIMENTATION

The purifying action of a sedimentation tank depends on the physical factors of velocity and time. If the dimensions of the tank are such that the flow is reduced only to a rate of thirty feet per minute the heavy mineral matter — gravel, sand and the like — will be removed but the finer organic particles will not be affected. Such a small tank as this is known as a detritus tank or grit chamber, and forms a part of practically all sewage works, generally in intimate connection with the screening process.

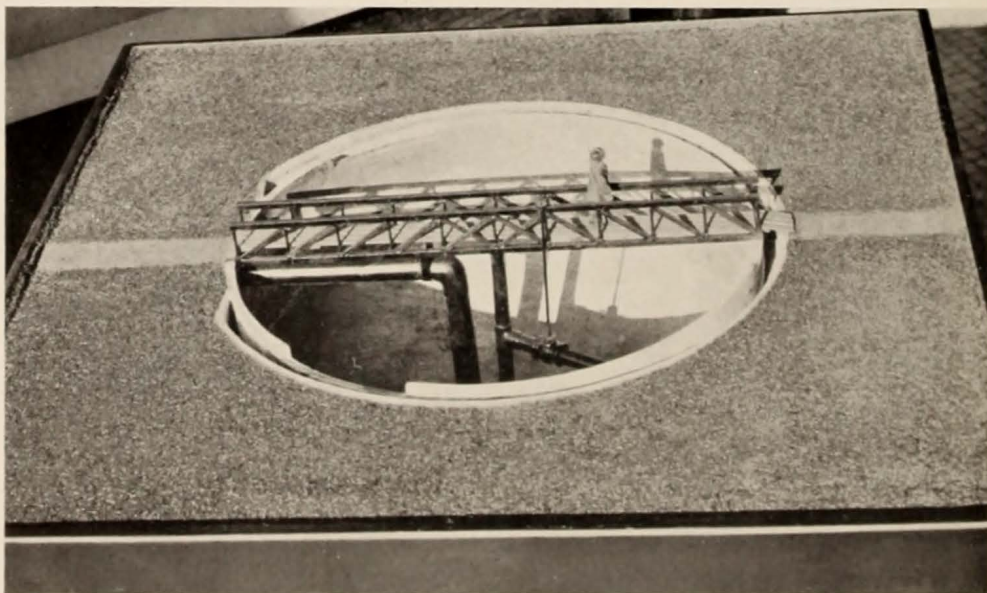
True sedimentation of organic solids requires a velocity as low as six feet per minute, or less maintained for a period of several hours; and the tanks used for such sedimentation are usually rectangular basins of concrete or masonry with a capacity of four to twelve hours flow of sewage. In place of shallow basins of this pattern English engineers, notably at the city of Birmingham, have obtained very satisfactory results by the use of deep tanks with conical or pyramidal bottoms. The sewage enters near the bottom and as it rises and spreads out in the conical section, progressively diminishes in velocity and leaves its suspended solid matter behind, so that the effluent flows off clear at the top. These deep tanks have the added advantage that the heavy sludge can be drawn off by a valve at the bottom

without emptying the liquid above. The ordinary shallow sedimentation basin will not remove more than from 50 to 65 per cent of the suspended solids, while the deep tanks at Birmingham effect a purification of 85 per cent.

Where still more complete removal of suspended solids seems to be called for, the force of gravity may be reënforced by the addition of chemicals which produce a flocculent precipitate, capable of carrying down with it the finer particles, even to some of those which exist in a state of colloidal suspension. This gives better purification but usually at a rather high cost.

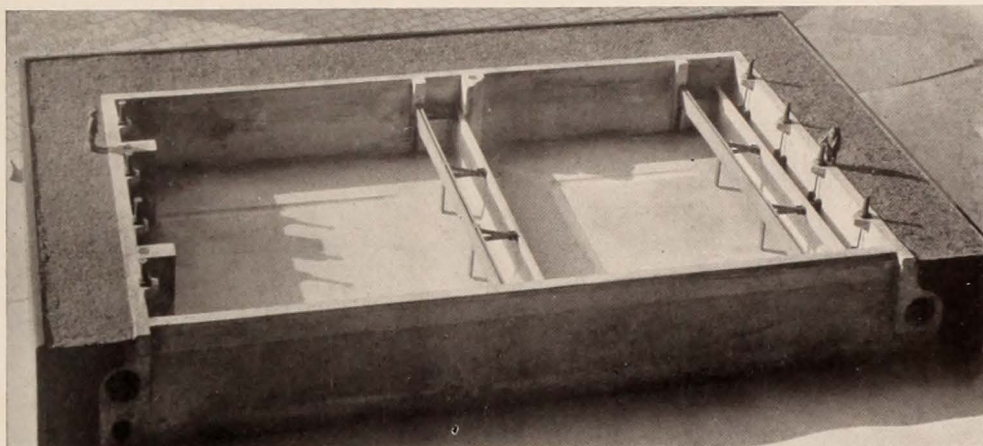
THE SLUDGE PROBLEM

In all processes of sedimentation a serious difficulty arises in connection with the disposal of the semi-solid sludge removed from the sewage and accumulated in the bottom of the basins. At the least there is produced some five to ten tons of wet sludge (containing 90 per cent of moisture) for every million gallons of sewage treated. For a community of one hundred persons (assuming 100 gallons of sewage per capita) this would mean one to two hundred pounds of wet sludge a day. With a village of one hundred persons it would be easy to deal with this semi-solid waste by burying it; but with a city of 100,000 inhabitants and 50 to 100 tons a



