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OF THE

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NO. 362

Municipal Research Series No. 4 October 1, 1914

METHODS OF SEWAGE DISPOSAL FOR TEXAS CITIES

BY

ROBERT M. JAMESON

Secretary of the Bureau of Municipal Research and Reference

Published by the University six times a month and entered as second class matter at the postoffice at Austin, Texas

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston.

Cultivated mind is the guardian genius of democracy . . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar.

PREFACE

I have tried to collect and digest the latest data upon the subject of Sewage and Sewage Disposal, being concerned only with the results of actual operation of the different processes in the cities. For this purpose, I have used texts and treatises freely. The most useful of these works are those by Fuller, Kershaw, Kinnicutt, Winslow and Pratt.

Dr. Herman G. James, with criticism and advice, has rendered me considerable service in the preparation of the paper. I also wish to thank Mr. M. C. Welborn, the City Engineer of Austin, and Prof. E. C. H. Bantel for their many kindnesses shown me in the preparation of this subject.

Robt. M. Jameson.

Austin, June, 1914.

EDITOR'S PREFACE

The first and second publications of the Bureau of Municipal Research and Reference dealt with the matter of a model charter for Texas cities. It was thought that, in view of the Home-Rule amendment and enabling act, the matter of perhaps the most immediate concern for cities over 5000 inhabitants is the question of charter framing or amendment.

Another matter of no less importance, and of even more urgency, as well as of wider application, is the problem of sewage disposal in Texas cities. The Thirty-third Legislature of Texas enacted a law[1] on March 27, 1913, forbidding the pollution of streams by sewage or other matter within the limits of any municipality. This law affects every incorporated municipality in the state which at present disposes of its sewage by emptying it into a water-course or other public body of water.

A period of three years, commencing ninety days after the adjournment of the Legislature (April 1, 1913), is given to comply with the provisions of the same, which means that there remain about two years for municipalities affected by the act—and there are many of them—to comply with its provisions. The question of sewage disposal is a very difficult and complex one, and the time remaining under the law is barely long enough for the construction of any considerable undertakings in that direction. This bulletin is intended, then, primarily for the benefit of those municipalities of the state which must, under the law, find some other way of disposing of their sewage than in the way now done. It is thought that the information herein contained, as well as that referred to in the bibliography, could be of real assistance in clearing the ground for the consideration of this important and pressing problem.

But it is not alone those cities of Texas which are compelled to alter their method of sewage disposal, as a result of the so-called anti-pollution bill, that it is hoped will be able to derive benefit from the material contained in this bulletin. There are other cities, in this state and in other states, that are troubled with the

[1]Appendix, p. 62.

problem and are looking for an improvement in their methods of sewage disposal, even when not affected by the act of a Legislature.

For all these cities, then, the Secretary of the Bureau of Municipal Research and Reference has collected information and reference which should greatly simplify at least the comprehension of the important considerations involved. His purpose has been not to treat the subject so technically as to be comprehensible only by city engineers, but in as popular and simple a way as the subject permits, in order that the intelligent laymen of the cities, who are to act under the law, may have some notion of the use to which the money will be put which they will have to vote for the building of sewage disposal plants.

HERMAN G. JAMES,
Director of the Bureau of Municipal Research and Reference.

June, 1914.

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Methods of Sewage Disposal for Texas Cities

PART I

METHODS OF SEWAGE DISPOSAL.

I.

BROAD IRRIGATION.

This method was very probably in use in the ancient city of Jerusalem, and the Chinese and Japanese adopted this process thousands of years ago. And from time immemorial irrigation has been the method practiced at the Craigentinny Meadows, whose fields receive the sewage[1] from the city of Edinburgh. The development of broad irrigation occurred primarily in England after the report of the Sewage of Towns Commission in 1858. The first sewage farm on the Continent was operated at Dantzig in 1869. Experiments were begun in Paris in 1865, and in Berlin in the year 1876.

In England, broad irrigation and land filtration constitute primarily a single process; that is, both methods are employed. Thirty thousand gallons per acre is an exceptional maximum, and the growing of crops is considered an essential part of the process. The sewage is generally subjected to sedimentation and screening as a preliminary treatment, and the lands are laid out very carefully. The land is made fairly level or carefully evened, according to the nature of the process in use. Provision is made for storm water, and the absorption of the sewage is facilitated in every possible way. Underdrains are generally preferred, except, or course, in clay soils. In England, some forty or fifty years ago, the method of broad irrigation was commended by the Royal Commission as a means of relieving certain rivers of pollution. The popularity of broad irrigation in England spread to the Continent, and the subject was carefully investigated not only in England, but at several important Continental cities. At Paris, in 1868.

[1]Foul and waste liquids.

the matter of broad irrigation was investigated from the chemical standpoint at Gennevilliers by Mille and Durand-Claye. In Germany this method was investigated by Rudolph Virchow, and at the Berlin sewage farms particularly in 1876. In Germany the process of sewage irrigation is carried on with precaution, and, as a rule, with more satisfactory results than in England. Sewage is not treated on clayey or peaty soils; the irrigation areas are of sand, carefully underdrained and equipped with well-designed distributing systems. Suspended solids are carefully removed.

A greater area of land is of course required for surface irrigation than for filtration. The proportions will depend on the nature of the land, the character of the sewage to be treated, and the extent to which crops will be grown. The chief objection to land filtration are that in most cases the sludge[1] is handled carelessly or not at all; there is danger that the purification of the sewage will become secondary to the cultivation of the crops; efficient management constitutes a very serious problem; and it is often difficult to obtain land satisfactory as to quantity, quality and price. The adoption of some preliminary process for mechanically settling some of the suspended solids in sewage depends on the nature of the land and the condition of the sewage.

Foul liquids are purified by land by indirect oxidation through the agency of bacteria, some soils being more satisfactory in this regard than others. Absorptive and retentive soils are little suited for filtration purposes. The depth and character of the surface soil will regulate to a large extent the rate of percolation of the liquid down to the subsoil and underdrains; but purification primarily is effected in the upper layers of the soil. Sand is rarely satisfactory; alluvial soils are very efficient; clay soils are to be avoided, though heavy soils can be improved by the addition of ashes or similar materials; warp land is valueless for sewage treatment; and chalk lands are to be adopted with considerable precaution. It must be remembered that soils and subsoils are of wide variation even in restricted areas, and therefore results may be expected to fluctuate.

The action of the soil on sewage consists of mechanical straining, mordant or "absorptive" effects, and biological changes. Very

[1]The more or less solid residue which remains after the treatment of sewage.

generally, the sewage from 500 to 1000 persons can be treated upon an acre of suitable land in cases where effective preliminary processes are adopted.

The quantity of clarified tank effluent[1] (per acre) which can be purified by different soils will appear in the following table:[2]

	Crude Sewage.		Settled Sewage.		Efficient Preliminary Treatment. Land Secondary.	
	Gallons	Population	Gallons	Population	Gallons	Population
Light sandy loam on gravel and sand	15,000	375	20,000	500	30,000	1,000
Sandy loam on gravel and sand	12,000	300	17,000	400	30,000	1,000
Peaty soil on gravel and sand	10,000	250	13,500	325	30,000	1,000
Sand and gravel	8,000	200	10,000	250	30,000	1,000
Gravelly loam on gravel and sand	6,000	150	8,000	200	20,000	666
Loam getting more clayey	4,500	125	6,000	150	15,000	500
Heavy loam on marl	3,000	75	5,000	130	12,000	400
Clay soil on clay	1,500	50	4,000	120	10,000	333
Stiff clay soil on dense clay	1,000	33	3,000	100	10,000	333

It is often difficult to obtain satisfactory lands for the establishment of sewage irrigation farms. In cases where individuals refuse to sell or are considerably reluctant in the matter, it has been recommended by the Rivers Pollution Commissioners (England) that, "subject to proper regulations to prevent abuse, additional powers be given to corporations, local boards, manufacturers, and others to take land compulsorily, under 'Provisional Order,' for the purpose of cleansing sewage or other foul liquids, either by irrigation, filtration, or otherwise."[3] And certainly here in the United States our municipalities ought not to be hindered in their sanitary growth and development by the whims and fancies of any individual or group of individuals. Before the final purchase of the lands required for a given population, there should be ascertained the number of gallons of liquid per acre the land will be able to purify efficiently. Naturally, land is expensive in the vicinity of towns, and therefore it will be advisable to locate the works some distance from the cities concerned. The method adopted will depend primarily on the contour of the land available, the nature of the soil and subsoil, and the volume of

[1]The liquid portions of the sewage run off after settling.

[2]Moore and Silcock, p. 610. The table is for English sewages, containing *less* water than in the case of American cities. The figures would therefore be reduced when applied to conditions in the United States.

[3]Corfield, p. 422.

sewage. The size of the plots used for sewage treatment will depend mainly upon the volume of sewage, and the method adopted —surface irrigation or filtration. Where a sufficient area of suitable land is available, disposal on land is very generally satisfactory for small communities. The following factors enter into the selection of the lands: the quality of the land; the composition of the sewage; the methods of sewage disposal upon the lands; kinds of crops to be planted; and the time required for agricultural operations. The best lands consist of a fine surface layer of alluvium overlaying a subsoil of gravel, chalk, or other porous material. No general rule can be expressed in regard to the proper site for sewage disposal works. The contour and slope of the surface of the land; the liability to floods; the nature of the soil and subsoil; the subsoil waters; the transportation facilities; the nature of the streams; the situation of the lands; the availability of a gas and water supply; and the nature of the adjacent property are factors that must be carefully noted in the final selection of a site for the sewage disposal works.

Local conditions will determine the method or methods of irrigation, and the efficiency of these methods will depend upon the abilities of the manager. The ridge-and-furrow system is of very general use. Care should be taken in regard to the properly drying off and the resting of the land; and the determination of the best method will depend upon the manager. Crops are secondary to the production of a good effluent. They assist in the purification of the sewage and, occasionally, sales of crops cover a considerable portion of the cost of treating the sewage. The cost of cleaning the land is a serious item of expense. The soil should be worked constantly, and the weeds burned in heaps. The market for sewage-grown produce is often prejudiced, and the transportation costs are frequently heavy.

