DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 22

SEWAGE IRRIGATION, PART II.—RAFTER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888–89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889–90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890–91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulation showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891–92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892–93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

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UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

SEWAGE IRRIGATION

PART II

BY

GEORGE W. RAFTER

WASHINGTON

GOVERNMENT PRINTING OFFICE

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, October 25, 1898.

SIR: I have the honor to transmit herewith a manuscript entitled Sewage Irrigation, Part II, prepared in October, 1897, by Mr. George W. Rafter, of Rochester, New York. This paper consists in part of material furnished for Water-Supply and Irrigation Paper No. 3, on Sewage Irrigation. In the printing of that paper it was found that the limit of 100 pages set by law would be exceeded in spite of considerable condensation in the form of statement. The original manuscript was therefore divided into two parts, the first, relating to the general subject and giving the practice abroad, having already appeared as Paper No. 3. The present manuscript, which has been considerably extended by Mr. Rafter, is devoted mainly to the discussion of data obtained in this country and in Canada, and of all the plants erected and operated, together with brief notes on the projected plants. There is included an appendix containing a list of publications relating to the subject.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

SEWAGE IRRIGATION, PART II.

By George W. Rafter.

RÉSUMÉ OF WATER-SUPPLY AND IRRIGATION PAPER NO. 3.

In a previous publication on sewage irrigation[1] we discussed the general principles governing the utilization of sewage in agriculture, as well as the relations of such utilization to the public health. It was shown, also, how the gradually increasing pollution of streams first led in England and other manufacturing countries, to a demand for sewage purification, and the probable value of sewage in agriculture was indicated.

In that paper the various methods of sewage disposal in common use were discussed, with special reference to the modern views about nitrification. Descriptions of methods of applying sewage were given with information as to the best crops for sewage farming, the proper quantity of sewage to be applied, limiting temperatures, cost of labor on sewage farms, sanitary condition of such farms, and a number of other important subjects which it is necessary that one should understand before embarking in sewage-utilization investments. Brief descriptions were also given of a number of the principal sewage farms in England, of the sewage farms of the city of Berlin, Germany, and of sewage utilization in France on the Plain of Gennevilliers.

In the present paper it is proposed to give additional data relating to stream pollution and sewage purification, together with a brief account, so far as it has been possible to obtain the information, of every sewage-disposal plant in the United States and the Dominion of Canada, whether now in use or abandoned, that has actually been built, or that has had plans prepared for its construction.

CLIMATIC AND GEOGRAPHIC DISTRIBUTION OF SEWAGE-DISPOSAL WORKS.

As regards rainfall, the United States divides naturally into three regions—the humid, subhumid, and arid. The humid region includes all of the country east of the Mississippi River, together with the States of Iowa, Missouri, Arkansas, and Louisiana west of that river.

[1] Water-Supply and Irrigation Paper No. 3, 1897, 100 pp., 4 pls.

It also includes portions of North Dakota, South Dakota, Nebraska, Kansas, Indian Territory, and Texas. The subhumid region may be taken to include the remainder of North Dakota, South Dakota, Nebraska, Kansas, Indian Territory, and Texas. The arid region embraces Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming, although limited areas in several of these States and Territories may be classed as humid.

The great lack of water in the subhumid and arid regions would naturally indicate a relatively large development of sewage irrigation in those portions of the United States. As a matter of fact, however, other conditions than mere shortage of water have controlled—for instance, the degree of advancement of the towns themselves—and we accordingly find, on the whole, more sewage irrigation and general purification in the humid East than in the subhumid and arid West. The Western towns are, nevertheless, advancing rapidly, and we may expect changes in the figures in the near future.

The following paragraph gives the approximate statistics of sewage purification in the United States to-day:

In the humid region there are sewage-purification plants in operation, actually building, projected, or built and abandoned, distributed by States as follows: Maine, 1; New Hampshire, 2; Massachusetts, 32; Rhode Island, 5; Connecticut, 7; New York, 33; New Jersey, 11; Pennsylvania, 5; Maryland, 1; West Virginia, 1; Louisiana, 1; Texas, 3; Ohio, 11; Michigan, 2; Illinois, 2; Wisconsin, 2;[1] Minnesota, 1; a total of 120 for the humid region. In the subhumid there is 1 in Nebraska. In the arid region Arizona has 1; Colorado, 4; California, 8; Montana, 1; Utah, 1; Wyoming, 1, or a total of 16. There are also six plants in the humid portion of the Dominion of Canada.[2]

The foregoing figures indicate a total for the United States and Canada of 143. About 120 of these plants have been either built or projected in the last ten or twelve years. This total includes, so far as can be learned, all the purification plants of every kind, whether irrigation, intermittent filtration, or combined chemical-purification and filtration and irrigation plants, either actually in operation now or formally projected and in such a state of advancement as probably to be carried out in a few years.

The intermittent-filtration plants are properly included in a paper on sewage irrigation, because the filtration areas either now are used for raising crops or are likely in the end to be so used. As to the propriety of including the chemical-purification plants, it may be pointed out that this system of purification has been adopted in several towns before all the controlling conditions were taken into account. In one case an

[1] Aside from three plants for purifying manufacturing wastes, etc., there are only two sewage-disposal works in Wisconsin.

[2] The foregoing statistics of the distribution of sewage-disposal works were prepared in September, 1897. At the present date (February, 1899) there are a few additions.

eastern town has adopted chemical purification and operated the plant at large expense, in spite of the existence of ideal conditions for irrigation and filtration in the immediate vicinity. It is probable, therefore, that, as soon as the advantages of irrigation and filtration are more fully known, a number of the chemical-purification plants will be changed to either irrigation or filtration, or, without a complete change of plant, the effluents from chemical-purification works will be further treated by either irrigation or filtration. This proposition is especially true of a number of chemical plants in the State of New York, where the capitalized cost of chemical treatment will be considerably in excess of that of intermittent filtration, even though sand of the proper quality were transported some distance and high-grade filtration areas constructed. It is in this view of the case that the statistics of chemical-purification plants are herein included. There are also a number of cities and villages in the Eastern part of the United States where crude sewage is discharged into ponds, lakes, and running streams, which either now are or are likely in the future to be the source of public water supplies. In the end the sewage of all such will require purification. In many cases proper land areas can be had in the immediate vicinity; hence we find an additional reason why a complete exhibit of the whole subject should be made at this time. All town authorities need to understand that, with other conditions equal, the capitalized cost of the land-purification processes is ordinarily less than that of the chemical. Farmers in the vicinities of towns need also to understand this, as well as the benefits to themselves to be derived from the utilization of sewage in agriculture.

ORIGIN OF SEWAGE IRRIGATION.

The growth in England of great manufacturing industries and the consequent pollution of the streams of that country at the beginning of the present century forced the English cities to consider the necessity for sewage purification at an earlier date than elsewhere. Sewage irrigation as a branch of applied science may therefore be said to have originated in England. At the present time a more general use of sewage purification may be found in that country than elsewhere, although, as we have seen in Water-Supply and Irrigation Paper No. 3, the Germans and the French have now extensive sewage-purification plants of a high order of excellence. Nevertheless it is true that a large proportion of the data of sewage disposal, as it exists to-day, must necessarily be drawn from English practice.

COMPARISON OF ENGLISH AND AMERICAN SEWAGE.

First of all, it is necessary that we establish in some way a measure of the relation which average English sewage bears to American. The great difficulty in making comparisons is the fact that the English chemists, following the lead of Dr. Frankland, have mostly used the combustion process in their sewage analyses, while in the United States the Wanklyn albuminoid-ammonia process has been almost exclusively used.

By way of explaining the terms used, it may be pointed out that free ammonia as determined by the Wanklyn process represents that portion of the nitrogenous matter present which has already, at the time of analysis, passed into a state of decay; whereas the albuminoid ammonia represents the nitrogenous matter which has not, at the time of analysis, undergone decay. These are the two main determinations of the Wanklyn process.

In the combustion process Dr. Frankland attained much greater refinement than is possible with the albuminoid-ammonia process of Wanklyn, and the only reason why the combustion process has not been universally adopted is because of the difficulty of working it. By its use we determine not only the different states of the nitrogen, but that portion of the organic matter present which is carbonaceous in its character, or, technically, the organic carbon. The organic nitrogen of the process is that portion of the nitrogenous matter due to living substances, and corresponds in a general way with the albuminoid ammonia of Wanklyn. The ammonia represents dead and usually animal matter, and is, in the opinion of Dr. Frankland, the chief index of recent sewage contamination.

There are four states of the nitrogen as found in contaminated water—ammonia, free ammonia, nitrite, and nitrate. The nitrates represent the final fixation of the ammonia by combination with a mineral base, and hence a state of innocuousness. By a comparison of these various states Dr. Frankland arrives at the previous sewage contamination, which is one of the most interesting determinations of his system.[1]

If we refer to the various reports of the Rivers Pollution Commission, the Royal Commission on Metropolitan Sewage Discharge, or the Royal Commission on Metropolitan Water Supply, or to the various reports of the English local government boards, we find the analyses usually given in terms of the combustion process, in which organic carbon, organic nitrogen, ammonia, and total combined nitrogen may be considered the chief controlling constituents. Referring to a table in the first report of the Rivers Pollution Commission, on pages 28 and 29, we find that in English water-closet towns the total solids in solution in the sewage amount, on an average, to 72.2 parts per 100,000; the organic carbon to 4.696 parts per 100,000; the organic nitrogen to 2.205 parts per 100,000; the ammonia to 6.703 parts per 100,000; the total combined nitrogen to 7.728 parts per 100,000; and the chlorine to 10.66 parts per 100,000. Of the suspended matters the minerals

[1] For a definition of these several elements of the combustion process in detail the reader is referred to Recent advances in water analyses, etc., by the author, in American Monthly Microscopical Journal, May, 1893, p. 127.

amounted to 24.18 parts per 100,000, and the organic to 20.50 parts per 100,000, giving a total of 44.69 parts. If we bear in mind that free ammonia, albuminoid ammonia, and organic nitrogen refer to the same things, and also that the organic nitrogen is usually about double the albuminoid, we may still make comparisons which are close enough for the ordinary purposes of agriculturists.

Comparing several series of analyses, both American and English, it becomes apparent that ordinary town sewage in England is usually considerably more concentrated than that of the American towns. It is very important to bear this in mind in applying English data to American conditions. The elaborate experiments conducted by the Massachusetts State board of health at Lawrence, which have been reported from year to year in the annual reports of that board from 1888 to the present time, indicate that there is a relation between the purifying capacity of different filtrating materials and the amount of impurity which can be removed from sewage of a given strength. This point is strongly brought out by the experiments. It follows, then, that if we prepare special areas for sewage purification in accordance with the indications of the Massachusetts experiments, we may expect to apply sowewhat larger volumes of average American dilute town sewage per unit of area than has usually been found expedient in English practice. If, therefore, we use English data without reference to the quality of the soil to which the sewage is to be applied, or of the sewage itself, we shall be likely to arrive at more or less erroneous conclusions.

As a summation of this part of our discussion, we may say that the chief object of sewage purification is to rid the sewage of a thousandth part, more or less, of the organic matter which it contains, and that all of the appliances for sewage purification and utilization may be considered as directed toward this one point.

POLLUTION OF RIVERS.

This division of the general subject has been discussed in Water-Supply and Irrigation Paper No. 3 under the general head of "Stream pollution." The following additional information is herewith presented by way of extending somewhat the discussion there given:[1]

As an exceedingly marked case of river pollution, we may refer to the report of the Passaic Valley Sewerage Commission, authorized by an act of the New Jersey legislature approved February 26, 1896. The report of the commission appointed under the terms of this act was issued in February, 1897, and therefore may be cited as one of the most recent extended studies on stream pollution to be had.

[1] For a more extended discussion of river-pollution questions the reader is referred to River pollution in the United States, by Charles C. Brown, a paper read before the Engineers' Club of St. Louis, June 18, 1890, and published in the Journal of the Association of Engineering Societies for October, 1890, Vol. X, No. 10, p. 475, and to Sewage Disposal in the United States, Chapter III. The two works give, with the present discussion, the bulk of the published information as to river pollution in the United States.

At its head waters, among the hills of Somerset County, New Jersey, the Passaic River is a pure, clear running stream. The same is true of its principal upper tributaries, the Rockaway and Pompton rivers; and while there is some manufacturing in the upper valleys, the river continues bright and inviting until it reaches Little Falls, at which place it receives the drainage from several residences and factories. After passing Paterson, 3 or 4 miles below Little Falls, its character completely changes, and from that point to Newark Bay, as stated by the Passaic commission, "its pollution is enormous, constant, and increasing yearly." About 436,000 persons now inhabit the district drained by the lower river, furnishing fully 70,000,000 gallons of sewage a day. So great is the extent of the pollution below Paterson that fish life, except a few hardy kinds, has entirely disappeared. The sewage-laden mud shores give out foul odors. Steam users report that the acids of the sewage-laden water have so affected their boilers as to make its use unadvisable. Formerly thousands frequented the river for pleasure purposes, but this is no longer a practice.[1]

In 1880 the population of the towns dischaging sewage into the lower Passaic River was 246,503, and in 1895 it was 436,423.

The ratio of increase in population of the lower Passaic district from 1880 to 1890 is placed at 43.2 per cent, and from 1890 to 1895 at 22.6 per cent. The river now receives the sewage of the cities of Paterson, Passaic, Orange, and Newark, and the towns of East Orange, Bloomfield, Montclair, Harrison, Kearny, East Newark, and part of Rutherford. All these places are growing rapidly, and sewerage facilities for a number of other places are an admitted necessity of the early future. The commission therefore considers it beyond question that the pollution of the lower Passaic is sure to increase enormously unless remedial measures be taken.

As a summation the commissioners state:

(1) That the daily discharge of 70,000,000 gallons of sewage into the Passaic River below the Great Falls of Paterson is beyond its power to assimilate.

(2) That through the stench the pollution has become a nuisance to residents along the banks, and has caused depreciation of property and injury to health.

(3) That fisheries have been destroyed.

(4) That the river has ceased to be desirable for pleasure purposes, boating, bathing, etc., no longer possessing the park value which so generous a stream should afford the large population on its banks.

(5) That the use of the river for manufacturing purposes is suffering on account of the pollution.

(6) In short, that the pollution of the lower Passaic River appears to the commissioners to be completely established as a public nuisance, as injurious to health, and as an increasing menace to property interests from the Great Falls at Paterson to below Newark.

[1]Abstract from report of Passaic Valley sewerage commission, pp. 10-11.

In discussing means of relief the commissioners state that the great progress in sanitary science of recent years has increased the demand for thorough methods of sewage disposal; hence it has been recognized in European countries, and throughout the thickly settled part of the United States, that methods of sewage disposal need a degree of care and thoroughness second only to the requirements of furnishing the same population with water and food. After reviewing the various methods of sewage purification the commissioners conclude that in the present case the conducting of the sewage to tidal waters is, on the whole, preferable. Their reason for this conclusion is, largely, that the available land areas in the Passaic Valley appear poorly adapted for irrigation and filtration processes. On this point the engineers to the commission, Messrs. A. Fteley and Charles E. A. Jacobson, state that the only lands within reach of sufficient area for irrigation works are the extensive meadows of the lower Passaic Valley, but unfortunately the character of the soil is so compact that, even with extensive and costly underdrainage, the amount of sewage which could be disposed of per unit of area would be so small as to require many thousands of acres; hence, Messrs. Fteley and Jacobson consider land disposal impracticable for the lower Passaic. They recommend the construction of an intercepting sewer at an estimated present cost of $6,500,000. The yearly cost of operation is placed at $125,000 in 1900 and $300,000 in 1930.

An extended series of chemical analyses made by Herbert B. Baldwin, chemist to the commission, is included in the report. In considering the effect of the sewage on the condition of the river, it is pointed out by Mr. Baldwin that the average discharge of sewage is a fairly constant quantity, but that the flow of the river is not. By way of illustrating this, we may point out that the flow of the Passaic River varies at Little Falls from a minimum of about 200 cubic feet to a maximum of about 20,000 cubic feet per second. The drainage area above Little Falls is 773 square miles. Whenever the river is either at or anywhere near its minimum flow, what may be termed the point of saturation is so far exceeded that the river inevitably becomes not only a nuisance, but a menace to health. On the one hand, the clearing of forests tends to decrease still further the minimum flow and to increase the length of the low-water period from year to year; on the other hand, the growth of towns and the extension of sewerage works tend to increase the pollution. Taking the two together, there is, therefore, a more rapid increase in actual stream pollution than is indicated by mere consideration of the percentages of increase of the quantity of sewage.

Moreover, the upper Passaic is the natural source of water supply for the north Jersey municipalities, and the probable taking of an appreciable part of the stream for such supplies will inevitably tend to aggravate existing conditions.

Chapter 83 of the Resolves of the Massachusetts Legislature of 1895 directed the State board of health to investigate the sanitary condition of the meadows on Neponset River, and submit the results of the examination, together with recommendations for the improvement of the sanitary condition of the meadows and the removal of the nuisance therefrom. The report of the board's engineers was made under date of October 1, 1896.

The Neponset Meadows, covering an area of 3,662¾ acres, of which little more than 600 acres appear to be in a condition adapted to agriculture, are subject to prolonged flooding nearly every year, and, with an increasing pollution of the stream, have become a serious public nuisance. The object of the report of the Massachusetts State board of health referred to is the abatement of this nuisance.

The Neponset River is connected with the Charles River by Mother Brook, which is legally entitled to receive one-third of the flow of Charles River. The drainage area of the Neponset River at its mouth, including one-third of the watershed of the Charles River above Mother Brook, is given as 180.3 square miles. The population of the several towns in the Neponset Basin above the lower end of the meadows was, in 1885, 15,097; in 1890, 17,361, and in 1895, 19,193. These towns are provided with public water supplies, but none of them have as yet a general system of sewerage.

The Neponset River may be divided into three portions: An upper portion, above the great meadows; a middle portion, including the meadows subject to overflow; and a lower portion, within the limits of the Boston metropolitan district.

The upper portion is about 10 miles in length, with a total fall of about 220 feet. Manufactories and mills are located throughout the valley, and the river is highly polluted by manufacturing wastes. The length of the middle portion is 11.25 miles. In much of this portion the river has very little fall and the flowing water is partially purified by dilution with water from purer tributaries and by sedimentation. The lower portion has considerable fall to tide water, and has high banks occupied by factories and dwelling houses. Practically all the water power of this section is made available by milldams. The minimum flow of the stream, as determined by the lowest level, reached in 1895, is about 54 cubic feet per second.

Chemical analyses of the water of the Neponset River were made by the Massachusetts State board of health in 1873, 1875, 1885, 1891, and 1895. A tabulation of the results shows a much more serious pollution in 1895 than in 1875. Thus, in 1875, at the Milton lower mills, free ammonia was 0.0112 part per 100,000; in 1891 it was 0.0274 part; and in 1895, 0.0526 part. In 1875 the albuminoid ammonia at Milton lower mills was 0.0171 part per 100,000; in 1891, 0.0329 part; and in 1895, 0.0342 part. Chlorine at Milton lower mills in 1875 was 0.46 part; in 1891, 1.18 parts, and in 1895, 1.47 parts.

The report states that, in order to improve the sanitary condition of the river and meadows, it will be necessary to prevent the further discharge into the stream of domestic and manufacturing sewage, unless it has been previously purified sufficiently to prevent offense to sight or smell. A system of sewerage was provided for by chapter 406 of the Massachusetts acts of 1895, by means of which it will be possible in future to prevent the pollution of the river below the great meadows, after some provision is made whereby the diversion of sewage from the river into the sewers is made compulsory and the further discharge of manufacturing wastes is prevented.

The town of Hyde Park is located on the Neponset River, just below its junction with Mother Brook. The pollution in the region above at the present time is caused almost entirely by the discharge into the river of manufacturing wastes, generally from paper mills and tanneries. Investigations with reference to the purification of wastes of this sort were begun by the Massachusetts State board of health in the summer of 1895, and a résumé of the results will be found in the following pages. The published results indicate that it will be feasible to purify the manufacturing wastes satisfactorily at a cost sufficiently small to avoid crippling the manufacturing industries. A study of the question of the purification of the sewage of a number of towns naturally draining into the Neponset River in the upper valley shows that the necessary purification can be best accomplished by separate treatment upon land, as is done in many other towns in Massachusetts.

The removal from the river of the crude sewage of the manufacturing establishments, as well as that of the towns in the valley, will tend to improve the sanitary condition of the channel of the stream by preventing further deposition of organic matter upon the sides and bottom and in the numerous shallow bays and coves.

The report further states that, in order to improve the sanitary condition of the meadows, it will be necessary to lower the level of the water in the river sufficiently to permit the satisfactory drainage of the meadows and to prevent being flooded during the summer season. To accomplish this it is considered that the river should be deepened sufficiently to carry off the summer flows and still keep the water surface below the level of the meadows. Applying the run-off data of the Sudbury River watershed, for which a record covering twenty-one years is available, it appears that the river channel should be enlarged enough to enable it to carry at least 720 cubic feet per second, which would be sufficient for anything except a summer rainfall in excess of that of August, 1889, when the run-off of the Sudbury River for the month amounted to 2.55 inches on the watershed, the rainfall of the previous month of July being 8.94 inches and of the previous August 4.18 inches. The run off-of August, 1889, of 2.55 inches, was the largest for any summer month during the period 1875 to 1896, covered by the Sudbury measurements. In 1882 the August run-off of the Sudbury was only 0.10 inch. In 1883 the September run-off was 0.08 inch. In 1883 the total run off of the Sudbury for the summer months, June to

August, inclusive, was only 0.86 inch. In 1889 the total run-off of the summer months was 4.81 inches. According to the report of the engineer, an examination of the rainfall records of eastern Massachusetts for the period of thirteen years indicates that summer flows as heavy as in August, 1889, may be expected about once in ten to fourteen years; while for about two or three times in a century it may happen that the flow for some one of the summer months will be considerably in excess of that for August, 1889.

The plan for draining the Neponset Meadows includes, in effect, the cutting of a new channel across a number of sharp bends, thus considerably shortening the length and increasing the slope. It also includes removing the flashboards of the dam of the Mattapan Paper Mill, which is situated on the river about half a mile up the stream from the north line of the town of Hyde Park. The estimated cost of the river improvement, not including cost of land and water damages, is $127,115. It is also estimated that the increase in valuation of the 3,655 acres of meadow resulting from this improvement would amount to $101,330.

In concluding his report, Mr. Goodenough, the engineer of the State board of health, states that the gain in valuation of the meadows, produced by draining them, probably does not represent the full economic value of the improvement. By leaving the river and meadows in their present condition they become not only a source of annoyance, but a menace to the health of those living in the vicinity, and ultimately unfavorably affect the value of all real estate in the vicinity. Moreover, if a portion of the improved meadows should be utilized for market gardening, the value of such portion would be much greater than if used for hay and pasturage alone.

In order to show the great pollution to which streams in manufacturing districts are subject from the discharge of manufacturing wastes, we may further refer to the report on river pollution in Connecticut, by Prof. S. W. Williston, from which extracts have been made in Water-Supply and Irrigation Paper No. 3, first considering the case of Quinnipiac River. That stream has a drainage area of about 150 square miles, with a population thereon in 1890 of fully 40,000. Meriden, the chief city of the drainage area, had a population in 1880 of 15,540, and in 1890 of 21,652.

A measurement of the flow of the Quinnipiac River made August 3, 1888, gave about 7 cubic feet per second. A measurement on Monday, August 6, before the mills started, gave 5.5 cubic feet per second; at 10 a. m. the same day the flow was nearly 20 cubic feet per second. The rainfall is such that in ordinary years we may expect fairly uniform daily stream flows in the vicinity of Meriden.

In 1888 there were in Meriden 23 manufacturing establishments, with 5,708 employees, of whom 3,608 used water-closets.

In a year these manufactories produce the following amounts of polluting materials:

Polluting materials used by manufactories in Meriden, Connecticut.

Mineral acids	pounds..	891,700
Alkalies	do....	198,500
Mineral salts	do....	7,000
Inorganic and organic oils	gallons..	18,445
Asphaltum	pounds..	1,000
Soap	do....	7,000
Cotton waste	do....	2,000

The organic matter scoured from wool is stated at over 500 pounds daily. The total amount of manufacturing wastes turned into the stream is estimated at from 2½ to 3 tons daily, one-fourth of which is organic.

At Yalesville and Wallingford Professor Williston found 6 manufacturing establishments, with 1,060 employees, of whom 485 used water-closets. The polluting material used per year by the 6 establishments was reported as follows:

Polluting materials used by manufactories in Yalesville and Wallingford, Connecticut.

	Pounds.
Organic matter (about)	50,000
Acids	173,000
Alkalies	41,000
Minerals and mineral oils (about)	90,000
Total	354,000

The sewers of New Britain, Connecticut, drain partly into a tributary of the Quinnipiac River and partly into a tributary of the Connecticut River. The population of New Britain in 1880 was 11,800, and in 1890, 16,519. Professor Williston's canvass showed 12 establishments, with 3,075 employees, using water-closets which drained into Pipers Brook, a tributary of the Connecticut.

The following quantities of chemicals per year were discharged from these 12 establishments:

Polluting materials discharged from manufactories in New Britain, Connecticut.

	Pounds.
Metal salts	700,000
Free acids	100,000
Lime salts	35,000
Alkali salts	100,000
Soap	25,000
Fatty matter	100,000
Vegetable refuse	20,000
Total	1,080,000

Waterbury, the chief city on the Naugatuck River, in Connecticut, had, in 1880, a population of 17,806, and in 1890 a population of 28,646.

In 1887, 26 manufacturing establishments employed 7,571 persons, of whom 7,140 used water-closets.

The annual pollution from manufacturing wastes at Waterbury was placed as follows:

Polluting materials discharged from manufactories in Waterbury, Connecticut.

	Pounds.
Free acids	500,000
Metal salts	2,500,000
Alkaline salts	75,000
Soap	50,000
Fatty matters	200,000
Total	3,325,000

A large amount of interesting recent information in regard to river pollution in the United States is now available, but lack of space precludes further reference to it in this place.[1] The examples given will serve to illustrate the immense amount of polluting wastes that are daily being thrown into the rivers.

SEWAGE PURIFICATION AT MANUFACTURING ESTABLISHMENTS.

In England the pollution of streams from manufacturing wastes became very serious many years ago, and as the result of careful consideration of this special phase of stream pollution a number of sewage-disposal plants have been devised, especially with reference to purifying the sewage of each manufacturing establishment at the mill. A large amount of information in regard to such plants, with detailed plans, may be found in the fourth report of the Rivers Pollution Commission. As American examples, a number of cases cited by Mr. Clark in his report to the Massachusetts drainage commission, together with several recent ones, may be mentioned.

(1) The Wansuch Mills at Providence, Rhode Island, manufacture woolen and worsted goods extensively. The yearly amount of refuse contained in the waste water from this mill is stated to include about 64,000 pounds of dyestuffs, 1,000,000 pounds of alkali, 4,000 pounds of acid, 53,000 pounds of fuller's earth, and 400,000 pounds of grease. The waste water which contains this polluting material, and which originally flowed directly into West River, is stated as about 400,000 gallons a day. A dyeing and bleaching company located on the stream below the Wansuch Mills brought suit, alleging serious injury to its operations. After protracted litigation the supreme court granted a permanent injunction. In compliance with the injunction attempts were made to purify the waste water before permitting it to enter the river. For this purpose an acre and a half of land was prepared for filtration

[1] See the annual reports of the several State boards of health. The annual reports of the Provincial Board of Health of Ontario may also be referred to. As further illustrating the pollution of streams by mill wastes, reference may be made to the Eighty-third Annual Report of the Philadelphia Water Department (1885), pages 308, 309, where the detail of the daily wastes from an extensive carpet, blanket, and cloth mill may be found. The same data are also given on page 64 of Sewage Disposal in the United States. See also the report of the Second Rivers Pollution Commission.

by making furrows 4 feet apart on the surface. This process was fairly successful when first tried, but the land soon became clogged on the surface. The filtration process was then abandoned, although it seems clear from present information that with a larger area it could have been made successful. Purification by chemical precipitation was then adopted and has, so far as known, been continued since. For this purpose a set of six connected basins was excavated on the land previously used for filtration.

