SEWAGE DISPOSAL IN CONNECTICUT

REPORT

OF THE

SEWAGE COMMISSION

TO THE
GENERAL ASSEMBLY
OF THE
State of Connecticut

January Session of 1899

HARTFORD, CONN.
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1899

MEMBERS OF THE COMMISSION.

EDWARD H. JENKINS, Ph.D., *Chairman*, New Haven.

ROBERT A. CAIRNS, C. E., *Secretary*. Waterbury.

JOHN S. CHENEY, South Manchester.

JOHN N. WOODRUFF, M.D., Sherman.

FAYETTE L. WRIGHT, Pomfret Center.

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REPORT OF THE COMMISSION.

To the General Assembly of the State of Connecticut:

The Sewage Commission herewith respectfully presents a Report, as required by law.

The General Assembly, at the January Session of 1897, passed the following:

SUBSTITUTE FOR HOUSE JOINT RESOLUTION No. 4.
(462.)

APPOINTING A SEWAGE COMMISSION.

Resolved by this Assembly:

Section 1. That the Governor be and he hereby is empowered to appoint five suitable persons as a commission, who shall serve without pay, except for their expenses, and shall investigate the subject of sewage disposal of the cities, boroughs, and towns of Connecticut.

Sec. 2. Said Commission shall have power to summon witnesses before it, with books, papers, and maps, and, at the conclusion of its investigation, shall formulate a report and submit the same to the next General Assembly.

Sec. 3. Any town, city, or borough may consult said Commission, and obtain its advice concerning sewage systems, methods of sewage disposal, and operations relating thereto, and shall pay to said Commission all expenses incurred by it in any service rendered to such town, city, or borough.

Sec. 4. Except as provided in Section 3, the expenses of said Commission, approved by the Governor, shall be paid by the State to an amount not exceeding one thousand dollars in any one year.

This resolution was approved by the Governor on June 12, 1897, and on September 17, 1897, the following were appointed members of the Commission:

ROBERT A. CAIRNS, C.E., Waterbury.
JOHN S. CHENEY, South Manchester.
EDWARD H. JENKINS, Ph.D., New Haven.
JOHN N. WOODRUFF, M.D., Sherman.
FAYETTE L. WRIGHT, Pomfret Center.

The work of the Commission is summarized in the following

REPORT OF THE SECRETARY.

In accordance with notice sent to each member by Dr. Jenkins, the Commissioners met at Hartford on the 5th day of October, 1897. Organization was effected by the election of Edward H. Jenkins, Ph.D., as Chairman, John N. Woodruff, M.D., Vice-Chairman, and Robert A. Cairns, C.E., Secretary.

On the first day of November of the same year, the Commission met at the Capitol by appointment with Governor Cooke, for the purpose of hearing his suggestions and recommendations in regard to the best course to be pursued in attempting with limited means to secure the results aimed at in the creation of the Commission.

November 15th and 16th were devoted to visiting the sewage disposal works in successful operation at Danbury, Bristol, and Meriden. The Commissioners were given every opportunity to thoroughly examine the workings of each system. The process at each of these works is essentially that defined as intermittent filtration.

December 3d a visit was made to Worcester, Massachusetts. The Commission was met by the Mayor and other city officials and taken in carriages to the Chemical Precipitation Works, at which some eighteen millions of gallons of sewage daily were undergoing the typical chemical process of purification. These works are credited with being in many respects as efficiently managed as any similar works in the world, and the members, as a result of the full explanation of every detail, made by the officers in charge, felt satisfied that they had seen the latest and best phases of this form of treatment.

At a meeting held in New Haven on January 30, 1898, a letter was presented from the engineer employed by New Britain, which asked the Commission to state its probable attitude toward a proposition to discharge the untreated sewage of that city into the Connecticut. As the request did not come from the city itself, the Commission could not consider it in the manner provided for in the act authorizing its appointment, and not having at its command the necessary data upon which a just opinion could be based, the secretary was instructed to make the following reply:

WATERBURY, CONN., January 20, 1898.

Samuel M. Gray, Esq.,
174 Weybossett Street,
Providence, R. I.

DEAR SIR: — At a meeting of the State Sewage Commission held to-day, your letter of December 24th, regarding the disposal of New Britain's sewage, was fully discussed.

This Commission cannot give an opinion on the subject without such information regarding the special conditions existing there as you are now gathering.

If a thorough study of the whole subject is made by you, and the results are submitted to us by the authorities of New Britain, we will then give the matter careful consideration.

The Commission is not provided with means for making such investigation itself.

Very respectfully,
R. A. CAIRNS, *Secretary.*

April 22, 1898, at Meriden, the principal subject for discussion was a request that the Commission visit Norfolk and give advice in regard to sewers and sewage disposal. It was decided to go there on April 28th. This was done, and the day was spent in a general examination of the locality, more particularly as to the best place and methods for disposal.

On May 5th the Commission met at Bridgeport and adopted the following report:

"The Norfolk Sewer District Committee, Norfolk, Conn.:

"GENTLEMEN: — The State Sewage Commission, after examining the local conditions in Norfolk, and carefully considering the problem of sewerage and sewage disposal there, would respectfully advise you as follows:

"That the welfare of the community and the continuance of the town's attractiveness imperatively demand the immediate construction of proper sanitary drains by which all the sewage of that portion of the town included within the limits of the sewer district shall be conveyed outside the district. When this has been done, all those open drains and hidden cesspools, which at present so greatly detract from the beauty and threaten the healthfulness of the village should be disinfected and filled up. The sanitary drains or sewers should be constructed in accordance with the best sanitary principles, nothing essential to their effectiveness being omitted through too great desire for economy. In this connection it should be observed that the employment of an expert sanitary engineer to prepare the general plan and give advice as to material and methods of construction will be found to be a wise investment.

"All storm water should be rigidly excluded from the sewers, and these should be so built as to keep out ground water, so far as possible. Steps should be taken to restrain all unnecessary or extravagant use of water from the Water Company's mains, so far as its use will increase the quantity to be provided for in the sewers and at the disposal plant. These precautions taken at the outset will result in the avoidance of much unnecessary expense and will enable you to accomplish better results with the means at your command.

" In regard to the disposal of the sewage so collected and conveyed to a point beyond the limits of the district, the Commission would advise you that, although a carefully managed disposal works is not necessarily a cause of offense to persons living at a distance of a few hundred feet, yet its location should preferably be somewhat removed from the neighborhood of dwellings.

" Simple subsidence in tanks, proposed as a means of clarifying sewage, does not remove any considerable part of its noxious elements, and is not to be considered for a moment as a method of preparing sewage for discharge into a stream.

" Various patent processes of sterilizing sewage are ineffectual, because, at best, they simply remove from it the germs of putrefaction, but do not destroy the putrescible matter of the sewage, which is speedily inoculated again with the germs in the rivers into which it is discharged.

" The only methods about which enough is known to pass judgment on their merits for any given place are dilution, chemical precipitation, and land filtration.

" The first method, — *i. e.*, discharge of the crude sewage into Blackberry River — we believe is not advisable, because of the objection of riparian owners below, who could, moreover, if a nuisance should be proved, stop the discharge of sewage into the stream, by injunction. If this system were adopted, it would be regarded as being probably only a temporary make-shift.

" Chemical precipitation, while not as effectual as land filtration, clarifies and considerably purifies the sewage, and, if properly done, would give an effluent quite unobjectionable, at present, to discharge into the stream. This system is practiced on a small scale in the town of New Rochelle, and we would suggest that some investigation of it by your committee might be desirable.

" Land filtration is, unquestionably, the most satisfactory system of disposal known at present, because, when properly managed, the foul matter of the sewage is destroyed within the pore of the filter itself. Unfortunately, it cannot be used in all cases, because sand of a certain grain is necessary in considerable quantity for the preparation of the filtration areas.

" We believe that the land of which your Commission now have the refusal might be quite suitable for precipitation tanks, but we do not think it is well suited for filtration beds. The place which was shown to us further down the stream on a sandy ridge covered with white birches appears to be very suitable for sand filtration and irrigation.

" Collection of the sewage of Norfolk by the 'separate' system, so-called, its conveyance below the village to a point on the sandy ridge above mentioned, and its disposal there by intermittent filtration through prepared beds of sands, or by broad irrigation, would seem to this Commission to be one very suitable solution of your local problem.

" The final choice as to which of the methods named should be adopted, and the special form of the disposal work, should be made after consultation with an engineer who is conversant with the details of both systems, and after a careful estimate of the cost of construction and maintenance.

" Allow us to express the hope that your people will proceed with the work of providing sanitary sewerage for your village, and not permit a locality for which nature has done so much to be deprived

of its remarkable advantages because of a distrust of its healthfulness; a distrust which will surely spring up unless the present conditions are speedily remedied."

Very respectfully,
R. A. CAIRNS, ***Secretary.***

At the Bridgeport meeting it was also decided that the Commission should spend two days in viewing works at various points in New York, New Jersey, and Pennsylvania. In accordance with this decision, the Commissioners met at New Rochelle, New York, on June 7th, and were shown the chemical precipitation process used there on a small scale. It appeared to be quite successful as a preparation for discharge into the waters of the Sound, where extensive dilution immediately takes place.

On June 8th the sand filtration beds at Plainfield, New Jersey, and the works at Wayne, Pennsylvania, were studied. The latter process is an interesting illustration of the utilization of a heavy, impervious, and generally unsuitable soil. By pumping the sewage to the top of a considerable slope, and allowing it to flow down through barriers of broken stone and tracts of grass land, considerable purification seems to be effected.

October 19th the Commission met at New Haven, the time being largely devoted to discussion of the report to be made to the General Assembly. It was decided to make a thorough examination of the Naugatuck Valley.

November 2d was spent in viewing the conditions at Derby, Ansonia, and Waterbury.

November 3d the river was examined for some distance below the sewer outlets at Torrington. The filtration fields at Litchfield were visited, and some time was spent in Winsted. The latter place has no system of sewerage.

November 29th the Commission met at Waterbury to consider the report and incidentally to learn something of the progress of the suit then being tried, involving an application for an injunction to restrain the city of Waterbury from discharging sewage into the Naugatuck River.

Upon invitation, the Commission met the Rivers Pollution Commission of New Jersey at the Lawyers' Club, New York city, on January 5, 1899, for the purpose of conference and a general interchange of views on subjects of common interest. We found that the New Jersey Commission was chiefly concerned with the Valley of the Passaic, and was studying the question of how best to divert the sewage which now makes that river very offensive. In a published report a similar commission, previously appointed, recommended a trunk sewer running through the valley, intercepting the sewage of the several cities, and discharging it into Newark Bay. As this body of water is shallow, fears are expressed lest the sewage so discharged should become a nuisance to the communities along its shores. The discussion touched upon the engineering questions involved in sewage disposal, as well as upon the legal and economic features of the problem, and the whole conference proved to be most interesting and instructive.

At a meeting held subsequently on the same day, several hours were devoted to formulating the conclusions and recommendations to be presented to the General Assembly as a part of the report.

R. A. CAIRNS, *Secretary.*

In addition to the work noticed in the secretary's report, the members of the Commission have also acquainted themselves as far as possible with recent work on the general subject of sewage disposal, and have endeavored to learn from personal inspection and all other available sources the present condition and needs of our own State in this regard and the possibilities of improvement.

The Commission has confined its report to a statement of the general system of sewage disposal now in use in this State, a discussion of its merits and its dangers, its effects on the waters of our rivers and harbors, a description of the only methods of disposal which can be substituted for the present one, with suggestions as to the general policy of the State with regard to the sewage disposal of cities.

It will be a disappointment to some that this report does not take up in detail the local problems which confront certain cities, districts, and river valleys of the State, and indicate what should be done for their relief.

Such a work, however, was a physical impossibility in view of the time and means at our disposal. Every city and town presents special problems and engineering difficulties not to be settled offhand by a State Commission, but by the careful surveys, plans, and estimates of a competent civil engineer. No one system of disposal is equally suited to all. The topography of the place, its present size and probable rate of growth, its financial condition and its position with regard to other large places, all have to be carefully considered before recommending a great outlay for sewage disposal. It can hardly be done gratuitously.

It may not be inappropriate to add that the members of this Commission undertook their duties and have done this work fully realizing the disadvantages under which they labored, and the inadequacy of the means provided by the Legislature to the end sought by it, but with the conviction that something ought to be immediately done, and that such a report as has been outlined above will be helpful, as a matter of general information, and in guiding legislation on the subject when it becomes necessary.

As provided in the joint resolution, the services of the Commissioners have been gratuitously rendered. Of the two thousand dollars provided by the State for necessary expenses, there were spent, up to January 16, 1899, $658.17.

NATURE OF SEWAGE.

Sewage is the water-borne waste of a family or of a community. Besides the mineral matters or salts, which are of small importance from a sanitary point of view, household waste contains a great variety of animal and vegetable remains which come from the food, the bathing, washing, and excreta of the household.

The different kinds of domestic waste which go into sewage become about equally offensive and all become dangerous to health if not promptly destroyed. The contents of water-closets may, to be sure, at certain times contain the special germs of typhoid or diarrhœal diseases, but these germs can also live for a time in any household waste water.

Where such diseases exist the excreta of the patient should be burned or all the bacterial life in them absolutely destroyed by disinfection before discharge into the other sewage. Nothing, however, is to be gained by attempting to make any separate disposal of the kitchen water and the excreta.

In any large community, factory wastes of the most varied character form a part of its sewage. To give a single example: Dr. Williston, in a valuable paper on Rivers Pollution (Conn. State Board of Health Report, 1887, p. 175), after thorough study of the matter, estimated that there are annually discharged into Piper's Brook — a tributary of Park

River, which receives the larger part of the sewage of New Britain — the following materials from manufacturing establishments in New Britain, which at that time employed 3,000 men out of a total population of 18,000:

Metal salts, ...	700,000	pounds
Free acids, ...	100,000	"
Lime salts, ...	35,000	"
Alkali salts, ...	100,000	"
Soap, ...	25,000	"
Fatty matters, ...	100,000	"
Vegetable refuse (from cotton, etc.), .	20,000	"
	1,080,000	

" The volume of sewage turned out daily by one manufacturing plant is often as great as the sewage of a village of considerable population, and the organic matters contained in manufacturing sewage are often much greater than in the same volume of town sewage." (Mass. State Board Health Report, 1896, p. 428.) Some factory wastes — from tanneries, wool scouring establishments, and paper mills — greatly increase the difficulty of purifying the sewage into which they are discharged.

The washings of streets and storm water also, which are quite generally led into sewers, largely increase the volume of their flow.

A part of this water-borne waste is solid material, merely suspended in the water, shreds of meat, fragments of vegetables and paper, straw, grease, excrement, etc., which could be removed from the sewage by skimming or filtering. A considerable part of the waste — and by far the more dangerous part from a sanitary point of view — is, unfortunately, dissolved in the water, just as sugar or salt are dissolved, and cannot be removed by any mechanical means. Such things are extracts of meat and vegetables, soap, urine, etc.

It is hardly necessary here to attempt any statement of the chemical composition of sewage. It never has the same composition in any two cities, and in any given sewer the character of the sewage varies with the hour of the day, the season of the year, and the state of the weather. Sufficient for our purpose is the statement of Mr. H. F. Mills, engineer of the Massachusetts State Board of Health, that sewage stronger than the average from American towns contains about 998 parts of water, one of mineral matter, and one of organic matter.

DECOMPOSITION OR DECAY OF SEWAGE.

Fresh sewage, while unsightly, is nearly or quite free from bad odor; but, either standing or flowing, it soon gets an evil smell, which is the sign of putrefactive decay. If left by itself the odor becomes very offensive; if largely diluted the smell is less and may be unnoticeable. If the sewage is distributed over a tract of land no odor may arise from it. Yet, whatever is done with it, the organic matters of the sewage sooner or later decompose and are prepared for assimilation by animals and plants.

This prompt decomposition or decay of sewage is inevitable. Attempts to prevent decay by sterilization with antiseptics must prove abortive. They may retard it, but by so doing only complicate the process and introduce new dangers, which then can be less easily overcome. Besides being inevitable, prompt decomposition is desirable, because by this means only can the wastes of life be so transformed as to become again useful in the economy of nature.

Moreover, the decomposition of liquid sewage does not necessarily involve the giving of noxious vapors or a powerful stench. It may be done, as will appear later, without noxious odors of any kind.

Nature of the Decomposition. — The decomposition of sewage consists in breaking up the very complex bodies that compose it into comparatively simple bodies which do not putrefy, are not dangerous to the community, and are taken up as food by plants and animals. To illustrate: Urine is a highly complex body, useless in its fresh state, and a source of trouble and nuisance because subject to putrefactive decay. But when poured over the ground it is decomposed within it, yielding carbonic acid, ammonia, and afterwards nitric acid, water, and some mineral matters, all of them innocuous and at once available to plant life. If left to stand by itself, or diluted with water, urine likewise decomposes, and if it stands long enough may come to the same thing in the end: water, carbonic acid, and nitrates; but it will reach this end by a slow and roundabout course of chemical changes, forming intermediate products which are an offense to the whole neighborhood. Here are two kinds of decomposition which at last reach the same end and destroy the sewage material; but one of them is rapid, odorless, and safe; the other is slow, offensive, unsafe.