Putrefying sewage must not be permitted to stand in puddles on the ground. The interval between the periods of the flow of the sewage should be regulated by the needs of the crops raised. Experiments indicate that varying amounts of sewage should be applied to different crops, the amounts ranging from less than 500 gross tons per acre per annum on heavy land, in wet seasons, to about 9000 tons per acre on grass lands. Care must be exercised on sewage irrigation farms that the sewage does not run merely over the land; the sewage must not flow merely onto the land, but through it. Further, the sewage should come in contact with the roots of the crops; it will be absorbed by them when the soil itself could not retain it. Of course the best soils are those which can satisfactorily retain the manure, and for this purpose a porous soil will be found to be the best purifier. Clay soils cannot be used. The Committee of the Local Government Board on Modes of Treating Town Sewage (England) concludes that "town sewage can best and most cleaply be disposed of and purified by the process of land irrigation for agricultural purposes where local conditions are favorable to its application."[1]

The amount of labor required will generally depend upon the method of working the land, and the nature of the crops grown. Workmen on sewage farms ordinarily enjoy particularly good health, contrary to the current opinion. "Sewage-sick" lands should be given an immediate rest, and a dressing of 1½ to 2 tons of lime per acre is advisable. As a general rule, sewage farms should not be sub-let by the municipal authorities to tenant farmers; nor should cattle be turned upon sewage lands.

The cost of the land treatment of sewage will depend primarily upon the local conditions; but it must be remembered that the disposal of the sewage in a satisfactory manner is the ultimate aim of all effort.

The following crops have been grown on sewage farms: Corn, walnuts, parsnips, carrots, potatoes, rhubarb, turnips, cauliflower, celery, onions, squashes, beans, peas, asparagus, tobacco, and timothy. The local conditions will determine the most suitable crops. Experiments have proved that the amounts of produce do not increase in proportion to additional amounts of sewage applied to the lands. The sewage should be applied to the fields in small quantities per acre. And, in some cases, a moderate profit can be realized by economical methods. In case of grasses, particularly in wet years, these crops should be stored and compressed in silos. They could then be kept until a satisfactory market, or other method of disposition, becomes available. The crops of the sewage farm should only receive the sewage as it is required. They should be planted upon a ridge, which will greatly

[1]Corfield, p. 376.

facilitate cultivation. The separation of the surface and storm water under the separate system[1] will further assist in the efficient management of the sewage farm.

It is paramount to the health and welfare of the city that a competent manager be selected to supervise the operations of the disposal works. He should receive a proper salary for his services, and should, among other things, make periodical analyses of the classes of the effluent being produced by the plant.

EUROPEAN EXPERIENCES.

Paris Sewage Farms.—In 1894, Rheims (population about 100,000) was the only city in France that treated all of its sewage effectively. The sewage was conducted to a purification field, where it was distributed, under pressure in a piping system, to trenches, largely made by plowing. The rate of application equaled about 3,200,000 U. S. gallons per acre, annually, or an average daily quantity of about 9000 gallons per acre. The sewage was purified in the porous soil and served for the fertilization of an agricultural area ceded by the city to a company.

This process was advocated in 1864 by Mille and Alfred Durand-Claye for the city of Paris, and since 1868 this method has been considerably investigated at Gennevilliers. The irrigation works for the treatment of Paris sewage were extended nearly 2000 acres under the law of July 10, 1889, and completed in 1895. The new purification field is able to receive 4,280,000 U. S. gallons per acre per year, equal to 11,800 U. S. gallons per acre daily on an average. This, however, constituted only a fraction of the total sewage flow, and the greater portion of the sewage still continued to be emptied into the Seine. Since July 10, 1894, however, work has progressed upon the irrigation sewage farms of the city of Paris, and since July 8, 1899, the discharge of the great intercepting sewers of Paris into the Seine ceased. The entire sewage

[1]The separate system provides separate sewers for the storm and sanitary and manufacturing sewage. The combined system carries off the storm and sanitary and manufacturing sewage in the same sewers. Storm sewage is the storm water flowing from city surfaces. Sanitary sewage is wastes of human and animal origin. Manufacturing sewage is foul wastes from factories. Sewers are open or closed drains for the removal of waste liquids. Drains are channels or pipes for the gradual removal of liquids. "Sewerage" refers to the entire *system* of sewers.

of Paris is now regularly applied to the purification fields. All the ordinary flows of sewage certainly are treated systematically on the irrigation fields. The cost of these works was about $9,000,000. The annual expense of operation and maintenance equals a sum of about $700,000.

Methods of Control.—The city owns about 3450 acres, renting these lands to farmers for an annual stipulated sum subject to the requirements of the purification process. The remaining 8650 acres belong to private parties who receive the sewage as the interests of cultivation demand, but without paying any ground rent.

The Commissions under the higher board of administration control the operation of the irrigation system. They are compelled by law to present half yearly reports and to present data concerning the operation of the system.

Purification.—Results have been obtained unequaled elsewhere either by sewage irrigation or other processes.

BERLIN'S SEWAGE FARMS.

These farms were first opened in 1876, and in March, 1910, the area totaled 43,009 acres. In 1910 about 77,000,000 U. S. gallons of sewage were treated daily by the Berlin farm, an amount equal to about 35 gallons per capita daily. This sewage is pumped to a light sandy soil, through which it percolates readily. There are twelve pumping stations which deliver the sewage to eight farms, three of which are south and five north of Berlin. The northern farms are about four to seventeen miles from the city, the southern farms eight to seventeen miles. The centers of the northern and southern farms from the center of the city are 9.5 and 12.5 miles, respectively.

It is noted from the report of March, 1910, that the sewage farms have been developed to the following extent:

	Farmed by city authorities.	Let to small farmers (market gardeners).	Permanently or temporarily unproductive.	Total.
Acreage prepared and under sewage treatment	16,657	3,956	395	21,008
Acreage unprepared and farmed in ordinary way	10,647	2,486	8,868	22,001
	27,304	6,442	9.263	43,009

At the end of 1910, 22,851 acres were used as follows:

A.	Used for broad irrigation, grass plots		7,994 acres
B.	Used for filtration beds	12,250 acres	
	Used for settling basins	502 acres	
			12,752 acres
C.	Subsidiary works		126 acres
D.	Occupation roads		1,979 acres
	Total		22,851 acres

On March 31, 1910, capital costs were about as follows:

Purchase	$ 9,861,878 00
Laying out, including sewage distribution, roads, etc.	4,455,604 00
Drainage	1,203,030 00
New buildings and sundries	1,949,488 00
Total on March 31, 1910	$17,470,000 00

The following table states the cost per acre of total area of land:

	Total area.	Land specially prepared
Purchase of land	$229 38	$431 52
Laying out, including distribution of sewage, roads, etc.	103 50	195 12
Draining land	27 90	52 68
New buildings and sundry expenses	45 42	85 26
Total capital expense per acre	$406 20	$764 58

For the year ending March 31, 1910, the following table outlines the receipts and expenditures of the sewage farms:

Receipts	$1,240,772 58
Net increase of valuation in live stock and dead stock	122,593 50
	$1,363,366 08
Deduct payments for maintenance	1,300,385 34
Profit on year's work	$ 62,980 74

Payment of interest and payment of loans........	$ 741,718 62
Deduct profit on year's work....................	62,980 74
Deficit, to be made good from taxes........	$ 678,737 88

About 3700 U. S. gallons per acre daily were filtered in 1910 through the prepared lands, about 21,000 acres. The annual rainfall averages about 23 inches. Wheat, oats, rye, barley, Indian corn, potatoes, beets, and carrots are raised. The effluent is said to be of good quality. It is conducted to fish ponds, the area of which in 1910 was 40 acres. About $80.00 per acre per year is derived from the fish ponds, or more than is ordinarily obtained from the sale of crops from land. Average yields of crops are obtained.

Most favorable conditions for sewage farming exist in arid regions, a fact illustrated by the early development of these farms in Wyoming, Colorado, and Nebraska. The first of the western irrigation works was introduced at Cheyenne, Wyoming, in 1883. About 1890, plants were in operation in Colorado Springs, Helena, Santa Rosa, Los Angeles, Hastings, and Trinidad. The plants at Salt Lake City, Hastings, and Pasadena, are among the largest and more widely known. Peas, beans, corn, grass, tomatoes, cabbages, turnips, alfalfa, and fruit trees are cultivated. These western sewage farms have very generally proved successful.

A general utilization of the manurial constituents of sewage at a commercial profit is practically impossible. It has been estimated that the sewage of English cities contains from one to four cents' worth of fertilizing matter per ton, and the consumption of water is considerably less in the English town than in the American city. So far as we should be concerned in this country, commercial utilization of sewage is subordinate to the greater problem of thorough purification. Nitrogen, potash, and phosphates are the principal fertilizing elements in sewage. According to the estimates of Messrs. Rafter and Baker, one million gallons of sewage under favorable circumstances might have a value ranging from $42.00 to $125.00. In the *Engineering Record* of November 24, 1910, Prof. J. A. Voilcker, Consulting Chemist to the Royal Agricultural Society of England, states that the "manurial value of sewage as it is now generally met with, and whether it be in the form of crude sewage, of sewage deprived of its solid matters, or of sewage sludge, is but very small." In arid regions the sewage will save the cost of water for irrigation. Hence some financial returns may be possible, but ordinarily sewage for irrigation purposes does not present very great hope of any financial returns to the average city in the arid regions.

There are those who object to sewage farms, because of the imminent danger to the public health and welfare. Fresh sewage is not offensive, though offensive deposits certainly arise in bad carriers. This emphasizes the necessity of filtration, and in some towns deodorization even is practiced. The nuisance from sewage farms is very generally only that of ordinary manure, and certainly need not be any greater. Indeed, some authorities declare there need be no nuisance at all. If there is a nuisance, it generally arises from inefficient management; and there is plenty of evidence available to prove that, when well managed, there is no evidence of disease ever being carried by sewage filtration and irrigation.