It is stated that about a barrel of lime is added to each 100,000 gallons of waste before pumping to the precipitation basins. This addition is made rudely, without either previously grinding or slacking the lime. The mill wastes flow continuously through the basins, with most of the deposition taking place in the first basin. The effluent from the last basin is said to appear to the eye about as foul as when it enters; this apparently indicates, in view of the satisfactory results gained elsewhere, defects in the practical management of the process. In the beginning sulphate of alumina was used as a precipitant, at a cost of about $6,000 per year for the whole amount treated, which, however, was considered too great an expense.

(2) At the Loraine mills, Saylesville, Rhode Island, a method of wool scouring is practiced by which the grease is recovered and most of the dirt is eliminated from the wash water before it is permitted to escape. The results at this mill indicate the recovery of about a ton of grease from each 18,000 pounds of wool washed. The cost of the plant for accomplishing this, not including buildings, was $2,500. The process is considered remunerative.

(3) Two mills in Millbury, Massachusetts, each scouring about 1,000 pounds of wool per day in the grease, retain the first scour in vats, which are cleaned periodically and their contents used as fertilizer. The process is considered remunerative at these mills.

(4) At the woolen mills of Robert Bleakie & Co., Hyde Park, Massachusetts, about 3,000 pounds of wool are scoured daily, the refuse from which, together with sewage and dyeing wastes, flows into a settling basin, whence the effluent passes into the stream. The settling basin consists of a cemented structure 80 feet long, 10 feet wide, and 3.5 feet deep; it is cleaned at intervals and the sludge is used for fertilizer, yielding for this purpose an estimated value of several hundred dollars a year.

(5) At Maxwell's tannery, Winchester, Massachusetts, a mechanical filter is used for straining bark and coarse lime from tannery wastes. The filter consists of a wooden box about 4 feet wide, 2 feet deep, and 60 feet long, divided into compartments filled with hay, through which the waste water filters. The effluent generally is clear, but of a deep mahogany color.

(6) The Nemasket mills at East Taunton, Massachusetts, applied to the State board of health in 1891 for advice with reference to disposing

of the sewage of the mill. The board advised that the waste water from the sinks be kept entirely separate from other wastes and conducted to a tight cesspool with an overflow therefrom into a filtering trench on the bank of the river. Also, that privies be provided in which all excrementaceous matters, both solid and liquid, be retained in water-tight vaults, to be cleaned from time to time, and the deposits buried in the ground not less than 100 feet from the Taunton River. The board expressed the opinion that by carrying out this plan the water supply of the city of Taunton, which is taken from Taunton River below the Nemasket mills, would not be contaminated by the mill wastes.

(7) The Menominee River Valley, in Wisconsin, adjacent to the city of Milwaukee, has been badly polluted for a number of years by wastes from large manufacturing establishments as well as from the public institutions of Milwaukee County. In 1893 the Wisconsin legislature instructed the State board of health to prepare plans and estimates for a sewerage system to serve this district. It also enacted further legislation, requiring all sewage to be filtered or otherwise purified to the satisfaction of the State board of health before being discharged into the stream. The act, however, failed to provide funds for preparing the plans, but most of the manufacturing establishments and public institutions have voluntarily introduced some method of treating their sewage. A recent letter from Dr. U. O. B. Wingate, secretary of the Wisconsin State board of health, indicates that the results obtained have been hardly satisfactory on account of adverse decisions of the Wisconsin courts[1] as to the powers of the State board, which have operated to prevent such supervision of sewage-disposal projects in Wisconsin as is now common in the more advanced States of the East and middle West.

The following are some of the particulars of the works actually constructed. At Schmidt's curled-hair works the solid matter of the liquid wastes is first screened out and the effluent then discharged upon porous soil, where it disappears. A similar system is in operation at McBride's sanitarium.

The National Soldiers' Home, with over 2,000 inmates and a daily flow of sewage of about 270,000 gallons, constructed an intermittent filtration system, the permanent success of which, however, is said to be doubtful because of the character of the soil of the filter areas.

At the shops of the Chicago and Northwestern Railway Company at Merrill Park a furnace has been provided for cremating the excrements.

The public institutions of Milwaukee County and the Miller Brewing Company have constructed combined chemical precipitation and mechanical filtration plants. The county institutions consist of a hospital, almshouse, two insane asylums, etc., having in all over 1,000 inmates. The flow of sewage is placed at from 250,000 to 400,000

[1] See also Sixteenth Ann. Rept. Wisconsin State board of health.

gallons a day. The sewage is first treated with lime and sulphate of alumina, and is subsequently filtered. The works are said to receive daily attention from a chemist, and thus far have furnished a clear effluent, free from odor, which does not undergo a secondary decomposition. However, according to information in Engineering News of January 13, 1895, it appears that this plant is not doing the work as thoroughly as it should because of overcrowding and too infrequent cleaning. The plant was originally designed to treat 480,000 gallons of sewage in twenty-four hours, which would certainly be a very large quantity from 1,000 inmates, even at insane asylums. If the present works actually have a capacity of 480,000 gallons in twenty-four hours, or, what is the same thing, a capacity for treating 480 gallons per capita per diem, they certainly ought to take care of the sewage from these institutions. The mechanical filter is said to be composed of limestone, Florida moss, and iron manganese. We understand that the process is patented, but probably does not represent the best practice in sewage purification at the present time, which may be the real reason for its failing to do the work properly.

The Miller Brewing Company, which produces perhaps 150,000 gallons of sewage a day, has a similar plant, the effluent from which is stated to be so unsatisfactory as to undergo secondary decomposition.

In a letter to Engineering News dated January 21, 1895, Dr. Wingate, the secretary of the Wisconsin State board of health, states that two of the plants which have been built in the Menominee Valley are satisfactory in their construction, but their management is unsatisfactory. He also states that the managers of the different institutions and manufacturing establishments have apparently the idea that constructing a plant is all that is necessary, that they have not furnished the necessary agents and help to keep the plants in proper condition, and that they have not managed them properly.[1]

Experience abroad has fully shown that purification works require attention; indeed, our own experience on this point is now so full, that it seems unnecessary for Americans to experiment further in that direction.

(8) In Ohio stream pollution from manufacturing wastes has assumed some importance, and the State board of health of that State has investigated a number of cases of such pollution, one of which may be referred to here. The Scioto Straw-Board Company, of Kenton, Ohio, discharges the wastes from its mill into the Scioto River. Complaints having been made to the State board of health that such discharge caused a public nuisance, an investigation was made in the summer of 1886. The following analyses of water from the Scioto River at Kenton indicate the extent of the pollution. In considering the significance of

[1] In a letter to the author, dated August 6, 1897, Dr. Wingate states that a drainage commission has been appointed to report to the next legislature, which will consider the whole question of Menominee Valley sewage disposal.

these analyses it should be understood that the Scioto River at Kenton is little more than a respectable brook. The average fall does not exceed 1 foot per mile for 30 miles. Analysis No. 1 is water from the Scioto River above the mill; No. 2, water from below the mill, and No. 3, from La Rue, a few miles below.

Analyses of water from Scioto River near Kenton.

[Grains per gallon.]

Number.	Lime.	Chlorine.	Mineral.	Organic and volatile.	Total solids.
1	8.98	0.25	20.30	9.68	29.98
2	63.32	6.49	84.09	130.63	214.72
3	13.33	1.45	31.26	18.19	49.45

So far as can be learned, the great increase in pollution of the stream did not affect the health of people living in the vicinity, although the fish in the stream were killed and there was at time of low water a serious effluvium nuisance. The remedy was the construction of a settling tank of from 3 to 5 acres. As to whether or not this has proved satisfactory there is no information at hand.[1]

(9) The waste waters at Tid's tannery, Stoneham, Massachusetts, were treated chemically during the years 1894 and 1895. The following results were obtained in the latter year. The total quantity of sewage pumped was 4,990,924 gallons, to which were applied as a precipitant 71,760 pounds of sulphate of alumina. The sludge amounted to 648,820 gallons, or 13 per cent of the sewage. It was disposed of to neighboring farmers, who carted it away for fertilizer. These works were first operated in 1893, by the city of Boston, in order to protect the Upper Mystic Lake.

(10) At Fitzgerald's tannery, also in Stoneham, Massachusetts, a series of precipitation tanks were constructed by the owner in 1895, arranged in such manner that the heavy particles of waste matter will settle as the sewage flows from one tank to another over separating partitions. In 1895, however, the quantity of sewage having increased to about 10,000 gallons daily in August, it was found necessary to use more chemical than the lime naturally present in the sewage. The owner thereupon constructed a vat for chemicals, and the Boston water department furnished and applied sulphate of alumina to the extent of 10,520 pounds from August, 1895, to January, 1896. The effluent from both these tanneries in Stoneham, while still highly colored from the tan bark, is stated to be on the whole fairly satisfactory. The use of a larger amount of chemicals would remove an additional amount of color, but at such increased cost as is considered not to be justified by the circumstances.

[1] The Ohio State board of health issued in 1898 a Preliminary report of an investigation of rivers, etc., of Ohio, which gives much information about the waters of that State.

MASSACHUSETTS EXPERIMENTS ON THE PURIFICATION OF FACTORY WASTES.

In the report of the Massachusetts State board of health for 1895 the results of investigations as to the disposal of waste liquors from various industrial processes are given. Among others may be found a discussion of the results obtained in the purification of the waste liquors from paper making, wool scouring, and tanning.

PAPER-MILL WASTES.

The experiments on purification of paper-mill wastes included the application for some time to a filter containing 60 inches in depth of sand of the effective size of 0.25 millimeter of the waste liquor resulting from cleansing rags in a paper mill by means of a boiling solution of caustic soda and lime. The rags cleaned are of all kinds and colors, and the resulting liquor, as stated, is very highly colored. It was applied to the filter at an average rate of 65,500 gallons per acre daily, with the result of great improvement in the appearance and analysis, although the effluent as it flows from the filter is still highly charged with organic matter in solution. The following is the analysis of the applied liquor: Free ammonia, 2.3 parts per 100,000; albuminoid ammonia, 4.1 parts; chlorine, 20 parts; oxygen consumed, 140 parts. The effluent shows: Free ammonia, 1.8 parts per 100,000; albuminoid ammonia, 2.29 parts; chlorine, 12.59 parts; nitrogen as nitrates, 0.105 part, and as nitrites, 0.0067 part; oxygen consumed, 84.36 parts. The nitrates and nitrites in the applied liquor are nil. It is clear, therefore, that some considerable nitrifying action has taken place in the filter, but it is the opinion of the board that the degree of alkalinity is so high as to prevent the full effect of nitrification.

WOOL-SCOURING WASTES.

The waste liquors of wool scouring were applied to a filter with the same depth of sand and effective size of grains as in the previous case, at the rate of 17,000 gallons per acre daily. The results, so far as obtained, show that while a considerable improvement of such a liquor can be obtained by intermittent filtration, still, owing to clogging of the upper layers of the sand, it appears desirable that a preliminary treatment, to remove a part of the dirt and fatty matters before filtration, should be applied. The average analyses of the waste liquor from wool washing and of the effluent were as follows: The applied liquor contained 17.3 parts of free ammonia per 100,000; albuminoid ammonia, 43.1 parts; chlorine, 60.13 parts; oxygen consumed, 232 parts. The effluent contained: Free ammonia, 27.8 parts per 100,000; albuminoid ammonia, 8.3 parts; chlorine, 47 parts; nitrates, 0.28 part, and no nitrites; oxygen consumed, 90 parts. The applied liquor was entirely free of both nitrates and nitrites. A refiltration of the effluent from the preceding experiment on waste liquor from wool scouring was made through two filters, one containing 60 inches in depth of sand of the same effective size of grain as before and the other containing 60 inches in depth of coke breeze. The effluent was applied to the two filters for three months, at the rate of 50,000 gallons per acre daily. The liquor passed through both the sand filter and the coke breeze very little changed, thus showing not only the stable character of the organic matters present, but that the high degree of alkalinity was probably prejudicial to nitrification.

An experiment was also made as to the treatment of the waste liquor from wool scouring by the preliminary precipitation of the fat and dirt by means of calcium chloride, followed by intermittent filtration. This treatment gives an almost complete clarification of the liquor, but it passed through a filter 5 feet in depth, with effective size of sand grain of 0.25 millimeter, with very little change.

TANNERY WASTES.

In order to test the efficiency of intermittent filtration as applied to tannery wastes, an experimental filter has been set up at Norwood, Massachusetts. On account of the conditions imposed by the location, the filter has only 2 feet of sand, the effective size of the sand grain being 0.14 millimeter. The sewage applied is a mixture of the waste liquors from all the processes carried on in the tannery; and it was applied to this shallow filter at an average rate of 55,000 gallons per acre daily. The results obtained were as follows: The applied sewage contained 3.1 parts of free ammonia per 100,000; albuminoid ammonia, 3.16 parts; chlorine, 312 parts; nitrates, 0.16 part; nitrites, 0.0015 part; oxygen consumed, 55 parts. The effluent contained: Free ammonia, 2.34 parts per 100,000; albuminoid ammonia, 0.6 part; chlorine, 290 parts; nitrates, 1.05 parts; nitrites, 0.01 part; oxygen consumed, 7.5 parts.

This sewage is said to be very strong and offensive, containing decaying animal tissues and the bran added to cause fermentation. It is also colored by the dyes used in finishing the hides, which, after a few weeks, the filter failed to remove completely. The applied sewage did not contain any amount of the spent tan liquor. The antiseptic qualities of the tannic acid would, without doubt, be very prejudicial to nitrification.

In cleaning hides a large amount of lime is used, in consequence of which in large tanneries there is an almost continuous stream of lime water flowing into and mixing with the other waste liquors. By properly arranged settling tanks and the regulation of this lime water, it is the opinion of the Massachusetts board that a large percentage of the sludge could be precipitated out. Experiments show that probably 60 per cent of the organic matter can be removed in this way, although even then the resulting supernatant sewage would still remain very rich in organic matter in solution.

The supernatant sewage from such treatment was applied to a small filter at the average rate of 120,000 gallons a day. After several months' operation this filter is stated to be in a state of active nitrification, giving a clear and nearly odorless effluent. It is the opinion of the Massachusetts board that by treatment of tannery sewage on this line it may be efficiently purified by filtration.

DYESTUFFS.

Among the many experiments carried out at Lawrence, perhaps as interesting as any, are those relating to the filtration of sewage containing dyestuffs. This division of the sewage question is specially interesting because of the large number of manufacturing establishments at various places, the refuse from which usually passes without treatment into streams. In England this phase of sewage purification became of considerable importance early in the present century, because, generally speaking, the streams of England are small, and even sixty years ago a number of them had become badly polluted by the waste dyes from woolen, cotton, and other fabric manufacturing establishments. As illustrating the conditions twenty-five years ago, the Second Rivers Pollution Commission gives in its third report a reproduction of a memorandum written with the water of the river Calder at a point where the Wakefield sewer enters that stream. This memorandum reads as follows: "Dedicated without permission to the local board of health, Wakefield. This memorandum written with water taken from the point of junction this day, between the river Calder and the town sewer. Could the odor only accompany this sheet it would add much to the interest of this memorandum."

The condition of the river Calder has been improved in recent years by the construction of a number of sewage purification works along its banks, although when seen by us in October, 1894, it was still far from being a limpid stream.

Without going into the detail of the Massachusetts experiments on the filtration of various dyes used in fabric manufacturing, we may simply state that indigo extract, logwood extract, alizarin base, archil B, rose azurine, benzo-azurine, methyline blue, orange 2 R, magenta, malachite green, and scarlet 2 R, when applied at varying rates—from 335,000 gallons per acre of archil B to 1,280,000 gallons per acre of methyline blue—gave an effluent absolutely free from color. Scarlet 2 R applied at the rate of 1,076,000 per acre gave an effluent as highly colored as the applied sewage, but when applied at the rate of 720,000 gallons per acre the effluent was without color. Patent blue, when applied at the rate of 56,000 gallons per acre, gave a slight color; it also gave a slight color when applied at the rate of 160,000 gallons per acre, but when applied at the rate of from 335,000 gallons per acre to 960,000 gallons, it gave, in each case, a strongly colored effluent.

Indigo extract, logwood extract, alizarin base, and archil B are dilute colors. The others are coal-tar colors in concentrated form. In most of the experiments the removal of the color, as already stated, was complete, as tested by viewing the effluents in tubes of from 200 to 600 millimeters depth.

Considering the large quantities of dyestuffs applied in these experiments, the conclusion may be drawn that dyes as likely to exist in ordinary city sewage are easily amenable to filtration treatment.

SPECIAL EXPERIMENTS.

In the course of the experiments at Lawrence a number were made as to the effect of antiseptics, as well as other substances, upon nitrification. Some of the more important of these experiments may be briefly referred to.

(1) For several weeks a considerable quantity of egg albumen, a substance nearly insoluble in water, was applied in one of the experimental tanks, the object being to determine to what extent it would be rendered soluble and converted into free ammonia. The indications of the first experiment were that about 61 per cent of the total nitrogen contained in the albumen applied was rendered soluble and converted into nitrates. A repetition indicated that possibly 90 per cent of the total nitrogen of the albumen was converted into nitrates.

(2) To one of the experimental tanks, which at the time of the first application was giving a perfectly nitrified effluent, a solution of ammonium chloride, in water containing 1 part of ammonia per 100,000, was applied in place of the sewage. Enough sodium carbonate was mixed with the ammonium chloride solution to combine with the chlorine of the ammonium chloride, and also with the nitric acid equivalent to the ammonia. Nitrification was complete from the first, the effluent being not only free from ammonia, but containing nearly all the nitrogen applied, as nitrates. The strength of the solution was gradually increased until it contained 34 parts per 100,000 of ammonia, after which complete nitrification was not at once obtained, but finally a nearly complete nitrification resulted.

(3) Experiments as to the the effect of an excess and deficiency of alkali were also made, showing that with alkali in excess nitrification was not in the least interfered with, but with a deficiency the process apparently stopped with the production of an enormous quantity of nitrites.

(4) Experiments as to the effect of acid upon nitrification were made, which showed that sewage containing a large percentage of sulphuric acid may have a major part of its nitrogenous constituents removed for a considerable time. If we are dealing with a sewage which contains moderate quantities of sulphuric acid occasionally, we may expect to purify it by intermittent filtration without any ill effects; but if the sewage contains sulphuric acid regularly, the acid should be neutralized by the addition of lime or some other alkali.

(5) Experiments as to the effect of common salt showed that when common salt was present in such quantity that the chlorine amounted to 1,200 parts per 100,000 the nitrification was quickly checked and the common-salt solution passed through the filter almost unchanged. If, however, common salt be added gradually, so that the filter may have the opportunity to adapt itself to the work required of it, the result was found to be very different. In an experiment of this character it was ascertained that with gradual increase of the common-salt solution nitrification continued. The practical result arrived at was that sewage containing a considerable quantity of common salt as one of its regular constituents may be purified by intermittent filtration without difficulty.

(6) Experiments as to the effect of sugar upon nitrification showed that if a considerable quantity of sugar is applied to intermittent filtration it will cause a decrease of nitrification. If, however, the filter can be gradually adapted to the special work of nitrifying sugar, the nitrification will finally become nearly as complete as when sugar is absent.

MECHANICAL ANALYSES OF SANDS.

The selection of the filtering materials is a very important point in constructing a filter. The Massachusetts State board of health has developed a method of sand analysis by which different sands may be compared and from their relative coarseness their efficiency as a filter material be foretold.

SIZE OF GRAIN.

As described in the twenty-third annual report of the board, the sand is first sifted through a series of sieves, each about twice as fine as the one next coarser. The sand passing the finest sieve is divided into several portions by beaker elutriation. Each portion is weighed, and the range and size of particles is determined either by micrometer measurement of the smaller particles or by computation of the diameters of larger particles by their weight. The diameters of all particles are taken as nearly as possible at the diameter of a square of equal volume. In each case the diameters are expressed in millimeters. As illustrating the results of such mechanical analyses in their application to filter material, we may quote the following as the percentage statement of the fine material used in experimental filter No. 5. In this filter the material with mean diameter less than 12.6 millimeters amounted to 99 per cent of the whole; material with less diameter than 6.2 millimeters to 96 per cent of the whole; mean diameter less than 2.2 millimeters, 92 per cent; mean diameter less than 0.98 millimeter, 89 per cent; mean diameter less than 0.46 millimeter, 80 per cent; diameter less than 0.24 millimeter, 67 per cent; diameter less than 0.12 millimeter, 51 per cent; diameter less than 0.06 millimeter, 33 per cent; diameter less than 0.03 millimeter, 16 per cent; diameter less than 0.01 millimeter, which would represent the organic matter, 6 per cent.

We have an example of the mechanical analysis of a coarse sand in the case of sand from filter No. 1. In this filter the material with mean diameter less than 12.6 millimeters amounted to 100 per cent of the whole; material with diameter less than 6.2 millimeters, to 97 per cent of the whole; mean diameter less than 2.2 millimeters, 85 per cent; mean diameter less than 0.98 millimeter, 53 per cent; mean diameter less than 0.46 millimeter, 7 per cent; mean diameter less than 0.24 millimeter, 1.5 per cent; mean diameter less than 0.12 millimeter, 0 per cent.

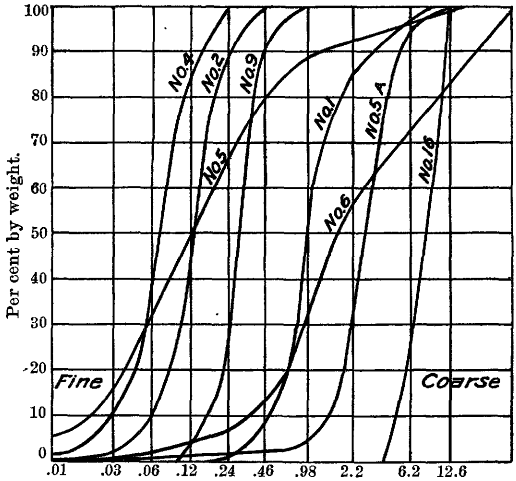

FIG. 1.—Mechanical composition of materials available for sewage filtration.

In the same way the results of the mechanical analysis of other sands used in the Lawrence experiments are expressed in the reports.

In order to compare the results of the mechanical analyses of the several sands experimented with as well as their relative values for filtration, we include the accompanying diagram, fig. 1, derived from the Massachusetts reports. The lines representing the diameters are spaced according to the logarithms of the diameters of the particles, as in this way materials of corresponding uniformity in range of size of particles give equally steep curves, regardless of the absolute size of the particles. The materials indicated by fig. 1 are stated by Mr. Hazen to include the whole range of the sands available for sewage purification.

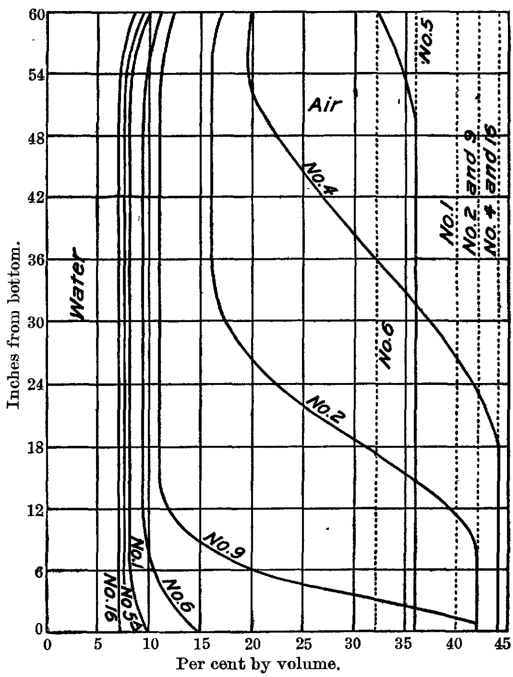

FIG. 2.—Air and water capacities of sewage filter materials. Full lines represent water capacity and dotted lines air capacity.

AIR AND WATER CAPACITIES OF SAND.

In order to estimate the filtering capacity of any given material, it is important to understand the air and water capacity of the filtering material when drained, the term "water capacity" being taken to designate the amount of water retained in the interstices after thorough draining. It is clear from what has preceded that the efficiency of the filtering process must depend largely upon these two elements. In fig. 2, also derived from the Massachusetts reports, the air and water capacities of the same materials illustrated by fig. 1 are shown, though in studying this diagram it should be borne in mind that the curves for air space and water capacity can be taken only as general averages, because the tenacity of the material can be varied greatly in packing. It is obvious that the amount of water will depend not only upon the closeness of the packing but also upon its uniformity, the tendency always being toward an increase of the water capacity. It will also depend at any given time upon the amount of organic matter stored from the material filtered. The water capacity will also depend largely upon the size of the particles, the finer sands holding much water, especially at the bottom, while with coarse sands the amount held will be nearly constant from top to bottom.[1]

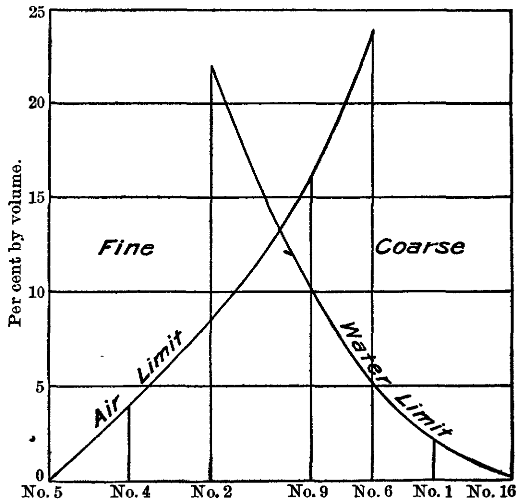

FIG. 3.—Limitation of size of single dose by air and water capacities.

LIMITATION OF SIZE OF DOSE.

The diagram, fig. 3, also taken from the Massachusetts reports, will illustrate the range of capacity with different materials in this particular. This figure illustrates the limit of size of a single dose with reference to air and water capacities. The various materials are indicated by vertical lines, while the per cent of total volume is indicated by horizontal lines, the lower portion of the two curves showing the maximum dose for any given material which can be applied at one time with good results. If the dose is greater than that indicated in the curve of water limit, it is probable that some will pass the filter before

[1] Reference to the twenty-third annual report of the Massachusetts board will furnish a discussion of these important practical questions in full detail.

complete purification. If the air limit is exceeded, the oxygen in the filter is liable to be exhausted before the oxidation is complete.

In the line of these studies the Massachusetts reports give a table showing the doses proved to be adapted to the various materials under the most favorable conditions of management. For material No. 16 of the preceding diagrams, as actually applied in practice at the experiment station, the dose was 2,800 gallons per acre, applied 500 times a week, this amount giving a daily average of 200,000 gallons per acre. For material No. 1 the size of dose is 40,000 gallons, applied 18 times a week, giving an average daily amount of 103,000 gallons per acre. For material No. 6 the size of dose is 70,000 gallons per acre, applied 6 times a week, giving a daily average of 60,000 gallons per acre. For material No. 9 the size of dose is 120,000 gallons an acre, applied 6 times a week, giving a daily average of 103,000 gallons per acre. For No. 2 the dose is 140,000 gallons an acre, 3 times a week, giving a daily average of 60,000 gallons per acre. For No. 4 the dose is 80,000 gallons, 3 times per week, giving a daily average of 34,000 gallons per acre. The depth of the material to which these applications were made was in every case, with the exception of No. 6, 5 feet; for No. 6 the depth was 4 feet.