DEEP SEDIMENTATION TANK

A deep open tank for sedimentation of sewage. Photograph of a model in the American Museum



Septic tank or modified sedimentation basin. Photograph of a model in the American Museum

day to dispose of, the task is far from simple. As a matter of fact this is still a problem which awaits satisfactory solution. Cities on the seacoast can carry their sewage sludge out to sea in tank steamers and dump it in deep water with reasonable success and economy. For inland communities there remain only the alternatives of burying or burning, both of which are costly and unsatisfactory. Utilization seems theoretically promising, but it has not been practically realized except with sewages like that of Bradford, England, which contain an enormous proportion of fats from industrial sources.

THE SEPTIC TANK

There is one form of the process of sedimentation which is specially designed to minimize the sludge problem and which, to a limited extent, does achieve that end. This is the septic tank, associated particularly with the work of Cameron, but in its essential features dating far beyond the year 1895, when he gave it that picturesque name. The septic tank is indeed only a scientifically controlled and regulated cesspool, a sedimentation basin in which the suspended solids are removed by physical processes, but in which they are afterward allowed to remain so that they may be decomposed and reduced to the liquid form by the action of putrefactive bacteria.

The first septic tanks were tightly closed, in the opinion that this was essential to the desired liquefaction. It has since been found, however, that this is unnecessary. All that is essential is that the sewage, or the sludge removed from the sewage, should be retained in a stagnant condition;

the bacteria growing in the liquid consume oxygen much faster than it can be absorbed from the surface, and anaërobic conditions are easily maintained. In such a still pool of sewage sludge, the putrefactive bacteria effect a hydrolytic cleavage of the organic compounds and ultimately split them up into such simple forms as nitrogen, hydrogen, carbon dioxide and marsh gas.

Aside from certain minor details as to size and construction, the Cameron septic tank is simply a brick or masonry basin, covered perhaps with a wooden roof to protect it from the wind, but with no special features to distinguish it from any other tank. If in operation the sludge is removed at frequent intervals, the tank is merely a sedimentation basin. If the sludge is not removed putrefaction sets in, the liquid becomes dark colored, bubbles rise from the bottom and burst at the top and sometimes a thick crust or scum forms over the whole surface. The solids are changed first to liquid and then to gaseous form. The amount of gas evolved is large, four or five gallons from a hundred gallons of sewage, and with closed tanks it is possible to collect this gas and burn it.

The net practical result of the septic process is an appreciable reduction in the amount of stored suspended solids, due in part to the liquefying action of the bacteria and in part to consolidation of the sludge, which makes it more compact and easier to handle. The action of the tank falls far short, however, of the hopes entertained by its original promoters. Half or two-thirds of the sludge still remains to be handled, and the tank itself frequently becomes a nuisance from the evolution of odors of decomposition. Several improved types of liquefying tanks have been suggested during the last few years, of which the one designed by Imhoff for the Emscher Drainage Board of North Germany has in particular attracted wide attention. It is a tank with an upper portion through which the fresh sewage flows and a deep compartment below in which the sludge accumulates and liquefies, and it is said to effect a remarkable destruction of sludge with no obnoxious odors.