Excellent results *can* be obtained by the method of broad irrigation, and the efficiency of the process will be determined largely by the nature of the soil; the construction of the beds; and the method of operation. The final effluent should be of a satisfactory quality, and the operation of the works should result in no serious local nuisance. Some four thousand persons are resident on the Berlin farms, but there is no evident detrimental influence upon the health of these people. And further, disease need not be spread by the crops grown on the fields, a fact clearly illustrated in the experience of Berlin and Paris.

CAPACITY.

On an average, 3000 to 12,000 gallons per acre can be applied daily. Conditions of soil and climate will enter into a consideration of these figures. It is probable that a more correct estimate will include 100 persons connected with the sewers for each acre of land. The sewage filtered through a sewage farm represents the highest degree of purity practically obtainable.

EXTENT OF USE.

In 1904 there were some fourteen municipal sewage farming projects in the United States, serving about 200,000 people. This method was first used in the United States at the State Insane Asylum near Augusta, Maine, in 1876. It is in fairly general use in the Far West. Sewage irrigation is on the wane in the arid districts of America. Experiments with this method have been obtained at Pullman, Illinois, at Los Angeles, California, where the practice has been abandoned, at Pasadena, California, in which city the sewage is irrigated on a city farm of some 460 acres; at Salt Lake City, Utah, which comprised 150 acres in 1904; and at Fresno, California, where a sewage farm was installed in 1907. On the whole, the evidence indicates that the method of broad irrigation is on a steady decline—in the arid regions as well as elsewhere. There is now scarcely a plant in which satisfactory sanitary results are obtained. The hygienic aspects of broad irrigation are disappointing. They cannot be corrected by health ordinances.

In America, this process is used at a few intermittent sand-filtration plants. In the arid regions, sewage farming is certainly not carried out in a sanitary and satisfactory way. In Europe, more success has attended sewage farms, but they have not been get-rich-quick propositions. They are, however, considerably in advance of farms of this type in America. Favorable soil conditions and careful and efficient management explain these differences. In England, sewage farming or broad irrigation is still in extensive use. On the whole, however, the method is on the wane, and filters of artificial construction are now being builded. It is probable that the Paris sewage farms will ultimately be abandoned, and this will also likely be the case in Berlin.

II.

SPRINKLING FILTERS.

"Sprinkling filters provide for the application of sewage in a comminuted form, usually as a spray, to fairly thick layers of coarse material, resembling in size that of contact filters. Essentially, this type of filtration is applicable to the elimination of nuisances due to the decomposition of the organic matter in sewage rather than to the substantially complete removal of objectionable bacteria."[1]

In June, 1889, two filters of gravel stones were put in operation at the Lawrence Experiment Station of the Massachusetts State Board of Health. These filters served as the foundation for the modern sprinkling filter as well as for the modern contact filter. The sprinkling filter developed to a practical basis in England. It is principally to Mr. Joseph Corbett, for some years city surveyor of Salford, England, to whom we are indebted for practical advances upon the Lawrence gravel filters. Mr. Stoddard and Col. Geo. E. Waring also recorded further experiments in regard to this method. The first sprinkling filter installation in America was recommended for adoption at Atlanta, Ga., by Mr. Rudolph Herring in January, 1903. Funds were not provided until 1910 for construction. In 1901 a small filter plant was installed at Madison, Wisconsin. The Waring device, including force aeration, was installed at Willow Grove, Pa., Wayne, Pa., East Cleveland, Ohio, and Homewood, N. Y., but the excessive cost of forced aeration prevented practical success. The Columbus sewage testing station demonstrated the practicability of operating sprinkling filters during severe winter weather, and that a non-putrescible effluent could be obtained at much less cost for construction and operation than under the systems outlined by the contact filter method or other processes. Experiment in regard to the sprinkling filter method have been recorded at the Institute of Technology, Boston, Mass. The first municipal sprinkling filter plant placed in service in America was opened in January, 1908, at Reading, Pa. Further data upon this subject have been obtained at the testing stations of Waterbury, Conn., Baltimore, Md., Gloversville, N. Y., Philadelphia, Pa., and Chicago, Ill. This method of sewage purification has been recommended for practically every large purification project since the completion of the Columbus tests in 1905. Sprinkling filters do not constitute a complete working process in themselves, but they represent the greatest advance step in the field of sanitary science during the first half decade of the century in America. They are more economical than intermittent sand filters or contact filters.

[1]Fuller, Chapter 21.

The first modern sprinkling filter plant for municipal use in the United States was designed in 1905 for Columbus, Ohio. The first one acre unit of the sprinkling filter plant at Reading, Pa., began operation in January, 1908. In November, 1908, the Columbus plant was opened, as was also the case with the filter project at Washington, Pa. The sprinkling filters at Mount Vernon, N. Y., were completed in 1910, and the Baltimore, Md., installation of 14 acres was almost finished in 1911. Sprinkling filter plants have been installed at Waterbury, Conn., Gloversville, N. Y., three plants at Atlanta, Ga., and at other places. Among these, we may mention York, Allentown, and Meadville, Pa., Rome, N. Y., and North Plainfield, N. J.

Sprinkling filters are capable of removing from 70 to 90 per cent of the applied bacteria. Data in regard to the efficiency of the sprinkling filter method have been obtained at Reading and Columbus. These reports, as well as those of other testing stations, should be carefully studied by those interested in this subject.

The strength of the sewage, the size and depth of the filtering material, and the quality of effluent desired, are factors that will determine the capacity of sprinkling filters to purify sewage. At the Columbus plant, 2,000,000 gallons per acre are purified daily on an average. At Baltimore, an average rate of 2.5 million gallons of sewage per acre daily is maintained with a sewage estimated to average about 125 gallons per capita daily. Fuller ("Sewage Disposal," p. 697) recommends a six-foot filter to be operated at an average rate of about 1,000,000 gallons per acre daily. This is for a sewage flow of separate sewers, approximating 100 gallons per capita daily.

The sewage should be freed practically of all suspended matter. It is wise to pass the sewage through adequate sedimentation tanks, and to protect the filters from floating scum and gas lifted sludge. At Atlanta and Baltimore, fine screens are employed. At Birmingham, England, Dortmund tanks and roughing filters have been used to clarify the influent to the sprinkling filter of the large works. As much suspended matter should be found in the effluent as in the influent. At Atlanta, final settling basins have not been provided, as the sprinkler effluent discharges into a muddy stream. At Reading, the sludge approximates about two cubic yards per million gallons, with a water content of about 95 per cent.

At Reading, there is no noticeable odor at a greater distance than 100 yards. At Columbus, odors are normally noticeable not more than 300 yards away.

Thirty thousand dollars to $50,000.00 will represent the cost of sprinkling filters per acre of effective area. Local conditions, of course, will enter into a consideration of these figures. As to the cost of operation, little definite data is available. Fuller ("Sewage Disposal," p. 719) believes that one man in charge, who is capable of arranging laboratory tests of a fairly simple nature, with one helper, ought to be able to take care of a plant having an area of three acres or thereabouts. In 1910, the Columbus plant was operated at a total cost of $9,876.66; $7,415.08 being expended on the regular payroll and some $1000.00 for repairs and extension. Four thousand five hundred and ninety-eight million gallons of sewage were pumped, and the total operating and maintenance cost was $2.14 per million gallons.

III.

CONTACT FILTERS.

In this method, sewage is applied to filters of fairly coarse material until the material of which the filters are composed is filled. Then the filter is allowed to stand for a short period with its pores filled, and finally the sewage is drained from the filters. Nitrification is produced and there is obtained an effluent fairly stable as to its residual organic matter. The effluent will ordinarily be inferior to the effluent of intermittent sand filters, as regards appearance, turbidity, organic matter, and bacterial contents.

Results of the experiments at Barking were reported by Mr. Dibden, where a filter one acre in area was established in September, 1893. In England, these plants have been installed at many places, the largest plant being situated at Manchester. In America, contact filters have been studied experimentally at Lawrence since 1894. Their adoption has been recommended at Columbus, Ohio, in 1898, Plainfield, New Jersey, and at Mansfield, Ohio. Since 1900, municipal installations of this process have increased. The method, however, was not very carefully considered at the testing stations conducted at Waterbury, Conn., Baltimore, Md., Gloversville, N. Y., Philadelphia, Pa., and Chicago, Ill.

Contact filters require a smaller head for their operation than sprinkling filters, and, further, they avoid certain odors incident to filters of the sprinkling type. Contact filters have not been adopted recently for large installations, but they have been constructed at a number of towns or small cities.

Experiments in regard to the efficiency of contact filters have been recorded at Lawrence, Mass., at the Columbus Sewage Testing Station, at the Experiment Station of the Massachusetts Institute of Technology, and at Plainfield, N. J. In general, the effluent has been so stable that it could be discharged into a considerable body of water without creating any nuisance.

Contact beds will ordinarily give a non-putrescible effluent, when they treat on an average from 125,000 to 150,000 gallons per acre daily for each foot in depth of effective filtering material. Winter conditions have not seriously interfered with the operations of well managed contact filters. Neither have contact filters given any trouble in regard to odors where the maintenance of the filters has been attended to carefully. Contact filters alone cost per acre from $15,000 to $35,000. The amount of excavation, the size and design of the individual filter units, and the cost in the town or city of suitable filtering material, are factors capable of materially affecting these conclusions. The most satisfactory cost data as to maintenance are probably available from Plainfield, N. J.

IV.

INTERMITTENT SAND FILTRATION.

In this method, comparatively small volumes of sewage are applied to areas of porous sand, permitting the sewage to drain from the pores of the sand, which become filled with air, and some hours or days later repeating the dose of sewage. As a result of this treatment, a large portion of the putrescible organic matter is converted into stable mineral matter (nitrates).