As stated in the report, it must be borne in mind that the above figures are applicable only to clean materials under favorable conditions, and that in order to apply large doses permanently with good results the surface material must be occasionally renewed, as already discussed.

PURIFICATION OBTAINED BY INTERMITTENT FILTRATION.

As to the degree of purification obtained by intermittent filtration, the Massachusetts experiments show that very high degrees are reached easily. By way of illustrating the matter we may simply cite that city sewage has been purified to the extent of removing from 95 to 99.5 per cent of the polluting material. Sewage containing from 500,000 to 1,000,000 bacteria per cubic centimeter has been experimentally so far purified of bacteria that the effluents have frequently contained as few as from 25 to 100 bacteria per cubic centimeter. In order to appreciate this degree of bacterial purification we may consider that well waters in common use frequently contain from 2,000 to 3,000 bacteria per cubic centimeter. As regards chemical and biological considerations there is therefore no reason why such sewage effluents are not fit to drink.

SUMMARY OF MASSACHUSETTS EXPERIMENTS.

The body of information in regard to sewage purification by intermittent filtration which is presented in the several reports of the Massachusetts State board of health has become so extensive that one must be an expert to keep in mind the many interesting and valuable results brought out. As assisting the general reader, who may not care to travel through the several thousand pages of matter given in these reports, reference may be made to the very excellent summary of the results obtained from intermittent filtration during seven years' experimentation, which appears on page 497 of the report of 1894, where may be found brief statements of yearly averages of the various kinds of filters experimented upon, as well as an outline of the most important features in the operation of each filter.

In concluding, it is pointed out that—

(1) The qualitative efficiency of the filters is lower in winter than in summer chiefly because of the inactivity of the nitrifying organisms when exposed to low temperature. The indications at present are that it is not advisable to allow exposed filters to rest in winter, even for limited periods.

(2) Qualitative deterioration is a serious matter in winter, because nitrification can not be promptly reestablished as in summer.

(3) It has been learned, however, that when nitrification is active at the beginning of winter it may by proper treatment be preserved during the cold season. To this end frost should not be allowed to penetrate into the interstices of the filters.

(4) The warmer the sewage, within limits, the better the results. Where high degrees of purification are imperative in winter the sewage may be heated to a temperature of 100° F. We may conclude, then, that the arrangement of the filter bed should be with reference to preserving, so far as possible, the heat actually present in the sewage as it arrives in the filter. For this purpose the trenching of the filter area is especially efficient, because it concentrates the heat, thus aiding in preserving the biological process in a state of efficiency.[1]

(5) In any case sewage should be so applied as to penetrate all portions of the filter, as otherwise the passage through will be rapid and irregular, thus tending to a low degree of purification.

(6) The composition of sewage, particularly as regards the kind of sewage, is a much more marked factor in winter than in summer. This is true even in the case of experimental filters, where special lines of treatment to keep the filters in operation are feasible.

VALUE OF COMMERCIAL FERTILIZERS.

In order to indicate the theoretical value of the nitrogen, phosphates, and potash of crude sewage, the following statement of trade values of fertilizing ingredients in raw materials and chemicals of commercial fertilizers, as used by the agricultural experiment stations of the country, is included. The valuations obtained by the use of these figures agree fairly well with the average retail price of standard materials. The price per pound, in cents, is as follows:

Value of chemical ingredients in commercial fertilizers.

	Cents.
Nitrogen in ammonia salts	17
Nitrogen in nitrates	15.5
Organic nitrogen in dry and fine-ground potash, meat, and blood, and in high-grade mixed fertilizers	17.5

[1] For an estimate in detail of the cost of heating sewage see Rafter and Baker's Sewage Disposal in the United States, p. 336.

	Cents.
Organic nitrogen in cotton-seed meal and castor pomace	16.5
Organic nitrogen in fine-ground bone and tankage	15
Organic nitrogen in fine-ground medium bone and tankage	12
Organic nitrogen in medium bone and tankage	9
Organic nitrogen in coarse bone and tankage	7
Organic nitrogen in hair, horn shavings, and coarse potash scraps	7
Phosphoric acid, soluble in water	6.5
Phosphoric acid, soluble in ammonium citrate	6
Phosphoric acid in fine bone and tankage	6
Phosphoric acid in fine medium bone and tankage	5
Phosphoric acid in medium bone and tankage	4
Phosphoric acid in coarse bone and tankage	3
Phosphoric acid in fine-ground fish, cotton-seed meal, castor pomace, and wood ashes	5
Phosphoric acid in fine-ground rock phosphate	2
Potash as high-grade sulphate in forms free from muriates (chlorides), in ashes, etc	5.5
Potash in kainit	4.5
Potash in muriate	4.5
Organic nitrogen in mixed fertilizers	17.5
Insoluble phosphoric acid in mixed fertilizers	2

Value of fertilizing ingredients in foods.

	Cents.
Organic nitrogen	17.5
Phosphoric acid	5
Potash	5.5

NECESSITY OF PURIFICATION OF SEWAGE AT TOWNS ON THE GREAT LAKES.[1]

According to statistics of the Eleventh Census, the basin of the Great Lakes, especially the area contiguous to Lakes Ontario, Erie, and Michigan, is, next to the Atlantic seaboard, the most densely populated area of the United States. Bordering on Lakes Ontario, Erie, and Michigan are great and rapidly growing cities from which all of the sewage now passes into these lakes. The surrounding regions are usually not greatly elevated above the lakes, and hence do not afford any opportunity for obtaining upland waters for municipal supplies. The water supplies of towns on the Great Lakes are not only now almost universally taken from these bodies of water, but must necessarily continue to be so taken in the future. At present the sewage of the Great Lake cities is discharged without treatment into the same bodies of water from which the public water supplies are taken. An exception is the city of Rochester, which wisely brings its water supply by gravity from Hemlock, an inland lake about 30 miles distant; but Buffalo, Erie, Cleveland, Detroit, Chicago, Milwaukee, and many other towns take their water supplies in the manner stated. Without going into details for all the Great Lakes, we will state that Lake Michigan alone receives at the present time the sewage of municipalities and small towns aggregating over 2,000,000 people, and this population is rapidly

[1] This chapter is presented to illustrate the vast importance which sewage-purification studies are rapidly assuming in the United States.

increasing, having about doubled in ten years. A similar increase in population has taken place in the cities and towns tributary to the lower Great Lakes. Thus, Detroit had a population in 1880 of 116,340, and in 1890, 205,876. Cleveland showed a population in 1880 of 160,146, and in 1890, 261,353. In 1880 Buffalo had 155,134; in 1890, 255,664.

EFFECT OF SEWAGE ON LAKE WATERS.

The modern studies all indicate that when organic matter in increasing quantities is continually poured into a body of fresh water, a point is quickly reached beyond which the body of fresh water. whether it be lake, pond, or running stream, has no power of further assimilation. Chemical analyses of the waters of the Great Lakes show a gradually increasing contamination during the last fifteen or twenty years. The evidence is multiplying that, with the present increase in population, the Great Lakes, if they continue to be used as common sewers, will soon become totally unfit for use as drinking water. When this time arrives one of two alternatives must be followed—either every source of water supply must be filtered or the sewage of the towns must be efficiently purified before it is allowed to flow into the lakes. In some cases the conditions are such that both remedies must be applied.

The question of the limit of permissible contamination of these waters is very likely to arise, either as to the number of bacteria, the microscopical forms, or the chemical constituents. The answer is, it will depend entirely upon the environment. If a given water is known to receive sewage, a very small quantity of organic matter, indicated either by the free and albuminoid ammonias or by the loss on ignition, may justly cast suspicion upon it. If, on the other hand, there is no sewage contamination and the organic matter present is clearly shown to be due to natural drainage from the surface of the ground, the ammonias and loss on ignition have very little significance. As to the number of bacteria, Dr. Koch, the originator of the method of gelatin cultures, laid down the principle that potable waters might show, when examined immediately on collection, as high as 1,000 bateria per cubic centimeter without condemning them. The more recent studies, however, tend to show that Koch's original figure was somewhat too high, and at present it is considered that a sanitarily unobjectionable water ought not to show more than 300 to 500 forms per cubic centimeter. When the number rises much above that amount the water is open to suspicion.

Bacteriological examinations of the water of the Great Lakes show that the water at Detroit is superior for domestic use to that at Buffalo. The difference must be ascribed to the vast amount of sewage poured into Lake Erie, and the incapacity of that body of water to purify itself thoroughly before reaching the Buffalo intake at the head of the Niagara River.

If space permitted, many analyses of the water of the Great Lakes might be quoted which show, on the whole, a gradually increasing contamination.[1]

One point of interest about the water supply of the city of Milwaukee may be noted. During the navigation seasons of 1892, 1893, and 1894 the United States Weather Bureau carried out an extended series of float experiments in order to determine the actual trend of the currents of the Great Lakes. As regards Lake Michigan, the experiments clearly show that there is a rapid whirl at the south end, with a strong current passing north along the east shore, while along the west shore the current flows south. This disposition of the currents undoubtedly favors the water supply of the city of Milwaukee, giving to that city water with less organic contamination than it would receive, either if there were no current or if the current set from the south to the north along the west side, bringing to Milwaukee the contaminated water of the Chicago lake front. As the currents now flow Chicago receives the contaminated water of Milwaukee.

At Chicago the barbarous practice of turning the sewage of a great city into the body of water from which the public water supply is taken has resulted so disastrously as to lead to the construction of what is known as the Chicago drainage canal, by which it is expected to deliver the greater part of the Chicago sewage into the head waters of the Illinois River, and so finally into the Mississippi. Partial investigations, made several years ago under the auspices of the Illinois State board of health, indicated a very rapid purification of the sewage-contaminated waters of the present Illinois and Michigan Canal as they flow to the south. The investigation has not been carried far enough to indicate what the results will be upon the Illinois River and the Mississippi when the project shall have been completed and the sewage of Chicago largely turned south. The known facts as to the increasing contamination of the Great Lakes would indicate the vast importance of determining the ultimate effect of such discharge. In considering such effect, moreover, one should bear in mind the difference between running streams and lakes with only slight currents.

DANGER OF WINTER TYPHOID.

As regards water supplies from the Great Lakes at places so far north as to render probable the closing of the lakes by ice nearly every winter, there is another serious view connected with taking water either contaminated or liable to be contaminated by sewage, which has thus far been generally overlooked. So long as the lakes remain open, usually the antagonisms of the aerobic forms of microbic life will be sufficient, except in cases of extremely severe contamination, to keep typhoid and other anaerobic forms mostly in subjection; but as soon as the lake surfaces are covered with ice an entirely new set of conditions

[1] The author has in preparation a paper on Water Supplies from the Great Lakes, in which full data will be given.

exist; the air is then excluded and the anaerobic forms develop at the expense of the aerobic. This undoubtedly explains the severe epidemics of winter typhoid which have occurred at Buffalo, New York; Lorain, Ohio; Windsor, Ontario; Ashland, Wisconsin; Duluth, Minnesota; Chicago, Illinois, and at a number of other places on the Great Lakes. The following are some of the particulars of these winter outbreaks:

In the latter part of February, 1894, on account of low water in the Niagara River, it became necessary to take the water supply of the city of Buffalo from an old inlet said to be in a current carrying the discharge from sewers higher up. From March 6 to 11, inclusive, the total number of typhoid cases reported was 36. On March 12, 26 new cases were reported. The next day the number was increased 100, and then by 88, 79, 52, and 25 on successive days, making a total of 406 cases from March 6 to 17, inclusive, and 370 cases in the six days from March 12 to 17, inclusive. These cases were mostly of such mild character that only 9 deaths were reported for the whole month. In March, 1893, only 4 deaths occurred, and in March, 1892, but 1.

The city of Lorain, Ohio, is located at the mouth of the Black River, which receives the sewage of Elyria, several miles distant. It also receives the sewage of Lorain, in which place sewers were first laid down in 1892, their use for water-closet drainage beginning in October or November of that year. The water supply of the town is taken from very near the end of the harbor jetties, where the sewage first has free access to the lake water. Lake Erie was closed with ice at Lorain during the months of January, February, and March, 1893. In March and April there was a serious epidemic of typhoid fever, 8 deaths occurring in a population of about 5,000. In 1895 the lake was again closed with ice during the months of February and March, and typhoid fever again became epidemic, there being 3 deaths in February, 2 in March, and 4 in April.

In February, 1896, typhoid fever became epidemic at Windsor, Ontario, a town on the Detroit River just opposite the city of Detroit. During the previous month of December, 1895, the total number of cases was 9; for January the total was 18; for February 82, and for March 13; making a total for the four months of 122. The cause of the outbreak is ascribed to the presence of the sewage of Walkerville in the Windsor water supply. The discharge of Walkerville sewage above the Windsor waterworks intake has been a source of controversy between Windsor and Walkerville for several years, and although more or less typhoid fever has existed at Windsor the outbreak in February, 1896, is the most serious winter epidemic thus far experienced there. As stated in the report of the Provincial Board of Health of Ontario, there was a severe freshet about January 25, 1896.

During the winter of 1894 a severe epidemic of typhoid fever occurred at Ashland, Wisconsin. Several hundred cases developed in a few weeks, and from the distribution there was every reason to ascribe their origin to the condition of the city water supply, which is taken from Chequamegon Bay, an arm of Lake Superior, on which the city is situated. This bay is about 12 miles long, with an average width of 5 miles. It varies in depth from 8 to 36 feet. A large breakwater has been constructed to the northwest of the city, on the city side of which is located the mouth of the intake pipe of the public water supply, about a mile from the shore. This arrangement is unfortunate, because it permits the sewage and storm water of the city to flow directly over the mouth of the intake pipe.

In February, 1894, the ground was covered with 2 feet of snow. In the last week of the month there were heavy rains and warm weather, which in a few days melted all the snow and washed the accumulations of the winter into the bay. Typhoid fever broke out in from ten to fifteen days thereafter, and in a week after the first case made its appearance there were over 300 cases. The epidemic lasted about eight weeks, and finally terminated with 450 cases and 26 deaths. Bacteriological examinations of the water showed that it contained as high as 36,000 bacteria to the cubic centimeter. Typhoid germs were found in one examination, and the bacillus coli communis in every examination made. This experience has led the city of Ashland to construct a sand filtration plant.

A severe epidemic of typhoid fever occurred at Duluth, Minnesota, a few winters ago under conditions similar to those at Ashland.

We have noted the insanitary conditions at Chicago on a previous page. By way of illustrating the prevalence of typhoid in that city we may refer to the following table, showing the number of deaths from that disease in Chicago from January, 1890, to December, 1893, inclusive, taken from the annual reports of the Chicago department of health:

Number of deaths in Chicago resulting from typhoid fever.

Month.	1890.	1891.	1892.	1893.
January	53	67	311	41
February	136	61	187	30
March	103	71	76	41
April	45	136	56	58
May	32	408	70	56
June	107	167	55	60
July	86	200	211	55
August	115	182	179	76
September	85	198	138	86
October	72	171	92	81
November	67	150	67	43
December	47	186	47	43
Total	1,008	1,997	1,489	670

The above table shows that typhoid fever was epidemic in Chicago in February and March, 1890, in April, May, June, and July, 1891, and in January and February, 1892. All these outbreaks, as well as the general high typhoid death rate, must be attributed entirely to the polluted water supply. The next year, 1893, was the year of the Columbian Exposition, and much greater efforts were made in that year to insure proper sanitary conditions in Chicago. That these efforts were well directed is shown by the great reduction in the typhoid death rate for that year.

In regard to typhoid fever, it may be assumed as axiomatic that it is a disease of the fall months, which under normal conditions attains its maximum in October and November. If, then, we find it seriously prevalent during the winter months, we must assume the existence of unnatural—and as regards the cases just presented, unnecessary—conditions. So far as known, the reason for its excessive development in cold weather is the one already given. As to the validity of this reason, it may be pointed out that similar winter outbreaks have occurred at Zurich[1] and Geneva, Switzerland. The evidence is therefore now so far multiplied as to render it practically certain that a winter outbreak of typhoid fever means not only sewage contamination of the water supply, but the existence of conditions different from those ordinarily obtaining while the lakes are open. Hence the several outbreaks of winter typhoid, of which we have record in the Great Lake cities and towns are, aside from others, a valid reason why sewage treatment of some sort is rapidly becoming imperative at the Great Lake towns.

AMERICAN SEWAGE-DISPOSAL PLANTS.

MAINE.

Augusta, State Insane Asylum.—So far as known, the credit of the first attempt at sewage irrigation in the United States belongs to Mr. C. B. Laken, treasurer of the State Insane Asylum at Augusta, Maine, who carried out a system of irrigation there about 1872. From a description in the Seventh Annual Report of the State Board of Health of Massachusetts (1876), it is learned that the sewage, which then amounted to about 7,000 gallons per day, first passed by gravity into large tanks, where it was mixed with absorbents—straw, leaves, muck, etc. The solid parts were from time to time carted onto land, while the liquid portion flowed off, to be used for irrigation. In the summer of 1875 an irrigated area of a few acres yielded three crops of fine hay. A portion of the sewage was also used in irrigating a vegetable garden. It is understood that after the death of Mr. Laken this irrigation was abandoned.

NEW HAMPSHIRE.

Concord, State Insane Asylum.—The sewage of this asylum was used for irrigation about the same time as that of the Augusta asylum. In

[1] For an account of an outbreak of winter typhoid at Zurich, Switzerland, see Mr. Preller's paper on The Zurich water supply, etc.: Proc. Inst. Civ. Eng., Vol. CXI, pp. 257-295.

this case it was necessary to pump the sewage to the irrigated area. The Eighth Annual Report of the State Board of Health of Massachusetts states that, although the crops were very much increased in value, the sewage had not been disposed of at Concord in the systematic way which would be necessary in dealing with larger quantities. It is not known whether this irrigation is now in use or not.

Rockingham County Poor Farm.—A sewage-disposal plant was first operated at the Rockingham County Poor Farm in 1895. The plant, which is designed to meet the needs of about 1,000 people, consists of two sets of collecting tanks, with filter beds, all so arranged as to admit of intermittent use, the whole inclosed in a building. Sewage is first received in a collecting tank 7 feet wide, 9.5 feet long, and 7 feet deep, where most of the sludge is deposited. The sewage then passes into a second tank, about half the size of the first, and connected therewith at the bottom. The effluent from the second tank flows upon a filter bed of coarse sand, 22 or 23 feet square and 5 feet in depth. The sludge is utilized for compost. The filter areas are ventilated by a force draft over and under them. From the information at hand it is inferred that this plant is a patented process, owned by the Glover Sanitary Sewage Company.[1]

MASSACHUSETTS.

Amherst.—This is a college town in the Connecticut Valley, with a population in 1890 of 4,512. A public water supply was constructed in 1879 and sewerage and sewage-disposal works in 1881. The sewers are on the separate system. In the absence of a water course suitable to receive the sewage, it was conducted to a settling tank, from which the liquid matter is drained onto land through ditches, and the sludge is periodically removed and spread upon land. Ordinarily the sludge is removed once a week by simply opening a valve and allowing it to flow into a bed excavated in the sand, where the water rapidly drains away.

About three-fourths of the sewage of the town is treated in this way, the remainder going to a field having a sandy soil, where it flows into absorption ditches. Three heavy crops of hay are cut yearly from the irrigated area, which previously gave only one light crop a year. This tract is not underdrained, and it is stated that the sewage does not give any trouble by collecting in hollows. The field has a slight slope.[2]

Brockton.—A good recent example of intermittent filtration pure and simple may be seen in the works recently constructed at Brockton, Massachusetts, a shoe-manufacturing town a short distance southwest of Boston, with a population in 1890 of 27,294. Waterworks were completed in 1880 and 1881, but a separate system of sanitary sewers was not put in operation until the latter part of 1894.

[1] Refer to Eng. and Bldg. Record, Vol. XXXIII, May 9, 1896.

[2] Refer to Twenty-fifth Ann. Rept. Mass. St. Bd. Health; Sewage Disposal in the United States; and Eng. News, Vol. XXVIII, July 21, 1892.

A.

B.

BROCKTON, MASSACHUSETTS, FILTRATION FIELDS.

A, Turnips and sweet corn; *B*, Pease, sweet corn, and beans.

By the application of meters the use of water at Brockton has been kept quite low. For the year ending November 30, 1894, the average daily consumption per capita was only 24.3 gallons, the highest figure being 39.4, for the month of June, and the lowest 18.7 gallons, for March. In the design of the sewers Mr. Snow, the city engineer, has made allowance for a daily consumption of 60 gallons per capita, as well as for a possible leakage by infiltration into the sewers. The main outlet sewer leading into the receiving reservoir is of brick, egg-shaped, varying from 26 by 39 inches to 22 by 48 inches in size, and about 2 miles long. The leakage by infiltration into the outlet sewer is estimated at about 120,000 gallons per day ordinarily, and in flood time at probably 350,000 gallons.

Inasmuch as there was no area available on which sewage could be delivered by gravity, it was necessary to raise the sewage to the filtration area by pumping. The force main provided for this purpose is of 24-inch cast iron, 16,640 feet in length, and rises 34.5 feet from the pump to the terminal chamber.

The filter area comprises some 30 acres, laid out in 23 beds. The soil of this area is mostly sand for the depth of several feet, but varies considerably in its mechanical constituents. In constructing the beds the natural material was not disturbed except at the surface; on 12 of them the sand was stripped from the subsoil; on 5, a thin layer of subsoil has been allowed to remain, and 6 of the beds have surfaces partly of the top sand and partly of subsoil. The general method of constructing these filter areas is the same as that followed elsewhere, and need not be especially referred to at length. The cost of the disposal works at Brockton is stated at $209,772, of which $59,536 was for the disposal area proper. The main items in the cost of the disposal area are 3,046 square yards of grubbing at $2 per yard, amounting to $6,092; 85,830 cubic yards of excavation in the filter beds, at 23 cents per yard, costing $19,739; trenching for and laying sewage-distributing pipes and underdrains, $12,631; land damages, $9,234. The balance of the $59,536 is made up of miscellaneous small items.

The experience with the sewage beds at Brockton has indicated that furrowed beds are far preferable for winter disposal to flat beds. During the winter of 1894 several of the beds were left with level surfaces, but the surface froze to such an extent on these as to prevent the sewage from penetrating them, whereas beds which had been furrowed the preceding fall took sewage readily during the entire winter. Accordingly, in the winter of 1895–96 all the beds in use were furrowed and no trouble was experienced during that season from freezing. The following, from the reports of the city engineer of Brockton, gives the average amount of sewage disposed of from month to month and its temperature as it reaches the beds.

Average amount and temperature of sewage received at Brockton sewage-disposal works.

Month.	Gallons per day.		Temperature.	
	1895.	1896.	1895.	1896.
			° F.	° F.
January	215,000	474,000	42.6	43.5
February	109,000	568,400	40.6	42.6
March	142,000	648,500	39.5	42.4
April	250,000	475,100	42.3	45.0
May	338,000	321,900	53.5	52.1
June	228,000	381,700	60.1	56.3
July	195,000	322,800	60.8	59.9
August	273,000	365,900	64.0	62.2
September	275,000	527,100	64.0	61.0
October	488,000	600,100	57.0	57.4
November	474,000	616,000	51.0	54.1
December	525,000	599,000	48.0	49.9

According to the report of the Massachusetts State board of health for 1895, the chemical analysis of the sewage and effluent from the underdrains at Brockton, made February 12, 1895, resulted as follows: Of the sewage, the total residue amounted to 84.4 parts per 100,000, of which 40.2 parts were dissolved and 44.2 parts suspended; the total loss on ignition was 38 parts, 12.4 dissolved and 25.6 in suspension; the free ammonia amounted to 3.46 parts per 100,000; the total albuminoid ammonia to 0.91 part, of which 0.244 was dissolved and 0.066 part in suspension; chloride amounted to 9.05 parts; nitrogen, as nitrates and nitrites, nil; the oxygen consumed in an unfiltered sample was 8.56 parts per 100,000, and in the filtered sample 3.12 parts per 100,000; the iron present in an unfiltered sample was 0.32 part, and in a filtered sample 0.08 part per 100,000. The hardness was 6.4.

The effluent of the same date showed an entire absence of turbidity and sediment, while the sewage was thick and contained a heavy black sediment. On Nessler's scale the colors showed 0.01; the residue on evaporation was 4 parts per 100,000; free ammonia, 0.0248 part; albuminoid ammonia, 0.0038; chlorine, 0.75 part; nitrogen as nitrates, 0.045 part; nitrites, nil; the oxygen consumed amounted to 0.024 part per 100,000; hardness, 0.6; and iron entirely absent. In regard to this effluent, it is proper to remark that it is stated to contain a large amount of ground water.

The design at Brockton includes a number of refinements, such as automatic arrangements for gaging the flow of sewage, which are very creditable to the city engineer, Mr. Snow, as well as to the municipal authorities of Brockton in general. Considering the scientific way in which the work there has been started, there is no reason why the degree of purification to be attained should not be very high, especially since the works are to be operated as intermittent filtration areas only, and we may hope in the future to obtain from Brockton further information of value and interest to all concerned in works of sewage disposal.

During the year 1896, notwithstanding the additional cost of considerable experimental work, the total cost of labor at disposal works was only $2,195.21, or at the rate of $12 per million gallons of sewage treated. This sum included several items, such as setting of trees, grading about building, and pipe testing, which were in the nature of permanent improvements. Labor expended on surface of beds amounted to $932.03; for tending gates, $254.98; and for removing snow, $51.04; a miscellaneous item of $295.40, and a few others making up the remainder. Probably where these works are more fully established the cost of a treatment which yields a very fair effluent will not exceed $7 or $8 per million gallons treated; or, taking into account the value of the crops raised, the works will be about self-sustaining.

In his annual report for 1896 Mr. Snow has given a considerable amount of interesting information as to the operation of the Brockton plant. From this report it is learned that a variety of crops was planted on the beds receiving both sewage and sludge, such as pease, beans, tomatoes, sweet corn, cabbages, and turnips. Some of the conclusions derived from last year's experience are as follows: Pease and beans it is considered will do best if planted on level beds rather than on mounds. The pea crop last year was successful, one of the leading hotels of Brockton taking the entire product. Beans are stated to have failed. Sweet corn, which takes a large amount of sewage and demands but little attention, should be planted 4 feet between rows and in hills 3 feet apart in the rows. Cabbage requires more care than sweet corn, and when sludge is applied to the surface of the bed the same must be irrigated as though the bed were not cropped. It is considered that on a coarse sand or gravel soil with a level surface turnips should receive large doses of sewage, while with heavier soil small doses and a ridged surface will give the best results. Turnips appear to require considerable moisture during the first growth and but little after the root is formed. Six beds were planted with field corn on May 10. The crop was cultivated on June 1, and again about July 1, with a horse hoe. All the beds did well, the yield of one amounting to 144 bushels of ears per acre, or about 70 bushels of shelled corn.[1]

Gardner.—This place is a manufacturing town, situated in the central part of the State, on a divide between the Connecticut and Merrimac rivers. The population in 1890 was 8,424. A sewage-disposal plant by intermittent filtration was constructed in 1891, in conformity with plans approved by the Massachusetts State board of health. This board

[1] Refer to Ann. Repts. of City Eng. of Brockton; Repts. Mass. St. Bd. of Health; and various articles in Eng. News.

required sewage purification at Gardner, because turning sewage into the only available water course would probably create a nuisance. The tract purchased by the town for the disposal area contained about 17 acres of sand and gravelly soil. Much of the material is too fine for efficient filtration. This was overcome by making filter beds largely artificial, they being formed of selected porous sand and gravel from the material. At present there are twelve thoroughly underdrained filter beds, with a total area of 1.04 acres, two supplementary beds not underdrained and with a total area of 0.37 acre, also two other small underdrained beds, containing altogether 0.14 acre. One of the small beds is used to receive sludge from the sludge tank.