DISPOSAL OF SEWAGE BY DILUTION

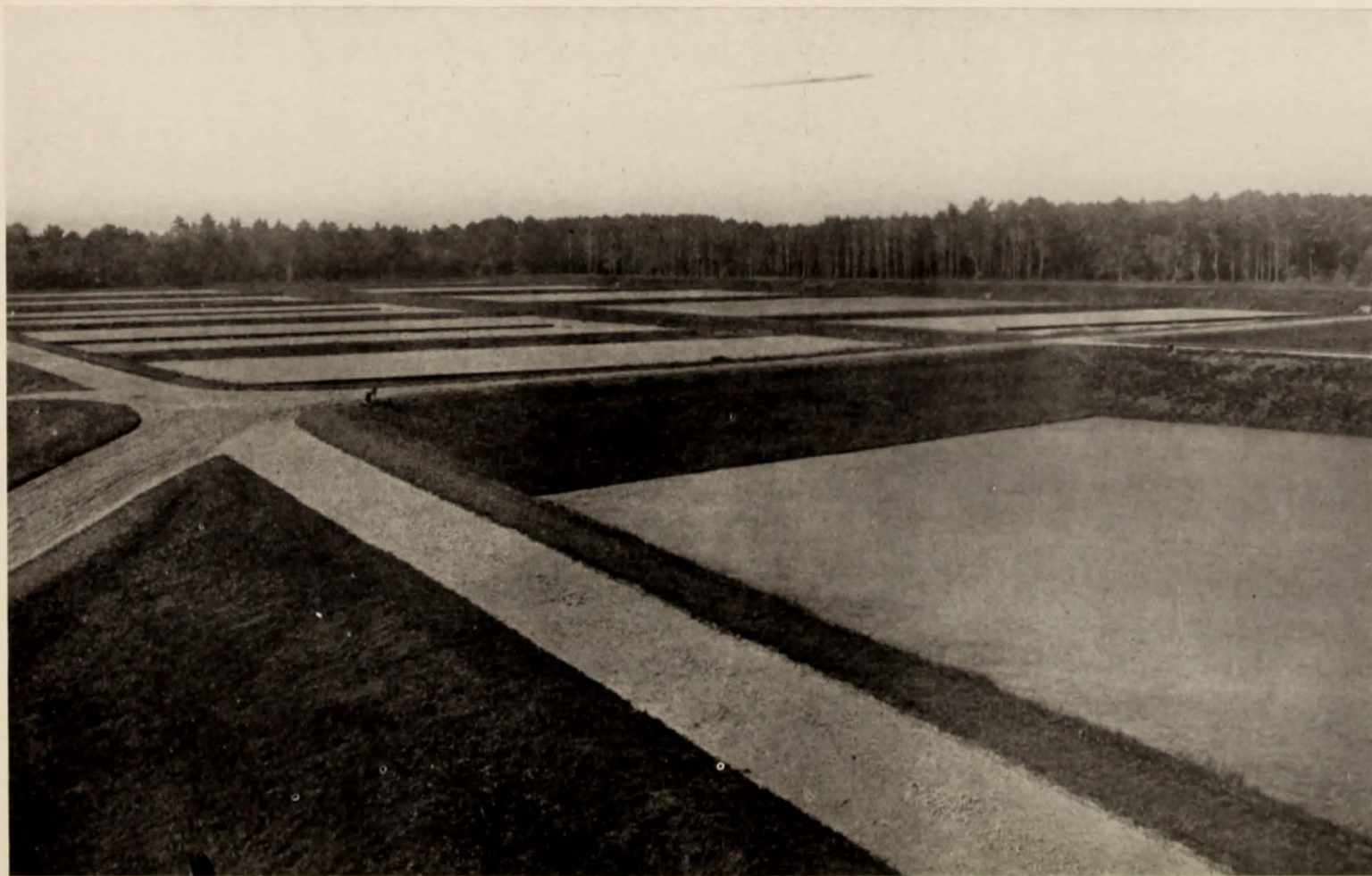
The processes so far considered are preliminary processes only, which remove from the sewage a larger or smaller proportion of its burden of suspended solids but which do not attempt ultimate purification of the organic constituents, either in solution or suspension. The final aim of sewage purification is to effect a transformation of these organic compounds into innocuous mineral substances by the action of oxygen, and this action is nitrification, practically brought about by the action of certain bacteria.

When sewage is discharged in small volume into a relatively large body of water this process takes place spontaneously. The bacteria normally present in the water attack the organic matter and oxidize it and at the same time the typical sewage bacteria, finding themselves in an unfavorable environment gradually die and disappear. Disposal by dilution, or the discharge of sewage under regulated conditions into adequate bodies of water, is a recognized method of sewage purification, much used in Germany, and often with success. The discharge of too large volumes of sewage into bodies of water which could not successfully digest them has however frequently caused grave nuisances and dangers to health, and the undue concentration of sewage in small bays and in restricted areas near shore may produce local conditions of the same sort. Most inland cities and many seaport cities as well are therefore compelled to seek some special method of sewage treatment before their wastes can be discharged into adjacent water courses.

BROAD IRRIGATION OR SEWAGE FARMING

The most obvious alternative to the disposal of sewage in water is its distribution over the surface of suitable land; and this process of "broad irrigation" is the primitive form from which our modern modes of sewage treatment are derived. Under proper conditions the living earth readily absorbs and digests the foreign materials, by the same processes which lead to the annual disappearance of manure from heavily fertilized land; and the organic matter is not only rendered harmless but is changed into a form in which it serves as food material for the higher plants.

Baldwin Latham, the distinguished English engineer, believed that he had discovered sewers and irrigation areas in the ancient city of Jerusalem; and in China excreta have been utilized for centuries as fertilizer for the fields. At Lausanne in Switzerland, at Milan in Italy, at Bunzlau in Prussia, irrigation was practised in the fifteenth and sixteenth centuries. The extensive development of the art dated, however, from the wave of sanitary reform which swept over England as a result of the *Report of the Health of Towns Commission* in 1844. This report marked the beginning of extensive sewerage construction in the modern sense and with sewerage, sewage disposal was urgently required. With the desire to dispose of polluting material, there grew up in these early days a parallel interest in the possible profit to be derived from crops grown on the irrigated land. The two aims are well balanced in the definition of sewage farming as "the dis-