Cause of the Decomposition of Sewage. — It is well understood that the decomposition or decay of animal and vegetable (" organic ") matters is due to the agency of micro-organisms, variously called microbes, bacteria, or germs. These are the most minute living things which we know, visible only under a powerful microscope, exceedingly simple in structure, amazingly prolific and capable of intense activity. There are different kinds or species of bacteria, requiring different media and environment in which to grow, different kinds of food for their support, and yielding different products of their activity. Conditions which favor one kind are deadly to certain other kinds. For example: The species which convert ammonia into nitrous and nitric acids, and which are specially useful in the safe destruction of sewage, require abundance of atmospheric air for their activity. If the air supply is limited they become inactive; if it is cut off, they die. On the other hand, the several species of microbe which cause meat or broth to putrefy cannot be active where much air is present. Perfect aeration, either directly or indirectly, destroys them.

In these days of microbiphobia it needs to be said that the existence of higher forms of life on the globe is dependent on the life and work of microbes; and that the large number of kinds, so far as we know, are perfectly innocuous as well as indispensable to us. Microbes are much like people, good and bad, but for the most part passively good and not actively bad. The microbes which cause specific diseases belong, of course, to the " criminal classes." But the microbes which silently, rapidly, and without offense make plant food out of sewage, and bear the burden of the world's work without proclamation or protest, correspond to the " forgotten man." But most of the talk is of the criminal microbes and their misdeeds, and most of the effort of sanitarians is to avoid injury from them, and many come to regard the whole community of microbes as against us, which is as irrational as to judge of the character of the citizens of Connecticut by observations at the state prison.

Fresh sewage contains a countless host of microbes belonging to a vast number of species, of the most diverse character, and capable of working the most diverse effects on the organic materials in which they live. But the kind of decomposition which sewage undergoes is determined by the kind of microbes which can freely develop and remain active in sewage; and the kind of microbes which can develop and remain active is, in turn, determined by the access or exclusion of air and light, by temperature, and by the chemical reaction of the whole.

These facts are of prime importance, for they furnish the basis of all good systems of sewage disposal. The prompt destruction of sewage, *i. e.*, the conversion of its organic matters into forms which are harmless and can be immediately appropriated by living animals or plants, is the end and aim of any rational system of sewage disposal. This can only be done practically by the work of microbes. Putrefactive processes are slow, a source of annoyance and discomfort, and often a menace to the health of a family or neighborhood. Processes of oxidation are more rapid and complete and are entirely inoffensive. By following certain well-ascertained laws, it is possible to elect which of these processes shall go on, what kind of microbe life shall do the work, and whether it shall proceed harmlessly and unobserved, or dangerously and with an all-pervading stench.

THE HISTORY OF SEWAGE DISPOSAL.

The history of sewage disposal has been much the same in all New England communities. In any new settlement the wastes of the house were used in the garden patch, about favorite fruit trees and shrubs, and over the bit of lawn. The waste water was thus well spread on the surface of the ground, intermittently and in moderate quantity. It was the safest disposal possible; and to this system, in greatly modified form, sanitary science is leading us back as the best system for cleansing the sewage of some of our large cities.

The next step — and in the wrong direction — was to use a sink drain, which ran the kitchen waste, the most evil kind of sewage, on to the land continually in one place and in too large amount for safety. Coarse grasses soon marked the spot, and in summer it was often an offense to the nostrils.

As population became more dense and water was used in large quantity, the cesspool was devised, and the whole dreadful mess was run into it. The cesspool was generally made with no bottom, so the filthy liquids drained off into the soil, while the solid matter was taken out when necessary: the most noisome job that ever fell to the lot of man, and one which stirred the whole neighborhood.

When the straggling village became a closely-built town — and often before then — wells, cesspools, and privies were not always far apart. The ground between them became charged with more filth than it could cleanse, and deodorized sewage and excreta crept into the wells. Then followed typhoid and other ailments. But the well was formerly the last thing to suspect. The well was almost like one of the family. Did not our parents and grandparents, from a "time whereof the memory of man runneth not to the contrary," drink from it? Though the old oaken bucket had given place to the punky pump log, and that in turn to some clanking modern monstrosity, surely the morals of the well itself could not have changed.

Sooner or later, however, enforced by village tragedies, conviction became general that the wells were fouled; and then their owners turned against them, and the *wells* were given up — not the cesspools. A water supply from some stream or lake was introduced, and peace reigned again. The quantity of sewage, however, is greatly increased with the introduction of a water supply which flows instead of needing to be pumped, and so the house drainage sometimes overtaxed not only the cleansing, but even the absorptive power of the soil. Gradually, too, it came to be understood that even where drinking water was not fouled, the discharge of liquid filth into the soil of a thickly-settled place may be dangerous to the public health; that people within city limits as a rule cannot cleanse their waste water on their own premises, nor can they be trusted to carry it off in a way which is unobjectionable. Hence the municipality, in the public interest, undertook this work, and built a sewer system to secure perfect drainage for houses, and generally for streets as well.

This sketch marks in a general way, and with the inherent defects of any mere diagram, the general course of things up to the present time. Many still fondly cling to the cesspool, some even make a cesspool of the disused well, and, if not stopped by the health board, will run the liquid waste from their houses into it, only connecting its *overflow* with the sewer.

In any thickly-settled community a sewerage system is at present a necessity, being the only practicable means of gathering and removing sewage before it becomes putrid and intolerable.

SEWAGE DISPOSAL IN CONNECTICUT.

There are in this State eighteen cities, which, according to the estimates of the State Board of Health (derived from the school census) had a population in 1896 of 481,000 (in some cases this includes the town, the boundaries of which include more than the incorporated city), being more than half the total population of the state (816,712). All of these cities have water supplies, and all, excepting Putnam, sewerage systems. The cities of Meriden and Danbury purify their sewage by land filtration. All the other cities discharge their sewage into water-ways: — " water carriage and dilution."

There are twenty-two boroughs in Connecticut, seventeen of which have a water supply, and eight have a sewerage system or at least some sewers. Of these, Bristol and Litchfield purify their sewage by land filtration. In other places the sewers discharge either into swamps or water-ways. In addition to these, seven towns have a water supply and some sanitary sewers, which discharge crude sewage.

There are twenty-one other towns which have a water supply but no considerable number of sewers. The particulars regarding these cities, boroughs, and towns appear in following tables, pages 18 to 20, which have been compiled from data given in Baker's Manual of American Water-works, 1897, and in Connecticut Board of Health Report, 1896, p. 341, with some additional details obtained by correspondence.

WATER SUPPLY AND SEWAGE DISPOSAL OF CONNECTICUT CITIES.

City or Town.	Population.	Source of Water Supply.	Sewer System.	Means of Sewage Disposal.
Ansonia, ...	13,000	Beaver brook and springs,	Sanitary and storm,	Naugatuck River.
Bridgeport,* ..	65,000	Poquonnock, Mill and Horse Tavern Rivs.,	“ “	River and Harbor.
Danbury, ...	19,473§	Surface water, impounding reservoir,	“ “	Land Filtration.
Derby, ...	8,500	Springs, small streams, impounding res'v'r,		
Hartford, ...	65,000	Brooks, impounding reservoirs,	“ “	Housatonic River.
Meriden, ...	30,000	Surface water, pumped,	Sanitary,	Connecticut River.
Middletown, ..	18,000	Laurel Brook, and stream from Higby		Land Filtration.
		mountain impounding reservoir,	Sanitary and storm,	Connecticut River.
New Britain,..	25,000	Shuttle Meadow Lake, Roaring Brook, and springs,		Piper's Brook via Park River to Conn. River.
New Haven,...	96,000	Lakes, impounding reservoir,	“ “	Rivers and Harbor.
New London,..	15,500	Lake Konomoc,	Sanitary only,	Thames River.
Norwalk,† ...	10,000	Silver Mine Brook and impounding res'v'r,	Sanitary and storm,	Norwalk River.
Norwich, ...	25,000	Brooks, springs, impounding reservoir,	Sanitary,	Thames River.
Putnam, ...	6,884	Roseland Lake, Little River,	Storm drains only,	Quin'g Riv. to Th'mes Riv.
Rockville, ...	9,000	Schenipsit Lake,	Sani'y sep'ate sys.,	Hockanum River.
So. Norwalk,‡	7,000	Brooks, surface water, impounding res'v'r,	Sanitary,	Norwalk River and South Norwalk Harbor.
Stamford, ...	18,000	Mill River, impounding reservoir,	Sanitary and storm,	Mill River (?).
Waterbury, ..	40,000	E. Mount. & Mad Riv's, west br'ch Naug.,	“ part'l st'rm,	Naugatuck River.
Willimantic, ..	10,000	Natchaug River,	Sanitary and storm,	Willimantic River.
	481,357			

* Water supplies Easton.

† Also supplies Winnepauk and South Norwalk.

‡ Also supplies East Norwalk.

§ Census of 1890.

WATER SUPPLY AND SEWAGE DISPOSAL OF CONNECTICUT BOROUGHS.

Borough.	Source of Water Supply.	Public Sewer System.	Sewage Disposal.
Bethel, ...	Surface water, impounding reservoir filter,	Sanitary and storm,	Saugatuck River.
Branford, ...	Water-works under construction,	None,	———
Bristol, ...	Springs, surface water, and Poland River,	Sanit'y and partial storm,	Land Filtration.
Colchester, ...	None,	None,	———
Danielson, ...	Higgins Brook,	None,	———
Fair Haven East,	Same as City of New Haven,	None,	Private dr'ns to Quin'piac.
Greenwich,* ..	Streams, imp'nding res'v'r, mechanical filter,	Sanitary,	Long Island Sound.
Guilford, ...	None,	None,	———
Jewett City,...	Impounding and storage reservoir,	None,	———
Litchfield, ...	Griswold Brook, driven wells,	Sanitary,	Land Filtration.
Naugatuck, ...	Straitville Brook,	Partial sanit'y and storm,	Naugatuck River.
New Canaan,..	Springs and Five-Mile River,	None,	———
Newtown, ...	None,	None,	———
Ridgefield, ...	None,	None,	———
Shelton, ...	Surface water, Curtis Brook,	Sanitary and storm,	Housatonic River.
Southington, .	Humiston's Brook, impounding reservoir,	None,	———
Stafford Springs,	Roaring Brook, impounding reservoir,	Partially sewered,	Willimantic River.
Stonington,‡ ..	Mistuxet Brook,	None,	———
Torrington. ...	Surface water, impounding reservoir,	Sanitary,	Naugatuck River.
Wallingford, ...	Lake Pistapaug,	Sewers,	Quinnipiac River.
West Haven,..	Springs, pumped to reservoir,	None,	———
Winsted, ...	Mad River, Rugg Brook, Highland Lake,	None,	———

* Port Chester and a part of Rye and Belle Haven also supplied.

† Plantsville also supplied.

‡ Groton and Mystic also supplied,

The following towns also have some sewers:

Town.	Water Supply.	System of Sewers.
East Hartford,..	Springs, Salem Br'k, impounding reservoir,	Partial sanitary and storm.
Farmington,...	Springs,	Sanitary, separate system.
New Milford,..	Surface water, tributary of Great Brook,	Sanitary and storm.
Norfolk,.......	Lake Wangum,	Separate system.
So. Manchester,	Small brooks and springs,	Sanitary and partial storm.
Thomaston,....	Springs and small brook,	Partial sanitary and storm.
Thompsonville,	Springs and distributing tank,	Sanitary.
Unionville,.....	Springs and stream,	Storm sewers.
Westport,.	Wells and stand pipe,	Partial storm.
Windsor,......	Springs,	Sewers.

The following towns have a partial water supply:

Town.	Water Supply.	Town.	Water Supply.
Canaan, ...	Springs and impounding reservoir.	Plainville, ...	Crescent Lake, surf'ce water.
Durham,..	Cold Spring.	Portland,.	Somasic Br'k and impounding reservoir.
Granby, ...	Salmon Brook.		
Hazardville, ..	Springs, pumped to tank.	Preston,.......	Spring.
		Sharon,..	Springs and Beardsley Pond.
Kent,.........	Br'k & small springs.		
Lakeville,.....	Mountain stream.	Simsbury, ...	Surf'e water of str'ms, spr'gs & imp. res'r.
Newington,...	Springs and stream.		
Manchester,...	Ponds and streams.	Terryville,....	Springs.
New Hartford,	South Mt. Brook.		
North Canaan,	Springs and impounding reservoir.	Winds'r Locks,	Spring & stand pipe.
No. Manch'st'r,	White's Br'k and impounding reservoir.	Woodbury,....	Brooks and springs, imp'ding reservoir.

To recapitulate: All of our cities have a water supply, all but one are sewered, and with two exceptions all are discharging their sewage into water-ways. Of our twenty-two boroughs, next to our cities the most thickly-settled districts, while seventeen have water supplies, only eight have any sewers, and six of these do not cleanse their sewage. The construction of sewers will be taken up by these boroughs as population increases, in a more or less haphazard way; and, if conditions continue as they are now, their sewage will probably be disposed of by water carriage for the most part.

Sewers will be built, because when a water supply has been introduced, as we have explained before, the evils arising from cesspools and drains are aggravated, and it becomes in time a necessity to remove the sewage from the neighborhood, increased in quantity by the introduction of a water supply. Passing from the boroughs to the towns, we find ten which have both sewers and a water supply, and all discharge sewage into water-ways. Nineteen other towns have a water supply but no sewers. In these places, no doubt, a considerable amount of sewage finds its way into streams, and the amount will increase rapidly with the growth of the towns and the inevitable introduction of sewers.

It is not necessary to make any estimate of the quantity of sewage daily or yearly poured into our streams, nor of the precise number of population which contributes to this discharge. It is probably true that the sewage of half of our population is poured uncleansed into our water-ways, and that the gross amount of sewage, as well as the proportion of population contributing to this pollution of our streams will increase in the ordinary course of things with the growth of our centers of population and the introduction of water-works and sewerage systems.

THE ULTIMATE DISPOSAL OF WATER-BORNE SEWAGE.

As most of our sewage is poured into streams or bays, we must follow it further to find out what finally becomes of it. If sewage is simply taken away from under our own sight and noses, to decompose under the sight and noses of another community, however remote from us, or to be put where it will accumulate and in time create a nuisance, it is neither good morals, good law, nor common sense to regard this as a "disposal." It is, therefore, necessary to inquire whether the ocean and our large streams which receive our sewage discharge can destroy or, rather, so transform its elements as to render them quite harmless and available as food to animal and vegetable life.

SEWAGE DISPOSAL IN THE OCEAN.

The ocean is not simply a great sink or cesspool to receive the offscouring of the nations and hide it. Nature has no cesspools.

As soon as sewage meets salt water the clay or mud flocks together and begins to sink. Sea birds gather what food they can from the solid parts of the sewage and fishes also feed upon it. With the fishes are included all the lower forms of animal life, some of them almost microscopic, which abound in sea water and feed wholly upon the solid matter suspended in it. These all are the ocean scavengers.

But the most dangerous and elusive things in sewage, those which are the hardest to manage in any system of treatment, are the nitrogenous matters, animal and vegetable, which are not suspended but are dissolved in the water, and are thus beyond the reach of birds or fish or any kind of animal life.

The algae and other higher forms of aquatic vegetation cannot live in concentrated sewage, but when it is sufficiently diluted they feed upon its dissolved elements, take them into their structure and assimilate them, thus making them innocuous. It is stated that under suitable conditions the algae can decompose volatile fatty acids, indol, skatol, and other offensive soluble matters of sewage. (Bokorny, Archiv. Hyg., 1894, **20** p. 281, ref. Jahresber. Ag. Chem., XVII, p. 49.)

But the soluble elements of sewage, whether concentrated or diluted, are undoubtedly decomposed and returned to living forms by the agency of bacteria living in the sea. The studies of Russell (*Botanical Gazette*, 1892, XVII, p. 312, and 1893, XVIII, pp. 411 and 439) indicate that while the microbes of sewage and of fresh water soon perish in sea water, species of bacteria peculiar to the ocean are found at all depths. Thus in Mediterranean sea water, from surface to bottom, 3,200 feet, bacteria abound in nearly the same proportion at all depths, below the limit of constant temperature, 280 to 4,200 individuals per fluid ounce, from 10 to 150 per cubic centimeter. The sea bottom is inhabited by active bacteria in vastly greater numbers than the water. This bacterial life is indigenous there, being different in kind from that of the water above. Now this bacterial life is believed to depend for its existence on the soluble nitrogenous matter in the sea water, taking energy from the polluted matter and breaking it up into simpler and harmless forms.

Much remains to be learned regarding the various forms of marine life in their relation to sewage disposal, but we know enough to convince us that the sea is not a mere diluent of sewage; it is no cesspool. It gathers up the wastes of human life, restores energy to them, and returns them to us clean and wholesome.

> "Ever at toil, it brings to loveliness
> All ancient wrath and wreck."

Much has been said by some writers of the enormous waste of fertilizing material which is annually poured into the sea in sewage, and attempts are continually made to extract from the filth, which goes to make up sewage, some valuable fertilizer for land. It would be an economy if this could be done without offense or danger to public health, and by suitable arrangements it is possible under some conditions to use sewage directly as a fertilizer, thus cleansing it and securing its fertilizing elements at the same time. But it needs also to be remembered that fertilizers poured into the sea are not forever wasted; that to a large extent — we cannot judge how large at present — they are again converted into human food, in part directly, without the intervention of vegetation, and are given back to us by our fisheries. Huxley estimated that the annual product of an acre of arable land is the equivalent of one ton of grain or 200 to 300 pounds of meat or cheese, "while an acre of sea bottom, in the *best fishing ground*, yields a greater weight of fish every week in the year."

SEWAGE IN STREAMS, "SELF-PURIFICATION" OF FLOWING WATER.

More immediately important is the inquiry whether our inland waters, the small streams and large rivers of our State, can purify sewage which is poured into them. Is sewage actually destroyed in considerable amount in our streams, or are its putrescible matters resolved into harmless forms?