The filter beds at Gardner are smaller than those used at Marlboro, Framingham, and other places in Massachusetts, described further on. The sewage is delivered upon the beds by troughs, and each bed is provided with an overflow to prevent washing away the banks in case the sewage should at any time rise too high.

The results obtained at Gardner are said to be satisfactory in summer, but in winter the area is too small for efficient filtration, a difficulty which can be remedied by providing a larger area. The sewage reaches the filter area during the winter at a temperature not much above 40° F.

The cost of preparing beds with piping was about 12 cents per square foot of area. The total cost, including tanks and accessories, was about 14 cents per square foot of filter areas.[1]

Greenfield.—This place had a population in 1890 of 5,252. Sewage has been used for irrigation upon a meadow owned by a private party since 1882. As originally designed, the sewage was systematically distributed over the meadow, but during the last few years, since the death of the former owner, apparently but little effort at such distribution has been made. In consequence, recent statements at hand indicate that the sewage has caused a nuisance.

Lenox.—This place had a population in 1890 of 2,889. A combined system of subsurface and surface irrigation, preceded by tank sedimentation, was adopted in 1876, at which time the population was probably somewhat less than 2,000. The total area originally employed was only about 1½ acres. In October, 1888, a new subsurface-disposal area was placed in operation, which, however, did not cover the whole 17 acres purchased. As to recent results no information is at hand. Lenox enjoys the distinction of being the first town in Massachusetts to construct sewage-disposal works.[2]

Marlboro.—Population in 1890, 13,805. The city is situated on the dividing ridge between the Sudbury and Assabet rivers. The greater part of the drainage, however, naturally flows into Sudbury River,

[1] Refer to Twenty-fourth Ann. Rept. Mass. St. Bd. Health, 1892; Sewage Disposal in the United States, 1894; and Eng. News, Vol. XXIX, Feb. 16, 1893.

[2] Refer to Twenty-fifth Ann. Rept. Mass. St. Bd. Health; Sewage Disposal in the United States; and Eng. News, Vol. XXVIII, July 14 and 21, 1892.

from which Boston takes a portion of its water supply. The city of Boston, therefore, had a direct interest in so disposing of the Marlboro sewage as to leave the Sudbury River unpolluted, and, after some negotiations, agreed to pay $62,000 toward constructing the sewage-disposal plant. The sewage flows to the disposal fields by gravity. The total area purchased by the city is 62 acres, upon which forty-four beds for the filtration of sewage and six similar beds for sludge disposal, all covering with their dividing embankments a total area of about 37 acres, have been laid out. Thus far four sludge beds and thirteen sewage beds, or a total of about 11.3 acres, have been prepared for use. The material, which is for the most part a somewhat fine, porous sand with an effective size of 0.12 to 0.14 millimeter, has been thoroughly underdrained by means of parallel lines of 4-inch pipes laid with open joints 50 feet apart and about 6 feet beneath the surface. Filter beds were prepared for use by the removal of the top loam and the leveling of the surface of each at a convenient elevation.

The principal industry at Marlboro is the manufacture of boots and shoes; and, aside from the wastes of the manufacturing establishments, the sewage is ordinary city sewage, varying in strength with the amount of ground water entering the sewers, which were constructed on the separate system. No underdrains were laid beneath the sewers, and during wet seasons a large amount of ground water gains access to them through the joints. The total length of sewers laid to the end of 1895 was a trifle over 22 miles. The amount of sewage is not definitely known. A measurement on May 12, 1892, indicated about 30,000 gallons per day; on May 25, 1892, after heavy rains, the flow was 790,000 gallons per day. No attempt has thus far been made to raise crops on the filter areas.

The results obtained in purification have been satisfactory; over 95 per cent of the organic matter, as represented by the albuminoid ammonia, having been removed. The winter temperature of the sewage as it reaches the fields is from 39° to 42° F. The winter experience indicates that the beds work much better when ridged—as seen in Pl. IV, showing the filter areas at Pawtucket, Rhode Island—than when left level.

It has not been the custom to employ a man constantly in caring for the sewage disposal, but only from time to time as required to change the flow of sewage and to remove scum from the surface of the beds, etc., payment being made by the hour for the time actually consumed. The cost of all work on account of the disposal plant during the year 1893 amounted to $497.19. There seems to be no doubt, therefore, if the amount of labor was sufficient, that the town could recoup itself for the expenditure by preparing more beds and raising crops thereon.[1]

[1] Refer to Twenty-fourth, Twenty-fifth, and Twenty-seventh Ann. Repts. Mass. St. Bd. Health; Sewage Disposal in the United States; and Eng. News, Vol. XXVIII, Aug. 25, 1892.

Concord, Massachusetts Reformatory.—The sewage of this institution was originally discharged into the Assabet River at a point near the institution, but in 1883 an act was passed by the Massachusetts legislature authorizing an expenditure of a sum not exceeding $5,000 for the disposal of the sewage by some other method. The plans adopted include arrangements for pumping the sewage upon an adjacent field, where it is used in broad irrigation of grass and corn crops, as well as other tilled crops to some extent. The soil of this field is light, free, and sandy, with the ground water at a considerable depth below the surface. Portable troughs are used for distributing the sewage to different parts of the field.

The labor is all done by convicts. Assuming a fair valuation for the labor actually used under normal conditions of employment, we have the following as the approximate annual cost of operation: 55 tons soft coal, at $4, $220; salary of attendant, $600; repairs and sundries, $80; total, $900.[1]

Medfield.—Population in 1890, 1,493. Sewers and sewage-disposal works were constructed in 1886, the sewage disposal including preliminary sedimentation and upward filtration through excelsior supplemented by intermittent filtration through natural soil. The material of the filter area is mostly coarse gravel, with ground water about 10 feet below the surfaces of the beds, which are underdrained. There are four beds which, as a general rule, take the sewage in turn for two days. The filter area consists of 1 acre of ground, graded nearly level. The entire cost of the disposal works, including cesspool, pipe from cesspool to outlet, earthwork, engineering, superintendence, and profit to contractor, was about $1,000. The annual expense of maintenance is stated at about $30 a year, the labor being chiefly to change regularly the gate whereby the sewage is diverted from one portion of the filtration area to another.

Analyses of the effluent from the Medfield area, made in October, 1893, showed that the quality was still quite as good as indicated by analyses made when the works were first operated in 1887.[2]

Mystic Valley.—These works, which are operated by chemical precipitation purely, were constructed in 1887 and 1888 by the city of Boston in order to protect the Upper Mystic Lake, whence the water supplies of the Charlestown district of the city of Boston and of the towns of Chelsea, Everett, and Somerville are derived.

Near the head of Upper Mystic Lake, in Winchester and Woburn, there are about a dozen tanneries, the drainage from which formerly passed directly into the lake, which was also considerably polluted by house drainage flowing into the Abbajona River, the influent stream of Mystic Lake. In 1878 a sewer was constructed intercepting all this objectionable drainage and delivering it into Lower Mystic Lake, which

[1] Refer to Seventh Ann. Rept. Mass. St. Bd. of Health, Lunacy, and Charity, Supplement, 1886.

[2] Refer to Nineteenth Ann. Rept. Mass. St. Bd. Health; Jour. Assoc. Eng. Socs., Vol. VII, July, 1888; and Eng. and Bldg. Recd., Vol. XVIII, 1888.

is subject to tidal action. Its delivery there, however, led to controversies between the adjoining towns and the city of Boston, which were finally settled by the construction of the Mystic Valley Chemical Purification Works. Inasmuch as the chief object of these works was to purify manufacturing wastes, they may easily be placed first among successful works of this character. A general view of the works is given in fig. 1 of Water-Supply and Irrigation Paper No. 3.

The works consist in detail of a pump well, connected with the main sewer by a branch sewer of brick, a sewage pump and engine, engine house, four settling tanks, a sludge well, sludge pump, and a series of settling basins for receiving the sludge. In the engine house there are three vats so arranged that the precipitant is fed from the middle vat, which is placed lower than the other two, in which the precipitant is dissolved. These vats are provided with steam coils for heating the water used and with a stirring apparatus driven by the engine. The precipitant is fed to the sewage as it flows from the branch sewer into the pump well, where the process of pumping thoroughly incorporates the chemicals. From the pump the sewage passes into the settling tanks. It is then allowed to remain quiescent for about three hours, when it is found that the sedimentation process is complete. The clarified effluent is then drawn off by removing stop planks. The sludge is pumped, as necessary, into a flume which conveys it to the sludge basins shown in fig. 1 of Water-Supply and Irrigation Paper No. 3.

The cost of the works, including the preparation of the sludge basins, was $10,410.

For the thirteen months ending January 31, 1892, the total quantity of sewage pumped and treated was 133,102,028 gallons. Sulphate of alumina is used as the precipitant, and during this period the total quantity consumed was 331,890 pounds; the amount of coal, 210.7 tons. The quantity of sludge removed during the same period was 2,334 cubic yards, which was mostly carted away by a neighboring farmer for fertilizer. The rate of application of participant was 1 part to 3,354 parts of sewage or 1.24 net tons per 1,000,000 gallons of sewage.

The operation of this plant by the city of Boston ended July 18, 1895, at which time the Metropolitan Sewage Commission assumed control of it. From January 1 to July 18, 1895, the average daily amount of sewage pumped and treated was 376,400 gallons, requiring 143,540 pounds of sulphate of alumina. The Metropolitan Commission has made the Mystic Valley sewer a part of the Metropolitan sewerage system and discontinued the chemical treatment. The first annual report of the Metropolitan water commissioner for the year ending January 31, 1896, states that this plant required the service of about 14 men to operate it, and that its discontinuance removes an annual expense of about $20,000.[1]

[1] Refer to annual reports Boston Waterworks; First Ann. Rept. Met. Water Com.; Sewage Disposal in the United States; a paper by W. F. Larned in Jour. Assoc. Eng. Socs. for June, 1888; and Eng. and Bldg. Recd., Vol. XIX, 1889.

Natick.—Natick is about 17 miles from Boston, on the Boston and Albany Railroad, and had in 1890 a population of 9,118. A public water supply has been in use since 1874. In 1885 Eliot C. Clark, engineer to the Massachusetts drainage commission, recommended that a joint sewage-disposal system be built for the towns of Natick, Framingham, and Ashland, and for the Sherborn Prison, situated a short distance from South Framingham, the principal village in Framingham town, with disposal on a gravelly and sandy area, which has since been selected by Framingham and Natick for this purpose. Mr. Clark's idea was that these several towns and the public institution should act in concert, but, unfortunately, the difficulty of reconciling local differences prevented the adoption of his scheme. The two towns of Framingham and Natick have, however, acted separately in utilizing the area selected by Mr. Clark. Framingham completed its sewerage and sewage-disposal system in 1889, while the Natick system was put in operation only during the year 1896.

The indifference of Natick as to sewage purification has been for a number of years particularly flagrant by reason of the flow of a considerable portion of the town sewage into Pegan Brook, a tributary of Lake Cochituate, one of the main sources of the Boston water supply. Negotiations have been had between the city of Boston and Natick looking to purification of this sewage, but without effect. Finally, a few years ago, the city of Boston constructed, at its own expense, on a sandy plateau adjacent to the lake, a filter area upon which the ordinary flow of Pegan Brook was diverted and purified by intermittent filtration. Some portion of the flood flow of the brook has, however, necessarily gone into the lake whenever heavy rains occurred.

The construction of the Natick works began in 1895, under the direction of Samuel M. Gray as engineer. The detailed plans prepared by him provide for bringing the sewage by gravity to a pumping station through a 30-inch circular brick sewer and 24-inch cast-iron pipe with lead joints. The 24-inch pipe is used where the main sewer passes near the head of Lake Cochituate, in order to prevent any possible leakage into that body of water.

The pumping station is provided with a screen chamber, receiving gallery, storage reservoir, pump wells, etc., and the usual accessories of such a plant. According to a statement made by Mr. Gray, when the sewage reaches the screen chamber it passes through iron bars placed three-quarters of an inch apart, after which it may be turned, as desired, either into reservoirs for storage or into a pump well, from which it may be raised directly to the filter areas. In this latter arrangement the pump can be regulated to take the flow as it comes, thereby saving the lift which would otherwise be necessary if it went to the reservoir. The total capacity of the reservoir is 500,000 gallons. The intention is that the night and Sunday flow be stored in the reservoir.

The sewage is delivered to the filter areas through 8,000 feet of 16-inch cast-iron force main, laid on a grade throughout its entire length, for the purpose of permitting the contents to flow entirely back into the pump well in case it becomes necessary to clean the interior surface of this pipe.

The tract of land appropriated for the disposal works was originally covered with a small growth of wood brush. The soil is sandy and generally well adapted to filtration, although there are thin layers of sandy clay in some of the beds which, as Mr. Gray believes, will make it necessary to lay underdrains. The effluent from the underdrains will be discharged into a small stream which enters the Sudbury River below the outlet of Lake Cochituate. It will be noticed, therefore, that the sewage, as well as the effluent, is entirely diverted from Lake Cochituate, in the same way as in the neighboring town of Framingham.

The entire plant as designed includes the preparation of 12 acres of filters to be underdrained with 3-inch tile, laid on a grade of 2 feet in a hundred, in lines 36 feet apart. The work in 1895 included the preparation of 2 filter beds of 1 acre each, from which the underdrains were omitted. Another bed was completed in 1896 with underdrains.[1]

Norfolk County Jail.—This institution has a land disposal plant of some sort, particulars of which, however, are not at hand.

North Brookfield.—The village of North Brookfield is situated in the town of Spencer, in which a water supply was introduced in 1883. The population of the whole town in 1890 was 8,747, having increased from 7,466 in 1880. North Brookfield proper, however, has a population of only about 3,000, which can be ultimately connected with the main sewer as built in 1893, when sewage-disposal works were also built, the system adopted being that of broad irrigation. According to a statement of Mr. Craig, the supervising engineer of the work, published in the Engineering News of March 22, 1894, it would appear that there are about 20 acres of a farm owned by the town which is well adapted to broad irrigation, the soil being naturally very light and dry, and not yielding heavy crops under ordinary methods of farming. In order to reach the highest point of this area it was necessary to employ an inverted siphon about 1,600 feet in length, which has been successfully constructed and operated, and a profile of which may be seen in Engineering News at the place indicated.

This sewage farm was first in working order in November, 1893, and no statements as to the results of broad irrigation are yet at hand. It is considered, however, that with the favorable soil of the locality very satisfactory results may be attained. This farm is also interesting as being very inexpensive, the total cost of the entire system of sewers, including flush tanks, screen chamber, and labor necessary in preparing the farm, being only $9,700. The sewage is first received in a storage tank, from which it is discharged intermittently to the farm.

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[1] Refer to Eng. News, Vol. XXXV, June 4, 1896.

Pegan Brook.—Some general statements in regard to the filter areas constructed for the purpose of excluding from Lake Cochituate the raw sewage of Natick, which previous to the construction of the Natick sewage-disposal works flowed into Pegan Brook and thence directly into the lake, have been made in discussing Natick (pp. 50–51), and a few detailed statements may now be added. The filter areas are three in number, constructed by removing the soil and placing it in embankments 5 feet high around and between the beds. The filter material, to the depth of 8 feet, is mostly sand, about as fine as ordinary plaster sand. The three beds are about 2, 0.75, and 1.25 acres, respectively. Their elevations are 140, 144, and 146.8 feet above the waterworks datum, 134.4 feet being the elevation of low water in the lake. The lowest bed, with an area of about 2 acres, is not underdrained. Water percolates freely through the sand, which is stated to be excellent filter material. Underdrains about 100 feet apart and 8 feet deep are laid beneath the upper beds. They consist of 8-inch vitrified tile pipe, laid with open joints wrapped with canvas. The underdrains were chiefly designed in order that samples of the effluent may be obtained for examination. An earth dam for diverting the water of the brook onto the filter beds and a pumping plant were included in the plans. The entire cost is stated at $12,585.11.

The Pegan Brook filters are of special interest, because, so far as known, they are the first filter areas ever constructed for the filtration of a polluted feeder to a natural lake which is the source of a public water supply. There may possibly be some such arrangement in use abroad, but certainly this is the first plant constructed for such purpose in the United States.[1]

Waltham, School for the Feeble-Minded.—An intermittent subsurface irrigation or filtration plant was constructed at this State institution about 1890. In 1893 permission was granted to connect the sewers of the school with the sewerage system of the city of Waltham, since which time it is understood that the disposal area has been out of service.

Sherborn Prison.—A number of years ago arrangements were made for disposing of the sewage of this State institution by subsurface irrigation. Information as to the extent and success of the project is not at hand. The works are believed to be out of use.

South Framingham.—The sewage-disposal works at South Framingham, Massachusetts, are of considerable interest as involving both broad irrigation and intermittent filtration, and also because real progress has been made here in raising crops on filter beds. Unfortunately, at South Framingham, as well as at about all the other sewage farms in the United States, no one has yet attempted to keep statistics as to the daily flow of sewage, the amount applied, and other important facts, data which must be at hand before definite conclusions can be

[1] Refer to Ann. Rept. Boston Waterworks for 1893, and Eng. and Bldg. Record, Vol. XXIX, Apr. 28, 1894.

A.

B.

SOUTH FRAMINGHAM, MASSACHUSETTS, SEWAGE FARM.

A, Sewage inlet to filter (field of growing corn in left foreground, larger corn in distance); *B*, Portion of cabbage field.

drawn as to the efficiency of the process at any given point. In favor of South Framingham it may be said that the cropping on the filter beds has been very successful, but as the results have been referred to on page 43 of Water-Supply and Sewage Irrigation Paper No. 3, a further account here is unnecessary.[1]

Wellesley College.—Previous to 1892 the sewage was mostly disposed of by passing it through small and imperfect artificial filters of peat and gravel, but, as the results were unsatisfactory, new works were constructed in that year for treatment by intermittent filtration. Additions to the works were made in 1893. The sewage to be treated is that of about 500 persons, for which purpose a filtration area of 1.55 acres has been provided.[2]

Westboro.—Population in 1890, 5,195. Construction of a sewerage system began in 1891. About 33 acres of land located on the right bank of the Assabet River have been acquired by the town for sewage-disposal purposes, nearly one-half of which may be classed as either swamp or meadow, subject to flooding at times of high water. The sewage is conducted to a settling tank on the disposal area, built in two compartments, with a total capacity of less than 1,000 gallons. Two filter beds, with a total area of a little over 2 acres, were prepared in 1892 by stripping off most of the loam and filling with coarse gravel, the material beneath being a fine compact sand nearly impervious to water. The information at hand indicates that this plant has not worked well.[2]

Worcester.—To show the relative degree of purification obtained by chemical processes of treatment in comparison with intermittent filtration and irrigation processes, brief reference may be made to the results obtained by the works at Worcester, Massachusetts, which may be considered not only the best example of a chemical-purification plant on a large scale thus far completed in the United States, but which, in the opinion of those competent to judge, is as good an example of this method of purification as can be found anywhere. The fact that it has not been successful in entirely mitigating the pollution of the Blackstone River, into which the effluent from the Worcester works flows, must be attributed to inherent difficulties of the chemical process, and not to any lack of proper application of that process at Worcester. Indeed, the author takes pleasure in saying that after having examined the large purification works abroad, as well as a greater portion of those in this country, he has nowhere seen a better example of the chemical treatment, pure and simple, than that at Worcester.

According to the report of the superintendent of sewers for the year 1895, it appears that in 1894, as an average, these works removed 49.35 per cent of the total amount of organic matter present in the sewage as determined by evaporation; of the amount in suspension, 94.45 per

[1] Refer to Report of Com. on Drain. and Sew., etc., Nov., 1889; several articles in Eng. News; and Sewage Disposal in the United States.

[2] Refer to Twenty-fifth Ann. Rept. Mass. St. Bd. Health, 1893.

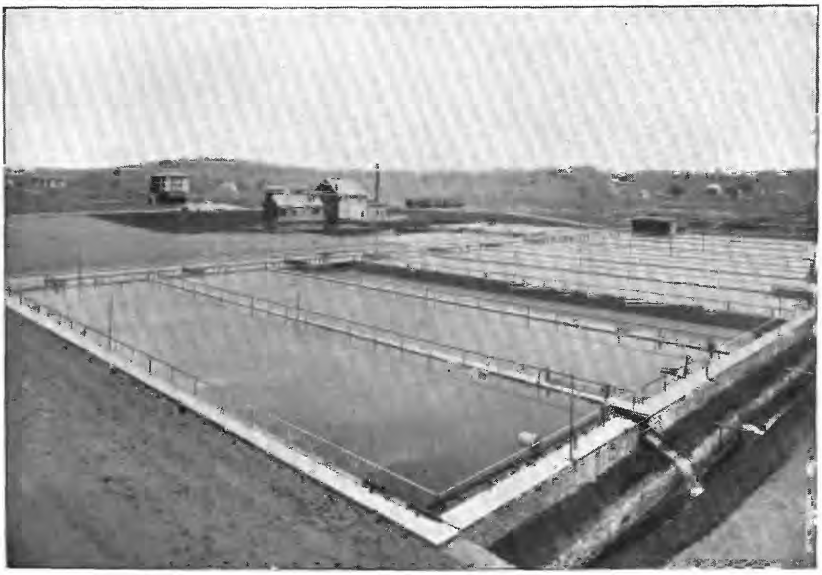
cent was removed; of the total amount, based on the albuminoid ammonia, 50.79 per cent was removed; of the amount in suspension, based on the albuminoid ammonia, 89.54 per cent was removed; the total amount by oxygen consumed was 43.84 per cent, and the amount in suspension by oxygen consumed 81.08 per cent.

Experience at Worcester indicates that different percentages were removed in the various seasons, as, for instance, in 1894 the total per cent of organic matter removed from the sewage as an average, from July to December, was, by evaporation, 55.02 per cent; the amount in suspension, also by evaporation, 95.76 per cent; the total amount of albuminoid ammonia, 53.78 per cent; the total amount by suspension in albuminoid ammonia, 94.36; total amount by oxygen consumed, 50.23 per cent; the amount in suspension by oxygen consumed, 92.42 per cent.

From December to July the total amount of organic matter removed by evaporation was 42.76 per cent; amount in suspension, 93.08; total amount by albuminoid ammonia, 46.63 per cent; amount in suspension by albuminoid ammonia, 83.26; total amount by oxygen consumed, 37.11; amount in suspension by oxygen consumed, 89.27 per cent.

The average analyses of the sewage for the year ending December 1, 1895, were as follows: Free ammonia, 1.16 parts per 100,000; total albuminoid ammonia, 0.518 part; dissolved albuminoid ammonia, 0.249 part; suspended, 0.270 part. The oxygen consumed in unfiltered sewage was 5.27 parts and in filtered sewage 2.91 parts per 100,000, and the chlorine, 5.98 parts. The average of the effluent for the same year was: Free ammonia, 1.008 parts; total albuminoid ammonia, 0.252 part, of which 0.228 part was dissolved, 0.024 part suspended. In unfiltered effluent the oxygen consumed amounted to 2.4 parts and in filtered effluent 2.27 parts, and the chlorine to 5.92 parts per 100,000. Taking the purification by percentage actually removed, we have, for the free ammonia, 13.02 per cent; total albuminoid ammonia, 51.63 per cent; dissolved albuminoid ammonia, 8.43 per cent; suspended albuminoid ammonia, 91.11 per cent; oxygen consumed, total, 54.35; in solution, 21.99; chlorine, 1.05 per cent. It will be noticed that the chemical process only moderately touches the free ammonia and the dissolved albuminoid ammonia.

The works at Worcester were constructed chiefly because of serious complaints on the Blackstone River as to the pollution caused by the Worcester sewage, which originally flowed into the stream in a raw state. The following gives the mean of a series of analyses of the stream as made by the Massachusetts State board of health in 1895: Color on Nessler's scale, 0.71 part per 100,000; total residue on evaporation, 22.15; loss on ignition, 5.18; free ammonia, 0.3246 part per 100,000; total albuminoid ammonia, 0.0898 part, of which 0.0597 part was dissolved and 0.0301 part was suspended; chlorine, 1.86 parts; nitrogen as nitrates, 0.0267 part; nitrogen as nitrites, 0.0063 part; hardness, 7.3.



A.

B.

WORKS AT WORCESTER, MASSACHUSETTS.

A, General view of precipitation tanks; *B*, Another view of precipitation tanks.

In considering these results it should be remembered that the sewerage system of the city of Worcester is a combined system, and that frequently at the time of heavy rains a considerable portion of the sewage flows into the Blackstone River entirely without treatment. The information in regard to the Worcester works is too extensive to be given in detail here. It may be found in the several annual reports of the city engineer and the superintendent of sewers of the city of Worcester, and also in the reports of the Massachusetts State board of health.

The litigation between the city of Worcester and the town of Millbury, a few miles down the river, on account of the pollution of the Blackstone River, may, however, be briefly mentioned by reason of its being the most extensive of legal proceedings involving stream pollution thus far taken in the United States. Without detailing all the steps, it may be stated that the objections of Millbury finally resulted in the passage of a mandatory act of the Massachusetts legislature requiring Worcester to purify its sewage before allowing it to flow into the Blackstone River. Under the provisions of this act the purification works were built and first operated in 1890.

In 1890 the population of Worcester was 84,655, while in 1895 it had increased to 98,678, and at the same time the pollution of the river was so bad that in the latter year Millbury again brought suit against Worcester. At the trial, in April, 1896, the case of the town of Millbury was supported by Allen Hazen, Col. George E. Waring, jr., Rudolph Hering, Mrs. Ellen H. Richards, and George W. Rafter, while Worcester's side was represented by Samuel M. Gray, Prof. William T. Sedgwick, Prof. H. P. Kinnicut, Charles A. Allen, Harrison P. Eddy, and F. A. McClure. The testimony touched nearly every phase of sewage purification and stream pollution. In a decree dated December 14, 1896, the presiding justice ordered that within three months Worcester should take steps to purify the stream. The preliminary steps to comply with this decree have been taken.

Worcester Insane Hospital.—These works were constructed in 1876, and have since successfully disposed of the sewage of about 600 people, the ordinary population of the hospital.

As shown on a previous page, some attempt has been made to dispose of sewage by broad irrigation at the State insane hospitals at Augusta, Maine, and Concord, New Hampshire, a short time before the sewage farm of the Worcester Insane Hospital was first operated. Neither, however, was entirely successful, and both have been abandoned. We must therefore give the credit to the authorities of the Worcester Hospital for instituting the first permanently successful sewage-irrigation farm in the United States.

The hospital building is situated on a considerable rise of ground, about 3,000 feet west of the main irrigation field, which includes 14 acres. There are also arrangements for drawing sewage along the line of the sewer leading from the hospital to the main field, which permits the irrigation of a total of from 30 to 40 acres. The entire hospital farm includes 257 acres.

The work was mostly constructed by the inmates of the hospital and no statement of cost can be made.[1]

PLANTS PROJECTED IN MASSACHUSETTS.

Information as to the number of projected sewage-purification plants in Massachusetts has been obtained from the annual reports of the State board of health, 1890 to 1895, inclusive, as follows:

Andover.—This town submitted plans for sewage disposal to the State board of health for approval in 1895. The plans proposed were rejected as thoroughly impracticable, and the sewer commissioners were instructed in a communication dated October 10, 1895, as to the proper lines on which to develop sewage purification for that place.