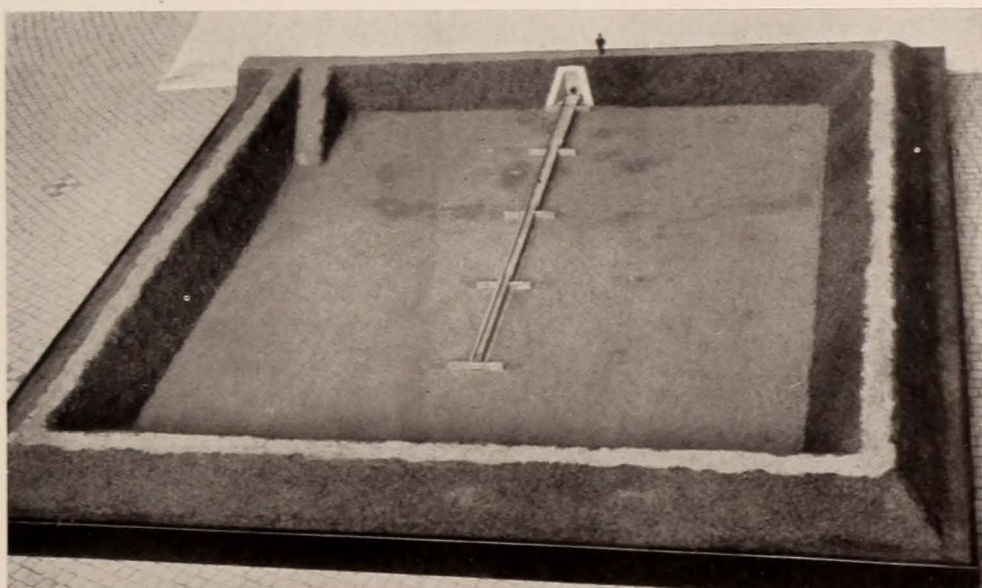


Courtesy of G. E. Bolling

INTERMITTENT SAND FILTERS, BROCKTON, MASSACHUSETTS

tribution of sewage over a large surface of ordinary agricultural land, having in view a maximum growth of vegetation (consistent with due purification)."

Progress in England along these lines was rapid, so that over two hundred irrigation areas of various sizes were in operation by 1883. Many are still in use to-day and on the continent, Paris and Berlin offer classic examples of this method of disposal. The Paris sewage is distributed on private land and it is not easy to form a sound judgment as to the success of the system. The Berlin farms on the other hand are operated by the city and offer an excellent example of sewage farming at its maximum of efficiency. The farms include 39,000 acres of excellent sandy soil, an area of over sixty square miles. Grass and cereals, potatoes and beets are cultivated and



Intermittent sand filter bed. Photograph of a model in the American Museum

dairies and distilleries are maintained for the utilization of the crops. Even the effluent drains are stocked with fish. The farms are operated by convict labor, and with German intelligence and German military discipline, the enterprise is not only successful as an experiment in sewage disposal but is also economically profitable, for the crops cover all costs of operation and pay for a part of the interest charges on the land.

In general, however, the results of broad irrigation have been by no means so favorable. The process requires large areas of land. The sewage of a community of one hundred persons would need from one to two acres; and the soil must be loose and sandy in character. Where, as in many English towns, the attempt is made to treat sewage on clayey soil, disaster

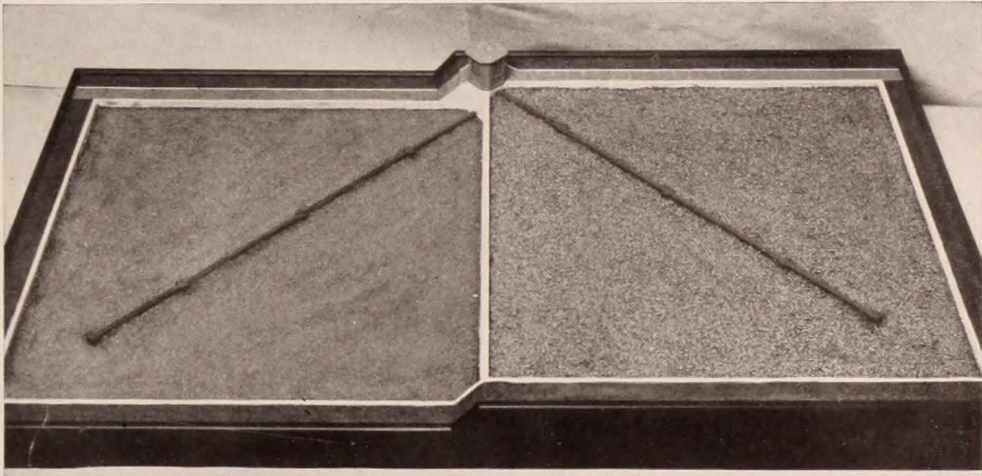
is almost sure to follow. The land clogs and becomes "sewage sick," a local nuisance is created and more or less unpurified sewage must be discharged into the nearest watercourse. Where local conditions and administrative efficiency are less favorable than at Berlin the economic advantage disappears. The most recent studies of the British Royal Commission indicate that cropping of irrigated land scarcely pays for itself — still less contributes toward the cost of sewage treatment. In the arid regions of the western part of the United States where every drop of water, as such, is precious and where the manurial value of sewage is reënforced by its water value, sewage farming becomes really profitable. In many parts of California and Colorado and other western states irrigation is clearly indicated as the best method of sewage treatment. Elsewhere, its application is more than problematical. The idea of converting the wastes of a city into walnut groves and fields of waving corn is an attractive one. The engineer, however, always wants to know the cost; and here, as in other modes of sewage utilization, it is poor policy to recover valuable elements that cost more to recover than their intrinsic value.