That streams which receive moderate quantities of sewage do, in some cases, become purer after flowing for even quite moderate distances is certain. There is still wide difference of opinion as to the possible limits of this self-purification, and the practical effect of it in making a stream, once polluted, again suitable for domestic use and in preventing nuisance to riparian property-owners. There is, however, practical agreement as to the fact of some purification and as to the purifying agencies in streams. The means of self-purification are sedimentation, dilution, chemical oxidation, biological oxidation caused by microbes, and the agency of animal and vegetable life.

Sedimentation. — The amount of sedimentation depends on the rate of flow of the stream and the character of the sewage. If either carries with it much sand, silt, or clay, the deposit of organic matter from the sewage will be much larger than otherwise when the river flow is slow enough to permit deposit at all. The matter deposited from sewage on the bottom of a river does not decay very rapidly; it silts up the river bed; as in the Thames near London, where it is stated that the sewage deposits are deeper than the waters of the river. When exposed by subsidence of the stream in summer it may cause a nuisance by putrefactive decay; in spring freshets it may be scoured away by the flood, and either borne out to sea, left on flowed meadows, or deposited in the river bed further down. While at any time such deposits would menace a water supply taken from the stream below them, and while, as shown by the observations of MacAdam (Jour. Roy. Micr. Soc., 2d Ser., Vol. IV, Feb., 1884, p. 1, ref. Rafter, Sew. Disp. in U. S., p. 94) the organic constituents of human excrement can be identified, even in muds which have been deposited a considerable time, it seems likely that some slow putrefactive decomposition goes on in a sewage mud, yielding gases which rise to the surface, and a residuum which is somewhat less rapidly putrescible when again mixed with the waters of the stream. But the real purification effected by sedimentation is surely very uncertain and insignificant.

Dilution of sewage makes the pollution less evident and tends to absorb evil odors, preventing their rapid escape into the air. But the purifying effect of dilution is due solely to the additional oxygen thus supplied to forms of animal and vegetable life which prey upon the solid and dissolved elements of the sewage, as will be noticed later.

Chemical Oxidation. — The slow oxidation of some kinds of dead organic matter was formerly thought to go on even at moderate temperatures by the union of the free oxygen of the air, either directly or by means of some "carrying agent," with combustible material, just as wood oxidizes or burns in a stove; the visible effects — smoke, heat, and light — being masked in the former case by the slowness of the process. Recent study has shown that in the cases under experiment this oxidation took place actively in the presence of microbic, bacterial life, less actively when this life was for any reason less active, and that it ceased altogether whenever microbe life was excluded, though all other conditions remained unchanged. The conclusion is justified that this microbe life is an efficient, if not the sole, cause of the oxidation. Hence investigators have come to regard chemical oxidation of organic matter as of minor importance in flowing streams, some questioning whether it has the slightest practical effect, and to ascribe the disappearance of organic matters to the agencies named below.

Biological Oxidation. — By this is meant the oxidation (burning) of organic matter through the activity of living micro-organisms (microbes, bacteria). We have elsewhere noticed the nature and work of these organisms, and here only call attention to the oxygen of the air as related to them. Air is inimical to that kind of bacterial action which causes putrefactive decay and the foul odors always attending it. On the other hand, air — or rather the oxygen which makes up one-fifth of its volume — is essential to the bacterial action which oxidizes or burns the elements of sewage, without giving off foul odors. To expose sewage freely and fully to the air in the presence of these bacteria under suitable conditions of heat and moisture is to ensure its destruction quietly and without offense. Now water dissolves air, and nearly 35 per cent of the dissolved air consists of free oxygen. (Roscoe & Schorlemmer, Treatise on Chem., Vol. I, p. 244.)

The following table shows the amount of dissolved gases contained in Thames water taken at different points. (R. & S., *loc. cit.*):

DISSOLVED GASES IN WATER OF THE THAMES RIVER (ENG.) AT THE PLACES NAMED.

	Kingston, cubic centimeters.	Hammersmith, cubic centimeters.	Somerset House, cubic centimeters.	Greenwich, cubic centimeters.	Woolwich, cubic centimeters.	Erith, cubic centimeters.
Total volume of gas per litre, .	52.7	....	62.9	71.25	63.05	74.3
Carbonic acid, . .	30.3	....	45 2	55.6	48.3	57.
Oxygen, ...	7.4	4.1	1.5	0.25	0.25	1.8
Nitrogen, . . .	15.0	15.1	16.2	15.4	14.5	15.5
Ratio of Oxygen to Nitrogen, .	1:2	1:3.7	1:10.8	1.61	1:58	1:8.6

The sample at Kingston is tolerably pure river water; the others are contaminated and mark the increasing pollution of the stream as it flows to the sea. The pure water contains 7.4 parts or quarts of oxygen dissolved in 1,000 quarts of water. In some way, entirely unknown to us, the microbes everywhere present in the water attack the organic matter, a small quantity of sewage, for example, and *with the help of the dissolved oxygen* burn the carbon to carbonic acid, and, if the operation is completed, leave the nitrogen combined with hydrogen to form ammonia. This in turn is oxidized to nitrous acid, and lastly to nitric acid, which is combined with mineral matter to form nitrate. The end products are carbonic acid, ammonia, nitrates, all of them perfectly innocuous in the stream and all readily available to plant life. This, in brief outline, is the present belief regarding sewage disposal by oxidation.

It can only be done where oxygen is constantly and abundantly present. If the supply is limited, carbon in the sewage will be destroyed as far as it can be, but there will be no nitrification (oxidization) of ammonia, and as the supply of oxygen decreases, less of the carbon is destroyed. When the oxygen is used up, all purification by this means ceases, the oxidizing bacteria cease to work, and the bacteria of putrefaction begin. The oxygen removed from water by these processes is replaced in time from the air, but not quickly enough, probably, to keep pace with rapid oxidation induced by bacteria, at least to any distance below the surface.

The more sewage is poured into a stream the greater the demand for oxygen and the less is present to meet this demand. The table above given shows this.

At Kingston, where the water was pure and no demands for free oxygen in it, there were 7.4 quarts of oxygen in every 1,000 quarts of water. At Hammersmith, where the stream contained sewage and "self-purification" was called for — and doubtless taking place — only 4.1 quarts; at Somerset House, 1.5 quarts; at Greenwich — a grossly polluted part of the river — half a pint of oxygen, only 1-30 the amount which the pure river water had.

When a clean tributary empties into the foul stream it brings with it free oxygen, and in this way dilution assists purification. As long as an abundance of free oxygen is present, self-purification may go on in rivers. Sewage itself contains none of it, and every addition of sewage reduces the supply of oxygen in the stream. Oxygen is dissolved constantly from the air by the stream, but by no means fast enough to supply the needs of the bacterial life in strongly polluted waters.

Pouring filth into flowing water is a very slow and dangerous way of destroying filth, but a short and easy way to destroy pure water.

The Agency of Animal and Vegetable Life. — This has already been alluded to in the discussion of sewage purification in the ocean, but we return to it here because we have somewhat more definite information regarding the animal life in sewage-polluted streams.

Among microscopic or extremely minute forms of animal life are certain kinds which are found in the greatest abundance in filthy water, and devour the solid matter in sewage, however finely divided it is. There is no evidence that the dissolved matter is used by them.

A very interesting account of them is given by Rafter in the Trans. Am. Soc. C. E., Vol. XXIV, pp. 70-76, from which some of the following statements are taken: As common representatives are (1) certain filth infusoria,[*] (2) certain hydroids, (3) certain rotifers, (4) numerous species of entomostracans which are probably the animals which do most service, (5) the fresh water shrimp, (6) the larvae of water insects. All of these forms multiply with prodigious rapidity under favoring conditions. The definite action of the entomostracans has been studied by Dr. H. C. Sorby (Jour. Roy. Micr. Soc., 1884, pp. 988-991). He says:

> "It is known that entomostraca will eat dead animal matter, though probably not entirely dependent on it. I have myself proved that they may be kept alive for many months by feeding them on human excrement, though they soon died without it. In stagnant,

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[*] It is not easy to give a description of the low forms of life here referred to which will be clear to those who are wholly unacquainted with them.

The *protozoa* are animals of the simplest form consisting of a single cell or having several cells alike in structure and use.

The *infusoria* are protozoans, mostly microscopic in size, aquatic and free-swimming by means of motile fibers.

The *hydroids* are animals, plant-like in form, very simple in structure, soft and gelatinous.

The *rotifers* are microscopic animals, having a head with circles of motile fibers about it, which, under the microscope, appear like revolving wheels, hence the name. They have an intestinal tract. The tail is well marked and variously modified for swimming, skipping, creeping, or rooting.

The *entomostraca* are much higher in the order of being than the classes named above, and may be well described as minute animals much resembling shrimps.

The *algae* are water plants varying greatly in shape from the delicately branched seaweeds to shapeless jelly-like masses.

The *confervoid algae* are many-celled green, thread-like plants, which form a green "scum" in stagnant pools.

The *diatoms* and *desmids* are single-celled microscopic algae, the former distinguished by their silicious coating.

muddy pools, where food abounds, I have found an average of 200 per gallon. In the case of fairly pure rivers, the total of free swimming animals (not small enough to pass a sieve with meshes 1-250 in. in diameter) is not more than one per gallon. I found, however, that where what may be called sewage was discharged into such water, the number per gallon rose to 27, and the percentage relationships between the different groups of entomostraca were greatly changed.

"There is, however, a very decided limit to the increase of entromostraca when the water of a river is rendered very impure by the discharge of too much sewage, probably because oxygen is deficient, and free sulphide of hydrogen present.

"We thus appear to be led to the conclusion that when the amount of sewage discharged into a river is not too great, it furnishes food for a vast number of animals, which perform a most important part in removing it. On the contrary, if the discharge be too great, it may be injurious to them, and this process of purification may cease. Possibly this explains why in certain cases a river which is usually unobjectionable may occasionally become offensive. It also seems to make it clear that the discharge of rather too much sewage may produce relatively very great and objectionable results."

Dr. Sorby suggests the possibility of the destruction of disease germs by minute infusoria as a fruitful field for further study. He also alludes to the vegetable life in polluted water, diatoms, desmids, and confervoid germs, and to the important office they may perform in decomposing carbonic acid — only in presence of light — and thus freeing oxygen for the use of animal life and counteracting putrefactive decay.

Regarding the fate of these low forms of life which appropriate sewage in polluted water, Prof. S. A. Forbes of the Illinois State Laboratory of Natural History has made important observations.

He finds "that the earliest food of the whitefish consists almost wholly of the smaller species of entomostraca"; "that the young *cyprinidae* (minnows) draw almost indiscriminately for their food supply upon protozoa, algae, and entomostraca." Entomostraca furnish 92 per cent. of the food of young perch, and from 50 to 70 per cent. of that of young bass, sunfishes, and pickerel. "I find that, taking together the young of all the genera studied, considering each genus as a unit, and combining the minute dipterous larvae with the entomostraca as having essentially the same relation, about 75 per cent. of the food taken by young fishes of all descriptions is made up of these elements."

Our knowledge of the food supply of the lower orders of animal life is still very meager, but enough is known to show the interdependence of all forms of animal life and that individual death and decay are not the end, but merely an incident, of the world's life and growth.

It may be asked, if the elements of sewage are noisome and contain the germs of disease, can the fish which feed upon these things be wholesome? They can. Fish are so organized that they can take with impunity, and digest and thus convert into their tissue, things which would be repulsive, indigestible, and unhealthful to man. And, after this making over, the product — fish food — is easily digestible and healthful to man. These disease germs of the sewage are very likely destroyed in the digestive tract of the fish; if not, they leave the body in the excrement. Certainly they do not continue to live in the tissue of the healthy fish. Even were that true, they would be destroyed in the cooking which fish always receive.

The sewage destroyed by animal life in our rivers is limited to the solid matter which is in suspension in water. Animals do not, as far as we know, utilize the dissolved matter.

Such are the means by which nature strives to prevent putrefaction in streams, and to take up promptly into new life the wastes of other life. Obviously, large quantities of foul matters may be disposed of in the ways just indicated. The vital questions are: How much can thus be cleansed? What is the precise relation between the volume of sewage and the volume of water necessary for its cleansing? What amount of time or distance of flow is required? No definite answer can be given, and there is very great discrepancy of opinion.

One of the most satisfactory series of observations on the self-purification of streams which has been noted by the Commission is found in Illinois State Board of Health, Ninth Report (referred to by Rafter, Sewage Disposal in U. S., p. 66).

At Bridgeport, the sewage-polluted water of the South Branch is pumped into the Illinois and Michigan canal and flows through it past Lockport, twenty-nine miles below. Between these points the canal receives nothing but the rainfall and some slight infiltration, stated to amount to nothing. When the tests to be referred to were made, summer of 1888, the pumps at Bridgeport, in continual action, discharged into the canal 50,000 cubic feet per minute, an amount on an average for each whole day about seven times in excess of the total of sewage flowing into the river from all sources. No water plants grow in the canal, the frequent passage of boats stirs up the canal to the bottom, the current itself prevents sedimentation, and frequent dredgings prove that there is no deposit of sewage. The place would seem an ideal one to study the joint effects of chemical and biological oxidation, and possibly of the destruction of sewage by minute animal and vegetable life; in other words, the self-purification of an ordinary stream receiving a large quantity of moderately dilute sewage, where the effects of subsidence, dilution, and conspicuous marine vegetation were eliminated.'[1]

Between May 1st and November 15th Professor J. H. Long made 750 analyses of water collected at the two points named, to determine how much sewage matter was destroyed between Bridgeport and Lockport. The average of all analyses from May to October, inclusive, is shown in the following table:

ANALYSES OF THE WATER OF THE ILLINOIS AND MICHIGAN CANAL.

Parts per 100,000.

	Total Solids.	Matters in Suspension.	Nitrogen in Nitrates.	Chlorine.	Hardness. Ca CO_3	Free Ammonia.	Albuminoid Ammonia.	Oxygen Consumed.
Bridgeport, . .	47.12	12.92	0.0	4.68	20.13	1.23	0.26	2.21
Lockport, . . .	43.12	6.98	0.0	4.61	20.77	1.08	0.20	1.62
Difference, . . .	4.00	5.94	0.0	0.01	0.64	0.15	0.06	0.59
Percentage decrease,	8.5	46.0	....	....	.....	12.2	23.1	26.7

Assuming that the total solids include matters in suspension, it would appear that at Lockport, while the total solid matter has been reduced by some 8½ per cent., *the solid matter in solution* has increased by 5.6 per cent.; that is, a considerable amount of suspended matter has been dissolved by the canal water between Bridgeport and Lockport. The " free ammonia " has been reduced by 12 per cent., and the " albuminoid ammonia" — our best measure of the nitrogenous organic matter — by 23.1 per cent.

At this same rate of purification, supposing no tributaries enter the stream, it would require a flow of 125 miles to clean the water as perfectly as it is ordinarily done by sand-filtration (90 per cent.), but the same rate of purification could not be maintained.

Prof. W. P. Mason states (Rafter and Baker, Sewage Disposal in the U. S., p. 69) "that the rate of purification varies directly as the amount of sewage contamination," and that "given a stream with a certain amount of pollution, the per cent. of such pollution which must disappear per mile of flow will continually decrease as the stream flows on." But without further discussion it is evident to the layman that the removal of 23 per cent. of the putrescible matter in polluted streams, in a flow of twenty-nine miles, is not a "purification" which can be of great practical account in the rivers of this State.

A somewhat careful study of the observations made on the self-purifying power of streams convinces us that, while the causes which effect this cleansing are probably understood, it has not been possible to measure their quantitative effects in water polluted with so nondescript and varying a material as sewage; that the self-cleansing must vary daily with temperature, flow of stream, quantity of sewage, and many other conditions, and that the statements as to the quantity of sewage which can safely be turned into a given stream are nothing more than the guesses of intelligent people with quite different ideas as to what constitutes "safety."

Streams undoubtedly have some self-purifying power. But as the free oxygen in a stream is diminished, the self-purifying power of the stream is diminished, and at the very time when the need for it is increased.

The question of how much sewage is permissible in the smaller streams of this State is specially difficult to answer, because the volume of water varies so enormously with the season. What is a raging torrent in spring becomes a very tame rivulet in August. In April certain streams could carry much more sewage than is run into them without creating any nuisance. In July and August the same streams would scarcely flow at all but for the sewage that makes them foul and offensive. The capacity of a stream for safe sewage disposal is its capacity measured when the natural waters of the stream are at their lowest, and conditions favor active putrefaction.

THE SYSTEM OF WATER CARRIAGE AND DILUTION.

When sewage can be carried to the ocean by a natural stream without injury to any riparian owners or the defilement of any water supply, this is unquestionably in most cases the cheapest and best method of disposal. New York is the most favorably situated of all our cities in this respect. The strong tides on both sides, twice daily, sweep out the city sewage into the deep waters of the sound and ocean, and as yet there is no evidence of any objectionable feature in this. It was the garbage, not the sewage, of New York which formerly made trouble along the shores of the lower bay and beyond.

The city of Boston, not so favorably situated as New York, pumps sewage into a receiving basin on Moon Island several miles below the city, near the harbor mouth, from which it is discharged twice daily into the young ebb tide. (See Mass. Board Health, 1889.) From this basin alone 15,000,000 gallons are discharged in this way within forty minutes. Careful observations made by the board show that two hours after it leaves the sewer no evidence of sewage is to be found in the tidal current into which it enters.

As this sewage enters the sea it rises to the surface and spreads till it has a depth of less than a foot. Half an hour after discharge has begun the sewage covers an area about half a mile in diameter. "In this condition the sewage, already considerably diluted, moves outward with the current, and further dilution takes place, the process going on most rapidly at the bottom of the layer of sewage.