This process originated in the laboratory in 1865 and 1870. The principles of this method were understood to some extent in

1865 by Dr. Alexander Mueller, a well known chemist of Berlin. At this period, Sir Edward Frankland investigated this method very carefully while on the Rivers Pollution Commission of Great Britain. Dr. Frankland developed the chemical aspects of the process as distinguished from the mechanical or physical, but he did not comprehend the biological significance of the method. The first application of this process occurred in 1871 at Merthyr-Tydvil, where a plant of some 20 acres was constructed by the late Mr. J. Bailey-Denton. This plant was operated at a rate of about 60,000 gallons per acre, daily, with the sewage applied about six hours out of the twenty-four. This plant has become practically an irrigated area or sewage farm.

Against the method of broad irrigation and chemical precipitation, this process made little effective headway in Europe. In 1877, Schloesing and Muntz in France demonstrated that the purification of sewage by this process is due to living organisms and that nitrification did not occur in soils which have been sterilized by heat or by chemicals. Dr. Mueller, of Berlin, patented a special process in 1878. Dr. Warrington, of England, in 1882, contributed further reliable information on this process. Further experiments in connection with this method were recorded by Winogradsky in 1890, and Professor Richards and Jordan in Massachusetts. About 1887, the Massachusetts State Board of Health established at Lawrence, Massachusetts, recorded experiments pertaining to the intermittent sand filtration of sewage, and developed the laws controlling this process from a biological, chemical, and engineering standpoint.

In 1904, there were 41 intermittent sand filters in operation in the United States, serving about 250,000 people. The majority of these plants were in New England, and about half of them in Massachusetts. Since 1904, some intermittent sand filter plants have been established in New England, and others enlarged. In New Jersey there are about fifteen intermittent sand filters in operation. In Ohio, there are about nine municipal and fifteen institutional sand filter plants.

Ordinarily a higher degree of purification can be obtained by this process than by any other method in use excepting the allied method of broad irrigation. The effluent is practically free from turbidity and odor, and it is stable. Filtered sewage generally contains only about 1 per cent of the number of bacteria present in raw sewage. The degree of removal will depend on the kind of sand.

Experiments with this method have been recorded at Lawrence, Mass., and by the Ohio State Board of Health. The reader is referred to the report of the Massachusetts State Board of Health for 1908, pp. 251-538, and to the special report of the Ohio State Board of Health published in 1908, p. 711.

One and five-tenths acres of intermittent sand filters per 1000 population at least should be provided for the treatment of sewage not well clarified by some preliminary process. If the filtering material is very fine, the area should exceed 1.5 acres. Concerning preliminary treatment, the evidence is by no means satisfactory. Further experiments with this method have been recorded at Baltimore, Md., Brockton, Mass., Clinton, Mass., Framingham, Mass., and Worcester, Mass. In the colder climates of the United States, intermittent sand filters must be operated with considerable care. Very generally the quality of the effluent will be somewhat impaired during the winter months. Fuller suggests that the sewage be applied in relatively large doses, and that the filter beds be arranged in alternate ridges and furrows or piles. Average quantities of trade wastes in domestic sewage will not interfere seriously with this process. The reader is referred to the report of the Massachusetts State Board of Health for 1909, pp. 339-403. Certain peculiar conditions in connection with trade wastes have been recorded at Worcester, Mass., Bristol, and New Britain, and South Manchester, Eng., Westborough, Mass., Hudson, Mass., and Shelby, Ohio.

The sewage should be applied at such a rate that the filter surface will be quickly covered with sewage. This point will be satisfactorily cared for by the ordinary high rate of application or, in small plants, by the automatic dosing devices.

Well designed plants, intelligently operated, have produced results with respect to odors entirely satisfactory to State Boards of Health. Intermittent sand filters, if overloaded, or in case the surfaces are not kept in a porous condition, are very liable to give trouble.

The cost of construction and operation will depend primarily upon local conditions. The reader is referred to the report of the Massachusetts State Board of Health for 1903, p. 452, Tables 91 and 92. Ordinarily, it costs about 20 cents per capita annually to operate filters. The investment costs will range from $500.00 (natural beds) to $5000.00 (artificial beds) per acre.

V.

PLAIN SEDIMENTATION.

The process of plain sedimentation consists in lowering the velocity of flowing sewage so that there are separated from the main body of liquids certain suspended matters of a critical specific gravity or hydraulic subsiding value with respect to the conditions of reduced velocity (Fuller, Chap. 13) The quality or quantity of suspended matters in sewage affect the results obtained by plain sedimentation. Some suspended matters subside quite promptly in basins. Others float upon the surface of the liquid, and others pass through the basin and appear in the effluent. Fresh sewage is capable of greater clarification by sedimentation than. stale sewage.

Formerly, sedimentation was used primarily to separate the fertilizing properties of the sewage from the waters with which they were diluted. Later, clarification and precipitation were attempted by the aid of coagulating chemicals. Then came the so-called biological methods of sewage treatment. And about 1895 sedimentation entered into the method of the septic process. Plain sedimentation has become very prominent recently. It has appeared as a separate treatment in connection with the disposal of sewage by dilution, and it has established itself as an aid to filtration. In recent plants, sedimentation is generally among the preliminary steps by which sewage is prepared for filtration. In the treatment of some trade wastes, the process of sedimentation has been of some service. In 1911, there were over 330 municipal treatment works in the United States. Three-fifths of these employed sedimentation in conjunction with the septic treatment, while about one-fifth employed plain sedimentation.

Grit chambers remove from sewage such mineral matters as sand and silt of street washings. Primarily, however, they remove the mineral matters, called grit. This simplifies and reduces the expense of the disposal of sludge from settling basins without offensive odors. Grit chambers are inadvisable in connection with sewers receiving sanitary wastes only.

Trade wastes now and then require grit chambers in connection with separate sewers. Further, grit chambers protect some types of pumps from clogging and abnormal wear. As to the results obtained in America from different arrangements of grit chambers, data are quite meagre. Testing stations have not, as a rule, furnished very satisfactory information on this point. Certain tests have been carried out and reported upon at Columbus, Ohio, Worcester, Mass., and Reading, Pa.

Data are meagre upon the efficiency of the removal of impurities by sedimentation. By means of sedimentation, it is generally possible to deposit about 50 to 75 per cent of the total suspended matters in American sewages. About 65 per cent is a pretty fair average. The reader is referred to the data reported at the Columbus Sewage Testing Station for further information in this regard. We cite below, however, the following table:

Percentage Removal of Constituents of Sewage in Sedimentation Basins of Different Sizes at the Columbus Testing Station.

	Capacity of tanks in hour's flow			
	0.3	1.5	6.0	8.0
Total suspended matter	22	34	63	66
Volatile suspended matter	19	29	54	58
Total settling suspended matters	33	51	96	100
Nitrogenous organic matters	10	19	30	31
Carbonaceous organic matters	6	15	26	31
Fats	18	....	....	50
Cubic yards of sludge per million gallons (87 per cent water)	1.76	2.55	5.75	....

These data should be used very discreetly.

The following tables are of interest:

REMOVAL OF SUSPENDED MATTER BY SEDIMENTATION. RESULTS TO SHOW REMOVAL AT DIFFERENT PERIODS AND DEPTHS.

Length of travel, feet.	Period of flow, hours.	Temperature, degrees Fahrenheit.		Total Suspended Matter.											
				Parts per million.				Per cent Removed.							
								For each 40 feet of travel.				Total.			
		Influent.	Effluent.	A	B	C	Av.	A	B	C	Av.	A	B	C	Av.
July 11, 8 a. m. to July 12, 8. a. m.															
0	0.0	71	....	149	149	149	149	....	....	....	....	....	....	....	....
40	0.8	....	....	110	109	107	109	26	27	28	27	26	27	28	27
80	1.7	....	....	84	91	86	87	18	12	14	15	44	39	42	42
120	2.5	....	....	72	82	72	77	8	6	10	6	52	45	52	48
160	3.3	....	....	78	65	75	73	....	11	....	3	48	56	50	51
200	4.2	....	....	67	73	70	70	3	....	....	2	55	51	50	53
	Weir	....	72	68	....	....	68	....	....	....	....	54	....	....	....
July 12, 8 a. m. to July 13, 8 a. m.															
0	0.0	70	....	196	196	196	196	....	....	....	....	....	....	....	....
40	0.8	....	....	108	125	110	114	45	36	44	42	45	36	44	42
80	1.7	....	....	90	100	100	97	9	13	5	9	54	49	49	51
120	2.5	....	....	87	87	77	84	2	7	12	6	56	56	61	57
160	3.3	....	....	86	85	75	82	....	1	1	1	56	57	62	58
200	4.2	....	....	85	76	63	75	1	4	6	4	57	61	68	62
	Weir	....	71	72	....	....	72	....	....	....	....	63	....	....	....
July 13, 8 a. m. to July 14, 8 a. m.															
0	0.0	70	....	318	318	318	318	....	....	....	....	....	....	....	....
40	0.8	....	....	89	114	108	104	72	63	66	67	72	63	66	67
80	1.7	....	....	65	78	73	72	8	12	11	10	80	75	77	77
120	2.5	....	....	70	68	59	66	....	4	4	2	78	79	81	79
160	3.3	....	....	66	65	58	63	....	1	1	1	79	80	82	80
200	4.2	....	....	61	60	54	58	1	1	1	2	81	81	83	82
	Weir	....	71	55	....	....	55	....	....	....	....	83	....	....	....

NOTES—"A" Samples collected at a point 1 foot beneath surface. "B" Samples collected at a point 3.5 feet beneath surface. "C" Samples collected at a point 6 feet beneath surface, 1 foot from bottom. "AV" equals average of samples at the three depths.

RESULTS SHOWING REMOVALS BY SEDIMENTATION OF TOTAL SUSPENDED MATTER IN STRONG, MEDIUM AND WEAK SEWAGES.