INTERMITTENT FILTRATION THROUGH SAND

The real art of sewage disposal began only when the crude process of broad irrigation was freed from the seductive hope of agricultural gain and developed intensively and scientifically as a means for sewage disposal pure and simple. Mainly through the experiments of the Massachusetts State Board of Health at Lawrence, it was shown that the essential process in sewage purification, either by dilution or broad irrigation, was an oxidation of organic compounds by the nitrifying bacteria, and that this process could be carried out much more efficiently by carefully controlling the conditions surrounding it. For a filter bed or substratum for the support of the growth of nitrifying bacteria, a fairly porous sand should be used, and the sewage should be applied in regulated intermittent doses with rests between for the supply of oxygen necessary to the process. By such means the rate of filtration can be raised from 5,000 to 10,000 gallons per acre per day (for broad irrigation) to 50,000 or 100,000 gallons. An intermittent filter of half an acre in area would therefore care for the sewage of five hundred persons while five acres of broad irrigation area would be needed for a similar population.

The construction of intermittent filters in regions like the northeastern part of the United States is extremely simple. This part of the country is

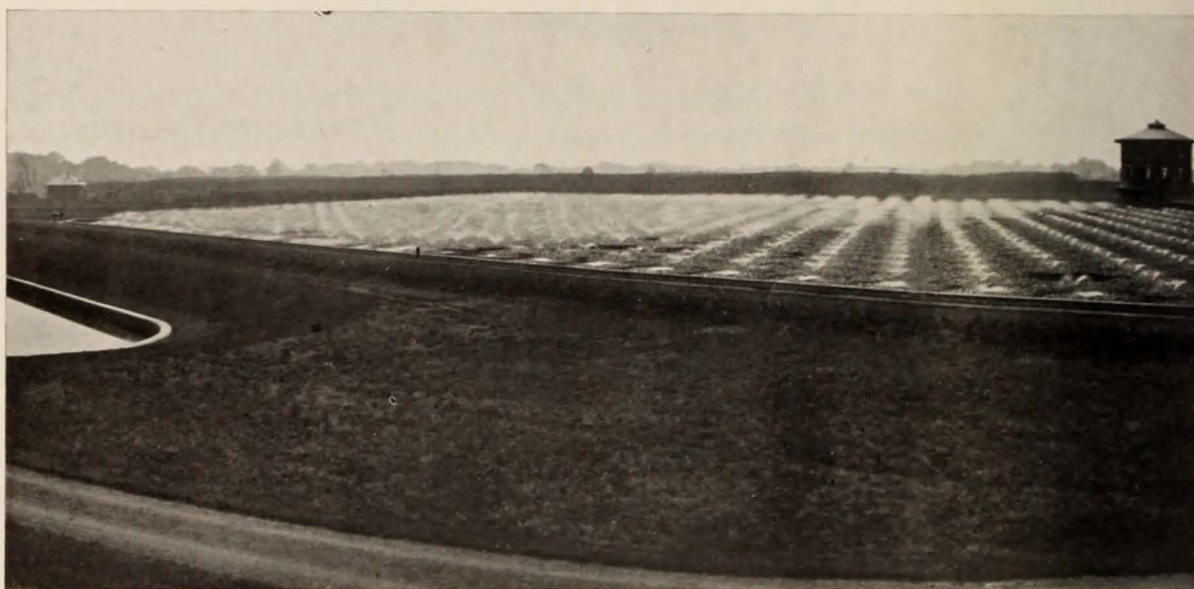
covered with deposits of glacial drift sand, ideal in character for sewage purification. All that is necessary is to expose and level off areas of this sand, to lay lines of underdrains a few feet below the surface to carry off the effluent, and to install devices for discharging the sewage on the surface. A bed may be dosed on one day out of three, or in smaller portions several times a day. In winter the beds are furrowed so that an ice roof forms on the top of the ridges while the sewage finds its way along the furrows between and, although less efficient in winter than in summer, the microbes do their work at all seasons well enough for practical purposes. The effluent from an intermittent filter, properly built and carefully operated, is a clear liquid, colorless or slightly yellowish in color, with no odor or only a slightly



Double contact beds for purification of sewage. Photograph of a model in the American Museum

musty one, practically free from putrescible organic matter and low in bacteria — a liquid that can be discharged with impunity into even the smallest watercourse.