"Up to a certain stage in the progress of this dilution, the surface of the sewage contains enough greasy matter to prevent waves, except when the wind blows very hard. When the dilution of the sewage has progressed so far that waves begin to form and its specific gravity has approached that of the sea water, it rapidly becomes mixed with water from greater depths, and very soon cannot be distinguished by the eye or nose from unpolluted sea water. The last change here described takes place in less than an hour and a half after the sewage is discharged, and at a distance from the outlet not exceeding two miles."

Not one of our Connecticut coast cities discharges its sewage directly into the deep waters of Long Island Sound. The sewage of New London, New Haven, Bridgeport, South Norwalk, and Stamford is discharged into a river or bay or arm of the sea, where it tarries for no one knows how long, and is in some cases an offense. New Haven's sewage, for example, is borne up and down the harbor and river with the ebb and flow of the tide, a part of it being left on the mud flats at low water. On quiet nights during the summer the odor of decaying sewage is very evident and extremely disagreeable in those streets which are near the water. This state of things will continue and become worse until the city is willing to complete the work contemplated in the original design, and build an intercepting sewer to receive and carry all the sewage much further down the harbor or beyond it.

A somewhat similar state of things was noted in Bridgeport in 1888, Connecticut State Board of Health Report, 1888, p. 337: "There are at least ten public sewer outlets on the east side and eighteen on the west side of the harbor, besides numerous private ones, emptying their foul contents in most instances upon the flats, which are uncovered except during high tide, and in some instances beneath the windows of habitations which have to be closed on hot summer nights, and under the noses of passers on the bridges, who, with averted faces, hasten on." Since then, as we are informed by a city official of Bridgeport, many of the sewers have been extended to active tide water.

These cases are cited as illustrations of the fact that even in places situated on tide water, the present method of "disposal" by water carriage is often so badly managed as to cause a public nuisance. Sewage discharged continuously into the tide water of a harbor is not promptly and completely removed, but hovers about, being carried back and forth by the set of the tide. If discharged only on the young ebb tide, in the channel and near enough to the open sea, there is a strong probability of its being completely and permanently removed. Such a plan, however, requires the construction of tanks large enough to hold the sewage delivered during eleven hours, and in most cases, if not all, the pumping of this sewage from the sewer outlets to these tanks.

But most of our Connecticut cities and large towns discharge their sewage not into the sea or an arm of the sea, but into streams — the Thames, Connecticut, Quinnipiac, Naugatuck, Housatonic, and their several tributaries, which are regarded as the " natural " outlets for sewage.

The system of these cities and towns is called " water carriage and dilution," and consists in pouring all of their sewage into the nearest available stream and let what will come of it. They trust it will hurt no one down stream, but at any rate they are rid of it.

" How if a' will not stan'?" asks the watch. " Why, then," replies Dogberry, " take no note of him, but let him go; and presently call the rest of the watch together, and thank God you are rid of a knave."

This apparent disregard of the rights of riparian owners below is not, however, deliberate. In the construction of works necessary for the public good, but unproductive of revenue, every effort to avoid expenditure is made, and rightly made, by temporary arrangements as to sewer construction and the discharge of sewage, till the requirements of public health and the growth and development of the special industries of the city or borough shall make a more complete system necessary and the means for its construction possible. (Kiersted, Sewage Disposal, 1894, p. 7.)

While this method has been so generally adopted without regard for the rights or comfort of riparian owners below, or in entire ignorance of its effects upon them, but solely because it was the cheapest and most convenient way of handling sewage, it is, nevertheless, true that in some cases it is a safe and unobjectionable way, at least so far as our present knowledge goes. We have already discussed the several purifying agencies which are at work in streams, and it is clear that a stream which is only moderately polluted may create no nuisance and may to some extent clean itself as it flows. If the quantity of sewage is relatively small, if the stream is rapid enough to keep its bed scoured and prevent the deposit of solid matter either on the bottom or on the banks, if it does not foul the water supply of any town or city, if the sewage does not make the water unfit for manufacturing uses, if it does not kill the fish in the streams, or taint the air about it, then little or no objection can be raised to the practice.

But to name these things is to catalogue the evils from which a considerable number of communities in this State are already suffering, and from which they will suffer much more until some of our large cities purify their crude sewage before sending it into our inland waters. Our cities are growing all the time, the quantity of sewage discharged into streams is thereby increased, and the practice which twenty years ago may have been unobjectionable has in many cases become unbearable.

An impression has become general that our water-ways were designed by nature to carry all our sewage, and that centers of population have a prescriptive right to them for that purpose, but the fact that the riparian owner has a right to the waters of the stream, unpolluted by sewage, seems to have been in some quarters entirely forgotten.

THE PRESENT EVILS OF THE SYSTEM OF WATER CARRIAGE IN CONNECTICUT.

These are all summed up in the statement that the carrying and cleansing capacity of some of our streams for sewage is overtaxed. The first of these evils is

Contamination of water and ice supplies. According to modern sanitary ideas, supported by convincing, if not irrefragible proof, water taken from a river at any point below the outfall of the sewers of a community of any size, is unfit for drinking unless filtered through sand, and will be the cause of a considerable amount of sickness and death yearly, even though no epidemics call attention to the matter, and the " annual death rate " is not exceptionally high. Wherever a city which has been using water from a sewage-polluted stream for a term of years puts in sand filtration works and filters the whole water supply through it, the death rate, particularly the death rate from typhoid and diarrhœal troubles, immediately falls.

Very striking was an epidemic of diarrhœal troubles in Hartford in 1878, which followed the use of river water to supplement the reservoir supply in a season of drought. (Conn. Bd. Health Rep., 1878, p. 87.) The onset of the disease was sudden, severe, and extensive, but limited to the region supplied with river water. In many cases recovery was slow, and in the next month there were an unusual number of cases of typho-malarial and typhoid fever, with a larger rate of mortality from typhoid than had been reported in eighteen years. Nearly every family in the affected district had one or more cases of disease, and in many none escaped. Investigation showed that a large sewer discharged 50 feet down stream from the intake, and the tide, which rises 18 inches at that point, though the water is not brackish, made an eddy at high water and sent some sewage back into the water supply. An outbreak of typhoid in Hartford in 1891-2 is also attributed to water pollution. (Conn. Bd. Health Rep., 1892, p. 206.)

We may cite one other illustration, even more striking, where the cause of sewage contamination was not so near at hand. (Mass. Bd. Health Rep., 1896, p. 568.)

The city of Lawrence, Mass., had for twenty years used for its supply the water of the Merrimac River, which above Lawrence received the sewage of Lowell and other places. The impression seemed to prevail that direct poisoning of the supply was not possible by the sewage of Lowell, nine miles above, with a fall of ten feet through a rapid a mile long on the way, which fall offered a fine chance for self-purification of the water by oxidation. The thought of drinking water from a river into which the sewage of 70,000 people had been poured only eight hours before was not, to be sure, appetizing. Every year the river grew more foul and the death rate from typhoid fever every year increased till, early in 1891, the Board of Health warned the people of Lawrence of their danger, and advised them to boil all drinking water until some permanent relief could be secured. The public took the alarm, and the typhoid death rate began to fall.

A sand filter was built to purify the whole city supply, and was first operated in September of 1893. What followed is shown by the figures in the following table, which gives the deaths from typhoid fever alone, per 10,000 inhabitants, for eleven years. The death rate crept up with increasing pollution of the water supply from 4.2 in 1885 to 13.75 in 1889 and 13.33 in 1890. In 1891 and 1892, after the warning given by the Board of Health, it fell to 11.11. In 1893, with the filter in use for four months, it was cut down to 8.66, and in 1896, the last year for which we have returns, to 1.86. More than one-half of the people who died of typhoid in 1896 used unfiltered water and not the city supply.

MORTALITY FROM TYPHOID FEVER IN LAWRENCE, MASS.

(Mass. State Bd. Health Rep., 1896, p. 568.)

Year.		Deaths from Typhoid per 10,000 Inhabitants.	Total No. of Deaths.
1885,		4.2	17
1886,		5.75	23
1887,		11.75	47
1888,		12.00	48
1889,		13.75	55
1890,		13.33	60
1891,	Warning by Board of Health,	12.20	55
1892,		11.11	50
1893,	Filter operated for 4 months,	8.66	39
1894,	Filtration continues,	5.00	24
1895,	" "	3.07	16
1896,	" "	1.86	10

But at present none of our Connecticut rivers furnishes a water supply below the points at which they receive any large amount of sewage (see description of Conn. Water Supplies, Conn. State Board Health Rep., 1896, pp. 289 and 344), and the water of those which are now polluted can never be brought into condition again to meet the requirements for a city water supply, according to modern ideas of sanitation, without sand filtration. The water in those rivers or parts of rivers which are now somewhat, but not grossly, polluted by sewage could, no doubt, be safely used for city water supplies, if it were necessary, by filtering it through suitably prepared and managed sand filters. The pollution by sewage of ponds from which ice is cut is not so serious a matter as the pollution of water supplies, because ice is not so universally used, and because the impurities tend to separate and remain in the water rather than in the ice. For this reason ice has often been gathered where drinking water would not have been taken. It is certain, however, that not only organic impurities but also bacteria in dormant condition may be included in ice taken from contaminated ponds or rivers, and ice should never be cut from bodies of water which would be deemed unfit for drinking — if the ice is to be used in contact with food or drink, or in family refrigerators.

Another evil of the present prevalent system of water carriage and dilution of sewage is stated to be

The destruction of fish. The effect of factory wastes has been studied by a number of investigators. Thus, Penny, and Adams, Fourth Report Rivers Pollution Com., Vol. II, p. 377, found that one part of the several chemicals and wastes dissolved (or, in some cases, suspended) in the number of parts of water given below was soon fatal to minnows and goldfish, while in double the quantity of water both lived during the period of observation.

DESTRUCTION OF FISH.

	Fatal to Minnows.				Fatal to Goldfish.		
Nitric or sulphuric acids, .	1	part in	50,000	water,	1	part in	......
Tannic acid, ...	1	"	14,000	"	1	"	7,000
Gallic acid, ...	1	"	7,000	"	1	"	7,000
Acetic acid, ...	1	"	8,750	"	1	"	......
Carbolic acid, . . .	1	"	70,000	"	1	"	3,000
Copper sulphate, ...	1	"	100,000	"	1	"	100.000
Sugar of lead, alum, salts of iron and potash, ...	1	"	4,000	"	1	"	4,000
Carbonate of soda, . .	1	"	17,500	"	1	"	......
Saturated solution of bleaching powder, . . .	1	"	16,000	"	1	"	......
Iodine and bromine, . .	1	"	35,000	"	1	"	......
Caustic potash, . . .	1	"	35,000	"	1	"	7,000
Galls, ...	1	"	2,808	"	1	"	936
Sumac and madder solutions,	1	"	7,000	"	1	"	......
Crude soap, ...	1	"	......	"	1	"	4,375
Ashes and furnace cinders,	1	"	140	"	1	"	140
Coal tar, ...	1	"	......	"	1	"	8,750
Heavy pitch oil, . . .	1	"	35,000	"	1	"	35,000

The bicarbonate and yellow and red prussiates of potash were comparatively harmless. In water containing one part of a saturated solution of chlorine to 2,000 of water, minnows and goldfish both lived. Linseed oil appeared to be innocuous. More extended and critical observations on the effects of factory wastes on fish life are now being carried out by König and Haselhoff, the first results of which are given in Landw. Jahrbücher, Bd. XXVI, 1897, p. 75.

Saare and Schwab (Archiv. fur Hygiene, Vol. 3, Part I, p. 81), experimenting with tench and trout, found that from 0.04 to 0.005 per cent. of bleaching solution killed tench, and that 0.0008 per cent. killed trout. Copper sulphate in 0.1 and potassium cyanide in 0.01 to 0.005 per cent. were also fatal to trout.

These tests, no doubt, show the maximum limit of concentration. It is reasonable to suppose that an amount of chemicals which a sound adult fish could endure during the period of observation would be very considerably greater than would suffice to kill the eggs or young of the fish or its food supply, or to render the water so distasteful that the fish would leave it. The effects on fish life of factory refuse and chemicals, and also of sawdust, which has been discharged into streams in lumbering regions in enormous quantities, have been more carefully studied than the effects of ordinary household sewage. There is an abundance of testimony regarding the disappearance of fish from streams into which sewage is discharged, but no clear demonstration of the effects of sewage alone, apart from all other causes. König and Haselhoff (Land. Jahrbücher, Bd. XXVI, 1897, p. 75) assert that ordinary sewage, *in its fresh state*, is not injurious to fish, unless the suspended matter — paper or wood-fiber — interferes with their gills. The observed poisoning of fish usually comes in the summer when putrefaction is rapid, and is caused by poisonous products given off during sewage decay. The sudden dying of fish in large numbers usually occurs in summer immediately after a rise in temperature attending a heavy downpour of rain. The rain sweeps a large amount of filth into the stream, and rapid putrefaction follows the rise in temperature. We believe, however, that the disappearance of fish in polluted streams is more often due to the presence in the water of waste chemicals than to the effects of house sewage.

C. Duncan and F. Hoppe-Seyler (Zeitschr für Physiol. Chem., 1893, Bd. 17, p. 165) have shown that tench and trout can live in running water which contains only about one-third the normal quantity of dissolved oxygen. But as sewage contains no dissolved oxygen and quickly takes up oxygen brought into contact with it, it is clear that the discharge of much sewage into a stream may reduce the amount of oxygen in it far below the limit which is required for fish life, while at the same time putrefaction of the sewage liberates products which are distinctly poisonous to fish life.

Charles A. Cameron (Chem. News, Vol. 44, No. 1131, p. 52) states that oysters are brought from the coast of Wexford and laid down in Dublin Bay to finish their growth. Formerly they did well, but with the growth of Dublin the harbor and river have become increasingly fouled, until now a large percentage of the oysters die soon after transplanting. At ebb tide the water around them smells of sewage, and analysis shows that it contains much nitrogenous matter. The oysters themselves have an evil odor, and the water in them abounds with the same organisms which occur in the sewage. Many cases of illness, which have followed the eating of these oysters, are attributed to the effects of sewage contamination.

The United States Commissioner of Fish and Fisheries, Hon. George M. Bowers (Report on the Pollution of Rivers, by Henry Talbot, Washington, 1898, p. 17), says:

"The data are sufficient to clearly establish the point that river pollution is both directly and indirectly most injurious to fish and fisheries by destroying fish and fish eggs, by driving fish away, by interfering with the fishing apparatus, and by killing or impairing the supply of minute animals and plants which are the basis of fish life."

The infection of oysters by sewage, noted by Cameron, has again been illustrated, in this state. The cause of an epidemic of typhoid at Middletown in 1894 was clearly traced to oysters which had been laid down to "fatten" in the Quinnipiac River, about 100 feet from a private sewer, which at the time carried the dejections of two persons who had the disease. None of the persons who ate these oysters *stewed* had typhoid, but at certain social gatherings, where they were eaten raw, twenty-four persons, about 25 per cent. of the guests who ate, took the disease. A full account of the epidemic is given in the Seventeenth Report, Conn. State Board of Health for 1894, p. 243.

These facts do not indicate that fish which have fed on particles of sewage are dangerous as food. (See p. 29.) In the case cited, the oysters were surrounded with water charged with the specific typhoid germ, which, of course, entered their shells and lodged on the edible portion. Even then, subsequent cooking destroyed the germs.

But the evils already named, which are tangible, easily described, and which can perhaps be measured to determine their effects and the damage wrought by them to riparian owners, are not, after all, the chief cause of the present distrust of the safety of our sewage disposal and of the call for more careful attention to the subject on the part of the public and the legislature.

There is a widespread conviction that the unlimited discharge of sewage into our rivers is rendering them more and more unwholesome to those who live near them; that a sewage-polluted stream is indirectly at least a cause of ill-health, if not of active disease, to the community living on its banks, and that until the present method of " disposing " of sewage is reformed, these evils will continue and increase.

Renewed attention is called to the right of the riparian owner to the water of the stream in its natural purity, undetained and not unnecessarily polluted, and to the fact that it has been ruled by our courts that the discharge of sewage into a stream is an unnecessary pollution.

Unsightly appearance. Still further, there is the objection, lightly waved aside by some as " purely sentimental," that the unlimited discharge of sewage into our water-ways makes them dark, murky, and disgusting in their appearance. What should be a delight, a rest to the eye and the spirit, serving much the same purpose as a public park or forest reservation, can only be looked upon now as an open sewer, a sluice-way for all the disgusting filth of neighbors who cannot or will not clean their own premises except by casting their filth into the highway.

Much of the unsightliness of rivers, and especially of their banks, is due to things not included in sewage, which are heedlessly cast into the stream by those whose sense of decency is small. Barrels and boxes, waste lumber and paper, dead animals, and many other kinds of refuse greet the eye in our streams and on their banks. The discharge from dye-works, tanneries, and certain other factories, either alone or when mixed with other wastes, greatly discolors the stream, and in some cases makes it inky black, so that its waters are in fact a pale ink. We believe the time will come when such unnecessary untidiness will be forbidden by law as well as by public sentiment. But when the water is low, and at the time of year when putrefaction is most active, solid animal and vegetable matters coming from the sewage itself frequently lodge on river banks and make them unattractive and even repulsive.