Braintree.—The sewerage committee of this town submitted plans for sewage disposal to the State board of health in 1893. In its answer, under date of July 6, 1893, the board suggested that inasmuch as the towns of Braintree and Weymouth were contiguous and were near the sea, the interests of both communities might be served by united action in the construction of an outlet to tide water.

Concord.—The committee on sewage of this town asked the advice of the State board of health on a proposed plan of sewage disposal in 1894. Under date of January 3, 1895, the board replied that, judging from the outline presented, the plan proposed could be commended as well adapted to the needs of the town, and that a system of intermittent filtration on the area proposed would be a proper method of disposing of the sewage of Concord.

Danvers.—In 1895 the board of health of this town applied to the State board for advice as to the disposal of sewage of three morocco factories in that place. In its answer, under date of December 5, 1895, the State board of health suggested, as a line of investigation, that probably the sewage should be first conducted into large settling tanks, where the sludge would deposit, and from which the liquid could be pumped to a filter bed and the sludge be frequently removed from the tanks, to be disposed of presumably either by burying or for use as manure in agriculture.

Foxboro Hospital for Dipsomaniacs and Inebriates.—Information as to an intermittent filtration plant proposed for this State institution may be found in the Twenty-third and Twenty-fourth Annual Reports of the Massachusetts State Board of Health.

Leicester.—Plans for sewage disposal for this town were submitted to the State board of health in June, 1893. They included preliminary sedimentation and filtration, the sludge to be allowed to drain out in beds, after which it will be carted away for use in agriculture.

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[1] Refer to the Forty-seventh Ann. Rept. of the Trustees of the Hospital for the year ending September 30, 1879.

Medfield Insane Asylum.—Plans for the disposal of the sewage of this State institution by means of intermittent filtration were submitted to the State board of health in 1892.

Pittsfield.—Chapter 357 of the acts of 1890 authorizes the city of Pittsfield to build a system of sewerage and sewage disposal, subject to the approval of the State board of health. The plans were presented to the board for its approval in 1891. They provide for the permanent disposal of the sewage by intermittent filtration, but permit a temporary discharge into the Housatonic River until June 1, 1900, after which date the sewage of the city must be treated before discharge, as provided in the plans.

Spencer.—This town was advised by the State board of health, under date of December 8, 1893, as to proper disposal of the town sewage by land treatment. The board pointed out that the wastes from the gas works which now enter the sewers of Spencer should be either excluded or so treated before admission as to remove all tarry or oily substances which would tend to clog the filters.

Bridgewater, State farm.—Under date of December 14, 1895, the State board of health advised the superintendent of the State farm at Bridgewater as to the purification of the sewage by land treatment, preferably by filtration through porous soil about 1¼ miles from the building.

Tewksbury.—The State board of health advised the authorities of this town in regard to land purification of the sewage under date of October 3, 1895.

Wakefield.—In 1892 the sewerage committee of Wakefield submitted to the State board of health plans for the sewerage and sewage disposal of the town, the sewage of the principal village of the town to be treated by filtration upon land, and the remainder of the sewage to be discharged into the main metropolitan sewer. In its answer to the application, under date of October 7, 1892, the State board of health gives general suggestions as to the best method of preparing the disposal areas.

At several other places in Massachusetts sewage-disposal works have been projected and are likely to be constructed in the next few years. The foregoing examples are sufficient to indicate the advanced state of sewage-purification questions in the Commonwealth of Massachusetts.

RHODE ISLAND.

Sewage-disposal works have been either constructed or projected in Rhode Island as follows:

Central Falls.—The present city of Central Falls was part of the old town of Lincoln, in Providence County. The population of the town of Lincoln for 1890 is given at 20,355. In 1892 a tract of land of about 35 acres was purchased for the disposal of the sewage of the western district of the city, at a cost of $20,000. The disposal plant, which for the present includes three filter beds of about one-fifth of an acre each, was constructed in 1896. Additional filter areas are to be constructed as required. The sewage flows to the disposal grounds by gravity. The cost of the work of preparation to date, including settling tank, is is about $9,500.[1]

Pawtucket.—Pawtucket, with a population of 32,577, according to the State census of 1895, is divided into two principal drainage districts, known as the Blackstone River district and the Moshassuck River district. The sewers of both the districts are of the combined system, those of the first district amounting to 27.16 miles, and those of the second district to 7 miles. The filter plant is connected with the sewers of the second district, which includes an area within the city of 960 acres and an approximate population of 9,500; 110 acres of this

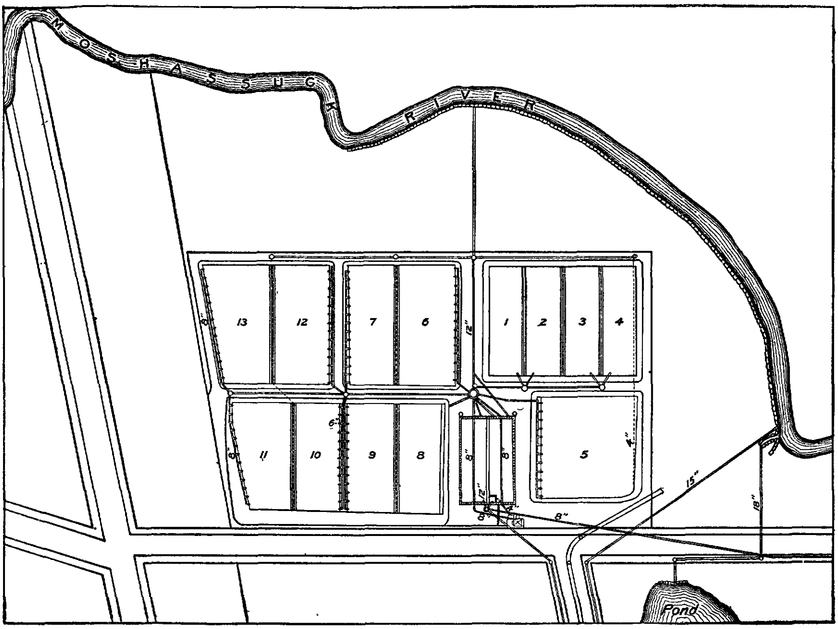

FIG. 4.—Plan of filter areas at Pawtucket, Rhode Island.

area is the most thickly settled portion of the city, having a stated population of 34 persons to the acre. Filter areas are located in the southern part of the city and border upon the Moshassuck River, as shown in Pl. IV. This stream is comparatively small, having an ordinary flow of from 30 to 45 cubic feet per second. It is very much polluted, both above and below the filter areas, by wastes from manufactories, and in view of future complications it was deemed best that the city should not be a party to this pollution. The filter areas, as already constructed, include a little less than 4 acres, about 2.4 acres being the actual area capable of receiving sewage. This is divided, as shown in fig. 4, into 13 beds, 4 of which are designed for sludge beds,

[1] Refer to Eng. and Bldg. Recd., Vol. XXXV, April 24, 1897.

FILTER AREAS AT PAWTUCKET, RHODE ISLAND, AS RIDGED FOR WINTER SERVICE.

and are laid out slightly lower than the other beds in order to receive the sludge from the bottom of the tanks.

Covered sewage tanks have been provided, into which the sewage is first received, and from which it is discharged upon the beds as desired. The sewage flows to these tanks from the city by gravity. Arrangements have also been made by which the flow of sewage can be shut off from the tanks automatically and turned into the storm overflow whenever the amount delivered is so increased by a storm as to tax the capacity of the tanks above the average or above any amount to which the apparatus has been adjusted. After the cessation of the storm and the consequent return of the sewage to the average rates, the gates to the settling tank open automatically, allowing the sewage to again flow into them. In ordinary use sewage is received into the tanks for about twenty-four hours and then turned upon the beds under irrigation at the rate of 100,000 gallons per acre.

Work was begun on the disposal areas in 1893. Generally speaking, the work at Pawtucket has been well carried out and the operation of the plant is successful.[1]

Cranston, State institutions.—The State institutions at Cranston, Rhode Island, include a house of correction, State almshouse, State hospital for the insane, State prison, the Sockanosset School for Boys, and the Oak Lawn School for Girls. They are situated in the midst of a tract of about 500 acres of land owned by the State. Sewage disposal by land treatment was first proposed at Cranston in 1884, and carried out in 1895, since which time it has been successfully operated.

The filtration is said to work well in winter, the sewage reaching the field ordinarily at temperatures of about 40°, 42°, or 43° F.[2]

Providence.—Sewage disposal on a large scale has also been projected for the city of Providence, which had a population in 1890 of 132,146. As the matter now stands, it is proposed to partially purify the sewage by chemical precipitation and discharge it into tide water at Fields Point. Main intercepting sewers have been under construction for the last few years with this end in view.[3]

Woonsocket.—Sewage-disposal works have also been projected for Woonsocket.

CONNECTICUT.

Bristol.—A recent example of a combination broad-irrigation and intermittent-filtration plant is at Bristol, Conn. The population of this town in 1890 was 7,382. In 1892 a number of suits were brought to restrain the discharge of crude sewage into a stream flowing through

[1] Refer to Eng. News, Vol. XXXV, January 2, 1896, where a very complete account by George A. Carpenter, city engineer of Pawtucket, designing and constructing engineer of these works, may be found.

[2] Refer to Seventeenth Ann. Rept. Bd. Charities and Corrections of R. I., 1895; also Eng. and Bldg. Record, Vol. XIII, March 4, 1896.

[3] The Providence sewage-disposal data are very extensive; for a digest of the same refer to Sewage Disposal in the United States.

the town. The suits have been held in abeyance pending the construction of sewage-purification works.

Plans for a sewerage and sewage-disposal system were prepared in 1892, but the actual work of construction was delayed about three years awaiting necessary legislation. Acting under the advice of Mr. McKenzie, the town's engineer, 80 acres of land were purchased at $35 per acre for the purpose of constructing filter beds and also for utilizing sewage by broad irrigation. The necessary sewers and a portion of the disposal area were constructed in the year 1895.

The filter areas as thus for prepared include about 6 acres. The material is coarse sand and gravel. Sewage is distributed to them by means of 15-inch and 12-inch carriers. The underdrains, so far as laid, are 8 inches and 6 inches in diameter and 25 feet apart. It is not intended to underdrain the irrigation area. The cost of preparing 6 acres of filter beds, with the necessary appurtenances, was about $9,000. No definite statements can yet be made as to the results of purification or irrigation at this place.

Danbury.—Population in 1890, 16,552. A few years ago the Wolf disinfecting process, which consists in dosing the sewage with sodium hypochlorite formed by a partial electrical decomposition of a solution of salt and water, was applied. The process, as applied at Danbury, proved inefficient, and suits were brought enjoining the city from discharging its sewage into Still River. The court recommended intermittent filtration, adjudged costs against the city, and required discontinuance of the discharge after May 1, 1897. Under these circumstances the town purchased an extensive tract of land, a portion of which is stated to have been prepared for use in intermittent filtration.[1]

Lake Wauremaug.—This lake, which is surrounded by a number of hotels and cottages, has abrupt, rough, and rugged shores, which render an economical, safe disposal of sewage somewhat difficult. Areas for land treatment are entirely lacking. Under these circumstances a committee of the State board of health in 1894 recommended the treatment of all human fæces and urine by a dry-earth system, and the treatment of laundry and sink wastes by filtration in trenches on sloping ground, somewhat after the method successfully used at Wayne, Pennsylvania. It is understood that these recommendations have since been carried out.

Litchfield.—Population in 1890, 3,304. The first sewage-irrigation field in Connecticut was inaugurated at this place in 1890. Area of same, 4 acres. No details as to method of operation or success attained are at hand.[2]

Manchester.—Population in 1890, 8,222. It is stated that a sewage-disposal plant by land purification has recently been constructed. No information as to details is at hand.

[1] Refer to Eng. News, Vol. XXXIV, August 29, 1895.

[2] Refer to Fourteenth Ann. Rept. Conn. St. Bd. Health, 1891.

Meriden.—The sewage-disposal works at Meriden furnish an example of combined irrigation and intermittent filtration. The population of Meriden was 21,652 in 1890. Waterworks were built in 1869.

The gradual extension of sewers having led to a considerable pollution of Harbor Brook, a small stream flowing through the central and lower part of the town, the question of sewage purification gradually became a leading one until a special committee was appointed, in 1891, to investigate and report on the general question. This committee submitted reports of engineers recommending broad irrigation, supplemented by intermittent filtration, on a tract of land of about 150 acres, which was subsequently purchased for this purpose. According to statements in Engineering News, the disposal area as originally planned included some 32 acres for broad irrigation and 14 filter beds, 8 of which are 150 feet by 350 feet and the balance one-half that size. That portion of the disposal area which has been laid out in beds is stated to consist of fine soil 3 feet deep, below which is a layer of sand and gravel of unknown depth, admirably suited for filtration. The fine, deep soil contains a layer of rather poor, brownish-black material about 8 inches thick, below which is red loam sand, finely divided and nearly without grit. The sand and gravel farther down are very coarse, most of the sand being coarser than ordinary building sand.

In constructing the filter areas only about 12 inches of the top soil was removed, leaving about 2 feet of the fine material above the coarser subsoil. The filter beds have been underdrained with 6-inch tile placed 2½ feet below the surface at their upper end and 5 feet below at their lower ends. Inspecting chambers are placed at the junction of each under drain with the main drain. The main drain discharges into water carriers leading to a neighboring river.

Sewage was first discharged upon the original filter areas in September, 1893. It was then reported that very little effluent appeared in the underdrains, and that the discharge from them grew less and less until finally practically none appeared. The clear inference is that the effluent passed on down below the drain pipes and sank into the coarse material below.

Considerable trouble has ensued at Meriden, chiefly by reason, apparently, of neglect of the fundamental principles of sewage purification and utilization, not only as worked out in detail by the experiments of the Massachusetts State board of health, but as practiced successfully for many years abroad. The beds have not only been overdosed, but in their original preparation the exceedingly fine material above the subsoil was partially left instead of being fully removed, with the result that the filtration was not only very slow, but the filtering material was soon clogged. In 1895 all the beds were stripped of top soil and fine sand. Since that time the results have been much better.

So far as can be learned, no special attempt has yet been made to grow crops upon the filter area, although the land utilized was selected by the designing engineer, Mr. Bassett, with special reference to such use. Possibly future reports from Meriden may indicate more satisfactory results. An attempt at sewage farming on a large scale at this disposal area would be watched with great interest by everybody. Markets for all kinds of produce are near at hand, and there seems to be no reason why, with proper management, a sewage farm here might not be very successful.[1]

Waterbury.—This town had a population in 1890 of 28,646. As we have seen on a previous page, the pollution of Naugatuck River by manufacturing wastes is very serious. It is understood that plans are now under way looking toward the purification of the sewage of Waterbury by land treatment.

NEW YORK.

Brewsters.—The so-called system of electrical treatment as used at Danbury, Connecticut, was also applied by the New York City department of public works for treating both sewage and water at Brewsters in the summer of 1893. So far as can be learned, the process has not been any more successful at Brewsters than at Danbury. In a paper read by Dr. Thomas M. Drown before the New England Water Works Association on March 14, 1894, it is shown that the so-called electrical purification is simply a process of disinfection by sodium chloride, in which electricity has nothing further to do with the process than that sodium hypochlorite is produced from salts naturally present in the sewage by electrolysis. It is probable that the cost of any treatment which includes the preparation of sodium hypochlorite by electrolysis is more expensive than it would be to buy this salt in the market and apply it by the ordinary methods of mixing used in chemical purification.

Brooklyn, Twenty-sixth ward.—Chemical-purification works have been recently constructed in the Twenty-sixth ward of the city of Brooklyn, in general accordance with the patented process of J. J. Powers. This process has also been carried out at Coney Island, Echota, Round Lake, White Plains, Sheepshead Bay, and other places in the State of New York. As originally operated, perchloride of iron was the only precipitant used, but in the more recent plans lime is also added and the sludge is further dosed with chlorine gas. Perchloride of iron costs about 3.5 cents a pound in New York. Chlorine is prepared from common salt, black oxide of manganese, and sulphuric acid. As to the cost of operating this system, the following approximate estimate of the daily expense at White Plains may be given:

[1] The works at Meriden were reported upon by Messrs. T. H. McKenzie, Simpson C. Heald, and Carroll P. Bassett. As to the views of each of these engineers, etc., see Eng. News, Vol. XXXIV, July 18, 1895, where an extended account of the works may be found.

Estimate of daily expense at chemical-purification works at White Plains, New York.

1 carboy of perchloride of iron	$4.75
1 barrel of lime	.75
Coal	.90
Engineer	2.25
Laborer and watchman, each, $1.50	3.00
Common salt, black oxide of manganese and sulphuric acid	.50
Oil and waste	.30
Miscellaneous	.50
Total	12.95

At the time this estimate was made, the average daily quantity of sewage treated was about 250,000 gallons. Assuming an average cost for treating this quantity of $12 instead of $12.95, we reach the figure of $48 per million gallons treated, which figure may, however, be expected to decrease somewhat with larger quantities of sewage treated. The figures show, however, that this is an exceedingly expensive process under any circumstances, as will be more readily realized when it is stated that the land processes, aside from yielding returns from the crops, do not ordinarily cost more than a few dollars per million gallons treated.

Chautauqua Assembly.—Chemical-precipitation works were constructed at the Chautauqua Assembly in 1893. This place has a summer population at times of several thousand. Measurements of the flow of sewage July 24, 1893, showed a total of 122,884 gallons in twenty-four hours.

According to an advertisement issued by the committee in charge of the Assembly grounds in October, 1892, the plans were required to embody a complete plant capable of sending out a clear and odorless effluent harmless to fish life, the object of the works being chiefly the maintenance of the cleanliness of the Chautauqua Lake beach in front of the Assembly grounds. The plans adopted were those of W. B. Landreth, and include the use of lime and sulphate of alumina as precipitants. The following analysis, made by Prof. Maurice Perkins, of Union College, in September, 1893, indicates the degree of purification obtained at this plant.

Analyses of water from chemical-precipitation works at Chautauqua Assembly.[1]

[Parts per 100,000.]

	Sewage.	Effluent.	Per cent removed.
Total solid residue	117.0	23.6	79.8
Mineral matter	59.2	14.4	75.7
Loss on ignition	57.8	9.2	84.1
Chlorine	6.0	6.0	0.0
Free ammonia	24.28	1.357	44.1
Albuminoid ammonia	2.088	.486	76.9

[1] Mr. Landreth has recently stated to the author that the results of this analysis have been fully verified by repeated analyses made each season since 1893.

If the results given in the foregoing are maintained permanently the Chautauqua Assembly sewage-disposal plant may be regarded as of a very high order.

In 1893, from July 1 to October 1 (ninety-two days), the cost of labor was: Superintendent and engineer, $255; helper, $131; total, $386, or at the rate of about $4.20 a day. The amount of chemicals used per diem is stated to average about as follows: Lime, 1 barrel; alumina sulphate, 30 to 40 pounds; copperas, 2 to 5 pounds. Fuel is estimated to cost about 30 cents a day. Taking labor at $4.20, fuel at 30 cents, and chemicals at $1.75, we reach a total of $6.25 a day. Assuming an average attendance of 4,000 people during the season, the daily cost per capita is found to be 0.156 cent, or at the rate of 57 cents per capita per year. Chemicals on the foregoing basis cost about 16.1 cents per capita per annum. Taking the actual flow of sewage as averaging about 125,000 gallons a day, we reach a cost per million gallons treated of $8.88 for lime, $7.76 for alum, and $1.28 for copperas, or a total of $17.92 per million gallons treated, which again indicates somewhat greater expense for chemical treatment than would be required for treating the same amount of sewage on land. Inasmuch, however, as the results were largely experimental in 1893, it is possible that later figures would show a marked reduction in cost. Chemical treatment will, however, even under the most favorable circumstances, cost more than land treatment, other conditions being, of course, assumed as equal.[1]

Far Rockaway.—Population in 1890, 2,288. Plans for sewerage and sewage disposal were approved by the New York State board of health in 1895; they include the collection of the sewage of the village at central points, from which it is to be pumped, by means of an electric motor and motor pumps, to a disposal field, where it will be purified by land treatment. It is understood that the work is at present under construction.

New Rochelle.—Population in 1890, 8,217; at present it is perhaps 11,000. A chemical purification plant, designed to treat eventually 750,000 gallons of sewage a day, was carried out in 1894 at an estimated cost of about $19,000. In addition to this sum, 2 acres of land purchased, right of way, legal expenses, etc., were estimated to cost about $4,380, or a total of about $23,380. Statements are lacking as to either the efficiency of the process or just the method of treatment pursued.[2]

Hemlock Lake.—The domestic water supply of the city of Rochester is obtained from Hemlock Lake, about 30 miles southerly from and at an elevation of 386 feet above the city. The works for bringing this supply to Rochester were constructed in 1874 and 1875, about which time the attention of the citizens of Rochester as well as those of the

[1] Refer to Eng. News, Vol. XXXI, February 1, 1894.

[2] Refer to Eng. News, Vol. XXXIII, February 28, 1895; and Eng. and Bldg. Record, Vol. XXXI, March 9, 1895.

surrounding cities and towns was attracted to the lake as a desirable point for summer residence. In 1892 there were in use about 120 cottages and several hotels and summer boarding houses, and the summer population about the margin of the lake, including transient visitors, was from 800 to 1,000 persons.

In order to care for the sewage and house wastes the city of Rochester constructed in 1886 a pail system by which the night soil and garbage from the cottages and hotels are collected and removed to the foot of the lake, where the material is deposited in narrow trenches in thin layers, and, after treating with lime, each layer is covered with about 6 inches of dry earth. This process is repeated daily until the trench is nearly filled, when the remainder is rounded up with earth and a new trench is started. The surface of the full trench is then cultivated and cropped, and after a suitable period the same land is again used. The trenches were originally made about 3 feet deep, but experience indicates much more rapid destruction of the organic matter near the surface than at the lower levels. It has been found that after a period of three years the same trench can be used again. The plant includes a building with convenient arrangements for washing the pails during the summer and for storing them in winter, as well as a flat-bottomed scow for transporting the sewage receptacles on the lake, and a tramway and pier, with a total length of 2,200 feet, by which they are transported from the lake to the place of treatment. The approximate cost of the plant to April 6, 1891, including surveys, building, scow, wagon road, tramway, carts, pails, and land, was about $10,000. The yearly cost of operation is from $1,500 to $1,700. In winter only a few of the dwellings are in use and the collections are made weekly by wagon.[1]

Bath, Soldiers' and Sailors' Home.—Mr. Power's patented process, described on page 62, is in use at this place, where the permanent population may be taken at from 1,200 to 1,500. Chemicals are stated to cost fully $2,000 a year. Including fuel, labor, and other expenses, the sewage purification costs about $3 per capita per annum. A good opportunity exists at this State institution to elevate the sewage by pumping onto porous lands owned by the State just back of the home, where it could be efficiently utilized in irrigation.

Batavia, State Institution for the Blind.—The average quantity of sewage of this institution is estimated at about 10,000 gallons a day, this quantity being based upon an average daily consumption of water of 50 gallons per capita for the 200 officers and inmates. Chemical-treatment works costing about $6,500 and an outlet sewer costing $6,000, or a total of $12,500, were constructed in 1890–91. No statements as to the efficiency of the process are at hand.

Vassar College.—Vassar College is situated near the town of Pough-

[1] Refer to Ann. Repts. Ex. Bd. City of Rochester, and Sewage Disposal in the United States. The city of Rochester is now (1899) purchasing a strip of land about Hemlock Lake, including all the cottages, and this collection system will accordingly soon be discontinued.

keepsie, a short distance back of the city, upon a small stream, which reaches the Hudson River by a roundabout course of something like 6 miles. For a number of years previous to 1895 the college sewage flowed to a series of covered tanks, where it underwent a rapid filtration through peat, gravel, and other substances. The effluent from this process, while considerably clarified, was still objected to as unfit to pass into a small outlet creek, the township health officer alleging that its discharge was injurious to riparian owners below.

After considerable discussion, in which various projects were suggested, a plan for disposal by intermittent filtration and broad irrigation was prepared and carried out by Messrs. Noyes and Hazen in the fall of 1895. Under this plan the sewage first passed into a screening chamber provided with a screen rack formed of iron bars $\frac{1}{4}$ by 2 inches in diameter, placed seven-eighths of an inch apart. The sewage enters the screening chamber parallel to the screen rack and not against it. The matter collected at the screen is taken out each day, and after draining on a platform is removed to the boiler house and burned. From the screening chamber the sewage flows to a reservoir of 44,000 gallons capacity, from which it was pumped to the disposal area, which consists of two filter beds with a total area of 1.03 acres exclusive of the embankment. The filtering material is a rather coarse sand with an effective size of grain of from 0.30 to 0.40 millimeter.

The level of the ground water was found to be about 15 feet below the prepared surface of the filter areas, and as there was a gully near by which afforded a free outlet for the ground water, underdraining was deemed unnecessary.

The filter beds provided are regarded as sufficient to receive the entire sewage of the college, but as there was a considerable area of sandy soil near by at a somewhat greater elevation, the force main was extended to a point commanding this area, so that during the growing season several acres of land can be utilized for broad irrigation. In this way the fundamental principle of effective sewage utilization has been recognized in these works, the sewage going to the land when necessary for the best results of agriculture and to the filter areas when not needed on crops, thus insuring an efficient filtration at all times without reference to cropping.

Complete records as to the quantity of sewage do not appear to have been kept, although during the months of February and March, 1896, the average daily quantity is stated as 56,000 gallons, the range being from 32,000 to 113,000 gallons. The sewers receive roof water and the higher quantities are stated as due to accessions from this source.

The total cost of the works as constructed, including the preliminary expense involved in considering the various projects proposed before the final adoption of the sewage-utilization project, is stated at $7,500, exclusive of the land.

Chemical examinations have been made of the water taken from the brook receiving the effluent, above the point where the effluent enters as well as below, with the result of showing that the stream below the effluent now carries no trace of sewage contamination. A great improvement in the condition of the stream is also shown by analyses made before and since the beginning of the filtration by Mrs. Ellen H. Richards, one of the trustees at Vassar College, and analyst of the Massachusetts State board of health. The examinations are to be continued for considerable length of time in order to gain information as to the final effect on the effluent and as to other questions of interest to those planning similar works. The enterprise of Vassar College in carrying out so thorough a system and also in causing systematic examinations to be made for the purpose of acquiring information for future guidance is highly commendable.[1]

PLANTS PROJECTED IN NEW YORK.

Albion.—Population in 1890, 4,586. Plans for sewage disposal by intermittent filtration were approved by the State board of health in 1890. The sewage will be delivered at the filtration fields by gravity, and the topographical conditions are such as to admit of utilization in agriculture by broad irrigation on porous, sandy lands.

Cobleskill.—Population in 1890, 1,822. Plans for sewage disposal by chemical purification were approved by the State board of health in 1893. No information is at hand as to whether or not land-purification processes have been considered.

Cortland.—Population in 1890, 8,590. Plans for purification of the sewage of the town by chemical treatment were approved by the State board of health in October, 1893. The plans also include possible filtration through land, should a high degree of purity be found necessary. It is proposed to use lime and sulphate of alumina as precipitants. The plans, as approved, include a tank area for from 9,000 to 10,000 people, with arrangements whereby the capacity can be increased as required. The report of the engineer does not state whether or not the locality would admit of land-purification processes.

Flatbush.—Under the health laws of the State of New York, the governor may, on presentation of evidence as to the existence of a nuisance, order the same to be abated under plans subject to the approval of the State board of health. In 1894 Governor Flower issued such an order with reference to the sewage of the village of Flatbush, on Long Island, which then grossly polluted Mill Creek. No information is at hand as to the action finally taken under this order.