Length of travel, feet.	Period of flow, hours.	Temperature, degrees Fahrenheit.		Total Suspended Matter.											
				Parts per million.				Per cent Removed.							
								For each 40 feet of travel.				Total.			
		Influ-ent.	Efflu-ent.	A	B	C	Av.	A	B	C	Av.	A	B	C	Av.
				July 11, 8 a. m. to July 12, 8 a. m.											
0	0.0	71	....	215	133	98	149	....	....	....	....	....	....	....	....
40	0.8	....	....	144	104	78	109	33	2	20	27	33	22	20	27
80	1.7	....	....	114	87	60	87	14	1	19	15	47	34	39	42
120	2.5	....	....	96	79	57	77	8	....	3	6	55	40	42	48
160	3.3	....	....	89	65	64	73	4	11	....	3	59	51	35	51
200	4.2	....	....	84	63	64	70	2	....	....	2	61	52	35	53
	Weir	....	72	85	54	64	61	....	....	....	....	60	52	34	59
				July 12, 8 a. m. to July 13, 8 a. m.											
0	0.0	70	....	348	184	57	196	....	....	....	....	....	....	....	....
40	0.8	....	....	179	120	44	114	49	35	23	42	49	35	23	42
80	1.7	....	....	143	97	43	97	10	12	2	9	59	47	25	51
120	2.5	....	....	123	88	40	84	6	5	5	6	65	52	30	57
160	3.3	....	....	113	81	48	82	2	4	....	1	67	56	16	58
200	4.2	....	....	106	73	46	75	3	4	....	4	70	60	19	62
	Weir	....	71	97	71	49	72	....	....	....	....	72	61	14	63
				July 13, 8 a. m. to July 14, 8 a. m.											
0	0.0	70	....	318	129	53	167	....	....	....	....	....	....	....	....
40	0.8	....	....	166	94	51	104	42	27	4	38	42	27	4	38
80	1.7	....	....	98	77	41	72	27	13	19	19	69	40	23	57
120	2.5	....	....	84	66	47	66	5	9	....	3	74	49	8	60
160	3.3	....	....	85	61	43	63	....	4	....	2	73	53	19	62
200	4.2	....	....	78	54	44	59	2	5	....	3	75	58	17	65
	Weir	....	71	68	50	46	55	....	....	....	....	79	61	13	67

Plain sedimentation should not extend beyond the point where the remaining sediment can be disposed of as cheaply and as satisfactorily by other means. Up to this limit, sedimentation is desirable. Of course, local conditions will influence any conclusions drawn here. The temperature and the age of the sewages are factors that are to be carefully considered.

Vertical tanks for purposes of clarification have been but slightly used in America. Four vertical tanks of the Dortmund type were used in 1893 at the World's Fair at Chicago, for the purification of the exposition sewage, with the aid of chemical precipitation. Further experiences with these tanks have been recorded at Kings Park, New York, Gloversville, New York, and at the Chicago Sanitary District. In America, the present tendency is to use two-story tanks, in which the sludge passes automatically to a sludge-digestion chamber below.

Cleaning and flushing of the sediment from sedimentation tanks should be done carefully unless it is desired to promote septicization. At Columbus, gasification occurred in from eight to seventeen days. The tanks were allowed to go uncleaned thirty-eight days in the winter. At Reading, cleanings have ranged from one month in summer to three months in winter. At Worcester, the sedimentation tanks were cleaned at intervals of four to eight weeks.

The utilization of sludge for its fertilizing properties or for commercial purposes does not give promise of economical success. Nitrogen, phosphorus, and grease are present in substantial quantities, but the cost of separating these constituents from municipal sewage sludge exceeds the proceeds of the sales. In America, sludge is disposed of by the following methods:

1. In about 200, or roughly, 60 per cent, of the municipal sewage plants in the United States, septicization, accompanied by sedimentation, is employed. This is considered the most available method.

2. At Worcester and Providence, chemical precipitation accompanied by sludge pressing is the prevailing method. In some cases, the sludge of plain sedimentation basins has been filter-pressed.

3. The application of sludge to land is the prevailing method for the disposal of sludge in inland cities.

4. Disposal of sludge by dilution is practiced along the coast and in the vicinity of rivers and lakes.
5. Lagooning.—This method has been employed at Reading since 1908.
6. Filling.—Toronto employs this method.
7. Digestion tanks.—Baltimore adopted this method.
8. Open trenching.
9. Covered trenching.—This method is in use at Kings Park, Long Island.
10. Incineration.
11. Destructive distillation.
12. Mechanical drying.
13. Use as filler for fertilizers after drying.

AIR DRYING OF SLUDGE.

This method is cheap, but is likely to be objectionable as to flies and odors. Quick lime and hypochlorite of lime have been resorted to, but without much success. At Frankfort and some other places in Germany, use has been made of "facilol," a tar product. The cost of this oil is given as $2.15 per 100 pounds, or about 13.5 cents per gallon. At Frankfort, one gallon is applied to from five to nine square yards.

DISPERSION IN WATER.

This method is followed at London, Glasgow, Manchester, Salford, Boston, and Providence. It is economical and inoffensive. As to inland cities, however, this method should not be considered seriously.

LAGOONING.

This method has been practiced at Reading for some four years, practically successfully. It has also been used at Philadelphia and at the Chicago Sewage Testing Station. Early experiences in Europe with this method were not generally successful.

FILLING OR DUMPING.

This method is used at Toronto, and is in very general use for the deposits removed from catch basins.

TRENCHING.

This method requires considerable area. The expense will become a considerable item in the case of large works. For this reason, it was abandoned at Birmingham, England. Further, severe winter weather complicates the process.

INCINERATION.

Freed satisfactorily of its water, sludge can be burned with other city refuse in modern incinerators or destructors. Some experiences were obtained with this method at Worcester and Coney Island, New York. The burning of sludge with coal was studied at Philadelphia in 1910 on a small scale.

DESTRUCTIVE DISTILLATION.

The cost of the process and the value of the coke and gases produced are not definitely known.

MECHANICAL DRYING.

No practical data of value are available except from Europe. Six centrifugal machines have been installed at Frankfort, four at Hanover, and two at Hamburg.

USE FOR FERTILIZERS.

Neither European nor American data are, on the whole, very promising as to commercial success in this respect.

SEPTICIZATION IN CONNECTION WITH SEDIMENTATION.

"Septicization is the term applied to the anaerobic decomposition of sewage whereby intensive growths of bacteria bring about the liquefaction of solid organic matter. It means the rotting of these solids until, when carried to its full, final limits, the organic matter is so thoroughly rotted that it may be said to be humified. There are two distinct phases of the septic process. One refers to the clarification of the sewage with a view to an improvement in its composition as compared with sewage, either for direct discharge into the water course, or as a preparation for filtration.

The other relates to the treatment of the sludge to facilitate its disposal."[1]

Septicization dates from about 1896, the year of the so-called septic tank development by Mr. Cameron and his associates at Exeter, England. Previously, the anaerobic decomposition of sewage occurred in cesspools. In England, the cities of Leeds and Manchester followed the development of Exeter. Chemical precipitation tanks were generally used as single story septic tanks. In America, there were, in 1904, 29 installations of septic tanks in towns of over 3000 population, serving an aggregate population of about 160,000. In 1906, the single story septic tank attained the height of its reputation. Recently, engineers have confined their attention to the two-story tanks of the Imhoff type, in which clarification occurs in the upper compartment and septicization of the sludge in the lower. In 1911 there were about 200 septic tanks in use in the United States.

Fuller does not offer septic tanks as the only mode of sewage treatment, unless the effluent is adequately dispersed in satisfactory volumes of water so as not to produce a nuisance. The question of bacterial removal is not yet well defined. "The septic tank shows a removal of the total bacteria of the influent, roughly corresponding to the percentage reduction in the total suspended matter. There are numerous exceptions to this rule."

In brief, the utility of the septic process is related very closely to the success with which the sludge and scum are prevented from appearing in the effluent.

CHEMICAL PRECIPITATION IN CONJUNCTION WITH SEDIMENTATION.

This method originated some fifty years ago in England. Between 1880 and 1890 the method of chemical precipitation attained the height of its fame. Stimulated largely by the investigations of Royal Commissions, and by the recommendation that this process be adopted by the Metropolitan District of London, 200 plants of this type were installed in England alone. This method was also adopted at a number of places on the continent of Europe and in America. In this connection, the reader is referred to the reports of the sewage disposal projects for the cities of Providence, R. I., and Worcester, Mass.

[1]Fuller, Chapter 14.

In 1904 there were eight other plants in the United States. Since then, the plants of East Orange, N. J., Mystic Valley, Mass., White Plains, N. Y., New Rochelle, N. Y., and Canton, Ohio, have been abandoned. This method is employed at Chautauqua, New York, and other summer resorts. For an adequate discussion of the principles of the process, the reader is referred to the reports of Messrs. Clark and Gage at Lawrence, in their review of twenty-one years' work at the Lawrence Experiment Station, in the 1908 report of the Massachusetts State Board of Health, pp. 457-459.

This treatment will ordinarily remove from normal sewage 50 to 55 per cent of the total organic matter, and about 90 per cent of the total suspended matter. The bacterial removal is about 80 to 90 per cent. The fresher the sewage, the greater the percentage of removal of impurities. Copperas and lime are the more efficient chemicals in use today. Sulphate of alumina is too expensive. Likewise, perchloride of iron. Recently, chemical precipitation plants have been abandoned. The increased cost as a preparatory treatment either for dilution or filtration is rarely justified.

VI.

COMPARATIVE SUMMARY.

Well Established Methods.—Chemical precipitation, intermittent sand filters, contact beds, sprinkling filters, settling tanks, septicization of sludge, the hypochlorite treatment for sterilization, and fine screening, are to be considered as the well established methods.

Recently Developed Methods.—In the applicability of sprinkling filters in northern climates, sterilization or disinfection methods, utility of plain sedimentation, the practicability of septicization, particularly in two-story tanks, and in the benefits of fine screens, there have been recently considerable developments in the knowledge and comprehensive understanding of the methods.

Methods of Limited Applicability.—Chemical precipitation and broad irrigation are now rarely adopted for new works.

Waning Methods.—Chemical precipitation and broad irrigation are losing ground in America. Intermittent sand filters are still being adopted where geological conditions are favorable.

Unestablished Methods.—The electrolytic treatment, strainers, slate beds, colloiders, aeration and ozonization, are not established on a recognized basis in America.

NEED FOR GOOD MANAGEMENT.

The cities of Worcester, Brockton, Providence, Plainfield, Reading, Columbus, Baltimore, and other places, have established laboratories and provided proper attendants for the intelligent management and supervision of the disposal of the local sewage.