Regarding this last objection it is to be said that, if " purely sentimental," it is, nevertheless, real and cannot be fairly met or brushed aside by calling it names. Sentiment is a fact, as real as sewage. Its reality is demonstrated to the most "practical " of men, who prides himself on his freedom from sentiment, by the fact that it has a market value, it can be measured in dollars and cents. A beautiful view, a fine shade tree, a clear stream of water, and agreeable neighbors enhance the value of a piece of real estate. Uncongenial surroundings, unkempt premises, a stream which rolls along the filth of a community or the refuse dye-stuffs of a factory are perfectly well recognized as a distinct damage to the value and the selling price of a piece of property. And the damage may be purely " sentimental," for no " nuisance " is established which would for a moment be considered by the courts.

We believe, too, that clean streams, like clean streets, clean houses, and clean places of amusement, have a great beneficial effect on the general moral and physical tone and well-being of the whole community, quite apart from any direct effect which is recognized by the sanitarian. Physical and moral cleanliness are closely associated, and either one promotes the other.

Danger to Health. Leaving now the " sentimental " objection to grossly polluted streams, we come to notice the second which has been named, *i. e.*, a widespread conviction that the unlimited discharge of sewage into our streams is rendering them generally unwholesome and indirectly at least a cause of ill health to the community living on their banks.

With reference to this objection it may be granted that no facts have fully demonstrated that illness, sporadic or epidemic, has ever been caused by proximity to a polluted stream except where specific poisons have been introduced into the system through drinking its water. It must also be said, however, that from the nature of the case such demonstration is quite impossible. In very few cases can a physician go further than to name the probable cause of any illness. There is always a variety of possible causes for a sickness, several of which may have operated together, and to no one of which the whole effect can be ascribed with absolute certainty.

If a person lived on the bank of a grossly polluted, evil-smelling stream, amid surroundings otherwise healthful, his physician would surely attribute any general debility and resulting illness to the proximity of this filthy stream, and the common sense of the neighborhood would unanimously endorse his opinion. Yet *proof* of his view would be entirely wanting and impossible to secure. The further the person named lived from the noisome stream, or the smaller the amount of obvious filth in the stream, the less unanimous would be the opinion of the neighborhood; and if the question of the cause of illness involved the cleaning of the stream at the expense of the community, a part of the public, at least, would be honestly convinced that the stream's pollution had absolutely nothing to do with the case, and medical experts would be found who would share this view.

The really important question in this State is, however, this: Can a stream, which is not so strongly charged with sewage as to make it a public nuisance, be indirectly a cause of ill health to individuals or communities living on its banks?

We believe the general opinion of sanitarians and physicians is that a moderate amount of sewage in the stream would probably not at all affect the health of riparian proprietors. In proportion, however, to the increase of sewage in the stream, is increased the possibility and probability of injury to the public health by a general depression of the tone of the system, and so of the disease-resisting power. The danger from this cause is all the greater because insidious and slow in its effects.

Legal rights of the riparian owners. We come now to the third element in the present agitation regarding sewage disposal, viz., the legal rights of the riparian owner to the water of the stream as it was wont to flow. The principles of law bearing on the matter have recently been clearly stated by Judge G. W. Wheeler in a decision rendered in the Superior Court, Fairfield County, August 1, 1895, in the case of Morgan *et al.* vs. the City of Danbury. The complaint of Morgan was substantially this: The city has rendered the stream filthy, noxious, and unclean by its sewage, and intends to increase the pollution by building new sewers. By this action the plaintiff has been largely deprived of the use of the waters of the river at his mill and water privilege; he and his workmen have been injuriously exposed to noxious and unhealthy odors; the air in the neighborhood has been corrupted and poisoned, endangering health; he has been unable to use or sell his mill and building lots; his dam has been partly filled up with filth; the value of his lands and water privilege have been greatly diminished, and will ultimately be wholly destroyed if the defendant is not enjoined.

We cannot do better than quote Judge Wheeler's decision in full as far as it relates to the rights of a riparian owner:

"Before considering the case as presented on the evidence let us first ascertain the rights under the law of a riparian proprietor (as is this plaintiff) in the waters of a running stream.

"In discussing the right of the riparian proprietor in the waters of a running stream, Butler, C. J., in Agawam Canal Co. vs. Edwards, 36 Ct., 497, says: 'But it is not a title to the waters; it is a usufruct merely; a right to use it while passing over the land. The same right pertains to the land of every other riparian proprietor on the same stream and its tributaries; and as each has a similar and equal usufructuary right, the common interest requires that the right should be exercised and enjoyed by each in such a reasonable manner as not to injure unnecessarily the rights of any other owner above or below. Each is therefore required by law to let the water flow as it has been wont to flow, that all may receive and enjoy it on their lands; and no one can divert or detain it unnecessarily without doing an injury to the usufractuary right of others below him.'

"Id. Harding vs. Stamford Water Co., 41 Ct., 92.
Wadsworth vs. Tillotson, 15 Ct., 373.

"While the riparian proprietor has a right to the use of the water in its natural state, subject to the equal right of other riparian proprietors, it is to be remembered that 'all running streams are to a certain extent polluted: and especially are they so when they flow through populous regions of country, and the waters are utilized for mechanical and manufacturing purposes. The washings of the manured and cultivated fields, and the natural drainage of the country, of necessity bring many impurities to the stream, but these and the like sources of pollution cannot, ordinarily, be restrained by the Court.'

"Wood vs. Sutcliffe, 2 Sim. (N. S.), 163.

"Therefore, when we speak of the right of each riparian proprietor to have the water of an actual stream flow through his land in its natural purity, those descriptive terms must be understood in a comparative sense; as no proprietor does receive, nor can be reasonably expected to receive, the water in a state of entire purity.

"What, then, is a reasonable use of the water of a stream by a riparian proprietor? It is such a use as will not unnecessarily injure the right of any other riparian owner. Each case must determine the reasonableness of the use after a consideration of all the facts involved. It is settled law that a question of this kind is one of fact, to be decided upon all the circumstances of each particular case.

"Keeny vs. Wood Mfg. Co., etc., 39 Ct., 581.

"And further, 'The question of reasonable use is to be determined in view of the rights of others.'

"Hurlbut vs. McKane, 55 Ct., 42.
Id. Mason vs. Hoyle, 56 Ct., 255.

"At the time the sewer system of Danbury was adopted the waters of the stream at Morgan's pond were used for mill purposes and not for drinking. Assuming that the stream at this point was a non-potable one and given over to secondary uses, as the defendant claims, what rights are reserved to the riparian proprietors (as is this plaintiff) in this non-potable stream? The plaintiff as riparian proprietor upon Still river is entitled to the primary and secondary uses of the waters of that stream, no matter what servitude be imposed upon that use. No additional and material servitude can be imposed unless it be acquired by grant or prescription. The conditions of the stream may be unfit for domestic uses and given over to secondary uses, but that cannot give this defendant the right to further pollute the stream in a material manner. Because others have polluted the stream is no reason why riparian proprietors should be compelled to suffer this defendant to further pollute the stream.

"In Indianapolis Water Co. vs. American Strawboard Co., 57 Fed. R., 1003, Baker, J., said: 'It is claimed that the people living along the river pollute the water by draining into it the filth and other refuse matter which accumulate on their premises. But it is no answer to a suit for creating and maintaining a nuisance that others, however many, are committing similar acts.' Each one is liable to a separate suit and may be restrained.' In the well-considered case of Mayor, etc., of Baltimore, vs. Warren Mfg. Co. *et al.*, 51 Md., 105, the Court said: 'It is distinctly alleged that the filth and excrement from those directions are discharged into the stream whereby the water flowing into the lake is greatly polluted. This source of pollution should be restrained, and even though there be other sources of pollution, or that many other persons are committing the same sort of nuisance, forms no reason why this particular cause or source of pollution should not be restrained.' What, then, is the remedy for the riparian proprietor whose rights in a stream have been invaded?

"Id. Ferguson vs. Firmenich Mfg. Co., 77 Ia., 578.

"In Wood vs. Sutcliffe, 42 Eng. Ch. R. (2 Sim. N. S.) 164, the Court says, 'if the granting of an injunction will restore, or tend to restore those parties to the position in which they previously stood, etc., and if the injury cannot be compensated in damages, and if they use diligence, they have a right in general to come to a court of equity and say: "Do not leave us to bring action after action for the purpose of recovering damages; but interfere with a strong hand, and prevent the continuance of the acts we complain of," etc. I say, in general, because the Court must regard not only the dry strict right, but the surrounding circumstances. I say seriously obstruct, because if the damage be small but continuous, it is serious. . . . . I say restore or tend to restore, because I conceive it is no answer to an application of this sort, for the defendant to say that other persons as well as he are polluting the stream, and that, therefore, the injunction will not restore the plaintiff to the enjoyment of his legal right, inasmuch as it will not prevent those other persons from continuing to pollute the water; for the plaintiff must sue each of the wrong-doers separately; unless, indeed, they are acting in partnership or in concert together, and the obtaining of an injunction against any one of the wrong-doers, though it may not actually restore, does tend to restore, the plaintiff to the enjoyment of his rights, as it is a step towards obtaining an injunction against each of them.'

"Id. Atty.-Gen'l vs. Leeds Corporation, 5 Ch. App. Cas. L. R., 595.
Id. Atty.-Gen'l vs. Prop'rs of Bradford Canal, 2 Eq. Cas. (L. R. 79).
Crossley vs. Lighttowler, L. R., 3 Eq. Cas., 279.
Clowes vs. Staffordshire, P. Co. 8 Ch. App. Cas., 125.
Chipman vs. Palmer, 77 N. Y., 51.
Schiever vs. Village of Johnstown, 71 Hun., 233.
Wood on Nuisances, p. 582, Sect's 439, 440.

"That the sewers were built by the defendant for a public purpose under authority of law and in the exercise by it of a governmental duty is of no importance. Its use of the stream (to the material injury of the plaintiff) under its charter without obtaining the right to the use of the stream by grant or prescription and without compensation, is an illegal use.

"Kellogg vs. New Britain, 62 Ct., 239.

"That the sewage system was constructed under competent engineers and with due care, is no justification for causing material injury to the plaintiff without right.

" In Indianapolis Water Co. vs. American Strawboard Co., 57 Fed. R., 1003, the Court said: 'It is urged that the defendant is prosecuting a business useful in its character, beneficial to the public, and furnishing employment to a large number of men, and that it is conducted with skill and prudence, and with the most improved machinery, and, if damages result, it arises from no fault of the defendant; and that in such cases the ancient rigor of the law has been modified in furtherance of industrial progress and development. This contention finds no support, either in principle or authority. It is rudimentary that no man can be deprived of life, liberty, or property but by due process of law, nor can private property be taken, even for a public use, without just compensation first having been made or received; and under no form of government having regard for man's inalienable rights can one be permitted to deprive another of his property without his consent and without compensation, on the plea that the injury to the one would be small, and the advantage to the other, or even to the public, would be great.'

" Id. Gladfelter vs. Walker, 40 Md., 11.
Bennoyer vs. Allen, et al., 56 Wisc., 503.

" That the sewer was constructed at great expense and without protest on the part of the plaintiff cannot raise an estoppel against his prosecution of this action.

" The defendant knew better than the plaintiff whether the construction of the sewer would prove injurious to the plaintiff. Until the plaintiff's rights were interfered with it was natural for him to submit without protest rather than embark in long and tedious litigation. The sewer might or might not become a nuisance to him; he must know the method of its use and the results of that use, before he can be charged with notice of its results. But the acts done by the defendant were done, it is claimed, with legislative sanction, and no presumption could arise that the acts to be done were to create a nuisance. The presumption was, and the plaintiff had a right to rely upon it, that the construction of the sewer would be in such a way as not to create a nuisance.

" Indianapolis Water Co. vs. American Strawboard Co., *supra.*

" In Village of Dwight vs. Hayes, 150 Ill., 273, the Court says: 'So far as the village expended money or incurred liability in the matter of constructing a proposed sewer, it must be held to have done so with full knowledge of the fact that the complainant had in no way obligated himself to allow the sewage to be discharged into the creek by any binding act or instrument, and that he was at liberty at any time to recall the consent which he had already given. And if under such circumstances, and without seeking to obtain from him any grant of the right of way over his land or the execution by him of any other binding obligation in the premises, the village authority saw fit to take steps towards the construction of the sewers, they are hardly in a position to invoke the doctrine of estoppel for the purpose of precluding the complainant from the assertion of his legal or equitable right in the premises.'

" Id. Atty.-Gen'l vs. Leeds Corporation L. R., 5 Ch. App. Cas., 595.
Woodyear vs. Schaefer, 57 Md., 1.
Snow vs. Williams, 16 Hun., 471.

" That the river is the only outlet for the drainage of the city, and public necessity requires its use, is no justification for such use. The lower proprietor has certain rights in the stream which can only be lost by his voluntary grant or by prescriptive use. It may be of advantage to his neighbor to invade those rights as it may be of advantage for a community to invade those rights; but he is protected by the law in his possession equally against each. They cannot be taken from him against his wish, save by condemnation, and if the necessity of the community requires that he give them up, it is for the community to secure authority from the legislative body, and that will be granted only upon compensation, if the grant is to be held valid. To take without compensation and against consent is to confiscate.

"This question has been before passed upon by the courts, and the doctrine of the law well stated in Wood on Nuisances, Sec. 434, to be, 'The fact that the public convenience, or that of the preservation of public health even, requires that the sewage of a town shall be removed, and that there is no other method by which it can be disposed of except to discharge it into a running stream, will not justify the discharge there to the injury of riparian owners, and the fact that the population of the town is large, and the number of persons to be affected by the nuisance few, makes no difference.'

"Id. Atty.-Gen'l vs. Colney Hatch Lunatic Asylum, (L. R.) 4 Ch. App. Cas., 154.
Atty.-Gen'l vs. Leeds, 5 Ch. (L. R.), 589."

In the case cited the city was enjoined from discharging sewage after a given date into the stream named in the complaint.

The case went on appeal to the Supreme Court (67 Conn., p. 484), which found no error.

The judges say, in their decisions: "The discharge of sewage and other noxious matter into an inland stream, to the injury of a riparian proprietor below, has been held to be an unlawful invasion of the rights of said proprietor, remediable by injunction, by the courts of nearly every state, by the federal courts, and by the courts of England." There follows the citation of numerous references.

In the case of Patrick Nolan vs. the City of New Britain, a verdict for $2,000 damages was awarded by a jury in 1897 on account of the pollution by sewage of a stream passing through his land, Piper's Brook — a tributary of Park River — and New Britain is now arranging for some change in its method of disposal. The Supreme Court of Errors, to which the case went on appeal (Patrick Nolan vs. New Britain, 69 Conn., p. 668), held that the pollution of a water-course with the sewage of a city, unless authorized by law, constitutes a public nuisance and renders the city liable in damages to a lower riparian proprietor who is specially injured thereby. No right to commit a public nuisance can be acquired by prescription nor to commit the acts which constitute such a nuisance as against a plaintiff who suffers a special injury thereby.

That this method of stopping the gross pollution of a stream by private suit against the municipality is likely to be adopted only after the nuisance has been long continued, is seen by the facts stated in letters to one of the members of this Commission, which were written by residents of Newington eleven years ago. In May, 1887, one of them wrote as follows:

"The following facts can be proved in court: (1) That before New Britain drained its sewage into the stream it was a clear, pure stream. Since then it looks dirty. (2) Fish were abundant in the stream, lamprey and silver eels, roach, suckers, etc. Now there are but few fish there, and fish have sometimes been seen to die in large numbers. (3) People used to cut and secure ice from the stream; now it is never done. (4) It stinks most vilely in the summer time when the water is low."

Another correspondent, in February of the same year, writes: "Hay cut along the banks has an unpleasant odor; the grass receiving the sediment of the overflow, or upon which the fogs rising from the stream settle, has the same odor which we perceive when passing through the fog. Cattle do not like the water. The Elmwood Creamery of West Hartford gives notice that they will not receive milk from cows which have to drink at the stream which runs from New Britain."

But it was ten years after this state of things obtained before it had become so aggravated that it was morally certain that a jury would give a verdict in favor of the rights of a single person as against the convenience, comfort, and financial status of a city. Only when this point had been reached was it safe for an individual to undertake the expense necessary for a legal tournament.

From what goes before it appears that:

(1) The system of water carriage and dilution is almost universally employed in Connecticut for sewage disposal.

(2) This system is the most economical one, and is apparently safe when the volume of sewage compared with the volume of the stream is relatively small at all seasons of the year, and where no town or city water supply is polluted.

(3) In some places the volume of sewage which the river can safely carry has already been exceeded, resulting in a public nuisance.

(4) If there is no change in our laws or in public opinion on the subject, with increasing population those inland waters

of our State into which sewage is now discharged will become more and more polluted, and other smaller streams which are now clear of sewage will be used by towns and boroughs as outlets for their sewage.

(5) When the pollution of any given stream has gone so far as to create an intolerable nuisance, which can be established in a court, any and every riparian owner can bring suit against any and every city or borough contributing to such pollution, which must result in an injunction, stopping further discharge of crude sewage into the stream. While pollution so great as to secure the intervention of the courts may be very remote in the case of our largest rivers, the Connecticut and the Thames, such a condition is imminent or already exists in some of the smaller streams.

(6) When the discharge of sewage into a stream has been forbidden, the city or town so enjoined must change the whole system and partially or completely destroy its own wastes on its own premises.

It remains to inquire what means can be used to do this. It is not our purpose to describe these in great detail, but to call attention to the general principle involved, and to give some examples of their efficiency.

THE STERILIZATION OF SEWAGE.

It has been proposed to sterilize sewage before its discharge into water-ways, thus destroying its odor, and partially or completely destroying that microbe life in it which causes putrefaction, incidentally, no doubt, destroying a small portion of the organic matter of the sewage itself. Such a process is utterly worthless as a means of disposal. Sterilization is merely a postponement of decomposition. As soon as the sterilized sewage falls into a river, the antiseptic or disinfectant loses its power, by dilution, evaporation, and chemical reaction, the sewage is immediately inoculated with the germs of decay, and decomposition begins.