Fort Plain.—Population in 1890, 2,864. This town is situated in the narrow portion of the Mohawk Valley at a place where little opportunity for land purification exists, except that the town incurs the expense of pumping. The cities of Rome, Little Falls, and Utica, on the Mohawk River above Fort Plain, discharge sewage into the river without treat-

[1] For an account of the Vassar College works, see the Engineering Record of June 27, 1896.

ment. Under these circumstances a chemical purification plant was approved by the State board of health in 1893.

Fonda.—This place, with a population in 1890 of 1,190, is also situated in the narrow valley of the Mohawk River below Fort Plain. For reasons similar to those stated in the case of Fort Plain a chemical-purification plant for this place has been approved by the State board of health.

Fulton.—Population in 1890, 4,214. This village is situated on the Oswego River, 12 miles from Lake Ontario. Chemical-purification works using lime and sulphate of alumina for precipitants, and estimated to cost $19,500, were approved by the State board of health in 1894. The water supply of the city of Oswego is taken from the Oswego River about 10 miles below. The engineer's report does not state whether land-purification processes are feasible or not.

Gowanda.—The present population of this place is stated at about 2,500. Sewage-disposal works by the process of sedimentation followed by upward filtration were presented to the State board of health in 1895. The details are too meager to give any certain indications as to the probable success of the process as specially applied at this place. The cost of the tanks is estimated at approximately $4,000, with a fixed charge of $800 per annum for maintenance.

Herkimer.—The township of Herkimer, which includes the village, had a population in 1890 of 4,666. The present population of the village is, however, stated at about 4,700. Plans for sewage-disposal works were approved by the State board of health in 1893. They include chemical precipitation applied substantially as at Fort Plain and other towns of the Mohawk Valley.

Holly.—Population in 1890, 1,381. Plans for sewage purification by intermittent filtration were approved by the State board of health in 1890. The topographical conditions are such as to permit the use of the sewage in broad irrigation.

Jamestown.—Population in 1890, 16,038. Sewage-disposal works have been projected, but whether land processes will be used is unknown.

Ilion.—Population in 1890, 4,057. Plans for chemical treatment by the use of lime and sulphate of alumina were approved by the State board of health in 1895. As at Fort Plain, Fonda, Herkimer, and other places in the lower Mohawk Valley, no information is given in the report as to the possibility of applying land purification. This universal omission must be considered extraordinary in view of the water supplies on the Hudson River at and about the mouth of the Mohawk and just below.

Lyons.—Population in 1890, 4,475. Plans for sewage disposal and sewerage were submitted to the State board of health for approval in the summer of 1897. They include purification of the sewage by irrigation and filtration.

Mount Vernon.—Population in 1890, 10,830. Plans for treating the sewage by J. J. Power's patented process were approved by the State board of health in 1893.

North Tarrytown.—Population in 1890, 3,179. Sewerage and sewage-disposal works for this place were approved by the State board of health in 1894. The purification is to be by chemical treatment. The details given in the published reports are exceedingly meager.

Oneida.—Population in 1890, 6,083. This village is situated in the Mohawk Valley above Utica. Plans for the purification of sewage by chemical treatment were approved by the State board of health in 1893.

Pelham Manor.—Plans for chemical treatment of the sewage of this place were adopted by the State board of health in 1894. From the meager details given in the reports it is inferred that Mr. Power's patented process is to be used.

Rochester.—Population in 1890, 133,896. General plans for treating the greater part of the sewage of that portion of Rochester lying east of the Genesee River, including at present a population of about 75,000 persons, were prepared in 1888, but have remained thus far in abeyance. The plans as prepared propose a partial chemical purification by lime treatment, with discharge of the effluent into the Genesee River. There is a fine opportunity to utilize the sewage of the east side at Rochester by broad irrigation on sandy soils in the neighboring town of Irondequoit, which are now largely devoted to growing vegetables for the Rochester market. In view of the successful experience on a similar soil at Gennevilliers, in France, as described in Water-Supply and Irrigation Paper No. 3, the author can not but think that if the city of Rochester were to finally construct a chemical-purification plant as proposed it would miss the great opportunity of its municipal life.

Williams Bridge.—Population in 1890, 1,685; estimated at present at about 5,000. Plans for chemical treatment of the sewage were approved by the State board of health in 1894. The details of the plans as given in the reports are very meager.

NEW JERSEY.

Atlantic City.—This place is a well-known seaside resort, which has many visitors in winter, but a much larger number in summer. Its population in June, 1890, was 13,055, against 5,477 in 1880. It is said that during the height of the summer season 150,000 people sometimes visit this place.

Atlantic City is one of the few places in the United States where the sewerage and sewage-disposal systems are owned and operated by a private company. The purification plant in use consists, in effect, of an elevated bed in which sand with hay below is used as a separating material and from which the effluent falls in small streams about 3 feet to gathering gutters leading to the effluent pipe. The results gained are extremely unsatisfactory. Indeed, with the large quantity treated at the present time it is doubtful if any improvement is effected. The answer to a recent letter of inquiry refers to the Atlantic City sewage-purification works as a great farce.

East Orange.—The population of this place in 1890 was 13,282. Sewage-disposal works with chemical treatment supplemented by filtration through land were constructed in 1887 and 1888. The chemicals used are lime and sulphate of alumina. So far as known, no attempt to raise crops on the filter areas has ever been made. The works are now out of use, the sewage going to the Passaic River by way of the Newark sewers.

Essex Fells.—This place is an improved suburban-residence district, with a daily flow of sewage of about 20,000 gallons. Originally the purification was merely such as could be obtained by sedimentation in a tank, supplemented by the flow of the effluent through a mass of broken stone, and thence into gravel. Two filter areas capable of purifying double the present flow were constructed early in 1897.[1]

Freehold.—Population in 1890, 2,932. A disposal plant by broad irrigation was brought into use in 1893. For this purpose 16 acres of land were purchased, upon which the sewage is delivered by gravity. A portion of this has an unfavorable peaty soil with a surface of from 6 to 12 inches of bog iron ore. The remainder is greensand, marl, and clayey gravel. The cost of the land, including right of way, was $4,120, and with fencing and preparation, $6,207. Engineering and superintendence cost $1,944. The entire force of labor consists of one man at $300 per annum. The disposal area was seeded with Hungarian grass the first year, which sold standing for $45, but the hay is said to have molded after being housed. An attempt to cure this grass the second year is also said to have failed. Probably if Hungarian grass is the proper crop to raise on this area, ensilage would be the best way to preserve it.[2]

Lawrenceville School.—A system of subsurface irrigation was carried out at this school in 1883. Additions thereto, either by intermittent filtration or by broad irrigation, were proposed in 1893. As to whether the improvements have all been carried out there is no information at hand.[3]

Long Branch.—The winter population of this place does not exceed 7,000 or 8,000, although the population in summer is estimated at from 80,000 to 100,000. Like Atlantic City, this place has granted a franchise for sewerage works to a private company. Chemical-precipitation and mechanical-separation sewage-disposal works were constructed in 1886. Definite information as to results is lacking.[4]

Morris Plains Asylum.—Works for sewage disposal by sedimenta-

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[1] Refer to Eng. and Bldg. Record, Vol. XXXVI, July 3, 1897.

[2] Refer to Seventeenth Ann. Rept. New Jersey St. Bd. of Health, 1893.

[3] Refer to Trans. Am. Soc. Civ. Eng., Vol. XVI, 1887; Eng. and Bldg. Record, Vol. XVI, 1886; and Sewage Disposal in the United States.

[4] Refer to Eleventh Ann. Rept. New Jersey St. Bd. of Health, 1887.

A.

B.

SEWAGE DISPOSAL AT PLAINFIELD, NEW JERSEY

A, Main carrier as seen from screen tank (before erection of building); *B*, Distributing channel in bed No. 1.

tion and subsurface irrigation were constructed at this State institution in 1887. The sewage is also dosed with a small quantity of sulphate of alumina. No information is at hand as to whether sewage irrigation could be profitably used.[1]

Plainfield.—The present population of Plainfield is about 13,000. It is chiefly a residence town, a very large portion of the residents being New York City business men. The construction of a water supply a few years ago has had the usual result of emphasizing the need of sewers, but no practical move was made in this direction until 1892. It was then resolved to construct a sewerage system with purification by intermittent filtration and broad irrigation. The construction of the works was begun in 1894 and completed in 1895. The land selected for sewage disposal lies at an elevation of from 50 to 70 feet above mean sea level and can be mostly reached with the sewage of the town without pumping. For one district, however, it is arranged in the future to drain to a pump well, from which the sewage will be raised by automatic electric pumps into a neighboring main, whence it can flow by gravity to the disposal works. The works at Plainfield are of further interest because of a trial there of cultivation of the filtration area. The result of such experiment with indian corn is well shown on Pl. I of Water-Supply and Irrigation Paper No. 3, and on Pl. V of this paper. The flow of sewage is stated at present to amount to from 11,000 to 13,000 gallons per hour at 11 a. m., gradually diminishing from that time to 5,000 gallons at about 4 p. m., and again increasing from 7 p. m. to 11,000 gallons per hour at 11 a. m., as stated. The total flow in twenty-four hours is stated as about 230,000 gallons. The works were constructed under the direction of A. J. Gavett.

Princeton College.—Sewage disposal by broad irrigation was carried out at Princeton several years ago. An average daily flow of sewage of from 7,000 to 10,000 gallons is purified on a sloping field of about 4 acres which has 6 inches of black soil resting upon a homogeneous clay subsoil. The entire area is drained to a depth of 4.5 feet with 2-inch tiles laid 30 feet apart. Sewage is applied from a line of troughs at the upper margin of the field, which are changed from place to place as necessary.[2]

Summit.—Population of the township in 1890, 3,502. Sewage purification by intermittent filtration was first operated in 1892. The disposal area consists of 26 acres of land, of which 10 acres have been laid out. The following bacteriological examination, made by Dr. Richard N. Connolly, bacteriologist to the Passaic River Commission, indicates defects of some sort in these works.

Sample of raw sewage taken December 31, 1896, showed bacilli coli communis very numerous, with a total number of bacteria per cubic centimeter of 1,112,250.

[1] Refer to Eleventh Ann. Rept. New Jersey St. Bd. of Health, 1887.
[2] Refer to Twentieth Ann. Rept. New Jersey St. Bd. Health, 1896.

A sample of the filtrate from the westerly outlet taken at the same time also showed bacilli coli communis very numerous, with a total number of bacteria per cubic centimeter of 1,098,900.

A sample of the filtrate from the northerly outlet, also taken at the same time, showed bacilli coli communis numerous, with a total number of bacteria per cubic centimeter of 645,440.[1]

Westfield.—This town had a population in 1897 of about 3,000. Sewerage and sewage-disposal works were carried out in 1895 and 1896. The method of disposal is by means of intermittent filtration and broad irrigation. For the former four level beds of about three-quarters of an acre each have been prepared on the highest part of the disposal field, which lies at an elevation of about 80 feet above tide water. The soil ranges from a fine sand to a coarse gravel. For the present 12 acres have been purchased, the portion not included in the filter beds to be used for broad irrigation. Thus far only one man is found necessary to take care of the sewage. The cost of the plant, including land, was $8,435.[2] F. A. Dunham was designing and constructing engineer.

PENNSYLVANIA.

Altoona.—Population in 1890, 30,337; in 1895 the population was estimated at 35,500. The town is located at the base of the Allegheny Mountains, between the elevations, 1,110 and 1,350 feet above tide, and near the head waters of the Juniata River. A sewage-disposal plant, constructed in 1896 and 1897, is designed to purify the sewage of a little less than one-half of the city, which originally drained southward toward Hollidaysburg, the county seat of Blair County, which is situated on the stream originally receiving the sewage a few miles down.

The pollution of the streams receiving the Altoona sewage has been a source of controversy for many years, and in 1882 suits were brought against the city for polluting springs on property about 11,400 feet southward from the city limit. This case was finally decided against the city, and claims of damages, interest, and costs to the amount of $6,555.36 were compromised in 1895 for $2,812.45.

Early in 1895 surveys for a sewage-disposal plant were made by Mr. Harvey Linton, city engineer. Messrs. Rudolph Hering and Allen Hazen were employed as consulting engineers. The details of the Altoona sewage-disposal operations are exceedingly interesting, but too extensive to be gone into here, and we may simply state that the filter beds have a capacity of about 750,000 gallons a day. The land purchased for sewage disposal amounts to nearly 96 acres and cost $12,000. Of this nearly 70 acres are available for sewage purification. The new works were first operated in June, 1897. It is intended to raise corn upon the filter areas.

The specifications for this work, as prepared mostly by Mr. Hazen,

[1] Refer to Eng. News, Vol. XXVIII, December 8, 1892, and Sewage Disposal in the United States.
[2] Refer to Twentieth Ann. Rept. New Jersey St. Bd. Health, 1896.

present some interesting features. The following is the clause covering grading and embankments:

The general object of this work is to divide up the land into a series of level plats surrounded by embankments, so that each can be separately flooded without disturbing the others, and to prevent the overflow of the land by the stream in time of flood.

. . . .

The land should be kept in as loose and porous condition as possible, and to that end all that part of the area to be filled shall be plowed 1 foot deep and left in loose condition before commencing to fill, and the elevations of the filling shall be carried to such additional elevation as may be directed by the engineer, to allow for subsequent settlement to bring all parts of the bed to the same ultimate elevation.

The dividing embankments shall be solidly constructed and rolled if necessary. The stone removed from the land may be largely placed in them if not otherwise required. The outside embankment as low as ordinary high water shall be paved with stones removed from the field in such exposed places as may be directed by the engineer, and the remainder of the slope and top carefully sodded with firm, healthy sods.

Land stones over 4 inches long are to be removed from the surface material as fast as the same is removed and are to be placed in the embankments or along the river to prevent washing, as will best serve the interests of the work, and as may be directed by the engineer.

After removing the stones the surface of the beds shall be carefully graded and smoothed and left in porous condition, free from compacting from wheels or hoofs, and ready for receiving sewage.[1]

Norristown, State Hospital for the Insane.—The total population of this institution is about 1,500, and the total daily consumption of water about 325,000 gallons, or 150 gallons per capita. A sewage-disposal plant, with purification by filtration and broad irrigation, was constructed in 1885. These works are said to have been specially successful.[2]

Reading.—Population in 1890, 58,661. The proprietary process of the Pennsylvania Sanitary Sewage Company was carried out in 1895. It is claimed that the works have sufficient capacity to purify 15,000,000 gallons of sewage a day. The following statement embodies the main points of these works:

The sewage falls by gravity into reservoirs 20 feet in diameter, with coke filters 12 inches deep, through which the sewage first passes in order to screen out the coarser suspended matter. The reservoirs are ventilated by special passages which surround the smoke flue and are expected to discharge foul odors at a height of about 100 feet.

The sewage is drawn from the reservoir into a suction chamber, from which it is pumped to filter beds on the river banks, about a mile from the pumping station. These beds are two-story structures of brick, stone, and iron, 250 by 50 feet, each story being subdivided into ten compartments, making a total of twenty compartments 25 by 50 feet. The filter beds are divided into upper and lower sections, in order to combine aeration with filtration. The filtering material of the upper section consists of fine sand 2 feet thick. After percolating through

[1] Proc. Eng. Club of Philadelphia, Vol. XIV, July–September, 1897.
[2] Refer to Colonel Waring's Sewerage and Land Drainage, 1889.

this the sewage falls 8 feet to a lower filter, which is formed of various grades and sizes of filtering material. Inlets are provided in which air is to be circulated in the coarser material of the lower section. The effluent water is discharged directly into the river.

The author can not but think that the proposition to purify 15,000,000 gallons of sewage a day by this plant must be intended as a joke.[1]

Wayne.—This place is a suburban village with a population in 1890 of 997. It has grown rapidly, and at present the population is much greater. There are no manufactories. Sewage disposal by surface irrigation was carried out in 1891. The disposal area includes 11 acres of sidehill land, with creek flowing through the middle. A portion of the land is timbered, as shown by fig. 2 in Water-Supply and Irrigation Paper No. 3 and by Pl. VII in this paper.

The sewage flows by gravity to the pumping station, whence it is forced to distribution wells on adjacent highlands, from which it flows down the sidehill through heaps of broken stone. At various places below cinder banks are formed. A very efficient filtration is said to be obtained by this process in course of a few hundred feet below. In 1892 the average daily quantity of sewage was established at about 200,000 gallons. During that year five crops of grass were raised on the irrigated land.[2] The effluent water is discharged into the river.

WEST VIRGINIA.

Weston, State Insane Hospital.—Plans for sewage disposal by chemical precipitation, supplemented by broad irrigation, on about 27 acres of land on which it was intended to grow crops were prepared in 1891. In view of the sewage farming offering an opportunity for employing a considerable number of harmless insane in light outdoor labor, it was believed that this project was an especially feasible one. Thus far, however, the West Virginia legislature has not appropriated the $40,000 necessary in order to carry out the project in full detail.[3]

TEXAS

Paris.—Population in 1890, 8,254. This town is finely located in northwestern Texas, about 14 miles from Red River, at an elevation of 588 feet above tide water.

Sewers were constructed in 1894, discharging into a small stream known as Bankers Creek. Soon after constructing a main sewer, farmers on this creek below the outfall brought suits for damages aggregating $15,000. Trial of one of them resulted in a verdict against the city of $900.

The suits had the effect of forcing attention to some other means of sewage disposal, and in the early part of 1897 a system of disposal

[1] Eng. and Bldg. Record, Vol. XXXI, May 4, 1895.

[2] Refer to the Am. Arch., July 2, 1892; Eng. News, Vol. XXVIII, November 3, 1892; and Sewage Disposal in the United States.

[3] Refer to Jour. of W. Va. House of Delegates, February 18, 1891.

by intermittent filtration was begun. For this purpose the city purchased 10 acres of land for $750, of which 5½ acres have been laid out. The cost of constructing 5½ acres of filters is given at $3,730. The present daily flow of sewage is from 35,000 to 40,000 gallons. The sewage-disposal areas are cared for by one man, who is paid at the rate of $420 a year. It is proposed to crop with alfalfa in 1898.[1]

San Antonio.—Population in 1890, 36,673. The city purchased 530 acres of land in 1895, with the expectation of establishing a sewage farm. Information is not at hand as to the present state of the enterprise.

Temple.—Population in 1890, 4,047. It is understood that this place has recently granted a franchise to a private company to construct and operate sewerage and sewage-disposal works.

OHIO.

Alliance.—Population in 1890, 6,707. A chemical-purification plant estimated to cost $18,400 has either been recently constructed or is about to be constructed at this place. As to just the present state of the project, no information is at hand.

Canton.—Population in 1890, 26,189; present population estimated at about 35,000. The outfall sewer originally discharged raw sewage into the main branch of the Nimishillen Creek. Complaints were made several years ago by the owners of land abutting on the creek below the outlet of the sewer, thus bringing the question of sewage purification before the city authorities, who acquired 28 acres of land at and about the sewer outfall for the purpose of providing some method of purification. Chemical treatment was finally decided upon as adequate to the requirements, although the relative cost of chemical purification versus land treatment does not appear to have been gone into. The works were constructed under the supervision of L. E. Chapin, city engineer.

The plant was first started in May, 1893, since which time all the sewage of the city has been treated. The following analyses, made by Dr. Curtis C. Howard, in which the results are stated in parts per 100,000, indicate the degree of purification effected. No. 1 is the average of 24 samples of the raw sewage, and No. 2 the average of 24 samples of effluent taken at the same time as No. 1.

Analyses of raw sewage and of effluent, at Canton, Ohio.

[Parts per 100,000.]

	No. 1.	No. 2.
Free ammonia	0.894	0.676
Albuminoid ammonia	.326	.112
Chlorine	2.14	2.05
Total solids	49.3	41

[1] Refer to Eng. News, Vol. XXXVIII, August 12, 1897.

The cost of the sewage-disposal plant at Canton to March 15, 1897, is as follows:

Land	$4,100.00
Construction	27,215.23
Material	14.70
Total	31,329.93

The cost of maintaining the works in 1896 was as follows:

Labor	$1,630.00
Coal	356.76
Lime	739.63
Alum	502.75
Oil and waste	33.01
Filter sacks	46.68
General repairs	61.91
Miscellaneous	44.50
New smokestack	137.00
Total for year	[1] 3,552.23

Fostoria.—The population in 1890 was 7,070. Plans for sewage disposal by land purification were prepared in 1895. As to whether they have yet been carried out no information is at hand. The conditions are such as to require pumping to the disposal field. Cost of disposal works is estimated as follows:

24½ acres of land, at $150	$3,675.00
Preparation for beds, including underdrainage, grading, force main, main carrier, and effluent drain	6,425.00
Reservoir, sludge and pump well, necessary buildings, boiler, and pumps	14,920.00
Total	25,020.00

Running expenses with coal as fuel are estimated at about $1,843 per year, without taking into account the profit to be realized from the sale of produce raised on the filter areas.[2]

Oberlin.—This place, which is the site of Oberlin College, had a population in 1890 of 4,376. A sewerage system, with disposal by broad irrigation, was constructed in 1893. The irrigation field includes 15 acres, purchased at a cost of $1,500. In 1894 the daily flow of sewage varied from 35,000 to 40,000 gallons. In addition to broad irrigation, 9 filter beds have also been prepared, of which 3 are devoted to raising woodland rye grass, 3 to alfalfa, and 3 to corn and garden vegetables.

The soil, which consists of yellow clay underlain at a few feet by stiff blue clay, is not specially favorable for sewage disposal. As to the best methods of treating such a soil, reference may be made to a description of the sewage farm at Wimbledon, England, in Water-Supply and Irrigation Paper No. 3. The Oberlin sewage farm is also especially interesting because of the small amount spent in preparation.

[1] Refer to Canton Municipal Reports and Tenth Ann. Rept. Ohio St. Bd. Health, 1895.

[2] Refer to Tenth Ann. Rept. Ohio St. Bd. Health, 1895.

The following are the figures:

6,000 feet of agricultural tile	$256
Tool house	55
Grading and incidentals	166
Small pump and tank	42
Land	1,500
Total	2,019

Some reports as to a nuisance at the Oberlin sewage farm having gained circulation, a committee of the Ohio State board of health inspected it in July, 1895. In their report the committee say that no just cause exists for complaint in respect to the Oberlin sewage farm.[1]

Sewage disposal plants are also reported as projected at Bowling Green, Cambridge, Chillicothe, Columbus, Glenville, Greenville, and Mansfield, Ohio.

MICHIGAN.

Wayne County Poor Farm.—A chemical precipitation plant, costing about $10,000, was first operated at this institution in 1896. Cost of operation, including chemicals and attendance, is estimated at about 80 cents per capita per annum for a population of 800.[2]

St. Johns.—Population in 1890, 3,127. A land-purification project has been proposed.

ILLINOIS.

Pullman.[3]—This farm was laid out in 1880 and 1881 by the Pullman Palace Car Company as a means of purifying the sewage of the model town of Pullman, which is about 14 miles south of Chicago and at present is included within the limits of that city. The population in 1893 was 11,000. The only body of water in the vicinity which could possibly receive crude or raw sewage is Lake Calumet, a lake about 3 miles long, $1\frac{1}{2}$ miles wide, and from 1 to 8 feet deep. The extreme shallowness of this lake, as well as the absence of current, renders it very undesirable as a place for disposing of crude sewage, and the country about Pullman is so flat that it was necessary to pump the sewage to the area selected for farming purposes. The area originally selected comprises about 1,500 acres, though thus far only a small part of this tract has been used. In 1892, with an average daily flow of sewage of about 1,850,000 gallons in twenty-four hours, the land in actual use did not exceed 140 acres.

This farm is of special interest in the present connection, because its original design recognized the principle of having filter areas on which any surplus sewage not needed for the best results in irrigation could be purified. It should not be overlooked that reports have frequently come from Pullman that the sewage was often allowed to flow into

[1] Refer to Ninth Ann. Rept. Ohio St. Bd. Health, 1894 and 1895.
[2] Refer to Eng. and Bldg. Record, Vol. XXXIV, July 11, 1896.
[3] The use of this farm for sewage disposal has recently been discontinued.

Lake Calumet in nearly its natural condition. On this point it may be remarked that the projectors have probably felt that little harm was done to anybody so long as no nuisance was created in the lake or along its margins. The fact that a portion of the ice supply of Chicago was taken from Lake Calumet during the winter has been considered with indifference. Owing, therefore, to either inefficient or indifferent management, the Pullman farm can not be referred to as a specially successful example of sewage purification, although, from the statements made, the utilization has justified in a commercial way the expectations of its projectors. The farm is stated to have yielded in some years a net profit of from 8 to 10 per cent. The designing engineer, Benezette Williams, of Chicago, is entitled to the credit of having made his design sixteen years ago in line with what is universally considered to be the best practice of the present day.

The soil at Pullman is the ordinary prairie black alluvium, about 1 foot in depth, and mostly underlain by a clay subsoil. It is therefore not the most favorable for utilizing a large volume of sewage on a small area. From what has been learned in regard to this farm, it is the author's opinion that a considerably larger area should be used. With this improvement, as well as some additions to the filter area in order to afford sufficient relief in wet weather, it is believed that sewage farming can be made very successful at Pullman, from the points of view of both purification and utilization.

The underdrains are of common agricultural tile, laid about 40 feet apart to an average depth of about 4½ feet. The most satisfactory crops are cabbage, cauliflower, celery, and other vegetables common to market gardening. For some reason the raising of potatoes has not been successful on this farm. Italian rye grass is also reported as unsuited to the conditions, but whether the difficulty is due to climate or soil, or both, is unknown. Very little live stock is kept, because market gardening for the Chicago market is more profitable. During the growing season about forty laborers are employed at the current rates of common labor in the vicinity of Chicago.

The distribution of sewage at Pullman is effected by the pipe-and-hydrant system. For this purpose vitrified tile pipes, tested by water pressure before laying, have been successfully used.

The foregoing short account of the Pullman sewage farm is given here, not because it is an example of the best work in sewage utilization, but because it was the first large sewage farm in the United States, and because, further, it was designed in accordance with the now universally recognized principle of intermittent filtration relief areas. In view of the large experience gained elsewhere, failure to purify the sewage efficiently at all times must, as has already been pointed out, be attributed to the management rather than to the method. Under this head it may be remarked that thus far the American farms, generally speaking, have not realized their full agricultural capacity by reason of defects in management. We need to develop here, as there have been developed abroad, a class of sewage-farm managers who, having made a specialty of this method of farming, shall be not only informed as to details but qualified to meet emergencies.

As regards sewage-purification works owned and operated by towns, it may be said that the entire separation of the management of the works from local politics will be the first necessary step toward increased efficiency.

World's Fair.—The sewage of the World's Columbian Exposition, in 1893, was purified by mechanical precipitation before discharged into Lake Michigan. The plant assigned for this purpose embodied the method of vertical tanks, an illustration of which may be found at page 556 of Sewage Disposal in the United States.[1]

This plant was placed in charge of Mr. Allen Hazen, who made extensive studies as to its efficiency. The daily quantity of sewage treated varied from about 6 million to 9 million gallons. The total cost of treatment per million gallons was $38.09. The works cost about $55,000, of which $20,000 was for the building.

The cost of the chief precipitant used varied from $20.40 to $47 per ton. Mr. Hazen's results are given in considerable detail, but can not be further gone into here. On the whole his report is adverse to the efficiency of the process.[2]

WISCONSIN.

Menominee Valley.—The sewage-disposal plants in Menominee Valley have been described on page 24, in connection with the discussion of purification of manufacturing wastes. They include Schmidt's Curled Hair Works, McBride's Sanitarium, the National Soldiers' Home, the public institutions of Milwaukee County, and the Miller Brewing Company.[3]

MINNESOTA.