The successful and economical use of the process of intermittent filtration is limited to those regions where ample areas of the right soil are easily available. In clayey or chalky regions, sand beds must be artificially constructed with material brought from a distance, and this would make the cost of the Massachusetts method almost prohibitive. In England where the sewage problem pressed hardest for solution, sand is usually not available and it was almost essential that further improvements should be made.

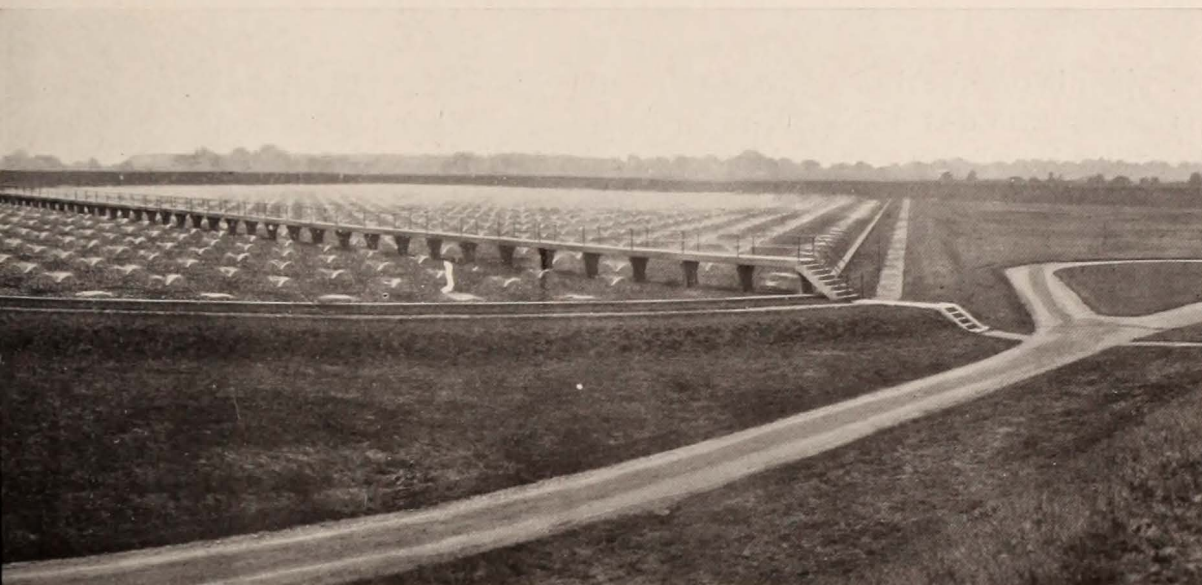


PANORAMIC VIEW OF TRICKLING FILTERS, COLUMBUS, OHIO

THE CONTACT BED

Mr. W. J. Dibdin, Chemist to the London County Council, was one of the first to attempt to modify the sewage filter so that it would operate at higher rates, and as a first step he naturally sought to build his beds of coarser material. In a notable series of experiments at the Barking outfall on the Thames, he found that the nitrifying bacteria could be grown on fragments of coke or stone as well as on sand and that purification could be effected in such beds if only the sewage were held in contact with the material, instead of being allowed to stream directly through. In sand filters, frictional resistance delays the passage of the sewage, so that time is given for the purifying process. With coarser materials, however, it is necessary to regulate the flow by making the beds water-tight and retaining the sewage in them until purification is completed. This was in outline the genesis of the contact bed.

Beds of this type are simply concrete or masonry basins, filled with crushed stone or coke or slag, in which sewage is allowed to stand for a period of about two hours. After one dose is withdrawn the bed stands empty for aëration for four hours or so and another dose is then introduced, three fillings a day being perhaps an average. A single contact treatment does not commonly yield an effluent sufficiently stable to discharge into a small stream. It is the general practise therefore to use double contact, treating the sewage first in a bed of coarse stone, perhaps one and one-half to two



inches in diameter, and then in a fine bed, of perhaps half-inch material. The rate of treatment, even so however, is much higher than that commonly used with sand beds, 500,000 gallons per acre per day against 100,000. Half an acre of contact beds would treat the sewage from a population of 2,500 against 500 for the intermittent filter. The effluent even from double contact is less highly purified than an intermittent filter effluent. It is dark and somewhat turbid, but it should be free from the tendency to putrefactive decomposition.

THE TRICKLING FILTER

Meanwhile the problem of purifying sewage at high rates was being attacked in another and even more promising manner. The fundamental combination of bacterial films, sewage and air can be effected in various ways. The late Colonel George E. Waring attempted it at Newport in 1894 by blowing air into a bed of coarse stone below, while sewage ran down through it from above. Theoretically this seems a satisfactory process but it has not yet been demonstrated that a sufficient supply of oxygen can be economically provided in this manner. Success was finally reached along another line by resorting to the device of applying sewage, not in bulk, but in a fine spray distributed as evenly as possible over the surface of the bed. By this means the rapid flow of large streams of sewage is prevented and the liquid trickles in thin films over the surfaces of the filling material while the spaces between are continually filled with air, the oxygen content

of which in practise does not become seriously exhausted. The condition is analogous to that which obtains in the process of vinegar manufacture when alcoholic liquor is allowed to run over shavings covered with growths of acetic acid bacteria. Under the name of the trickling bed (called also sprinkling bed or percolating bed) this has come to be considered one of the most promising and effective of all devices for sewage purification.