Colonel Waring, a recognized authority, says (Proper Disposal of Sewage, Yale Med. Jour., Nov., 1896): "There can be no proper disposal that does not secure rapid resolution into elements. In fact, no other result is admissible from the point of view of the sanitarian. Disinfection, as by the use of chlorides and of other germicide methods, simply arrests the necessary process, with a certainty that whenever and wherever the power of the germicide shall cease, whether from dilution in a stream of water, from evaporation, or from whatever cause, the processes of decomposition or putrefaction must inevitably begin."

SEDIMENTATION OF SEWAGE.

This method consists in holding the sewage in large settling tanks till all the lighter material has risen to the surface and the heavier solid sewage particles, sand, etc., have fallen to the bottom.

By skimming the surface and leaving the settlings, the sewage can be discharged into the stream somewhat clarified and so a little better in its appearance. As a means of *purification* by itself, however, sedimentation is worthless. As we have seen, the most dangerous, because the most putrescible, portion of sewage is in solution and therefore is not removed by resting in a tank. The sewage is decidedly worse for the "treatment," because nothing could be devised more favorable to putrefactive decay, the very thing which it is sought to avoid.

In some cases, however, sedimentation may be useful, but only as a preliminary to further treatment.

CHEMICAL PRECIPITATION AND PURIFICATION.

By this process the stream of sewage at its outfall is continually dosed and thoroughly mixed with certain chemicals in solution or suspension in water (copperas and milk of lime are most commonly employed), and passes on to large settling tanks. By this reaction of the chemicals with each other, and with the matters suspended and dissolved in the sewage, a flocculent, bulky precipitate is formed and falls to the bottom of the tanks, leaving the sewage quite clear and much less foul than before. The process is sedimentation, hastened and made more complete by chemical reaction.

Often the sewage passes through the tanks continuously, slowly enough to deposit its sludge, and so off over a weir. In other works, a tank is filled with the sewage, which stands long enough to deposit and is then drawn off. In all cases the tanks are periodically cleared, the semi-fluid sludge being pumped out and allowed to drain till dry enough to handle or put through hydraulic presses and made into cakes, which are sold or given away to farmers or buried at the works.

Much has been said of the valuable fertilizing materials thus saved from sewage, but facts do not bear out the claims. The most available part of the nitrogen and potash in the sewage is not thrown down by the precipitation process, and the large amount of water in the sludge, even after pressing, makes the cost of freight on the fertilizing matter in it very high.

The average composition of pressed sewage sludge from the London works at Crossness is stated by Dibdin (Purification of Sewage and Water, p. 39) to be as follows:

	Per Cent.
Moisture,	58.06
Organic Matter,	16.69
Mineral, "	25.25
	100.00

The organic matter contains:

	Per Cent on Pressed Sludge.	Per Cent. Nitrogen.
Saline Ammonia,	0.035	0.87
Organic Nitrogen, calculated as Ammonia,	1.025	

The mineral matter contains:

	Per Cent.
Carbonate Lime,	7.94
Free Lime,	2.45
Silica,	8.08
Oxide of Iron,	0.97
Oxide of Alumina,	3.39
Phosphoric Acid (phosphate of lime, 1.44),	0.658
Magnesia,	trace.

Three dollars a ton, *delivered,* would be a high valuation for such material, considered as fertilizer.

On this point Shaw (Municipal Government in Great Britain, p. 124) says, describing the sewage disposal in Glasgow: "No very profitable use can be made of the sludge cakes, but it is calculated that they will at least pay for the cost of their removal to farming lands."

In Birmingham (Ib., p. 183) trouble was had with the sludge at first, but now it is spaded into shallow trenches, covered with fresh soil, and so absorbed by the land as a fertilizer.

Speaking of the disposal of London sewage, he says (Ib., p. 270): "There is a fleet of six great sludge steamers that carry the soft mud from the precipitation tanks out to the deep sea. It has been demonstrated that no successful use of the sludge can at present be made for agricultural purposes." Its use "was found to pay only a fraction of the expense of compression and transportation."

In Worcester, Mass., as the Commission is informed by the manager of the works, the sludge, after draining and drying, may contain 90 per cent. of moisture, and is given away, more than 10,000 two-horse loads being annually taken. By the presses, 3,500 gallons of sludge can be compressed into 1½ cubic yards of cake, containing 50 to 60 per cent. of moisture.

But the main question is, How far does this chemical treatment purify sewage? It makes the sewage clear and nearly or quite colorless, but never pure enough to permit of its discharge into a potable stream. Careful experiments on chemical precipitation have been made by the Massachusetts State Board of Health at their Experiment Station at Lawrence, Mass., under the direction of Mr. Allan Hazen, which are described in the Massachusetts State Board Health Report, 1890, pp. 735-791. These experiments, made with a variety of chemicals which have been used in various works for the purpose, are thus summarized (loc. cit., p. 668):

> "The best results that we have obtained — and we know of no others that are so good — leave as much as one-third of the nitrogenous organic matter of the sewage in the effluent; this is an abundant food supply for the unlimited growth of the large number of bacteria that remain. The number is called large, because five per cent. of 700,000, or 35,000, in a thimbleful, is a large number; and, if any of these are disease-producing germs, there would be no safety in turning such a liquid into a drinking-water stream; and whether it would be admissible to turn a liquid containing from one-third to one-half as much nitrogenous organic matter as sewage, with abundant bacteria, into any other stream, would depend upon nearly the same conditions that would attend discharging a less amount of sewage into the same stream. There would, however, be this difference, and it is an important one — the objectionable appearance would have been removed, and would not come again, unless, collecting in pools or in eddies or on flats, or rising to the surface on a liquid having greater specific gravity, putrefaction of the remaining organic matter should follow. The remaining organic matter would probably not putrefy as readily as the original sewage diluted to the same extent; but that it is not so stable a compound that it will not readily decompose under favorable conditions, is shown by the fact that five-sixths of it may be nitrified while moving slowly for one day over gravel stones in intermittent filtration.
>
> "Such an effluent as may be obtained from chemical precipitation

of sewage, turned into a large and rapidly-flowing stream, or into a tidal current that would soon take it to sea, would be disposed of without making a nuisance, when crude sewage might be very objectionable. Under such circumstances, and there may be others where the conditions for intermittent filtration are unfavorable, the partial purification of sewage by chemical precipitation may be the best practicable way to avoid a nuisance. But the incompleteness of the purification and the cost of 30[†] cents per inhabitant yearly for chemicals, together with the additional expense of manipulation and disposing of the sludge, will be likely to confine the application of chemical precipitation in the purification of sewage to narrow limits."

The remaining methods of sewage disposal which we shall notice may be classed together under the heading of purification by biological processes.

PURIFICATION BY BIOLOGICAL PROCESSES.

While very various in the size and equipment of the disposal works which these systems require, they are all alike in the general principle involved — all use the same purifying agent. This agent is microbe life of several different kinds, which in one way or another decomposes the putrescible matters of sewage, changing them into forms which are invisible and odorless, and which do not create a nuisance or defile the waters in which they are carried. These biological methods of sewage disposal are the ones to which modern sanitary science is leading us back. They have so far passed the experimental stage that experts are convinced that they are correct in principle and are practicable for use on an extensive scale. It is probable that by further experiment and experience they will be greatly improved both in efficiency, initial cost, and cost of maintenance.

It would carry us too far to discuss in detail the many engineering devices used in the systems to be described, the special conditions which each system is best suited to meet, the expense involved in establishing and in maintaining the plant. We can only describe in a general way these systems of disposal, enough to show the principle involved, and their efficiency in cleansing sewage. The first which we shall notice is

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[†] At Worcester it is reported that the total cost of chemicals, labor, and expenses of operating the plant amounts to 29 cents per capita yearly. The expense per capita will naturally be larger where the amount of sewage handled is small.

BROAD IRRIGATION.

By this method sewage is run over land occupied by growing crops and supplies them with both water and plant food, the cleaned water, so far as it is not evaporated through the plants, filtering through to the subsoil, where it passes into the ground water. The special arrangements for securing this flow depend on the nature of the soil and the topography of the irrigated district. The essentials are that the flow must not be continuous, but intermittent, and that the quantity of sewage used must not be in excess of the requirements of the crop. At certain times, as during harvest, the sewage must be entirely withheld from the fields, and, of course, during cold weather, when there is little or no growing vegetation, a given area will take care of much less sewage than when the weather is warm and the crops are growing, and, consequently, evaporating water rapidly.

The general application of this system of sewage disposal is greatly limited by the fact that the sewage must be taken care of every day in the year, while successful sewage farming requires that the sewage should be withheld from the land at certain times, and that in rainy weather, when the volume of sewage is much larger, the crops need it least and the land can take up less of it.

It has been well known for many decades that impure and putrid water could be deodorized and cleaned by filtering it through even a shallow layer of earth. The full explanation of this well-known fact has only recently become known. We shall refer to this more in detail further on, in describing the system of "intermittent filtration." It will suffice here to say that, when properly managed, sewage may be cleansed very effectively by broad irrigation as above described; its dangerous elements are broken up, converted into plant food, and pass into the vegetation, while the effluent water, clear and sparkling, is either pure enough for drinking, or at least contains nothing putrescible and may safely be discharged into water-ways. Many sewage farms are now in successful operation in England and on the continent of Europe, the most widely known perhaps being those at Gennevilliers, near Paris, where a small portion of the sewage of Paris is treated, and the sewage farms near Berlin. The question is naturally raised by those who are unfamiliar with these sewage farms whether they are not noisome and offensive, whether those working on them are not poisoned, or at least injured in health by their occupation, and whether the crops raised with the help of sewage irrigation are not likely to be a source of infectious disease, like typhoid.

Dr. Alfred Carpenter, who lived in the neighborhood and had for years been familiar with the Beddington sewage farm, in a paper read to the British Medical Association in 1888, concludes (cited by Rafter, Sewage Disposal in the U. S., p. 251):

> "(1) That the application of the sewage of a water-closet town to land in close proximity to dwelling houses is not injurious to the health of the inhabitants of those houses provided the sewage be fresh; that it be applied in an intermittent manner, and the effluent be capable of rapid removal from the irrigated fields. (2) The judicious application of sewage to soil of almost any kind, if it (the soil) be mainly inorganic, will satisfactorily cleanse the effluent water, and fit it for discharge into any ordinary stream, provided the area treated is not less than an acre of land for each 250 persons.* (3) That vegetable products grown upon fields irrigated by sewage are satisfactory and safe as articles of food for both animals and man. (4) That sewage farms, if properly managed, do not set up either parasitic or epidemic disease among those working on the farms or among the cattle fed upon its produce." . . .
>
> (6) That sewage farms may be carried on in perfect safety close to populations. It is not, however, argued that the effluent water is safe to use for dietetic purposes. . . .

In the neighborhood of Berlin 17,000 acres of land are used for sewage irrigation, the works having been in use, in part, since 1876. During the five-year period from 1885 to 1890, the average annual population, as given by Mr. Roechling (Proc. Inst. C. E., Vol. CIX, Sess. 1891-92, Part III) was 1,598, — 986 men (most of them under sentence for misdemeanors), 285 women, and 327 persons under 15 years of age. Since the larger part of the population consists of paupers and incipient criminals, ill-health and a large death rate might be anticipated. But the annual death rates for the five-year period were 11.24, 9.22, 14.83, 6.79, and 4.81, a mean of 9.75. The mean death rate from zymotic diseases was 2.53. The only source of drinking water is wells, but in only one case has there been trouble from a well. No disease in cattle has resulted on the sewage farms or those adjoining. Further evidence could be given, all of which goes to show that sewage

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* The sewage population which can be served by an acre of land must depend on the volume of the sewage. The larger the volume of sewage, per capita, other things being equal, the smaller the sewage population which an acre of land will care for. In this country as a rule the volume of sewage per inhabitant is larger than in England.

farms, properly managed, have not been a source of annoyance or disease.

It is stated that the sewage farms of Berlin began with the proportion of one acre to 250 sewage population. This was reduced to 100 in a few years, and the director hopes to reduce it to 75 and even 50, and thus to make a slight profit as well as to get rid of all evil odors, and to avoid an alleged increasing pollution of the ground water.

It seems that sewage farming as a means of complete sewage disposal is impracticable for most large cities, but as an incident and help to sewage disposal it is very valuable and may in some cases greatly lessen the expense of disposal.

The system is especially adapted for the use of isolated public institutions, schools, hospitals, asylums, and prisons, in which the amount of sewage is comparatively small, where storm water is excluded, and where there is a large area of grass land controlled by the institution.

INTERMITTENT FILTRATION.

To this process we wish to call special attention because it is more effective than any other in destroying the putrescible matters of sewage, as well as the bacteria which cause putrefaction; it is being operated successfully in many cities and villages in this country; three of our Connecticut cities have adopted it and it seems likely to be commonly adopted where sewerage systems are for the first time introduced, or to be substituted for dilution when the latter system has to be abandoned.

The process is, in brief, this: Sewage is made to flow over prepared filter beds of fine material, sand, coke, or cinders, till the material is saturated at the surface; the stream is then turned to a second bed, while the sewage sinks slowly through the saturated bed to the underdrains, and the effluent water passes off through them to some water-way. After draining and resting a while, the first bed is ready to receive sewage again, and the process is repeated.

Nature of the Process. Let us notice this more in detail. Here is a bed, newly built, consisting of an acre of level sand, like that of the Wallingford plains, for instance, four feet or more in depth, the whole area bounded by an embankment, having sewer outfalls at the corners. The gates are opened and 15,000 gallons of crude sewage are quickly discharged over the surface, so that the whole is covered to the depth of half an inch or more, when the gates are closed. The sewage disappears rapidly into the sand. The next day the surface of the bed is quite dry and generally ready to be flowed again with sewage, and so on.

After several applications of sewage to the surface, water begins to flow out from the underdrains. It may be clear or only slightly cloudy, without any smell, but when allowed to stand in a warm place for some time it becomes turbid and offensive. Chemical tests of this drainage water, or effluent, show that it is polluted, but less so than the sewage which went on to the surface above. But examinations of the effluent made day after day show that it is all the while becoming cleaner; it putrefies less rapidly on standing. Within a few days or weeks, the time depending on a variety of conditions, the effluent will not putrefy on standing. Fish will live in it indefinitely and chemical analysis shows that it is as pure, so far as organic contamination goes, as most well waters are, and that 90 per cent. or more of the soluble organic matter of the sewage has disappeared. Bacteriological tests show that from 90 to 99 per cent. of the bacterial life of the sewage has also gone. Next the quantity of sewage applied is gradually increased to 60,000 gallons daily, and still it is almost completely purified in passing through the sand "filter."

What has become of the foul matter? The first thought is that it has been retained by the "filter" and is gradually polluting it so that shortly it will become clogged and putrid and will let the sewage through uncleansed. But this is not true. There are filters at the Lawrence Experiment Station and also large filter areas in other places which have been purifying city sewage continuously for eight years without clogging, or becoming putrid and which do better work to-day than in the months immediately following their construction. Moreover, examination of the sand in the interior of these filters shows that it has no bad odor and is almost as clear of organic matter as when it was first put in. The enormous quantity of filth poured into the sand during a term of years has not evaporated, it has not gone through, it has not staid in the filter. The only other thing possible has happened to it — it has been burned up.

It is beside our purpose to follow the history of those observations and investigations, from the time of Way down to the present, which have made clear the nature of the work which goes on within the "filter" or to present the proof in detail of the facts regarding its operation. We here state only what has been well established regarding the action of the filter and the conditions of its activity.

We have before referred to the work of microbes or bacteria in decomposing sewage.

Let us notice now, briefly, what goes on in the sand filter. About half the space in the filter, the chinks between the particles, is filled with air. The sewage flowing down over the sand particles is thus spread in a thin sheet in contact with this air. Those microbes or bacteria which oxidize or burn nitrogenous organic matters are thus well supplied with food, and with the air (oxygen) which is essential to their life and growth. They immediately multiply rapidly and begin to decompose the organic matter *by oxidation* (burning), changing its complex elements into carbonic acid, water, ammonia, nitrates, and nitrates. On the other hand, the sorts of bacteria which cause putrefactive decomposition, while well supplied with food, cannot thrive in the presence of air, and so do not multiply rapidly. The oxidizing bacteria begin to get the upper hand, the bacteria of putrefaction are in the minority, the effluent begins to show less foulness than the sewage.

If the sewage were continually poured on the sand, the oxygen within the filter would be speedily exhausted or expelled by the foul water, and then the tables be turned in favor of the putrefying forces. Instead, the flow of sewage is discontinued for a time, and as that which was first put on sinks through the sand, it draws after it a fresh supply of air, and after the period of rest leaves the sand fully aerated, and having a much larger population of oxidizing bacteria and a much smaller population of bacteria of putrefaction than at the beginning. The oxidizing bacteria appear to attach themselves to the surface of the sand grains in a jelly-like mass of extreme thinness. The next flowage of sewage, as a result of this increased number of oxidizing bacteria, is purified more than the last, a larger part of its organic matter is destroyed, and nitrates, the "ashes" or harmless end product of the burning of the nitrogen of animal and vegetable waste, appear in the effluent.

And so the process goes on, constantly increasing in efficiency, under proper management, up to the point of maximum work of microbe life in the filter. The dead organic matter of the sewage is not the only thing which is destroyed. The bacteria of putrefaction, which the sewage brought, are also destroyed within the filter in as great, and even greater, proportion than the organic matter.