Rochester Hospital for the Insane.—Sewage disposal by chemical precipitation supplemented by intermittent filtration was first operated at this State institution in 1890. The population of the hospital is stated at about 1,050 persons, with a total sewage flow of 60,000 gallons a day. The sewage first flows to tanks of sufficient capacity to handle 75,000 gallons a day, from which, after treatment with chemicals, the effluent is pumped to a filtration area with about 16 inches of surface loam, below which is sand and gravel. This area is underdrained with 3-inch tile laid in lines about 25 feet apart. In spite of the low winter temperature of Minnesota, it is stated that no trouble has been experienced in securing sufficient winter purification. The sewage probably

[1] Additional illustrations of this plant are given in Eng. News, Vol. XX, August 3, 1893.

[2] The full results of Mr. Hazen's studies of the World's Columbian Exposition sewage-disposal plant may be found in the Twenty-fifth Ann. Rept. Mass St. Bd. Health, 1893.

[3] Refer to Eng. News, Vol. XXXIII, June 13, 1895, and Sixteenth Rept. Wis. St. Bd. Health, 1895-96.

reaches the precipitation tank in cold weather with a temperature of about 45° F.[1]

NEBRASKA.

Hastings.—Population in 1890, 13,584. Stated present population, 15,000 to 18,000. A sewage farm of about 70 acres was carried out in 1891 or 1892. The soil of this farm is open and porous, and, so far as known, has not been underdrained. No information is at hand as to the success experienced in cropping.[2]

COLORADO.

Colorado Springs.—Population in 1890, 11,140. A sewerage system was carried out in 1888 and a sewage farm in 1889. Soon after opening the sewage works a ranchman living 2 miles below the outfall, which is into a small stream with a normal flow of about 50 cubic feet per second and at times with no flow at all, instituted injunction proceedings, claiming that his well was so polluted as to render the water unfit for drinking, and that the water in his irrigating ditch, of which the head gate is about three-quarters of a mile below the sewer outfall, was so foul that stock would not drink it. The matter was arbitrated and the suit withdrawn, the city paying all costs of proceedings and agreeing to divert the sewage and utilize it for irrigation.

A contract was then made between the city and the owner of a tract of about 35 acres of land upon which the sewage could be conveniently diverted by gravity, the city agreeing to pay $300 annually for five years, and the owner on his part agreeing to use the sewage for irrigation purposes in such manner as he deemed best, provided, however, that the sewage be prevented from flowing directly into the creek, and provided further, that if the method of irrigation was not satisfactory to parties on the stream below, the city should take possession of the land and use such methods as it thought best. At the expiration of the contract the city was to have the option of buying the land at a stipulated price. Whether or not this has been done is not known. The irrigation, however, is said to have been very successful. In 1892 sewage was used on 25 acres—15 acres in meadow and alfalfa and 10 acres in vegetables. The crops produced have been very large, and owing to close proximity to market the farm is said to be a paying investment.

As illustrating the demand for water in this section, it is stated that farmers several miles below the sewer outfall, seeing the sewage farm well supplied with water at times when their farms were suffering from shortage, have threatened to enjoin the city from using the sewage for this purpose, and thus compelling it to turn the sewage into the stream for their benefit.[3]

Leadville.—Population in 1890, 10,634. The sewerage system of this

[1] Refer to Sixth Biennial Rept. of Trustees, 1890, Eng. and Bldg. Recd., Vol. XXIII, and Sewage Disposal in the United States.

[2] Refer to Eng. News, Vol. XXIX, March 9, 1893, and Sewage Disposal in the United States.

[3] Refer to Eng. News, Vol. XXIX, February 23, 1893, and Sewage Disposal in the United States.

A.

B.

SEWAGE IRRIGATION AT SALT LAKE CITY, UTAH.

A, Main ditch, outlet gate, and field of corn; *B*, Lateral ditch and method of irrigating corn.

place was built in 1886 by the Leadville Sewerage Company. The original sewage-disposal works as constructed by this company included a sand and gravel filter about 6 or 7 feet deep, with a surface area of 24 square feet. Whether this extensive sewage-disposal plant is still in use is not known.

Trinidad.—Population in 1890, 5,523. A sewerage system was first operated in 1892. Sewage is first received in a settling tank 50 feet long, 5 feet wide, and 4 feet deep, from which it flows upon land. To the end of 1892 about $1,200 had been expended in preparing the irrigation area to receive sewage. Blue grass was originally proposed as a crop on the farm, because it was supposed that this grass would stand more frequent irrigation than any other crop. A private party owns the irrigation area, on which the city delivers the sewage and pays $500 a year to the owner.

MONTANA.

Helena.—The population in 1890 was 13,134. A sewerage system was first operated in 1889. At this place the sewage is utilized only in the growing season. During times when the ground is so frozen that there is no absorption, sewage flows in natural channels upon the surface. The lower end of the outfall sewer connects directly with the distributing ditches of the farm, which includes 40 acres of land, purchased for $6,100. It is leased at an annual rental of $200. Crops raised are vegetables and nursery stock.

UTAH.

Salt Lake City.—Population in 1890, 44,843. A sewage farm was carried out at this place under the direction of F. C. Kelsey, city engineer, in 1895 and 1896. The daily flow of sewage is stated at 4,000,000 gallons. In addition storm water to the amount of 15,000,000 gallons per day may be expected at different times. The land acquired by the city amounts to 183 acres, of which 80 acres have been plowed and are under cultivation in 1897. It fronts on the Jordan River and the main ditch is extended to the stream, so that when the outfall sewer is running full the flow can be diverted directly to the river without passing over the land. Settling basins to the extent of 30 acres have been prepared.

Sewage was first delivered on the farm on July 11, 1896. No crops were planted that year except 5 acres of corn for fodder. It is intended to improve the farm by erecting buildings, planting shade trees along the highways, and an orchard of 6 acres, which is too high for irrigation, but thus far the money has not been furnished for these improvements.

The results of this extensive sewage irrigation at Salt Lake City will be looked for with interest, the more especially as, when the sewage farm was first proposed, it was thought that neighboring farmers would be willing to take the sewage for irrigation, because all land at Salt Lake City necessarily requires irrigation. The farmers, however, refused to take it, mainly, it is said, from ignorance, thinking it would damage the crops, clog the ground, and be otherwise injurious. It was for this reason that the city embarked in sewage farming.[1]

The total cost of the sewage farm to January 1, 1897, was: Land, $14,763.45; plowing, $273.42; preparation of surface, etc., $3,452.64; total, $18,489.51.

The total cost of handling the sewage for the last six months of 1896 was $683.36. Assuming an average of 4,000,000 gallons a day, this would be at the rate of about 93 cents per million gallons handled for the six-months period. Probably when the sewage farm is in full operation the cost will be greater, but it will be met by sale of crops.

ARIZONA.

Phœnix.—Population in 1890, 3,152. The waterworks, sewerage, and sewage disposal at this place are all owned by the Arizona Water Works and Sewage Company. According to the information at hand, 160 acres of land have been provided for a sewage farm, on which sewage is largely used for irrigating garden truck by Chinese gardeners. The results are understood to be satisfactory. A view of an irrigated field will be found in Pl. VII.

CALIFORNIA.

Fresno.—Population in 1890, 10,818. Sewers were constructed in 1889. In 1890 a contract was made with Alexander McBean, of Oakland, to take the sewage and purify it by irrigation, the city paying therefor $5,000 per year. Mr. McBean purchased 80 acres of land at the outfall, and during the first year the sewage ran upon it without special attention or care, except when some neighbor saw fit to take it for irrigation. The second year distribution ditches were constructed and the land leased to Chinese gardeners for vegetable gardens and vineyards. The land is now all under cultivation with the various kinds of vegetables commonly in the market, such as potatoes, yams, parsnips, lettuce, celery, beans, peas, and corn. Statements as to the amount of sewage are lacking.[2]

Los Angeles.—Sewage irrigation at Los Angeles is of considerable interest, because the most extensive sewage farming by private owners in the United States is practiced there. The population, according to the census of 1890, was 50,395. In 1894 a conservative estimate placed it at 70,000.

Los Angeles is built upon both sides of a torrential stream, Los Angeles River, at a point about 20 miles from its mouth, and at a distance of about 12 miles from the Pacific Ocean. Sewage irrigation here was originally carried on by a private company, which took the sewage as delivered from the main outfall sewer and conveyed it by ditches to an area on which it was utilized in agriculture as required on various small tracts, the surplus being allowed to flow away into

[1] Refer to the Salt Lake City Municipal Rept. for 1896, and Eng. News, Vol. XXXVII, March 13, 1897.
[2] Refer to Sewage Disposal in the United States.

A. SEWAGE IRRIGATION AT PHŒNIX, ARIZONA.

B. SIDEHILL IRRIGATION AT WAYNE, PENNSYLVANIA.

the stream unpurified. In the course of time the area originally irrigated became city property, and a large portion of it having been sold for residence sites, many of the landowners objected to sewage irrigation and obtained injunctions restraining its use in this way. According to the statements made there was at one time considerable nuisance from the sewage irrigation. The ditches were not kept clean, and under the hot sun of southern California they gave forth a strong odor. The objection was also made that sewage irrigation was detrimental to the health of the community, but so far as can be learned no facts have ever been produced to support this objection.

The sewage has been mostly used in growing vegetables for the Los Angeles market, and, according to the statements made, its commercial value for such purpose has been considerable.

As the result of several years' discussion the city of Los Angeles has recently constructed a main outfall sewer leading to the Pacific Ocean, along the line of which numerous valves have been placed, as is done at other places where successful sewage irrigation has been practiced, not only for drawing off the sewage for use in agriculture, but for restricting its use to such times as it may be needed.

The soil for a considerable portion of the distance along the main sewer is light and sandy and especially adapted to successful sewage purification, and it is believed that a considerable use of sewage for this purpose will be developed soon.

In 1895 and 1896 a total area of about 1,550 acres was irrigated along the line of the new outfall sewer, the amount of sewage used upon this acreage varying from 8 to 10 cubic feet per second. An area of 800 acres near the city is mainly devoted to raising vegetables. The balance was planted in corn and other fall crops, among which were about 100 acres in potatoes and cabbage. According to the reports of the city engineer for the years 1895 and 1896, the following revenue was realized from the sale of sewage:

Revenue realized from the sale of sewage at Los Angeles, California, in 1895 and 1896.

1895.		
Receipts from the sale of sewage		$3,278.00
Maintenance:		
Salary of superintendent	$1,000.00	
Assistance and labor	625.47	
Repairs, etc	512.50	
		2,137.97
Net revenue		1,140.03
1896.		
Receipts from sale of sewage		$4,009.50
Maintenance:		
Salary of superintendent	$1,200.00	
Assistance and labor	1,675.40	
Repairs, etc	184.80	
		3,060.20
Net revenue		949.30

In 1883 the city of Los Angeles entered into contract with the South Side Irrigation Company, obligating itself to give to said company all the sewage flowing through the San Pedro street sewer, amounting to about 3.58 cubic feet per second. In October, 1895, a second contract was made with the same company, whereby the city agreed to deliver until the expiration of the former contract an additional quantity of 2.39 cubic feet per second, or a total until 1903 of a little less than 6 cubic feet per second. In consideration of the last amount the company has laid a 24-inch cement pipe, 6,000 feet of which lies within the city limits and which will become the property of the city in 1903. The company also has the right to use an additional quantity of sewage by paying the prevailing price for it, which during the height of the irrigation season, in April and May, has been placed at $8 per twenty-four hours for 2 cubic feet per second. The rate is also made $5 for a day run of twelve hours and $3 for a night run, to suit the convenience of the irrigators.

The sewage now controlled by the South Side Irrigation Company is mainly used for irrigating about 2,200 acres of land devoted to vegetable gardening. The sewage is distributed throughout the land irrigated by ordinary open-earth ditches. This land now pays an annual rental of $12 per acre for river-water irrigation and $18 per acre for sewage irrigation, or $6 per acre in favor of the sewage.

On sandy soil with good subdrainage the South-Side Irrigation Company now irrigate successfully during the whole year. Experience has shown that when not actually needing the sewage for irrigation it is better to flood the land than to permit the sewage to go to waste.[1]

Pasadena.—Population in 1890, 4,882. Sewers were constructed from 1887 to 1891, and a city sewage farm was brought into operation in 1893. Its soil is a light sandy loam, with good natural drainage, and includes at the present time an area of 800 acres. The flow of sewage is estimated at about 3 cubic feet per second. According to statements of Mr. Burr Bassell, of the 300 acres actually owned by the city, 140 are used for raising grain and have never been irrigated. Sewage has been used upon the remaining cultivated area as follows: Walnut orchard (4 years old), 60 acres; alfalfa, 25 acres; corn, 25 acres; vege-

[1] In a paper by Mr. Burr Bassell, deputy city engineer of Los Angeles, on the Operation of the Los Angeles outfall sewer and sewage irrigation, which appeared in the Journal of the Association of Engineering Societies for August, 1897, many additional interesting details may be found. In the discussion of Mr. Burr Bassell's paper, James D. Schuyler, a leading California irrigation engineer, pointed out that, in view of the conspicuous success achieved in sewage farming abroad, the policy of constructing an outfall sewer to the ocean must be regarded as questionable, particularly in southern California, where the soil and climatic conditions are all extremely favorable for successful sewage farming. Mr. Schuyler expressed the hope that in the future growth of Los Angeles, when the capacity of the present outfall has been reached, extension of the system would be made in the line of utilization by irrigation and the establishment of a city sewage farm rather than in the duplication of the present sewer to the ocean. Mr. Schuyler gave a large amount of valuable information as to the comparative cost of river water and sewage irrigation in the vicinity of Los Angeles.

In addition to Mr. Bassell's paper, refer to Report of a board of engineers upon the disposal of the sewage of Los Angeles, etc., 1889, Eng. News, Vol. XXIX, February 23, 1893, and Sewage Disposal in the United States.

tables, potatoes, etc., 50 acres. The farm is self-sustaining, cost for maintenance and revenue being each about $2,500 per annum.

The experience at Los Angeles and Pasadena seems to be conclusive that there is no valid objection to the use of sewage for the irrigation and growth of all kinds of agricultural products. It is apparently a question merely of proper application. As showing the immense advantage of sewage disposal in the vicinity of Pasadena, it may be mentioned that bare land is worth at least $100 an acre without water, while watered land is held at about $600 an acre. The Pasadena sewage farm originally cost $125 an acre, or a total, including some extra expenses, of about $40,000.[1]

Redding.—Population in 1890, 1,821. A separate sewerage system was built by the town in 1889. Bassett & Rouhey, of Sacramento, the contractors for the sewage work, entered into an agreement to dispose of the sewage for forty years. For this purpose they purchased a tract of about 100 acres of land and prepared a portion of it for the utilization of sewage by irrigation. The area selected is comparatively level, with the soil a sandy and gravelly loam 4 to 6 feet deep, underlain by gravel. The sewage is applied directly to the land, either by running in furrows between rows or by spreading over the surface, according to the special requirements of each crop. The chief crops raised are corn, asparagus, potatoes, turnips, beets, and other garden truck. It has also been used for orchards and nursery stock. When used in this manner the trees were irrigated between the rows.[2]

San Luis Obispo.—Population in 1890, 2,995. Plans for sewage disposal by broad irrigation and intermittent filtration were prepared about 1888. No information is at hand as to whether or not they have been carried out.[3]

Santa Rosa.—Population in 1890, 5,220. Complaints of the pollution of the creek into which the sewage of the town was originally discharged, followed by a lawsuit, led to the purchase by the city of 18 or 19 acres of land on which the sewage has been purified since about 1889. The farm is leased to tenants, who take care of the sewage as rental, using it for gardening purposes.

Stockton.—Population in 1890, 14,224. The sewage of this place is stated to be used for irrigating purposes, but to what extent is not known.

DOMINION OF CANADA.

Berlin.—Berlin is the county seat of Waterloo County, and according to the census of 1891 had a population of 7,425. The chief industries of the town are manufacturing establishments, among which are included a large tannery and a glue factory. A public water supply

[1] Refer to Burr Bassell's paper in Jour. of Assoc. of Eng. Socs., Vol. XIX, August, 1897; and to Sewage Disposal in the United States.

[2] Refer to Sewage Disposal in the United States.

[3] Refer to Colonel Waring's Sewerage and Land Drainage, 1889.

was built in 1888. Construction of sewers began in 1892, and in March, 1893, the actual quantity of sewage was about 50,000 gallons per day, diluted by some 75,000 gallons of subsoil water, making a total of 125,000 gallons in all. A sewage farm was completed in the fall of 1892 and first brought into use in 1893. In January, 1893, the temperature of the sewage as it arrived at the farm was found to be 48° F. The farm is located a mile south of the closely built-up section of the town. A stream, with a summer flow of about 200 cubic feet per minute, passes through the farm and receives the effluent.

The field purchased by the town for sewage-disposal purposes has an area of 20 acres, about an acre of which is included in the stream. The total area aside from the stream can easily be used for sewage farming by slight grading, as the greatest elevation is only 3 feet above the end of the outfall sewer. The surface soil is loam or sand, and the subsoil is of gravelly clay.

The designing engineer recommended that Italian rye grass be raised on the two north divisions of the farm, and on the remainder mangolds and other root crops, onions, oats, and clover. On the lowlands bordering the stream it is proposed to raise osiers, they having been raised with profit in Brantford, where dependence is had upon the freshets of the Grand River for irrigation. It is stated that the farm is suitably arranged for every known system of irrigation and every variety of crops. This farm is interesting from the fact that, as at the Croyden-Beddington farm, no settling tank has been provided, preference being given to the application of the solid matter directly to the land, where it can be dug in or raked off, as may be found most desirable. When in the course of time the amount of sewage has increased so that it exceeds the capacity of the farm for disposal by broad irrigation, it is proposed to construct filter areas at the south end, where gravel may be obtained within reasonable distance. The 20 acres purchased cost $2,000, and the cost of grading and underdraining the 7 acres already prepared was about $3,000, the underdraining and grading having cost at this rate a little over $400 per acre.

The results of cropping at Berlin are stated to have been substantially as follows: In 1894, 2,000 cabbage plants were set on about one-half an acre of land, of which 1,500 grew to marketable heads and were sold at the usual market price of 3 cents each. The cabbages were irrigated regularly and grew well. No attempt was made to hoe around them or hill them up, the surface of the ground being left entirely smooth.

The cultivation of Italian rye grass at Berlin does not seem to have been successful. The rye-grass seed was sown broadcast and soon came up, covering the ground with a mass of roots which are stated to have very much retarded the absorption of sewage. This experiment was made on a filter bed in a manner quite different from the ordinary practice of rye-grass cropping abroad. A chief difficulty of this trial appears to have been an improper preparation of the land, depressions being left into which the sewage settled and which soon became foul. Abroad, on the contrary, this crop is not raised on beds at all, but on land so prepared as to avoid pondage of the sewage; besides this, the amount of sewage applied is regulated to the necessities of the crop and to the quality of the land, whereas at Berlin, so far as can be learned, the sewage application was made without special reference to the conditions. Under these circumstances the failure at Berlin can apparently have no other significance than to illustrate an erroneous method of procedure.

In 1895 a large area was devoted to cabbage, but by reason of a late frost many of the plants were killed. Later the cabbages were reset and the seeds of onions, carrots, mangolds, corn, and beans were planted. These crops are stated to have all done well except the corn and beans. The following is a detailed statement of the sale of produce from the Berlin farm in 1895, as compiled from the proceedings of the committee of the town council in charge of the farm:

August, 1,217 heads cabbage, at 2½ cents	$30
September, 1,771 heads cabbage, at 2½ cents	44
October, 2,272 heads cabbage, at 2½ cents	57
October, 134 bushels carrots, at 15 cents	20
October, 648 bushels carrots, at 15 cents	97
Corn (failure)	7
Pease (not irrigated to any extent)	15
November, 1,350 heads cabbage, at 2½ cents	34
Total	304

In addition to the foregoing, 150 kegs of sauerkraut, of 50 pounds each, were made from cabbage not sold in the head. These were held at $3 per keg.

The mangolds yielded 648 bushels from one-half an acre, giving at this rate the enormous yield of 1,296 bushels per acre. Those raised were easily sold to farmers for feeding stock. The experience, so far as gained at Berlin, indicates that mangolds will stand very heavy dosing of sewage.[1]

In 1896, complaints having been made by the local board of health of Waterloo Township to the effect that the sewage of Berlin was creating a nuisance in Berlin Creek, the matter was investigated by a committee of the board, which reported in effect that the farm had been managed on more economical lines than was desirable, such misplaced economy being the chief cause of the nuisance complained of. From this point of view the committee of the Provincial board suggested that the town council and local board of health of Berlin be instructed to adopt sufficient and adequate means whereby the whole sewage of the town could be applied on the beds in succession and completely purified before flowing to the creek. After making several

[1] Refer to Eng. News, Vol. XXIX, April 6, 1893, and Vol. XXXV, June 11, 1896; and to Rept. Prov. Bd. Health, 1896.

other recommendations the committee concluded its report with the statement that the farm could be made productive without there being any reasonable ground for complaint.

Hamilton.—Purification works by chemical precipitation have been approved for this place by the Provincial Board of Health. In order to insure efficient operation, a committee of the Provincial board which examined the plans in October, 1896, reported that in its opinion the management of the works, when constructed, should be left to the care and supervision of the city engineer, who should also be made responsible for the subordinate engineer in charge. The committee believed that with such management an effluent can be poured into Hamilton Bay of a purity compatible with the best interests of the public health. The works are under construction at the present time.

London.—It is understood that plans for sewage disposal by intermittent filtration are about to be carried out at this place. The land selected for the disposal fields is sandy and stated to be well adapted for the purpose.

London Hospital.—The works at London Hospital were constructed in 1888 and 1889 under the general direction of the architect in chief of the Ontario department of public works.

Previous to the construction of the disposal works the sewage from the hospital debouched into a small stream tributary to the south branch of the Thames River, which flows through the city of London. The drainage area of this stream is so small that it becomes nearly dry during the summer. The population of the hospital is over 1,000, and the daily amount of sewage 60,000 gallons. It became necessary, therefore, that some method of disposal be used other than of allowing the flow of raw sewage into the brook. The plan as carried out involves the flow of sewage into a receiving tank, from which it is pumped, as required, onto the disposal area of 30 acres, situated not far away. The general method is intermittent filtration, supplemented by broad irrigation. For this purpose an area of about 5 acres at the highest portion of the disposal area was leveled and laid out in absorption ditches. The balance of the field has been provided with a main carrier and distribution ditches, for use as an irrigation area whenever the filtration area is overworked or whenever during the growing season the sewage can be profitably utilized thereon for crops.

The filtration area is divided into three sections, onto each of which the sewage is run for one day, thereby giving two days' rest for a section after each application. The details of this work may be found in various publications in regard to sewage disposal.

Ontario Agricultural College.—Sewage purification by treatment with porous carbon supplemented by filtration through land was carried out at this institution in 1889. The daily amount of sewage averages 3,000 gallons. On its way to the settling tank it receives about 12 pounds of ferozone precipitant daily, and is allowed to settle for twenty-four hours. The effluent is discharged on the filtering ground, which consists of a flat bed of gravel, clay, and loam, 100 by 75 feet in area, divided into two beds, each of which receives on alternate days the sewage for twenty-four hours. These beds are underdrained with tile drains, laid to a depth of from 2½ to 3 feet.

Waterloo.—Waterloo is located 2 miles south of Berlin, the town described previously, with which it is connected by a tramway. The population in 1891 was 2,941. Sewage-disposal works by intermittent filtration were constructed at this place in 1895. For the final works provision has been made for ten filter areas. The soil is sand and gravel. Each bed is 132 by 200 feet, giving an area of 26,400 square feet per bed. This area also includes the embankments, so that the actual purification area is somewhat less. As at Berlin, the sewage will be delivered upon the land without a preliminary screening out of the solid matters, the experience so far gained at the neighboring town of Berlin having indicated that there is little or no necessity for screening. Up to April, 1896, the total expenditure was about $2,000. The cost of the land is stated at about $80 per acre.

Concluding the foregoing account of sewage-disposal plants in the United States and Canada, we wish to state again that in such extreme condensation as is needful in a paper of this kind many important details are necessarily omitted. Complete descriptions of these works would require several hundred pages.

PUBLICATIONS RELATING TO SEWAGE UTILIZATION AND DISPOSAL.

The following books, pamphlets, reports, etc., are in the author's collection and have been consulted frequently in discussing questions of sewage utilization and disposal. There is no pretense to completeness in this list, including, as it does, only such as have been brought together without special effort. The books here included are a fairly good beginning for a library of sewage utilization and disposal and some of the more important cognate questions.

Adams (Julius W.). Sewers and drains in populous districts. 8vo. New York, 1880.

Contains short chapter on sewage disposal.

American Public Health Association, Proceedings of.

American Society of Civil Engineers, Transactions of.

Association of Engineering Societies, Journal of.

Association of Municipal and Sanitary Engineers and Surveyors, Proceedings of. Vols. I–XXI.

Contain a large number of valuable practical papers on sewerage, sewage disposal, and river pollution in England, as prepared by the engineers of the various works. Many of these papers are indispensable to anyone who wishes to study the question from a practical point of view.

Austin (Henry). Report on the means of deodorizing and utilizing the sewage of towns. Paper; 8vo. London, 1857.

Discusses a large number of the more important questions in sewage utilization in such a way as to be of great value to the student of the present day.

Backhouse (Benjamin). An account of Liernur's sewerage system in its present state of development based upon personal inquiry. By the chairman of the city of Sydney Improvement Board. Pamphlet; 8vo. London, 1887.

Baker (Henry B.). Report on best method of disposition of excreta and waste matters, at Harbor Point, Michigan.

Baker (M. N.). Sewage purification in America. Paper; 12mo. New York, 1893.

Baker (M. N.). Sewerage and sewage purification. 16mo. New York, 1896.

Baumeister (R.). The cleaning and sewerage of cities—sewerage, sewage disposal, street cleaning. Translation; 8vo. New York, 1891.

A concise statement of the German views on sewerage, sewage disposal, and street cleaning. Contains illustrations and is especially valuable for the reader who wishes to survey the whole field of the German view without reading a large number of works. As remarked in the introduction, prepared by Rudolph Hering, the American reader should remember that this work was prepared primarily for German engineers and for the conditions prevalent in the German Empire.

Birmingham sewage inquiry. 8vo. Birmingham and London, 1871.

This report contains a very thorough review of sewage purification as it existed in 1871, together with description and cuts of the pail system as used in Liverpool, Manchester, Rochdale, Birmingham, etc. The reader should remember, however, in reading the old reports, that many of the appliances which are illustrated have been improved within recent dates, and that the statements and illustrations can only be safely taken after one has obtained full knowledge of the subject and consequent power of selection.

Birmingham system of refuse disposal. Printed by order of the Birmingham Health Committee. Pamphlet; 8vo. Birmingham, 1893.

Blythe (A. Wynter). A manual of public health. 8vo. London, 1890.

Blythe (A. Wynter). Lectures on sanitary law. 8vo. London, 1893.

Contains twelve lectures on sanitary law delivered by the author at the College of Medicine as part of the usual course of instruction in sanitary science. Examples of by-laws relating to offensive trades, the law relating to adulteration, etc., are given in the appendix.

Boston main drainage works. 8vo. Boston, 1885.

Contains a full account of the construction of the main drainage works of the city of Boston, where, by reason of the nearness of the ocean, it was deemed preferable to dispose of the city sewage by discharge at high tide into the waters of the lower harbor.

Boulnois (H. Percy). Municipal and sanitary engineer's handbook. 8vo. London, 1893.

Brookman (F. W.). Utilization of town refuse at Rochdale. Reprint from the Journal of Society of Chemical Industry, April 30, 1895. London, 1895.

Buck. Treatise on hygiene and public health. 2 vols. 8vo. New York, 1879.