PART II

DESCRIPTIVE ANALYSES OF PLANTS.

BIRMINGHAM, ENGLAND.

The quantity of sludge that has to be dealt with in Birmingham amounts to about 1100 tons per day. The commercial value of this sludge as it is taken from the tanks is less than nothing. As it sometimes contains metal salts, which render it worthless as manure, it is generally serviceable only where poor land is in need of nitrogenous feeding. The sludge is regarded as worthless from a commercial point of view, and experiments have been conducted for years with the idea of getting rid of it as speedily as possible without creating a nuisance.

In 1901 the attempt to septicize the sludge by itself was made without success. A year or two later it was noticed that there was an entire absence of odor from sludge that had been well rotted, and this led to further observations which confirmed the first, that completely septicized sludge was devoid of fetid odor. In the end of the year 1903, a large septic tank, which had been in use for four years without being cleaned, was emptied, and the same feature was noticed. In January, 1904, 20 large septic tanks were emptied, and after all the water was removed, thick sludge was pumped on an eight-acre field, where it lay to considerable depth until the summer weather dried it sufficiently to admit of deep steam plowing. The inodorous character of septic sludge was then thoroughly established, and since then septic sludge has not been trenched into the ground, but has been used to make up depressions and irregular hollows at various places in the valley of the Thames, acres of sludge lying out at one time without resulting in the slightest nuisance.

DRYING BEDS.

In 1909 drying beds were prepared, and the drying area now at Water Orton is about 45 acres in extent, or about two square feet per inhabitant in the main sewage district. It is laid out in plots 150 feet square, underdrained by 4-inch agricultural tile pipes laid in herring-bone fashion toward a main leader, which in turn takes the drainage to a well, where it is pumped to bacteria beds to be treated as sewage, as mere filtration through the ground does not render it fit to enter the river without further treatment. The drying bed consists of a 3-inch layer of washed engine ashes, underlying a 3-inch layer of finer ashes, and each bed is surrounded by earthen embankments about 2 feet high. The area is provided with two permanent 2-foot gauge tramways laid to suit locomotive haulage, with conveniently placed turnouts and crossings to allow temporary rails to be laid through the bed for the collection of dried sludge.

The time required for drying varies with the weather, but in dry weather it quickly cracks and admits the air. When it has become sufficiently dry to be lifted in lumps it should be conveyed to the tip, as it is troublesome to workmen when it gets into the dry-as-dust condition, and eye protectors have to be provided in such cases.[1]

HAMBURG, GERMANY.

Up to 1842, rain water and kitchen waste in Hamburg were drained through open or partly covered gutters into wooden or brick-lined ditches which were connected with the Elbe, the Alster, or the canals. In 1843, an English engineer, William Lindley, proposed a canal system which was executed in part and gradually extended to include the suburbs.

The construction of the Geest-Stammseil (trunk sewer), which is still in existence, was begun in the early seventies and finished in 1875. Portions of it reached a depth of 20 meters (66 feet) under the surface, and 3 kilometers (1.86 miles) were regular tunnel construction. The system was extended in 1898 at a cost of about $2,380,000, the new work being finished in 1904. The greater portion of this was tunnel construction necessitating the use of compressed air. Some of the pipes had to be laid across the broad "upper harbor," a complicated work performed at great cost. The House of Burgesses has granted an additional $999,-600 for making other extensions.

[1]Daily Consular and Trade Reports, Washington, March 15, 1913, No. 61.

SEPARATE SEWER SYSTEMS.

The part of the city south of the Elbe river has a special sewer system entirely independent of that of the northern side. The present length of the whole system is 248.54 miles, covering a territory of 12,355 acres. It also includes Wandsbek and a portion of the city of Altona. The cost of the entire system was $9,044,000.

The old sewer system is used only in cases of emergency. The pipes are so laid that the sewage is carried to the outlet without artificial aid, except in two suburbs, where the use of pumps is required. These pumps are operated by electricity (4 electric motors to 4 centrifugal pumps). The power is furnished by the garbage burning plant on the Bullerdeich.

The system on the north side of the city connects with one huge outlet. At the mouth of the sewer is a swinging dredger connected with a sand-catcher device, by means of which the heavy material is removed. There is also a movable grate which holds back the large floating obstacles.

AID OF TIDAL WATERS.

Hamburg is so situated, fortunately, as to have natural and powerful flush waters in the tides of the northern and southern Elbe. The action of the tide stirs the refuse continually and facilitates its destruction. The material collected and removed at the mouth of the discharging mains is taken in barges to lowlands belonging to the state, on the south side of the Elbe, and there spread out for fertilizing purposes. No effort is made to sell this material at present. Garbage is collected and incinerated. The cost of the upkeep of the sewer system is about $83,300 per annum.[1]

BALTIMORE, MD.

The Disposal Plant of the city of Baltimore, Md., is constructed on the unit system, so that additions may be made as the sewers are gradually extended. The method of treating the sewage is as follows: At the mouth of the Outfall Sewer are installed screens

[1]Daily Consular and Trade Reports, Washington, February 13, 1912, No. 37.

that will catch things that will be removed and burned. The sewage passes through the Meter-house, which measures its flow; then through Hydrolytic Tanks, about 450 feet long, requiring eight hours for passage, a sufficient length of time to allow the solids to settle, the liquid passing on to an intercepting channel, to and through what is called the "Gatehouse," which distributes it to the stone Sprinkling Filters located at a level 15 feet below the Hydrolytic Tanks, giving a hydraulic head of sufficient force to spray the sewage over these stone beds through nozzles or jets spaced 15 feet apart. The hydraulic head is controlled by butterfly valves, causing the sprays to rise and fall, varying from close to the nozzles out to the limit of 15 feet, thus utilizing the entire surface of the stone bed, a large portion of which would be wasted if the sprays were stationary. These nozzles throw a square spray, thereby saving additional space, which would be lost if the sprays were circular, as where circular sprays are used with the edges of the circles touching there are triangular areas between the circles which are not used.

The spraying of the sewage through the air is essential to the aeration and purification of the sewage. As the sewage falls on these beds, it trickles down through 8½ feet of broken stone, varying in size from 1 inch to 2½ inches. The passing of the sewage through these beds forms a gelatine-like film on the stones, in which certain bacteria multiply by the million, attacking and killing the injurious bacteria in the sewage. The bacteria do the work by fighting each other. The sewage on reaching the bottom of these stone beds is practically pure. It is then carried by intercepting channels to a central channel under the stone beds, which finally delivers the purified sewage to the settling basins, requiring three hours to pass through. These settling basins are not for the purpose of causing additional purification, but to clarify the fluid, as there are certain mineral substances in the sewage which bacteria do not annihilate, such as is found in the Mississippi river, which is muddy but not injurious to drink. The sewage then passes with a drop of 18 feet through the powerhouse, in which turbines are placed, operated by the flow of the sewage. They, in turn, run dynamos, which generate electricity, giving sufficient power to light the plant, run the sludge pumps, and lift the clarified sewage to a water tower for flushing purposes. In other words, by the simple gravity flow of the sewage, it is purified and power is obtained to run and light the plant at practically no cost.

There was expended in 1911 a net amount of $1,421,848.56 toward construction expenses, administrative and special expenses. A net amount of $2,427,738.52 was expended in 1912 on construction, administrative, and special expenses. Contracts to the sum of $3,023,321.64 were let during 1912. Trees have been planted and roads built at the Disposal Plant, which, with the electric lights produced by the flow of the sewage, make this improvement one of great attraction. It is well worth a visit from any taxpayer who is interested in the improvement of the city. Persons from all parts of the world visit Baltimore for the purpose of inspecting this plant, and even strangers are more familiar with the work going on in Baltimore than are many of the Baltimoreans.[1]

WORCESTER, MASS.

PURIFICATION OF SEWAGE.

All of the sewage delivered at the works is passed through the grit chambers, which have collected (1912) 577 cubic yards of deposit, or 0.10 cubic yards per million gallons of sewage. This deposit has been disposed of on waste land.

After passing through the grit chambers, the sewage is treated either by intermittent sand filtration, or by chemical precipitation with milk-of-lime, except a relatively small amount used for experimental purposes. The quantity of sewage treated in each way during 1912 may be shown as follows:

	Million Gallons Total.	Million Gallons Daily.	Per Cent of total.
Chemical precipitation	4,201	11.48	72.4
Sand filtration	1,560	4.26	26.8
Experimental treatment	46	0.13	0.8
Total	5,807	15.87	100.0

The quantity of sewage which can be treated on the sand filters is limited by the capacity of the area provided. The strongest

[1]Annual Reports of the Sewage Commission of the City of Baltimore, 1910, 1911, 1912.

sewage is selected for sand filtration because this method of treatment gives a much higher degree of purification than does chemical precipitation. The area available during 1912 has been 73.1 acres, and the flow per acre per day has averaged 58,000 gallons.

The only preliminary treatment in preparation for sand filtration consists in passing the sewage through one of two settling basins reserved for this purpose. This affords a detention period of about one-half hour and is sufficient to remove the coarsest and heaviest of the suspended matter in the sewage. The total quantity of sludge produced in this way during 1912 was 5,850,000 gallons, or 3750 gallons per million gallons of sewage. This sludge contained 4.94 per cent solids, a total of 1205 tons. It has been disposed of by pumping onto the sludge beds as in previous years.

The clogging matter removed from the surface of the filters amounted to 23,371 cubic yards, which is equivalent to 320 cubic yards per acre and 15.0 cubic yards per million gallons of sewage filtered. This quantity is large compared with that of the last few years. The explanation of this lies partly in the fact that several beds were harrowed on account of a hard layer just beneath the surface. Before harrowing or ploughing filter beds, it is advisable to remove a large proportion of the dirty sand.

The purification effected by the sand filters, measured by the albuminoid ammonia, amounts to 87.1 per cent of the total organic matter, and 66.7 per cent of the dissolved organic matter. The quantity of the effluent averages a little better than last year.