"The cause of the death of the ordinary sewage bacteria in the tanks, especially during nitrification, is not yet entirely clear. It may be that the activity of the nitrifying organisms is of itself inimical to the ordinary bacteria; but further experiments will be necessary in order to explain all the facts in our possession." — Massachusetts State Board of Health, Part II, Report on Water Supply and Sewerage, 1888-1890, p. 847.

We speak of the process as "intermittent filtration," but it is clear that mechanical filtration is a very subordinate part of it. Simple as this operation appears at first sight, it depends for success on the most extraordinary and interesting biological processes. The filter bed is a farm where certain species of micro-organisms are grown by the acre, to the exclusion of hurtful species. Inadequate as the simple means seem to the end desired, these filter beds, properly managed, can pick out and burn up the one or two parts of dissolved organic matter from each thousand parts of water, they can change the foul sewage which lies on their surface into good drinking water at a depth of five feet, and can do this continuously year after year without any considerable fouling of the filtering sand, except within a few inches of the surface. The principle involved in intermittent filtration is the same which governs the purification of sewage by broad irrigation, previously described. The process can, of course, be much more readily observed and studied in the sand filters than on larger areas covered with farm crops.

Materials which are suitable for filter beds. In general, any coarse or fine gravel or sand, as well as coke and cinder, can be used for the purpose, and either, under proper management, will cleanse sewage effectively. Thus at the Lawrence Station, 97 per cent. of the organic nitrogenous matter of sewage and 99 per cent. of the bacteria were removed from it by "filtration" through a bed of pebbles, which were as large as robin's eggs, and this process was continued for some months. (Mass. State Bd. Health Rep., 1890, p. 578.) On the other hand, the filtration of sewage through river silt, which was mostly a very fine sand, yielded clear effluents as pure as the other. But convenience of management, as well as the amount of sewage which can be daily cleansed on a given area, depend very much on the fineness — the mechanical condition — of the filter material. If the material is very coarse, great care is needed to evenly distribute the sewage over the whole surface, and it must be run on the bed very slowly, as otherwise it will pass through the filter too quickly without giving time for oxidation or cleansing. If the material, on the other hand, is too fine, it holds the sewage so strongly by capillary attraction that its passage through the filter is greatly retarded, and the necessary time allowed for drainage and aeration is so great that the quantity of sewage purified in a given time is very limited. Peat cannot under any circumstances be used as a filtering medium for sewage; good arable soil is also unsuitable for the purpose. The light, leachy soils of this State, such as are found at Wallingford, Meriden, and many other places, are admirable materials for making sewage filters.

Efficiency of Sand Filters. In a following table are given data showing, in the last three columns, the percentage purification effected by experiment filters at the Lawrence Station, for the year 1895, each filter having an area of 1/200 acre (Mass. State Bd. Health, Rep. 1895, p. 461), as measured by the percentage removal of albuminoid ammonia (putrescible nitrogenous matter) and bacteria, and by the percentage reduction of " oxygen consumed."

EFFICIENCY OF LAND FILTERS.

No. of Filter.	Depth of Sand, inches.	Size of Sand.		In Operation Since	Av. Rate of Filtration Gals. per Acre, Daily.	Average Per Cent. Removed of		
		Effective Size* (Millimeters), 10 per cent. finer than,	Uniformity** Coefficient.			Albuminoid Ammonia.	Oxygen Consumed.	Bacteria.
1	63	0.48	2.4	Jan. 10, 1888,	67,000	89	86	97.55
2	60	0.08	2.0	Dec. 19, 1887,	34,000	97	95	99.98
4	60	0.04	2.7	Dec. 19, 1887,	15,000	98	96	99.99
5a	63	1.40	2.4	Sept. 14, 1891,	66,000	85	83	94.50
6	44	0.35	7.8	Jan. 12, 1888,	56,000	90	89	99.10
9a	60	0.17	2.0	Nov. 18, 1890,	66,000	90	89	98.70
10	60	0.35	7.8	July 18, 1894,	30,000	94	90	99.50

* The "effective size" of a sample of sand is such a size that ten per cent. of the material is of smaller grains and ninety per cent. of larger grains than the size given. The results obtained at Lawrence indicate that the finer ten per cent. have as much influence upon the action of a material in filtration as the coarser ninety per cent.

** The "uniformity coefficient" designates the ratio of the size of grain which has sixty per cent. finer than itself to the size which has ten per cent. finer than itself.

For discussion of the physical properties of sands and gravels, with reference to their use for filtration, see Mass. State B'd Health Rep't, 1892, p. 541.

Here are filters, some of which have been in continuous use for eight years, disposing of from 15,000 to 66,000 gallons per acre of sewage daily, and removing from 83 to 96 per cent. of the putrescible nitrogenous matter, and from 94½ to 99.99 per cent. of bacteria.

These results show that with skillful management, from 30,000 to 70,000 gallons of sewage may be purified every twenty-four hours on an acre of filter bed. Other experiments indicate that an acre of land will purify 100,000 gallons of crude sewage per day *during the spring, summer, and fall,* but the amount which can be purified per acre *in winter,* in this latitude, is very much less.

Professor L. P. Kinnicutt (Jour. Am. Chem. Soc., Vol. XX, No. 3, Mar., 1898, p. 187) states that from observations made at several disposal works in Massachusetts, he believes that twice, at least, and possibly four times, as much area is required in winter as in summer. If less skill is used in management, the amount purified will be smaller or else the degree of purification will be lower both summer and winter. Much larger quantities of sewage could have been handled on these beds if those operating them had been content with a less thorough purification. Under ordinary conditions and working on a large scale, it is quite probable that the degree of purification would be considerably lower than in the Lawrence experiment.

Odor from the beds. It is often stated that these filtration beds are odorless. It is true that at some seasons no odor can be noticed even in their immediate neighborhood. But it is not true that they are always free from odor, even when properly managed. On warm days in March, when the frost is coming out of the ground, and on close "muggy" days in summer, there is a distinct sewage smell noticeable at a short distance from the beds. This comes largely from the moist sludge, the solid matter in the sewage, which remains on the surface until raked up. The odor is not intense, it is not widespread, but it is certainly there. It would not be wise to use for sewage disposal a small tract of land, close to a popular highway or in a thickly-populated district. The city should own enough land, unsettled, to make the odors unnoticeable in dwelling houses. A well-managed sewage farm ought not to be as offensive to the public as a well-managed rendering establishment, but neither of them should be installed in a thickly-settled place.

Permanency of the filter beds. After six years of careful experiment at the Lawrence Station, these conclusions have been reached (Mass. State Bd. Health, Rep't 1894, p. 490): "(1) With the same main body of sand, sewage filters may continue to purify sewage for an indefinite time, provided they receive proper treatment to insure sufficient ventilation for the oxidation and nitrification of the applied organic matters. (2) That the permanency of sewage filters is independent of the size of the filtering material, and is directly dependent upon the treatment which they receive."

Two years later (Mass. State Bd. Health, Rep't 1896, p. 471) the Board reports: "There are now at the Station six filters, 1/200 of an acre in area and containing different grades of filtering material, which have been in operation for periods varying from five to nine years. . . . Since 1893 there has been no removal of filtering material from any of the large experimental filters, and the removal or destruction of the large amount of organic matters of the sewage has been accomplished without impairing the action or shortening the life of the filter. That is to say, this organic matter has either passed from the filters into the air in gaseous forms of carbon and nitrogen, or has united with a base and passed away in the effluent in the form of mineral salts in solution."

Effects of frost. On this point the observations made by the Massachusetts Board of Health and the experience of the Massachusetts Municipal Sewage Disposal Works have special value, as they apply directly to our conditions. Our winters are not more rigorous than theirs. The Massachusetts State Board of Health, Report 1894, p. 530, sums up the present knowledge on the subject as follows:

> "(1) In Massachusetts the qualitative efficiency of sewage filters may be less in winter, owing chiefly to inactivity of micro-organisms caused by exposure to low temperature; and from our present knowledge it does not seem advisable to allow filters exposed to the weather to rest in winter, even for limited periods. . . . (2) Qualitative deterioration is a serious matter in winter, because when a period of biological reconstruction is necessary, nitrification cannot be promptly re-established, as is the case in summer, but requires a period of several weeks and possibly months. (3) While nitrification cannot be readily re-established in winter, it has been learned that in those cases where this process was in a satisfactory state at the beginning of the winter it could, by proper treatment, be preserved during the cold season. . . . (6) The less exposure to cold winter weather which the surface of the filter undergoes, the greater the number of heat units saved, and the better will be the results, both quantitatively and qualitatively. (7) The application of sewage to limited portions, such as trenches, in the case of filters of fine materials, concentrates the heat, thereby aiding in preserving the biological processes and in maintaining the qualitative efficiency. . . . (9) The composition of sewage, and particularly the amount of sludge applied to filters, is a much more marked factor in winter than in summer, even in the case of experimental filters where especial lines of treatment to keep the filters in operation are feasible."

In this connection we may cite an experience of the Framingham Sewer Committee (Rep. Sewer Com., Framingham, Mass., 1893, p. 120):

> "Much apprehension was felt by many of our citizens, when this system was first recommended to the town, that, during extreme cold weather, much difficulty would be encountered in disposing of the sewage. During the last winter, which has been the coldest known for years, several practical tests were made, to determine exactly how long it would take to remove the frost from the soil. These tests were made at the suggestion of representatives of the State Board of Health, and were successful far beyond our most sanguine expectations. They were as follows:
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> "January 9, 18 inches frost, 10 inches snow; temperature 6 degrees below zero; pumped 300,000 gallons sewage; January 10, pumped on same bed 150,000 gallons sewage; underdrain started in six hours; January 11, frost entirely out in some places; January 12, frost almost entirely gone, and sewage all disappeared; tempera-

ture of sewage 50 Fahrenheit; area of bed, seven-eighths acre. No sewage matter has been pumped on the bed since September.

"On January 16th, another test was made on bed of one acre. Pumped 500,000 gallons sewage, temperature 49 Fahrenheit; January 17, pumped 175,000 gallons. On this bed there was fifteen inches of snow and from twenty to thirty inches of frost. Temperature of weather January 16th, 6 below; 17th, 20 below; 18th, 4 below zero. Underdrain started in 7 hours from commencement of pumping. January 18, frost all gone in some places; 19th, frost nearly all disappeared and sewage had entirely disappeared. Not more than ten inches of frost has been encountered there previous to this year."

Practical experience in sand filtration of sewage. More convincing, perhaps, to some, than the results obtained with small experimental filters under the management of chemists and bacteriologists will be the actual results of the work of sewage disposal works in cities and boroughs, managed by practical men, on the general plan suggested by the experiments of investigators. South Framingham excludes storm water from its sewers, and in 1889 began to purify its sewage by intermittent filtration. A full description of the plant, with a plan of the beds, is found in Massachusetts State Board Health, Report 1892, p. 560. There are seventy acres of land owned by the town, of which twelve acres are prepared for filtration beds. On a large part of these, crops have been raised with favorable effect on the purification of the sewage. The following extracts from the town reports will show what the actual working of the beds has been for eight years.

Report of 1890. "At the irrigation field the sewage has been disposed of on an area not exceeding one and a half acres. Most of the sewage during the winter has been directed by means of shallow ditches to flow over stump land. The surplus, — a comparatively small quantity, — was turned into the beds. Both beds and unprepared land have worked very satisfactorily. The greatest depth of frost at the farm over which the sewage flowed was three inches; this, in five hours after commencement of pumping, had completely disappeared. No sewage is to be seen outside of the ditches forty-five minutes after the pumps have stopped."

Report of 1891. "At the sewage field no trouble has been experienced in disposing of the sewage. In the summer season nearly all has been allowed to flow on the stubble land; during the last three months two of the filtration beds have been used. No trouble from frost has been experienced in either method of disposal. No complaint has been made to us of any offensive odors arising from the sewage fields and we do not anticipate any difficulty from that source."

Report of 1892. "At the sewage farm no trouble has been experienced in disposing of the sewage, and its treatment has met the approval of the State Board of Health, who, in their last report, commented favorably on the disposition of sewage at the Framingham sewage farm. Some experiments have been made the past year in raising crops at the irrigation field, and enough has been accomplished to convince your Committee that quite an income can be derived by the town from this means; and your Committee believes that the raising of crops should be increased from year to year as the condition of the ground will admit of it. This can be done with little or no extra expense."

Report of 1894. "At the sewer farm everything is in a most satisfactory condition. No trouble has been experienced in disposing of the sewage, and an analysis made by the State Board of Health samples being taken every two (2) weeks during the entire year, shows that ninety-eight (98) per cent. of the impurities have been removed from the sewage. . . . There were raised on the filter beds the past year, a large quantity of field corn, squash, beans, potatoes, and cabbage, which, owing to Section 17 of the town's by-laws, we are obliged to sell at public auction, selling much below their value, by reason of the uncertainty of just how much each bed would yield. . . . Your Committee believe that in a few years the sewer farm will, if properly managed, become self-sustaining."

Report of 1896. "At the sewer farm everything is in a most satisfactory condition. During the year three (3) new beds have been constructed and all the banks have been leveled up and the appearance of the whole farm has been much improved. The crops which have been raised, mostly field corn, were fully as abundant as formerly, but, owing to the low price of Western corn, we were unable to obtain as high a price as the year previous, but the amount sold netted the town three hundred and seven dollars and eighty-five cents ($307.85). The analysis of the effluent at the sewer farm, by the State Board of Health," shows satisfactory purification.

Report of 1897. "We have also been obliged to make over three of the filter beds, the surfaces of which had become *quite uneven*, so that their efficiency had become impaired to quite an extent. . . . The amount of sewage continues to increase, the average daily amount now being about 400,000 gallons."

Report of 1898. "The buildings and grounds at the pumping station are in good order, and the plant is operated at a very small expense for labor. The sewer farm is in a satisfactory condition, the filter beds are doing their work well, as is shown by the analysis of the effluent water made at intervals by the State Board of Health. The crop of corn raised the past season sold at auction for $290.50."

Late in October, 1898, in reply to letters of inquiry addressed to the managers of all sewage filtration works in Massachusetts, we received the following information regarding the practical working of the beds:

Medfield. (System introduced in 1886.) "No trouble with odor from the beds, nor with freezing in winter, nor with clogging of the beds."

Gardner, Mass. (System introduced in 1891.) "No trouble with odors. Owing to scarcity of suitable filter material, our filter beds having an area of only about two and one-half acres, and to the formation of ice, we cannot scrape and clean the surface of the beds in winter, so that they become somewhat clogged during the extreme cold weather. We do not notice any decrease in efficiency of the beds from year to year. Each spring, after the ice is gone, we plow the surface deeply, after cleaning off the winter's deposit, then harrow and smooth the beds, and they work just as well as ever. Our minimum flow of sewage is about 225,000 gallons daily."

Westboro, Mass. (System introduced in 1893.) "We have no reason for complaint of odors; the sludge hole near the gatehouse is the only thing that ever smells, and twenty rods from that you would not know it was in existence. The beds never freeze. We have one hundred and fifty thousand gallons of spring water a day through the winter months, so we can cover the beds, that the soil of the beds does not freeze, so they filter all winter. The decrease in efficiency is very slight, if any. We plant the beds to corn every year, which helps to remove the foul matter. I might say the beds are working very satisfactorily.

Brockton, Mass. (System introduced in 1894.) "There is no serious trouble at any time from odor from the filter beds. Odor is most noticeable during the months of March and April, when the frost is coming out of the ground. The nearest dwelling is one-half mile distant from the beds, except the house occupied by the man in charge, who, together with his wife and children, live there throughout the year."

"During the first winter after the beds were put in operation there was trouble with frost. The next winter all the beds were furrowed. Flowing in these furrows the sewage exposes less surface to the air and hence holds its heat better. Subsidence cannot take place till the sewage has thawed the sand below, and meantime a thin sheet of ice forms over the surface. Subsidence of the liquid sewage follows, but the thin ice sheet spanning the trenches protects them in great measure from further freezing. In time, however, an impervious layer of sludge forms in the bottom of the trenches, which impairs the rapidity of the filter. The objectionable feature of furrows is the increased difficulty of cleaning them in the spring. As long as the sludge deposit remains frozen, no odor results; but when spring comes the odors are manifest, though not constituting a nuisance by any means. The deposits were removed early in April, since which time no odor sufficient to be called objectionable by the most sensitive has been apparent."

Regarding the permanence of the beds, the engineer says: "The clogging of sand usually extends but a few inches below the surface, so that the bed, after being raked and allowed to rest for a short time, is as efficient as before. I would say in addition that we have twenty-three beds of one acre each, and we use from six to eight beds daily.

Natick, Mass. (System introduced in 1896.) "Our filter beds are two miles from the center of the town — nearest farmhouses about half a mile distant. Our system is just entering on its third year; only 250 connections; very much ground water enters the system, which assists the filtration, and no large amount of organic matter remains on the surface, which is frequently scraped. There is an odor noticeable in the vicinity at times, but not continuous. On account of the small number of connections and the large amount of ground water entering the system (two-thirds of entire pumping of 250,000 gallons per day), and the short time in use, we have had no difficulty as yet with clogging of the beds. By watching gates and changing twice or more times a day, what freezes on the beds in winter will thaw out soon after the introduction of sewage the next morning. We are working six beds, each a square acre. In the summer and fall one bed will handle the pumping of two days without change, while in the winter and early spring three beds are often employed in one day. Heavy snowfalls also cause some trouble."

The first works for the disposal of town sewage by intermittent filtration in Massachusetts were built at Lenox in 1876. Amherst followed in 1881, Medfield in 1886, Framingham in 1889, Gardner and Marlborough in 1891, Westborough in 1893, Brockton 1894, Leicester and Natick in 1896. Brief descriptions of these several plants and analyses of their sewage and effluent waters will be found in the Reports of Massachusetts State Board of Health, 1893, pp. 563-594; 1895, pp. 601-635; 1896, pp. 581-597.