Burke (N. R.). A handbook of sewage utilization. 12mo. London, 1872.

Burn (R. Scott). Outlines of modern farming. 6th edition. 12mo. London, 1888.

Treats extensively among other subjects of the utilization of town sewage, irrigation, etc.

Callis (Robert W.). Lectures on sewers. Large 8vo. London, 1686.

Contains a series of lectures on sewers as delivered by the author, at Grace Inn, in August, 1622.

Chandler (C. F.). Report on the waters of the Hudson River, made to the water commissioners in the city of Albany. Paper; 8vo. New York, 1885.

The author, in 1885, takes the ground that the Hudson River was at the time a proper water supply for the city of Albany.

Chicago drainage and water supply. Preliminary report of a commission consisting of Rudolph Hering, Benezette Williams, and Samuel G. Artingstall. Paper; 8vo. Chicago, 1887.

Clippart (John H.). The principles and practice of land drainage. 3d edition. 12mo. Cincinnati, 1888.

Connecticut State Board of Health, 1884 to 1895, inclusive.

These reports contain a large amount of original work on pollution of water supplies and stream pollution generally as performed under the direction of the State board of health during the period included.

Cooley (Lyman E.).* The Lakes and Gulf waterway as related to the Chicago sanitary problem. Paper; large 8vo. Chicago.

Coplin (W. M. L. and Bevan D.). A manual of practical hygiene. 8vo. Philadelphia, 1893.

Corfield (W. H.). The treatment and utilization of sewage. 3d edition, revised and enlarged by the author and Louis C. Parks. 8vo. London, 1887.

In this work the question of sewage utilization is examined at considerable length, and many useful conclusions are reached.

Crimp (W. Santo). Sewage disposal works. A guide to the construction of works for the prevention of pollution by sewage of rivers and estuaries. 1st edition. 8vo. London, 1890. 2d edition. London, 1894.

Contains descriptions up to date of a large number of the more important English sewage disposal works.

Dempsey (G. D.). Drainage of lands, towns, and buildings. Revised edition with large additions of recent practices in drainage engineering, by D. Kinnear Clark. 12mo. London, 1890.

Denton (J. Bailey). Sanitary works and sewage utilization. Paper; 8vo. London, 1869.

Denton (J. Bailey). Ten years' experience in works of intermittent downward filtration. 8vo. London.

Dibdin (W. J.). Report of experiments on the filtration of sewage effluent (from the London main drainage works) during the years 1892–1895, inclusive. Paper; 4to. London, 1895.

Engineering News. From 1892 to 1897, inclusive.

This journal contains more or less complete descriptions of the more interesting and important of the American works.

Engineering Record.

This journal has published a vast amount of information in regard to sewerage and sewage disposal both at home and abroad, and in 1889 published an index to matter pertaining to sewerage and sewage disposal which had appeared in Vols. V to XVII (December, 1881–June, 1888). There has also appeared a large amount of matter in the volumes from XVIII to XXXIV (the current volume).

Framingham, Massachusetts. System of sewage disposal. A report of a committee on drainage and sewerage and construction of a sewerage system. Statement in detail of cost of construction, plans, etc. 8vo. South Framingham, 1889.

Frankland (Percy and Mrs. Percy). Micro organisms in water, their significance, identification, and removal. 8vo. London, 1894.

Contains a statement of the relation of sewage-polluted water to disease.

French (Henry F.). Farm drainage. The principles, practice, and methods of draining land, etc. 12mo. New York, 1884.

Gerhardt (William Paul). The disposal of sewage at isolated country houses. Paper; 8vo. Providence, 1890.

Gerhardt (William Paul). The disposal of household wastes. 16mo. New York, 1890.

Gerhardt (William Paul). Sanitary engineering. Reprint from the Journal of the Franklin Institute, June–August, 1895. Paper; 8vo. Philadelphia, 1895.

Gray (Samuel M.). Proposed plan of a sewerage system for the disposal of the sewage of the city of Providence. Made by order of the city council of the city of Providence. Paper; 8vo. Providence, 1884.

Contains an account of a large number of sewage purification plants abroad as visited by Mr. Gray, together with recommendations for the partial purification of sewage of Providence by chemical treatment, followed by its discharge into tide water at a point where it could not become a nuisance along the adjacent beaches.

Gray (Samuel M.). Report showing location and size of the main intercepting sewers of the city of Providence and other information called for by the common council by resolutions of various dates in 1886. Paper; 8vo. Providence, 1886.

Griffiths (A. B.). A treatise on manures. 12mo. London, 1889.

Hall (William Hammond). Irrigation in California. 2 vols. 8vo. San Francisco, 1888, 1889. A report on irrigation in California as made by the State engineer.

A good text-book of American irrigation practice.

Harris (Joseph). Talks on manures. New and enlarged edition. 12mo. New York, 1888.

Hawkshaw (Sir John). Report as commissioner appointed to inquire as to the purification of the river Clyde. Paper; 4to. London, 1876.

Contains information as to the pollution of the river Clyde and its tributaries as they existed in 1876.

Hazen (Allen). Filtration of public water supplies. 8vo. New York, 1895.

Contains data as to quality of filtering material, construction of filters, etc.

Hazen (Allen). A practical plan for sand filtration as a means of securing a better water supply to the city of Philadelphia. Report to the Woman's Health Protective Association of Philadelphia. Paper; 8vo. 10 pp. 1896.

Health in country homes. The disposal of sewage. A series of articles reprinted from the New York Evening Post. Paper; 8vo.

Health of Towns Commission. This commission made two reports—the first, 1844, published in two 8vo. vols.; the second, in 1845, also in two 8vo. vols.

These two reports may be taken as the beginning of sanitary science in England and in the civilized world generally. These reports should be studied by any person wishing to study the whole subject of sewage utilization, by way of showing the magnitude of the evil which has been combatted and greatly mitigated since 1844.

Hill (John W.). Sewage disposal and water supply. A paper read before the Ohio Society of Surveyors and Civil Engineers, January 18, 1893. Reprinted for private circulation. Paper; 8vo.

Hill (John W.). Water supplies for eight cities in relation to typhoid-fever rates. An address before the Society of Municipal Improvements, Chicago, October 9, 1896. Paper; 12mo. 8 pp. Cincinnati, 1896.

Hill (John W.). The hygiene of water. A lecture delivered before the Teachers' Institute, Cincinnati, Ohio, September 11, 1896. Reprint from the Dietetic and Hygienic Gazette, October, 1896. Paper; small 4to. 10 pp. 1896.

Hutchinson (Christopher Clarke). On the disposal of sewage sludge. A paper read before the Society of Chemical Industry, February 4, 1884. Paper; 8vo. London, 1884.

Institution of Civil Engineers, Proceedings of. Vols. I–CXX. 8vo. London, 1838–1895.

Contain a large amount of information on river pollution and sewage deodorization, filtration, interception, irrigation, manure, precipitation, and sewage utilization generally. Detailed subject indexes have been issued from Vols. I-LVIII and from Vols. LIX-CXVIII, to which reference may be made for nearly every phase of the subject as discussed in England for the last forty to fifty years.

Johnson (Samuel W.). How crops feed. A treatise on the atmosphere and the soil as related to the growth of agricultural plants. 12mo. New York, 1890.

Johnson (Samuel W.). How crops grow. A treatise on the chemical composition, structure, and life of the plant. 12mo. New York, 1890.

Jones (Charles). Refuse destructors. 2d edition. 8vo. London, 1894.

Contains detailed information as to the result of garbage destruction by fire, as well as a paper on the utilization of town refuse for power production, by Thomas Tomlinson.

Kiersted (Wyncoop). A discussion of the prevailing theories and practice relating to sewage disposal. 12mo. New York, 1894.

The author believes that the rivers of the country are, on the whole, the natural place for disposing of sewage. In his view the natural forces of nitrification will purify the sewage in streams somewhat the same as on land.

Kinzett (C. T.). Nature's hygiene. A systematic manual of natural hygiene. 4th edition. 8vo. London, 1894.

Krepp (Charles Frederick). The sewage question. A general review of all systems and methods. 8vo. London, 1867.

Especially devoted to showing the superiority of the pneumatic system of Capt. Charles Liernur.

Kuichling (E.). Report on the proposed trunk sewer for the east side of the city of Rochester, New York. Pamphlet; 8vo. Rochester, 1889.

Contains a résumé of the various methods of sewage disposal and leans to the conclusion that for the conditions existing in Rochester a chemical treatment would be preferable.

Latham (Baldwin). Sanitary engineering. A guide to the construction of works on sewerage and house drainage. 2d edition. 8vo. London, 1878.

This work was reprinted by Engineering News in 1877.

Lawes (J. Parry). Reports of sewer air investigations, as made to the London County Council. Paper. London, 1894.

Leffmann (Henry) and **Beam** (William). Examination of water for sanitation and domestic purposes. 12mo. Philadelphia, 1889.

Lehmann (K. B.). Methods of practical hygiene. 2 vols. 8vo. London, 1893.

Translated from the German by W. Crooks.

Local Government Board. Reports of the medical officer.

The reports of the medical officer of the privy council and local government board have contained for many years much information of interest and value relating to sewage purification and utilization. The student of the subject will find in these reports a vast amount of important matter. In the supplement to the report of the medical officer for 1891 may be found a study of enteric fever in the valley of the river Lee. In the supplement to the report for 1887 may be found papers giving full statistics of diarrhea and diphtheria in England. The first of these is a report by Dr. Ballard of the cause of the mortality from diarrhea which is observed principally in the summer seasons of the year in English communities, and the second is a statistical study by Dr. Longstaff on the geographical distribution of diphtheria in England and Wales. Dr. Ballard's statistical inquiry included the years from 1880 to 1888, while Dr. Longstaff's included the twenty-six years ending with 1880. The relation of these two diseases to sanitary conditions is set forth in many tables and diagrams with great clearness.

Lowcock (Richard Sidney). Experiments on the filtration of sewage. Excerpt from Proceedings Institution Civil Engineers, Vol. CXV. Paper; 8vo. London, 1893.

Mason (William P.). Water supply, chemical and sanitary. 8vo. New York, 1896.

Contains an excellent statement of drinking water as affected by sewage pollution in its relations to disease.

Massachusetts Drainage Commission, Report of. 8vo. Boston, 1886.

This commission was anthorized by the Massachusetts legislature to consider and report systems of drainage for the Mystic, Blackstone, and Charles river valleys. In 1885 a report of great value was submitted, in which questions of stream pollution and sewage disposal are discussed at length. The engineer of the commission, Elliot C. Clark, also submitted a report in which he gave the details of the problem of prevention of stream pollution and methods of sewage purification as applied to the river valleys named. One of the best of the early American reports.

Massachusetts State Board of Health, Reports of.

This splendid series of sanitary reports now includes 27 volumes of annual reports and 2 special reports on the purification of sewage and water and on the examination of water supplies, besides special reports on the sewerage of the Mystic and Charles river valleys, and on the Metropolitan water supply of Boston, making 31 volumes in all. These are indispensable to any person who desires to study thoroughly the subject of sewage purification and utilization in the United States. Stream pollution, sewerage, and sewage disposal were first discussed in the Fourth Annual Report, and have been discussed in some phase ever since. In the Nineteenth Annual Report may be found the preliminary account of the special experiments on intermittent filtration carried out by the board at Lawrence.

Menzies (William). A treatise on the sanitary management and utilization of sewage. Large 8vo. London, 1865.

Metropolitan sewage discharge. Report of Royal Commissioners. 4 vols. of reports; minutes of evidence; appendixes, etc. 4to. London, 1884, 1885.

Presents every phase of question of disposal of sewage of London as it existed twelve years ago.

Metropolitan water supply, Report of Royal Commission on. 6 vols. General report; minutes of evidence; appendixes; index; plans, etc. 4to. London, 1893.

The most recent and extensive information as to pollution of streams and its effect on the water supply of the metropolis as applied to the rivers Thames and Lee, from which that supply is drawn.

Miles (Manly). Silos, ensilage, and silage. 12mo. New York, 1892.

A practical treatise on the construction of silos and the practical working of the process of ensilage.

Milwaukee, Wisconsin. Report of the Commission of Engineers on the collection and final disposal of the sewage and on the water supply of the city of Milwaukee. Paper; 8vo. Milwaukee, 1889.

Monson (Edward). The advantage of a separate system of drainage. Paper; 8vo. London, 1875.

Monson (Edward). Metropolitan sewage and what to do with it; a scheme of sewage disposal for the metropolis and the author's scheme of drainage for the lower Thames Valley, etc., the whole being a complete system of sewage clarification and purification. 8vo. London, 1883.

Moore (E. C. S.). Sanitary engineering. Occasional papers, Royal Engineers' Institute, being part of the professional papers of the Corps of Royal Engineers, Vol. XVII. 8vo. London, 1892.

Contains concise notes on various matters relating to sewerage and sewage disposal, as prepared specially for the use of the Royal Engineers.

Munroe (John M. H.). Composition and manurial value of filtered pressed sewage sludge. Reprint from the Journal of the Society of Chemical Industry, January 29, 1885. Manchester, 1885.

National Board of Health, Report for 1881.

This volume contains a report of the results of an examination made in 1880 of several sewerage works in Europe by Rudolph Hering. The information given, while extremely valuable in 1880, is of less interest now, by reason of being more recently covered. Mr. Hering gives a literature list which is still of value.

New Jersey State Board of Health, Vols. I–XVIII.

Contains information as to sewage-disposal works and stream pollution in New Jersey.

New York State Board of Health, Reports 1 to 16.

A large amount of information as to sewage disposal and stream pollution may be found in these reports, together with the detail plans of sewage-disposal plants thus far designed for towns in New York.

Palmberg (Albert). A treatise on public health and its applications in different European countries. Translated from the French. Edited by Arthur Newsholme. 8vo. London, 1893.

Contains a review of sanitary administration and legislation in the principal European countries.

Parks (Edward A.). A manual of practical hygiene. Edited by De Chaumont, with an appendix, giving the American practice in matters relating to hygiene, prepared by and under the supervision of Frederick N. Owen. 2 vols. Large 8vo. New York, 1884. From the last London edition.

Parks (Louis C.). Hygiene and public health. 12mo. Philadelphia, 1889.

Pennsylvania State Board of Health, Vols. I–X.

Contain many general discussions on stream pollution, sewerage, and sewage disposal.

Philadelphia Water Department, Annual Reports of the Chief Engineer, 1883 to 1886, inclusive.

These reports contain the results of an investigation as to the pollution of the water supply of the city of Philadelphia by sewage, together with the reports on additional supplies from unpolluted or nearly unpolluted sources, with methods of preventing pollution, etc. They may be referred to for much valuable information on the general question of pollution of streams and its attendant evils.

Philbrick (Edward S.). American sanitary engineering. 8vo. New York, 1881.

Philbrick (Edward S.). The disposal of sewage in suburban residences. Paper; 12mo. New York, 1883.

Platt (S. Sidney). Description of the sewage-disposal works at Roch Mills, Rochdale, England. Paper; 12mo. 4 pp. Rochdale, 1896.

Pollution of water supplies. Report of a committee of the American Public Health Association. Read at the annual meeting at Milwaukee, November 20–23, 1888. Paper; 8vo. Concord, 1889.

Provincial Board of Health of Ontario. Reports 1–4.

Contain information as to sewage-disposal works and stream pollution in the Dominion of Canada.

Rafter (George W.) and **Baker** (M. N.). Sewage disposal in the United States. 8vo. New York, 1893.

This work is dedicated to the health and prosperity of American cities, and contains descriptions and references to practically all the sewage-disposal works in the United States up to the summer of 1893.

Rauch (John H.). The sanitary problems of Chicago, past and present. Reprint from the Second Annual Report of the Illinois State Board of Health. Paper; 8vo.

Reeves (R. Harris). Sewer ventilation and sewage treatment. 12mo. London, 1889.

Contains desciiption of special methods of chemical treatment and ventilation designed by the author.

Rivers Pollution Commission (first commission). 5 vols. 4to. London, 1866, 1867.

This commission made three reports. The first report deals generally with the best methods of preventing the pollution of rivers, with special reference to the conditions prevailing at that time on the river Thames. The second report deals with the river Lee. The third report deals with the rivers Ayr and Calder.

Rivers Pollution Commission (second commission). Report of the commissioners appointed in 1868, to inquire into the best means of preventing the pollution of rivers. 10 vols. 4to. London, 1870, 1871, 1872, 1874.

This commission made six reports in all. The first report, in two volumes, treats of the pollution of the basin of the rivers Mersey and Ribble and of the best means of preventing pollution therein. The second report is taken up with a description of the A, B, C process of treating sewage. The third report, in two volumes, discusses the pollution arising from the woolen manufacture and processes connected therewith. The fourth report treats of the pollution of the rivers of Scotland, and gives special consideration, among other subjects, to the pollution arising from paper-mill wastes, etc. The fifth report, in two volumes, treats of the pollution arising from mining operations and metal manufactures. The sixth report, in one volume, treats of the general subject of domestic water supply of Great Britain. In this report Dr. Edwin Franklin, the chemist member of the commission, has here worked out in detail the method of water analysis which he designated as the combustion method. A large amount of information about water supplies from cultivated and uncultivated areas and the contamination of water from manured and unmanured, cropped and uncropped land is given, the whole forming a vast body of sanitary information pertinent to present conditions.

Royal Sanitary Commission, Report of. Second report. 4to. London, 1871.

Contains a history of the English sanitary laws up to that date, with suggestions for new statute, etc.

Sanitary Institute, Transactions of. Vols. I–XII.

Contains many practical papers on sewerage and sewage disposal. 8vo. London.

Sewage disposal. Report of a committee appointed by the president of the local government board to inquire into the several modes of treating town sewage. Paper; 8vo. London, 1876.

Contains many details of sewerage work carried out in England to that date, with a large number of analyses of raw and effluent sewage at several sewage farms. In appendix No. 7 is given a list of a large number of patented processes for treating sewage and producing artificial manure therefrom, as taken out from between the years 1856 and 1875 inclusive. The report is also accompanied by a folio of plans, giving details of a number of the more interesting sewage-disposal works of that date.

Sewage disposal at Los Angeles, California. A report of the board of engineers upon the disposal of the sewage of Los Angeles city and its sewer system, presented to the mayor and common council of the city of Los Angeles, December 23, 1889. Paper; 8vo. 1889.

Contains the preliminary information as to sewage utilization at Los Angeles.

Sewage disposal at the London, Ontario, Asylum. Report of the Provincial Board of Health of Ontario. Paper; 8vo. Toronto, 1890.

Contains the report and detailed plans as snbmitted by Col. George E. Waring, jr.

Sewage disposal at the Rhode Island State institutions. Seventeenth Annual Report of the Board of State Charities and Corrections of Rhode Island, 1885. Paper; 8vo. Providence, 1886.

Contains the report and plans of Samuel M. Gray upon the disposal of the sewage of the State institutions at Cranston, Rhode Island.

Sewage disposal at the Rochester, Minnesota, State Hospital for the Insane. Sixth Biennial Report of the Trustees and Officers of the State Hospital, Rochester, Minnesota. 8vo. Minneapolis, 1890.

Contains report and detailed plans of the purification works at the Rochester Hospital.

Sewage farm competition of the Royal Agricultural Society of England. Report of judges appointed in the sewage farm competitions. Reprint from the journal of the Royal Agricultural Society. 8vo. London, 1880.

Sewage of the District of Columbia. Report by Rudolph Hering, Samuel M. Gray, and Frederick P. Stearns. Paper; 8vo. Washington, 1890.

Sewage of the Metropolis. Report from a select committee, ordered by the House of Commons to be printed July 14, 1864. Paper; 4to. London, 1864.

This committee was appointed specially to inquire into plans for dealing with the sewage of the metropolis (London) and other large towns with a view to its utilization in agriculture. The committee concluded that it is not only possible to utilize the sewage of towns, but that such an undertaking may be made to result in pecuniary advantage to the rate payers of the towns whose sewage is thus utilized. A large amount of evidence was taken by calling before the committee a number of the eminent engineers and English sanitarians of the day.

Sewage of Towns, Report from the select committee on. Two reports, in 2 volumes. First report ordered to be printed April 10, 1862, and the second report April 29, 1862. 4to. London, 1882.

Sewage of Towns Commission. Three reports. 8vo. London, 1858, 1861, 1865.

These reports contain the detail of elaborate investigations made by a royal commission appointed to inquire into the best mode of distributing the sewage of towns and applying it to beneficial and profitable uses. Elaborate cultivation and feeding experiments were pursued, extending over a period of several years, the resnlts of which were presented in great detail in the second and third reports. In the appendix to the first report may be found an account of a visit made by a committee of the commission to Milan, Italy, for the purpose of examining the sewage utilization works which had been carried out at that place. This committee reported under date of December, 1857, that the experience of the irrigation aronnd Milan adds a striking proof to those already obtained as to the value in agriculture of a command of pure water and of the immense increase of that valne obtained by the addition of sewage combined with the higher temperatnre derived by the liqnid in its passage through the town.

Sewage purification. Return of the particulars of the means adopted by local authorities for the purification or disposal of sewage, as made to the municipal authorities of the borough of Rochdale. 4to. 1872.

Contains details as to the population of towns, area of sewage farms or disposal areas, average rainfall of district, cost of land, number of years in operation, method of managing farm, information as to nuisances from effluent, etc. Also contains the particulars as to a large number of precipitating plants in operation in England in 1872.

Sewage treatment at the Barking and Crossness outfalls. Report by the engineer for the year 1894, ordered printed by the main drainage committee July 11, 1895. The same for the year 1893, ordered printed by the main drainage committee May 31, 1894. Five pamphlets in all. 4to. London.

Sewage utilization at the State Lunatic Asylum at Worcester, Massachusetts. Forty-seventh Annual Report of the Trustees, for the year ending September 30, 1879. Paper; 8vo. Boston, 1880.

Contains plans of the sewage utilization works as carried out in 1876 and as still in successful use at that institution.

Shedd (J. Herbert). Report on sewerage of the city of Providence. Paper; 8vo. Providence, 1874.

Slater (J. W.). Sewage treatment, purification, and ntilization. 12mo. London, 1888.

Largely devoted to description and discussion of special processes of chemical purificafion. Contains a list of patents granted for sewage purification processes by chemical treatment, from 1886, inclusive. The total number of patents listed in that period is given at page 454, of whieh 11 have been taken out by the author of the work.

Snow (F. Herbert). Report on sewer assessments. Paper; 8vo. Brockton, 1894.

Staley (Cady) and **Pierson** (George S.). A separate system of sewerage, its theory and construction. Second edition; 8vo. New York, 1892.

Contains short chapter on sewage disposal.

Storer (F. H.). Agriculture in some of its relations with chemistry. 2 vols. 8vo. New York, 1888.

Professor Storer's two volumes contain a survey of the whole field of scientific agriculture to date. As regards sewage utilization, following the English views of ten to fifteen years ago, he is disposed to say that it can not be made commercially successful. His work should be consulted by every person interested in the subject.

Tidy (C. Meynott). The treatment of sewage. 16mo. New York, 1887.

Tieman (F.) and **Gartner** (A.). Die chemische und mikroskopisch-bakteriologische Untersuchung des Wassers. Paper; 8vo. Braunschweig, 1889.

Tottenham Local Board of Health. A report on the disposal of sewage of the district, made by the Tottenham local board in May, 1870. 8vo. London, 1870.

Turner (George). Report on the outbreak of enteric fever in the southeast of London. Made to the public health department May 18, 1892. Paper; 4to. London, 1892.

Verwaltungs-bericht des Magistrats zu Berlin. Bericht der Deputation für die Verwaltung der Kanalisations Werke.

This is the annual official statement of the committee in charge of the sewerage system of the city. It contains full details as to the management of the sewage farms and the various scientific observations carried out there. It is from these statements that the tables given by Mr. Roechling in his paper on the sewerage works of Berlin have been prepared. The last statement at hand is that of the year from April 1, 1892, to March 31, 1893.

Wanklyn (J. Alfred). Water analysis. Practical treatise on the examination of potable water. 7th ed. 12 mo. New York, 1890.

Wardle (Thomas). Sewage treatment and disposal. 8 vo. London.

While this work has no date on the title-page, the preface is dated June 30, 1893. Its author, Thomas Wardle, esq., is a practicing English chemist of standing, who has himself perfected chemical processes of purification. The work contains much valuable information in regard to recent sewage disposal, and may be profitably consulted, although it is largely devoted to showing the superior value of Mr. Wardle's methods of purification over all others.

Waring (George E., jr.). The sanitary drainage of houses and towns. 4th edition, revised and enlarged. 12mo. Boston, 1883.

An excellent exposition of many of the fundamental questions.

Waring (George E., jr.). Draining for profit and draining for health. 2d edition, 12mo. New York, 1883.

Waring (George E., jr.). Sewage disposal of isolated houses and large institutions. Reprint from the American Architect, March 12 to April 9, 1892.

Waring (George E., jr.). Modern methods of sewage disposal. 12mo. New York, 1894. A second edition has been published in 1896.

Waring (George E., jr.). Purification of sewage by forced aeration. Report of an experimental investigation of the value of the process of purifying sewage by means of artificially aerated bacterial filters. Paper; 8vo. Newport, Rhode Island, 1895.

Waring (George E., jr.). The disposal of a city's waste. Reprint from North American Review for July, 1895. Paper; 8vo.

Waring (George E., jr.). A report on the final disposition of the waste of New York by the department of street cleaning. Paper; 8vo. New York, 1896.

Water supplies of Illinois and the pollution of its streams. A preliminary report to the Illinois State board of health, by John H. Rauch, secretary; with 2 appendixes: (1) Chemical investigations of the water supplies of Illinois, by Prof. J. H. Long; (2) The Illinois River Basin in its relations to sanitary engineering, by Lyman E. Cooley.

The beginning of very valuable studies, which unfortunately for sanitary science have not as yet been continued.

Wheeler (W. H.). The drainage of fens and lowlands. 8vo. London, 1888.

Wilcox (L.). Irrigation farming. A handbook for the practical application of water in the production of crops. 12mo. New York, 1895.

Wilson (George). A handbook of hygiene and sanitary science. 5th edition. 12mo. Philadelphia, 1885.

Worcester, Massachusetts. Reports of the city engineer in relation to the disposal of the sewage of the city of Worcester, made in 1889, in response to a request of the joint standing committee of the common council on sewers.

Contains an interesting account of a number of foreign sewage disposal works visited by the city engineer, as well as opinions of B. S. Brundell and James Mansergh in regard to the probable success of agricultural utilization at Worcester in comparison with sewage utilization in England, basing their opinions on the statements submitted as regards climate, etc. The sewage disposal works at Worcester were completed and put in operation in 1890. More recent reports, those of the superintendent of sewers, give detailed information as to cost of operation and degree of purification obtained. They may be consulted for a complete exhibit of the working from month to month of such a chemical-purification plant.

Worcester sewage and the Blackstone River. Reports on the pollution of the Blackstone River by the Worcester sewage, etc., with a project for the purification of the sewage of Worcester, by Col. George E. Waring, jr.

The French literature on sewage disposal is quite extensive, but is necessarily omitted because of lack of space. A number of new works and reports in English, which have appeared since the compilation of this list, are also omitted because of lack of space.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894-95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Big Horn Range and Big Horn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895-96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett, and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calender year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896-97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton, and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897-98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton, and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

WATER-SUPPLY AND IRRIGATION PAPERS, 1896-1899.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Postage stamps, checks, and drafts can not be accepted. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by W. F. Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Approved June 11, 1896; Stat. L., vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Survey is 1,000. This quantity falls far short of the demand, so that it is impossible to supply all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or who have furnished data. Requests made for a certain paper and stating a reason for asking for it are granted whenever practicable, but it is impossible to comply with general demands, such as to have all of the series sent indiscriminately.

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