Chemical precipitation has required the use of 1902 tons of lime, a larger quantity than has been used for several years. This fact is due to the increased volume of sewage so treated. The quantity of lime used per million gallons of sewage (905 pounds) is less than for several years.

The sludge produced by the lime treatment amounts to 19,116,000 gallons, an average of 4551 gallons per million gallons of sewage treated. The total quantity of sludge is considerably more than last year, but the proportion of sludge to sewage is considerably less than last year. The actual quantity of dry solids per million gallons of sewage (1204 tons) is practically the same as for the preceding year.

Of this sludge, 5,900,000 gallons, containing 1701 tons of dry solids, were pumped onto the old sludge beds because of lack of funds.

The remaining sludge, amounting to 13,216,000 gallons, was pumped to the storage tanks, and, after drawing off about 19 per cent as clear water, the resulting sludge was pressed with the formation of 11,357 tons of cake containing 3358 tons of dry solid matter. The pressed sludge has been hauled by the trolley motor car to the sludge dump, as in previous years. The farmers in the vicinity continue to take a small proportion of it to use for fertilizer.

The results of chemical precipitation, measured by albuminoid ammonia, show a removal of 77.8 per cent of the suspended organic matter. The percentage of organic matter in the average effluent is considerably less than last year.

The experimental Imhoff tank and sprinkler filters have been continued in operation throughout the year. The net cost of operation and maintenance of the purification works for the fiscal year, including all administrative expenses, amounts to $49,977.34, or 32.5 cents per capita. The cost of purification may be subdivided as follows:

*Cost of Operation.	Total.	Per Mil. Gals.
Chemical precipitation	$20,582.11	$4.90
Sludge pressing	14,867.84	5.31
Sand filtration	12,509.29	8.02

The cost of chemical precipitation includes the cost of pumping about one-third of the resulting sludge onto the old sludge beds. If all of the sludge had been pressed, the cost of sludge pressing would have been increased about 40 per cent. The cost of sludge pressing per million gallons of sewage chemically treated is estimated on the basis of the proportion of sludge pressed.

The actual cost of chemical precipitation and sludge disposal per million gallons of sewage treated was $8.44.

The total purification effected by the entire plant for the year, measured by albuminoid ammonia, amounts to 57.7 per cent of the total organic matter and 87.2 per cent of the suspended or-

*The above costs include the amount expended in laboratory, the same being apportioned equally to the three accounts. In addition to these costs, $2018.10 has been expended in experimental work not chargeable to any of these three accounts.

ganic matter. The percentage purification is slightly less than last year, but the quality of the average effluent is a little better than formerly. The purification during the warm season, from July to December, when putrefactive conditions are most likely to occur, was considerably higher than last year.

CONCLUSIONS.

"From the results of operation of this experimental plant, it appears to be perfectly feasible to treat Worcester sewage by means of Imhoff tanks and sprinkler filters. Results of experimental treatment of chemical effluent indicated that the advantages gained by chemical precipitation as a preliminary treatment were not commensurate with the cost. The Imhoff tank was quite as efficient in sludge-digestion as experimental septic tanks have been, and much more efficient so far as the sedimentation of the sewage is concerned. It was operated without the production of the offensive odors characteristic of the septic tank and the sludge itself was disposed of without creating a nuisance. The effluent from the Imhoff tank was normally as fresh in appearance and odor as the sewage flowing into the tank.

"More than twenty times as much sewage per unit of area was treated by the sprinkler filters as could be treated by intermittent sand filtration, and more than ten times as much per cubic yard of filter. Four times as much sewage was treated by these experimental filters as could be treated satisfactorily by experimental contact beds. In order to obtain equal nitrification with contact beds, at least three contacts would be required.

"Judging from this experimental plant, the cost of operation of Imhoff tanks and sprinkler filters per million gallons of sewage treated would be very much less than the cost of operation of chemical precipitation or sand filtration as carried on at Worcester."[1]

COLUMBUS, OHIO.

The cost of the improved sewage works at Columbus, Ohio, totaled $1,351,020.00. Further detailed data in this respect is available in Mr. John H. Gregory's paper, "The Improved Water

[1]Annual Report of the Superintendent of Sewers of the City of Worcester for the year ending November 30, 1912.

and Sewage Works for Columbus, Ohio," published in the Proceedings of the American Society of Civil Engineers, Vol. 36, No. 1, January, 1910.

The successful treatment of sewage is so closely related to the method of its collection that a description of the works ought to be preceded by at least a general description of the sewerage system. Today the opinion seems to prevail that the difficulties of successfully treating sewage decreases with the rapidity of its collection. At Columbus, the length of the sewers, the flat grades, the presence of grit dams and consequent septic pools, and pumping, all combine to increase the difficulties of treatment. Large quantities of grit are washed into the sewers where the combined system of sewage is in use, and this grit has been a source of trouble at both the pumping stations and the purification works. When the river is in flood, sewage treatment is not necessary. The dry flow sewage of the city is roughly screened by two vertical bar screens, the bars being 1 inch and ½ inch apart in the clear, in the front and rear screens, respectively. The Purification Works consist of preliminary sedimentation tanks, sprinkling filters, and final sedimentation tanks. The preliminary sedimentation tanks are 412 feet in length by 236 feet in width, and are divided into six separate compartments, any two or more of which may be used together. The force main discharges into a 66-inch circular distributing conduit, which is a part of the inlet wall of the tanks, and from which the sewage is discharged through 24-inch circular sluice gates into any one or combination of four small tanks, each of which is 150 feet long and 59 feet wide from the center line of the walls. Each of these tanks has a capacity of 700,000 gallons, and it is in these tanks that practically all of the detritus in the sewage is removed. From these smaller tanks, the liquor flows through 24-inch circular sluice gates into a 66-inch circular collecting and distributing channel, which is the dividing wall between the small and large tanks. From this channel the sewage flows through sluice gates, similar to those above mentioned, into either one or both of two larger tanks which are duplicates of each other. Each one of these larger tanks is 262 feet long and 118 feet wide from the center line of the side walls, and it is in these tanks that the finer organic solids are removed. The capacity of these tanks is 2,700,000 gallons each. The floors of all the tanks have a slope of 1 to 50, and the drains 1 to 250. The sludge drains discharge into a common egg-shaped drain in the bottom of the dividing wall between the small and large tanks, and this common drain is continued to the river into which the sludge is discharged during floods. There is a branch on the north side of this drain, and it leads to a temporary sludge disposal area where sludge may be disposed of when necessary during the low water season of the year. At the outlet end of the large sedimentation tanks, the liquor passes through 24-inch circular sluice gates into a 66-inch collecting conduit, which is a part of the outlet wall. This conduit has a branch at the center, which conducts the tank liquor to the gatehouse, which is in the center of the sprinkling filter area.

The sprinkling filters are built on the plan of a hexagon, with a circular gatehouse in the center. The filter beds are equilateral (502 feet) triangles in shape, and only four of the six beds have been built. Each bed comprises an area of 2.5 acres, and has two duplicate and separate filtering units. Each filter unit is made up of a distributing system, a collecting system, and the filtering material. The distributing system consists of a 30-inch, reinforced concrete tube for a main, and 5 and 6-inch vitrified sewer pipes encased in concrete for the laterals, which are built in parallel rows 13 feet and $3\frac{5}{8}$ inches apart. The liquor is conducted from the main distributor to the laterals, and from the lateral distributors to the surface of the bed, through 3-inch cast-iron risers, and is sprayed into the air by a sprinkling nozzle, which is attached to the exposed end of the riser. The risers are spaced 15 feet 4 inches on centers.

The collection system consists of a concrete floor which slopes to main drains which are built below the floor level, and which receive the discharge of the lateral collectors. These laterals are parallel rows of half tiles which are notched in the sides, and which cover practically the whole floor. The filtering material, which consists of broken limestone, has an average depth of 5.5 feet, and the bottom 8 inches is 3 to 4 inches in diameter, while the rest varies in size from 1 to 3 inches. The main collectors of all the sprinkling filters discharge into a circular well in the gatehouse, and from this well the filter effluent flows into a 66-

inch circular conduit, from which it may be discharged into the final sedimentation basins, or to the river.

The purpose of the treatment of the sewage is to prevent the gross pollution of the Scioto river below the city. The bacterial pollution of the streams is not so important because there are no public water supplies taken from the river below the city. The equipment which has been provided for the treatment of the sewage consists of preliminary sedimentation tanks, hand-operated sprinkling filters, and final sedimentation basins. The modification of the sewage which is effected by its treatment at the works, and a varying dilution which the river provides, are the two agencies which are relied upon to prevent the production of a nuisance. At certain times the dilution which the river provides is so great that treatment of the sewage is not necessary at all. At other times, the slight purification which is effected by plain sedimentation is sufficient, and the degree of modification of the sewage which must be effected by the works increases as the dilution increases, until the critical stage is reached during the "low water-warm weather" season of the year.

The purpose of the preliminary tank treatment is to effect a removal of the coarser solids, which results in a partial purification of the sewage and prepares it for the oxidizing process which follows. When the untreated sewage is discharged from the force main into the tanks, the velocity of flow is so greatly reduced that the solids settle to the floors of the tanks, and this deposit is known as sludge. The two problems which are involved in the tank treatment are the production of a satisfactory effluent and the disposal of the sludge. During the year 1912, one small and one large tank were kept in service, and the average total period of flow, based upon a complete displacement of the liquor, was 4.86 hours. The average period of flow for the small or detritus tank was 1.04 hours, with an average velocity flow of 2.40 feet per minute, and, for the large tank, 3.82 hours, with an average velocity of 1.14 per minute.

After the coarser solids of the sewage have been removed by sedimentation in the preliminary treatment tanks, the liquor is ready for the purification process, which consists of an oxidation of the soluble constituents, and as a result of which they are converted from an unstable polluting nature to a stable non-polluting condition. The oxidation is effected by chemical and bacterial agencies, and the sprinkling filter is simply a device which promotes such activities. The spraying of the tank liquor in the air favors the release of certain offensive gases, and also promotes aeration, or the absorption of oxygen from the air.