As in the case of contact beds, almost any hard non-friable material may be used for the construction of trickling filters. In America the size of the filling material is generally between one and four inches and the depth of the beds between five and eight feet. Mr. Rudolph Hering in a very enlightening review of the underlying principles of sewage treatment has recently pointed out that there are three fundamental variables in this process of purification, air supply, total area of bacterial films and time of exposure. The area of bacterial films is conditioned by the size of the filling material and the depth of the bed (the smallest material, of course, giving the greatest surface) and the time of exposure is controlled by the rate at which sewage is applied. Reduced to its lowest terms a trickling filter is simply a heap of stone or other material of such size, depth and texture as to support a bacterial growth sufficient for the work in hand.

The distribution of the sewage over the surface constitutes the most serious difficulty in the construction and operation of the trickling bed. In England, many of the disposal areas are equipped with mechanical distributors of great complexity. Some are designed on the principle of the lawn sprinkler and are revolved by the propulsive force of the sewage as it is discharged. Others are in the form of great movable weirs which pass back and forth on rectangular beds, dripping sewage as they go. At Hanley a mechanical distributor was installed for a quarter acre bed which weighed twelve tons and wore out a forty-five pound bridge rail in two and a half years.

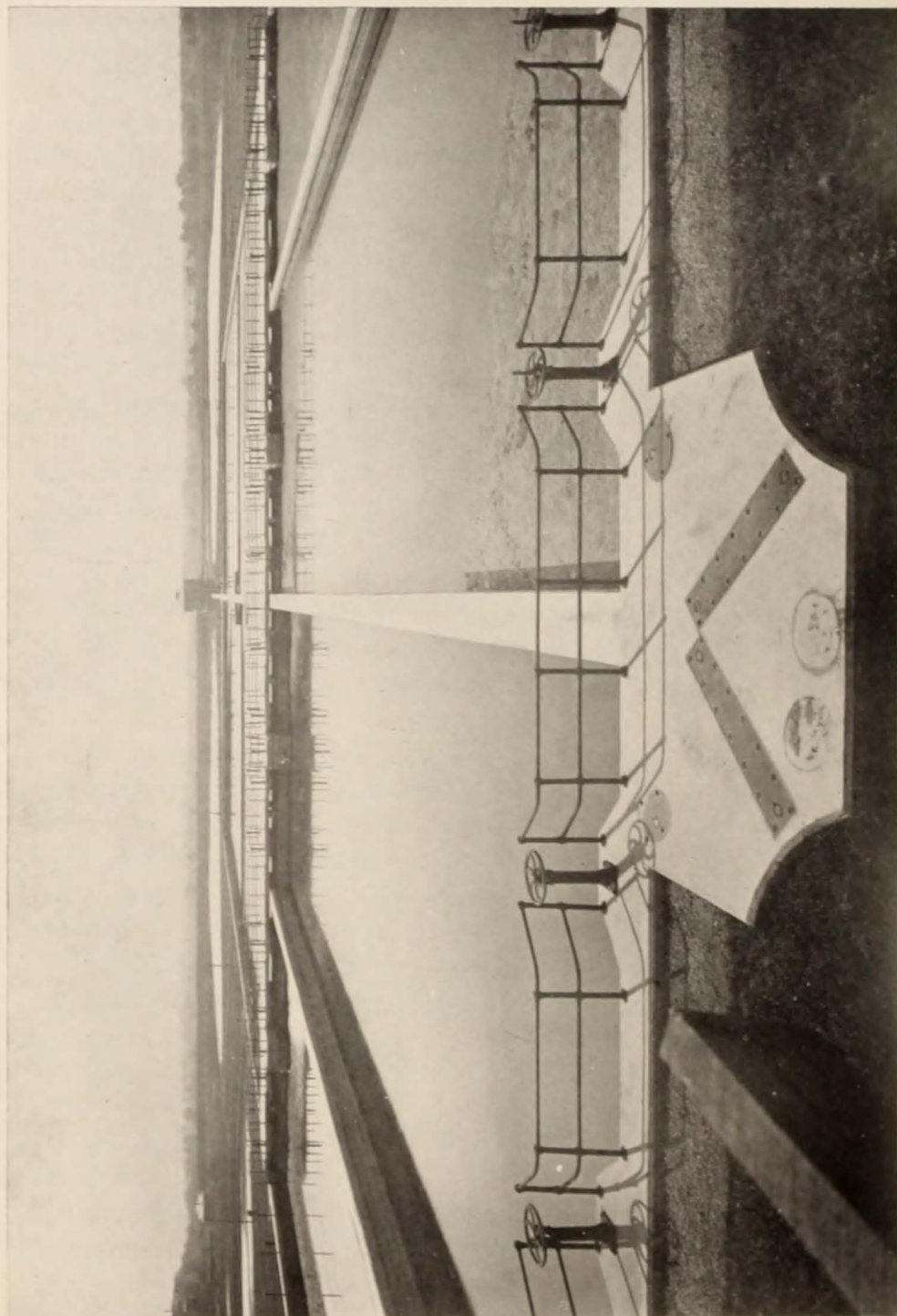
At other English plants, like the most famous of all at Birmingham, and at most American disposal areas, the sewage is distributed by spraying it upward from fixed sprinkler nozzles. This method effects a less perfect distribution than that attained by the English mechanical apparatus but the cost of construction and renewal is much less.

The trickling filter can be operated at a rate of 2,000,000 gallons per acre per day, or four times as fast as the contact bed. Half an acre of trickling beds would care for the sewage from 10,000 persons while a similar area would only do for 2500 persons with the contact bed and for 500 with the intermittent filter. Furthermore trickling beds are practically free from the clogging which menaces the permanency of the contact process.

for the suspended matter comes through trickling beds in the long run in about the same amount in which it goes on at the top, changed only in its chemical nature. The effluent is far less well purified than that of a sand filter. It is more turbid even than contact effluent and in appearance may not even seem very different from untreated sewage; however, the essential changes have been brought about. The more unstable organic bodies have been oxidized and the effluent contains a sufficient excess of oxygen so that succeeding changes will be nitrifications and not putrefactions. At Birmingham, England, where the trickling process has been most ably and exhaustively studied, a sewage flow of 30 million gallons a day is treated first in sedimentation and septic tanks and then on trickling beds, having a total area of about thirty acres; and in dismissing an injunction granted against the city by a lower court the Master of the Rolls has recently decided that the effluent from the Birmingham works actually improves the character of the river into which it is discharged. The large plants recently constructed in the United States at Columbus, Ohio (twenty million gallons), at Washington, Pa. (one million gallons), at Reading, Pa. (two million gallons) and at Mt. Vernon, N. Y. (three million gallons) are all of the trickling type. The trickling filter is indeed an ideal mechanism for solving the essential problem of sewage disposal. It exhibits the simplicity of all scientific applications, which are merely intelligent intensifications of natural processes. A pile of stones on which bacterial growth may gather and a regulated supply of air and sewage are the only desiderata. We meet the conditions resulting from an abnormal aggregation of human life in the city by setting up a second city of microbes. The dangerous organic waste material produced in the city of human habitations is carried out to the city of microbes on their hills of rocks, and we rely on them to turn it over into a harmless mineral form.

SEWAGE DISINFECTION

So far nothing has been said about the problem of bacterial removal. In general this is a subsidiary question in sewage purification. Frequently the elimination of offensive organic decomposition is all that is necessary and bacteria can be allowed to pass with the effluent into the stream, to be removed by the quite distinct processes of water purification from any water taken out for human consumption. Sand filtration effects a very considerable purification in living and lifeless constituents alike; but the



SEPTIC TANKS, COLUMBUS, OHIO

Twenty million gallons of sewage a day can be treated in this recently constructed plant

contact and trickling beds are essentially oxidizing mechanisms without filtering action adequate for the removal of micro-organisms. It is true that in the unfavorable environment of the septic tank and trickling filter, many sewage organisms do die out, but their elimination is incomplete and uncertain. If a nearly germ-free effluent is required some special method must be adopted for bacterial removal. This particular problem has come into great importance of late in connection with the protection of shellfish industries, menaced by the sewage of seaboard cities. Fortunately there has been worked out to meet this need a simple and efficient method, a new chemical treatment, not designed as in the old precipitation processes to remove suspended solids but merely to destroy living germs. The application of ordinary bleaching powder, or chloride of lime, in small amounts of fifteen to thirty parts of bleaching powder to a million parts of sewage will effect a satisfactory reduction of bacteria at a very reasonable cost, as shown first by Mr. S. Rideal in England and by Prof. E. B. Phelps in this country. Baltimore, Maryland, has adopted this procedure as have certain small towns on the New Jersey coast; and it promises to be of use in dealing with certain phases of the New York Harbor problems.

There are many questions still to be solved in the purification of sewage. The removal of suspended matter, for example, urgently demands further careful study; yet the work of the last ten years in England and the United States has blocked out the main outlines of satisfactory sewage disposal practice. The engineer can to-day successfully meet any demand for the purification of domestic sewage; and this purification may be carried to any degree of perfection for which the community in question is prepared to pay. If a clear and sparkling effluent, highly purified bacterially, is desired he can design an intermittent filter for that purpose. If merely a stable effluent which may be discharged into a stream without creating a nuisance is wanted, he can build a trickling filter. If, on the other hand, a disinfected but not organically purified effluent is called for, that end, too, may be attained.

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