The purpose of the final settling basins is the removal of the coarser suspended matter from the sprinkling filter effluents. During the past year, the final settling basins were not in service because of the construction work which was in progress, and the total efficiency of the works was consequently somewhat decreased thereby.

The efficiency of the treatment of the sewage at the works during the past year, when based on analytical data, is shown in the following table of results:

Suspended Matter.			Oxygen Consumed from Potassium Permanganate.			Oxygen Consumed as Dissolved Oxygen.		
Mean Annual Values in Parts Per Million.		Per cent Removed	Mean Annual Values in Parts Per Million.		Per cent Reduced	Mean Annual Values in Parts Per Million.		Per cent Reduced
Crude Sewage	Final Effluent		Crude Sewage	Final Effluent		Crude Sewage	Final Effluent	
245	88	64	62	18	71	198	28	86

The purpose of sewage treatment at Columbus is to prevent offensive conditions from arising in the Scioto river below the city, and the experience of past years has shown that offensive conditions are apt to arise only during times of warm weather, which are accompanied by a minimum flow in the river.

The operating force at the Purification Works consists of one Chief Chemist, one Assistant Chemist, three Attendants, and three laborers, and a monthly summary of expenditures for the year 1912 is as follows:[1]

[1]Annual Reports of the Division of Sewage Disposal of the City of Columbus, Ohio, for the year ending December 31, 1912.

Month.	Main Sewage Pumping Station.	Sewage Purification Works.	East Side Sewage Pumping Station.	Night Soil Station.	Total.
Salaries	$8,767.81	$3,333.83	$2,760.00		$14,861.64
Labor	2,921.50	2,342.25	709.50	$1,609.49	7,582.74
Coal	3,661.97				3,661.97
Supplies	1,075.53	391.24	197.01	62.62	1,726.40
Repairs	627.56	66.79	604.07		1,298.42
Gas		136.50	764.20		900.70
Automobile		499.00			499.00
Telephone	149.52	113.68	45.00		308.20
Current		70.95	152.61	32.58	256.14
Livery		198.50			198.50
Laboratory		150.72			150.72
*Prof. services					50.00
*Insurance					19.00
Totals	$17,203.89	$7,303.46	$5,232.39	$1,704.69	$31,513.43

***These two items are not to be classified under the expenditures of any particular station.**

PLAINFIELD, N. J.

The sewage disposal works of Plainfield, N. J., consist of four septic tanks of a combined capacity of 1,350,000 gallons, eight primary and eight secondary beds, having a total net area of 3½ acres. Two tanks and eight beds were constructed in 1900 and the others in 1905. The sewage from the 44 miles of sewers is almost entirely domestic. The total flow of sewage is now about 1,650,000 gallons per day. The total population of Plainfield, by the U. S. Census in 1910, was 20,550.

The analyses of the final effluent show that it has continued to be satisfactory without exception as regards appearance, odors, and the reduction of organic matter and bacteria, and there is no putrefaction of the effluent after dilution with the stream flow. The septic tanks have given better service during the past year than previously, as the bacterial functions seem to have become somewhat more advantageously established than hitherto. Ordinarily, two tanks are used at a time, each pair in rotation, with the period of service considerably longer than was the case a year ago. In April, 1909, all four of the septic tanks were cleaned out, the amount of scum and sludge being estimated at 1600 cubic yards, equivalent to 2.4 cubic yards per million gallons of sewage treated since the tanks were cleaned in February, 1908. The sludge was drained out onto the lower sand filters, and the dried sludge was applied to lands.

The contact beds have had the scum removed from their surfaces at frequent intervals during the past year. The primary beds were considerably clogged and needed cleaning a year ago. To remedy the difficulty temporarily, without going to the expense of removing and washing the entire body of filtering material, several trenches about 4 feet wide were made in each of the primary beds, each having three rows of half-round pipe or horse-shoe tile, the ditches being filled with coarse stone around and over the drains to the normal surface level. With a view to minimizing the odors, the outlet channel conveying the effluent from the septic tanks to the contact beds was covered with concrete, and the pipes distributing the septic effluent to the primary beds were changed so they fill the beds from the bottom instead of at the surface, as formerly. The secondary beds are still filled at the surface. These changes resulted in a decided reduction of odors.[1]

The floors of the tanks have a 1.5 to 3.0 per cent slope to an outlet gate, which allows the sludge to enter a pipe leading to a discarded sand filter situated between the secondary contact beds and Green Brook. This sludge bed is about 190x160 feet (0.7 acre) in plan, formed by earth embankments, and is made of about 2 feet of sand, of an effective size about 0.20 to 0.25 mm. The bed has five rows of 3-inch underdrains emptying directly into the brook. The sludge is usually treated with no disinfectant, and is hauled away during the late fall months by farmers and for use on the poor farm. When it has been necessary for the Sewer Committee to remove the sludge from the sludge bed, the cost has been about $250.00, which represents 22 cents per million gallons of sewage treated. The volume of sludge decreases about one-third during drying, which takes three or four months. Odor is noticeable when the sludge is running on to the sludge bed, but after a few days the odor is but slight 100 feet from the bed. At its worst, the odor extends slightly over ¼ mile from the plant, affecting possibly some 20 to 25 dwellings for short periods.[2]

The Plainfield, N. J., sewage disposal plant and that at Mans-

[1] "Sewage Purification Results at Plainfield, N. J., 1909," Andrew J. Gavett, *Engineering News*, May 6, 1910.

[2] "The Results of Septic Tank Treatment of Sewage at Plainfield, N. J.," R. S. Lanphear, *Engineering Record*, January 13, 1912.

field, Ohio, were the first contact filter systems installed in this country. The Plainfield plant is probably the only one of this type in this country which has been tested carefully in actual practice. The Plainfield plant, in its present condition, removes about 85 to 90 per cent of the suspended solids (20 to 25 per cent by filters) and 80 to 85 per cent of the organic matter as determined by oxygen consumed (about 50 per cent by filters). The bacterial efficiency is from 65 to 80 per cent, some 80 to 90 per cent of which is the work of the filters. The Plainfield plant is undoubtedly a pioneer of this particular method of sewage purification with American sewage, and, while experience has shown where many improvements can now be made, the original design embodied all the then available features of which the method was possessed.[1]

[1] "Changes in the Design of the Plainfield Sewage Disposal Plant," R. S. Lanphear, *Engineering Record,* August 10, 1912.

APPENDIX

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THE TEXAS LAW.

The Texas Law upon the subject of Sewage and Sewage Disposal follows:

"An Act to prevent the pollution of the water courses or other public bodies of water of the State of Texas, providing a penalty therefor and providing means for the abatement thereof.

"Be it enacted by the Legislature of the State of Texas:

"SECTION 1. That it shall be unlawful for any person, firm or corporation, private or municipal, to pollute any water course or other public body of water from which water is taken for the use of farm live stock, and for drinking and domestic purposes, in the State of Texas, by the discharge, directly or indirectly, of any sewage or unclean water, or unclean or polluting matter, or thing, therein, or in such proximity thereto as that it will probably reach and pollute the waters of such water course or other public body of water from which water is taken for the use of farm live stock and for drinking and domestic purposes. A violation of this provision shall be punished by a fine of not less than one hundred dollars, and not more than one thousand dollars. When the offense shall have been committed by a firm, partnership or association, each member thereof who has knowledge of the commission of such offense, shall be held guilty. When committed by a private corporation, the officers and members of the board of directors, having knowledge of the commission of such offense, shall each be deemed guilty, and when by municipal corporation, the Mayor and each member of the Board of Aldermen or Commission, having knowledge of the commission of such offense, as the case may be, shall be held guilty as representatives of the municipality; and each person so indicated, as above, shall be subject to the punishment provided hereinabove. Provided, however, that the payment of the fine by one of the persons so named shall be a satisfaction of the penalty as against his associates for the offenses for which he may have been convicted. Provided, the provisions of this act shall not apply to any place or premises located without the limits of an incorporated town or city, nor to manufacturing plants whose effluents contain no organic matter that will putrify, or any poisonous compounds, or any bacteria dangerous to public health or destructive to the fish life of streams or other public bodies of water.

"SEC. 2. Upon the conviction of any person under Section 1 of this Act, it shall be the duty of the court, or judge of the court, in which such conviction is had, to issue a writ of injunction, enjoining and restraining the person or persons or corporation responsible for such pollution from a further continuance of such pollution; and for a violation of such injunction, the said court and the judge thereof shall have the power of fine and imprisonment, as for contempt of court, within the limits prescribed by law in other cases; provided, that this remedy by injunction and punishment for violation thereof shall be cumulative of the penalty fixed by Section 1 of this Act; and the assessment of a fine for contempt shall be no bar to a prosecution under Section 1; neither shall a conviction and payment of fine under Section 1 be a bar to contempt proceedings under this section.

"SEC. 3. Any city or town of this State, with a population of more than fifty thousand inhabitants, which has already an established sewerage system dependent upon any water course or other public body of water, from which water is taken for the use of farm live stock and for drinking and domestic purposes, or which discharges into any water course or other public body of water, from which water is taken for the use of farm live stock and for drinking and domestic purposes, shall have three years from and after the taking effect of this Act within which to make other provisions for such sewage. Cities and towns of less population than fifty thousand inhabitants shall have three years within which to make other arrangements for the disposal of such sewage. Any person, firm or corporation, private or municipal, coming under or affected by the terms of this bill or any independent contractor having the disposal of the sewage of any city or town, shall have three years within which to make other arrangements for the disposal of such sewage, or other matter which may pollute the water, as defined in this bill.

"SEC. 4. The Texas State Board of Health is authorized, and it is hereby made its duty, to enforce the provisions of this Act; and to this end, the Governor shall appoint, by and with the consent of the Senate, an inspector, to act under the direction of the said Board of Health and the State Health Officer, making such investigations, inspections and reports, and performing such other duties in respect to the enforcement of this Act as the said Board of Health and the State Health Officer may require.

"SEC. 5. There being now no adequate provision of law to prevent the pollution of the water courses within this State, an imperative public necessity and emergency exists, and this Act shall take effect and be in force immediately upon its passage."