In our own State the system of sewage disposal by sand filtration was adopted in Meriden and Litchfield in 1892, in Bristol in 1895, and in Danbury in 1897. In all these places in Massachusetts and Connecticut the system is to-day in successful operation. It is also in use in many other places, chiefly in this latitude or to the south of it, but these are named because they are in our immediate neighborhood.

Need of strict regimen in management. A study of the means by which sewage is cleansed in the sand filters, as well as of the experience of those who have practically operated them, makes it clear that they require constant care and great regularity in their treatment. The sand filters are not dead, they are teeming with active life, and this life depends on certain things: food supply, air, heat, etc., and on regularity in the supply of these things. To leave the sewage running on a bed for twelve hours beyond the prescribed time, because of a severe storm or a circus in the next town, is as culpable as to leave a herd of cows or a barn full of horses without food or drink for the same length of time, and may be vastly more harmful to the property and health of the community. If sewage stands too long on a filter, the air supply is reduced below the normal, the nitrifying microbes are checked in their work, perhaps destroyed in part, and thus the filter is made less efficient, not for a single day only, but for a considerable period of convalescence. If excessive quantities of sewage are poured on, the whole filter may become foul and require weeks to clear itself. "It becomes evident that the efficiency of a filter depends much upon steadily following a course of action, and requiring every part of it to accomplish the same work at regular intervals of time. The filter becomes a delicate organization, adapted to what is required of it, if its possibilties are not exceeded; but any change from the requirements is likely to render necessary weeks of time before the filter can become adapted to the changed conditions." (Mass. State Bd. Health, Part II, Report on Water Supply and Sewerage, 1888-1890, p. 25.) No chemical or bacteriological skill is necessary for the detail of management on the sewage field, but there is needed a man who is absolutely faithful in carrying out the directions of the city engineer or selectmen, who is intelligent, and who has acquired experience in meeting all the vicissitudes of weather and knows the individual peculiarities of the beds. The Commission have had occasion to observe the havoc wrought by a field superintendent without these qualifications, and to see a disposal field, which had been working perfectly, made inefficient and a menace to health because of a city election. A superintendent, who was faithful and competent but incapacitated from further work, presumably, because of his views on questions of national finance or legislative representation, was replaced by a man utterly without experience in managing a sewage field. But the new man had these qualifications: he was presumably sound in his views on national finance; he had great influence in his end of the ward; he had worked for the ticket and therefore he had earned the patriot's reward — steady light work and sure pay from the public funds. As well might a city overturn its fire and engineering departments, or its police force, after an election, as the management of its sewage disposal works. "Offensive partisanship" gets a new meaning and illustration when, in the way just referred to, the sewage disposal works of a city are neglected or mismanaged. The same trouble has been experienced in England. "There cannot be too plain speaking upon this matter. It has for years been a standing evil, and many who have had to do with sewage treatment have keenly felt the disadvantages they have been laboring under when they see a delicately worked-out process handed over to the fumbling of a farm laborer, or superannuated foreman, or an engine driver, without the slightest knowledge of the real engine which he has to drive, namely, the process entrusted to his charge." (Purification of Sewage and Water, Dibdin, p. 82.)

The data which have been given above make it clear that where land and suitable filtering material are available, the system of intermittent filtration will thoroughly cleanse sewage so that the effluent from it may safely be discharged into any water-way not used as a water supply, and that this effluent can neither putrefy by itself nor induce putrefaction in other waters. There may be cases where, for various reasons, this method is inapplicable and some other way must be found. But where suitable filter beds can be made, near at hand. and the sewage delivered to them at any reasonable cost, filtration with auxiliary sewage farming seems to offer the best solution of the question of sewage disposal for our larger towns and cities.

Thus we come back again to the old farm way of getting rid of dish water! Throw it on the surface, not always in one place, never in a steady stream, but always intermittently. The housekeeper of fifty years ago unwittingly cultivated nitrifying microbes and cleansed her waste water by their help, without offense to any one. The modern city, with modern knowledge, may, and in some cases must, do the same thing for its sewage. Smaller cities and boroughs which have not yet provided themselves with a sewer system would do well at the outset to get a sewage disposal field, if possible near at hand, in an unsettled neighborhood, before the growth of the place has made such property hard to secure. A few acres can then be prepared to take care of the present flow of sewage, and more can be put in order as the growth of the place makes it necessary.

It sometimes happens that a village grows in such a way that there is immediate need of a system of sewers and provision for sewage disposal, with due allowance for subsequent enlargement, long before the village has a population large enough to bear the initial expense of such an undertaking. It is suggested that in such cases a wealthy citizen, who wishes to leave some memorial of himself in his native town, could do nothing which would contribute more to the health and comfort of its inhabitants than to establish and equip a tract of land for sewage disposal by filtration with or without farm irrigation. While such a place might not gratify the æsthetic sense, perhaps, as a watering-trough, with a verse of Scripture, or a chime of bells, or a stained-glass window might gratify it, it would yet teach a daily lesson of cleanliness, and it would protect the community from much preventable sickness and death. In itself it would be far from unsightly, which is more than can be said of very many "memorial" atrocities.

DIBDEN'S METHOD OF SEWAGE FILTRATION.

In England, where sand suitable for making sewage filters is not as common as in this part of the United States, certain porous materials, especially coke, cinders, clinker, burned clay, etc., have been substituted. Mr. W. J. Bibdin, a chemist of experience, as the outcome of experiments made with London sewage, has devised a filtration system, differing in construction and management from that already described, but similar in principle, *i. e.*, the organic matter of the sewage is destroyed by microbe action. This system, at first applied to the effluents from chemical precipitation works, has now been used successfully for crude sewage and also for factory wastes. Sutton, England, was the first town to introduce the system, which is thus described by Professor L. P. Kinnicutt (Jour. Am. Chem. Soc., Vol. XX, No. 3, Mar., 1898, p. 189):

"The population draining into the sewers is about 13,000, and the dry weather flow equals about 400,000 gallons per day. The sewage system is on the 'separate' plan, rainfall being excluded, yet during wet weather a large volume of subsoil water gains access to the sewers. The town contains few, if any, manufacturing establishments, and the sewage may be considered as a strong domestic sewage.

"Sutton formerly purified its sewage by the use of chemicals, and one of the precipitating tanks was utilized for the construction of a (Dibden) filter. On the floor of the tank, whose area was 183 square yards, was laid a six-inch drain, connected with nineteen lateral drains three inches in diameter. The main drain was provided with a six-inch valve, so that the filter could be emptied or filled at will. The pipes were covered with very coarse, burnt clay, and upon this was placed a layer of burnt clay three feet deep, the smallest pieces of which could not pass through a half-inch mesh. The total capacity of this filter was 218 cubic yards, and when filled with burnt clay it would hold 13,500 gallons.

"The crude sewage, after passing through iron screens to intercept large pieces of paper, is carried directly to the filter, the flow being stopped as soon as the sewage level reaches within an inch or so of the burnt clay. The time required for filling the filter is about one hour. The filter is allowed to remain full for about two hours, and then emptied, the time occupied in emptying it being one and one-half hours. The filter is then allowed to rest for two hours, after which it is again charged. The effluent obtained is clear and without any strong odor, and appears to the eye equal to the best effluent obtained by the chemical precipitation process. From analyses made three or four times each month, from November, 1896, to June, 1897, and published in the *Surveyor* for July 9, 1897, the amount of purification, as calculated from the albuminoid ammonia, equals about fifty-eight per cent., while the amount of suspended matter is reduced from fifty to two and three-tenths grains per gallon.

"The work of the filter compares favorably with the results obtained by many of the chemical precipitation processes, and, though twelve months is possibly too short a period from which to draw conclusions, the city is now constructing three more bacteria filters, and there seems to be no question that the above method leads one to entertain the view that, with domestic sewage, a purification equal to that obtained by chemical precipitation is possible with comparatively small, artificially prepared filters; and from experiments which are now being made, it seems possible that some similar plan can be used with the sewage of a manufacturing city.

"The effluent obtained by the bacteria filter when running at the rate of 1,000,000 gallons per acre is not sufficiently pure to drain into a water-course, whose volume only equals or is less than the volume of the effluent; and when the stream runs through a thickly populated district, as is the case in Sutton, the first effluent must be run through another filter of the same size and construction, filled, however, with burnt clay, all of which is small enough to pass through a half-inch mesh. The effluent from this second filter, at the time of my visit, was bright, clear, and without odor. The average amount of albuminoid ammonia in this effluent, during the seven months from November to June, was 0.243 part in 100,000 parts, the original sewage containing 1.130 parts, and the amount of suspended matter was reduced to 0.703 grain per gallon."

In the Jour. Soc. Chem. Ind., 1898, April, p. 315, Dibden gives the results of the operation of the Sutton filters for eighteen months, on crude sewage. The degree of purification is measured by the oxygen consumed, reduction of albuminoid ammonia, increase of nitrites, etc. From February, 1897, to March, 1898, inclusive, the average monthly purification ranged from 48 to 90 per cent. of the albuminoid ammonia contained in the crude sewage, the average of all being 77 per cent. The Dibden system is stated to have also worked successfully with sewage strongly polluted with some special factory waste. It is stated that at Leeds during six months 200,000 gallons per day have been successfully purified, the effluents being bright, odorless, save for a slightly earthy smell at times, and absolutely non-putrescible. Fish have lived and thrived in them for three months.

The town of Oswestry, England, population 10,000, has adopted this system after experiments lasting nearly a year, during which 15,000 gallons of crude sewage were daily treated, removing about 95 per cent. of the organic matters on the average. The following brief description of the experimental works is taken from the Oswestry and Border Counties Advertiser, kindly sent to us by Mr. R. O. Wynne-Roberts, the borough surveyor and engineer:

> "Some £30 were spent in the making of the necessary tanks. . . . A stream of the partially separated sewage flows into a gauge tank. It then passes over a two-inch notch, by which 15,000 gallons per day are dealt with, and along wooden troughs on to beds of riddled cinders, taken from the rubbish heaps. There are four of these beds, each 16 yards in superficial area, and having a depth of 4 feet 6 inches. During its passage through the cinders the sewage, which contains the germs of its own destruction, is purified by the bacteria which are cultivated. In the filter beds these creatures live on the filth, and while the tank stands full, purify the liquid. . . . The four beds are used alternately, and Mr. Roberts, by an ingenious and simple contrivance, has devised an arrangement by which they are controlled automatically. The sewage from the gauging tank is received in a center basin, and flows thence by a valve on to one of the beds. When the water reaches a certain level it overflows along a pipe into a tumbling basin which, when partially full, tips over, and in doing so closes the valve of bed No. 1, and opens that of No. 2, which is the next to receive the sewage. Two hours are taken to fill a tank, and in that time, it is stated by experts, the bacteria have had ample time to do their work. Bed No. 2 next overflows and automatically closes its own valve, and opens that of No. 3, at the same time discharging the sewage of No. 1, which has been standing full. This discharge takes ten or fifteen minutes, after which the bed remains empty for some hours, and the bacteria in the filters get their necessary supply of air. Though this treatment is continually going on, there is no filth left in the cinders, the millions of microbes having

destroyed all trace of it. From these beds the effluent, which is of the usual light gray color when leaving bacteria-filters, passes on to another bed made of screenings from the rubbish heap, through which it percolates. This is the end of the treatment, and the final effluent is remarkably good, both in appearance and taste. In looks it is little different from spring water, and it has absolutely no smell."

A description of the works for treating all the sewage of Oswestry, communicated to us by Mr. Wynne-Roberts, is as follows:

"The Town Council were so satisfied with the results of the experiments that they voted £200 to construct large filter beds; to this sum they have already added £620, making a total of £820, spent out of revenue. The large beds are arranged in two series, called, for distinction, the Primary and Secondary Beds. The Primary Beds are nine in number, each measuring 60 feet by 60 feet by 4½ feet deep. The Secondary Beds, also nine in number, measure 60 feet by 50 feet by 4 feet deep. The Primary Bed takes about 1½ hours to fill, and will stand full for about 3 hours, during which time the bacteria perform their purifying functions. The whole of the beds are made of simple earth embankments with the usual slopes, no concrete or brickwork used whatever. The beds are underdrained by means of 4-inch agricultural drain pipes, laid in parallel rows three feet apart, connecting to the main collecting channel and thence to the center valve. The center valve was designed by our surveyor and is automatic in action. The sewage flows through a trough on the top and is distributed to the various beds in their turn. At the same time the outlet pipes are opened according to the time the beds have been standing full. By means of these center valves manual labor, superintending the working of the beds, is reduced in daytime to a minimum, while it dispenses with night and Sunday labor entirely. The cost of the complete series of beds will be about £1,500, the land cost £1,000, making a total of £2,500. The annual burden will be about £100."

Dibden's system of filtration is well worth further study, as it may possibly be suited for places which cannot get access to suitable filtration areas of sufficient size. An acre of filter surface, arranged on Dibden's plan, will apparently take care of vastly more sewage per day than an acre of sand filter, through the degree of purification effected, where large quantities of sewage are treated, is not so great.

Roscoe, in a report on the effluents from disposal works (Jour. Soc. Chem. Ind., 1896, p. 916), says: "So far as chemical results are concerned, land filtration far excels the results of either coke or cinder filtration"; but it is pointed out that the volume of effluent which can be treated permanently on land is limited, as compared with the volume which can be treated by artificial filters.

THE SEPTIC TANK.

The last method of treating sewage which we shall notice is the so-called septic tank. This is rather to be regarded as a method of preparing sewage for intermittent filtration than a system complete in itself. We have already spoken of the two great classes of microbes, those which live only where air (oxygen) is absent, or its supply very limited, and those which require abundance of air. In the first class are the microbes of putrefaction which decompose the organic matters of sewage, yielding gaseous and solid products which have an offensive odor. The septice tank is a device for decomposing sewage by the microbes of putrefaction, with exclusion of air. One has recently been installed at Exeter, England, planned by Mr. Cameron, and thus described by Professor Kinnicutt (Jour. Am. Chem. Soc., Vol. XX, No. 3, March, 1898, p. 192):

> "The plant consists of the so-called septic tank, which is an underground tank built of cement concrete, sixty-four feet long, eighteen feet wide, and of an average depth of seven feet, having a capacity of about 53,000 gallons, and of five filters made of coke breeze and furnace clinkers, about five feet in depth and covering all together an area of 400 square yards, having a capacity of 695 cubic yards. The crude sewage, as it arrives at the plant, passes through a railing to prevent large objects from entering the tank, while all small particles and solids in suspension pass freely to a grit chamber, which is divided in two, each part having an inlet into tne tank. The inlets are close to the bottom of the tank, and the aperture of the inlet pipes is smaller on the tank side than on the sewer side, so that the sewage enters the tank with considerable force. The outlets are also underneath the surface of the water so as not to admit air or light, and so arranged that the water at the middle depth alone escapes. They are gauged so that the rate of flow may be measured; usually it is about 3,000 gallons per hour. The sewage from the septic tank is discharged simultaneously on two of the bacteria filters, arranged according to Dibden's method. When these two filters are full they are emptied of their contents, and, while being emptied, the sewage from the tank passes on to others. The fifth filter remains idle one week, when it takes the place of the one that has longest been in use. Thus each filter remains idle one week out of every four. The filling and emptying of these filters is done automatically by an ingenious arrangement patented by Mr. Cameron and is said to be most satisfactory.
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> " The action inside the tank is essentially of a putrefactive nature, no nitrates being formed. The organic matter is decomposed, or rather broken up into simpler forms, a large amount being rendered soluble, while at the same time ammonia and, I believe, free nitrogen, are being formed. According to analyses made by Dibden, the amount of oxidizable organic matter in solution is reduced about 30.8 per cent., the free ammonia about 26.9 per cent., the albuminoid

ammonia about 17 per cent., and the suspended solids about 55 per cent. Pearmain and Moor, who have made a report on the process, state that there is no accumulation of sludge in the tank beyond a small amount of thin black sediment, which they report is so slight that a year's accumulation would scarcely be worth the trouble of removing. F. J. Commin, in a report on the process, published in the *Lancet* for December, 1896, says that the deposit is very fine and inorganic, and that in a small tank, after seven months' continual working, and after quite 2,000,000 gallons of sewage had passed through the tank, the deposit was less than four inches over a surface of twenty-four feet by nine feet.

"On top of the liquid in the tank there is a layer of flocculent matter from two to two and one-half inches in thickness, and from all accounts this seems to have been formed during the first few weeks that the tank was used and not to have increased much in thickness since that time. It appears to be composed of organic matter, formed, I believe, from the suspended matter in the sewage; and from all the information I have been able to obtain, it seems as though the organic matter in this flocculent layer was at first partially decomposed by the putrefactive organisms. Portions of it then sank to the bottom of the tank, where further action took place. Bubbles of gas collected around the fragments that had been carried down, causing them to rise to the surface, and this process went on till the residue that remained at the bottom contained very little organic decomposable matter. . . .

"According to Dibden the liquid that comes from the tank is of a brownish yellow color, offensive, and contains 2.73 grains per gallon of free ammonia, 0.175 grain of albuminoid ammonia, and the amount of oxygen absorbed from potassium permanganate in four hours is 1.405 grains per gallon. It contains no nitrates nor nitrites. The original sewage contained at the same time 3.778 grains free ammonia, 0.212 grain albuminoid ammonia, and the oxygen absorbed from the potassium permanganate was 2.028 grains per gallon. This liquid is passed upon the filters as has been described, and the effluent from these filters contains 1.705 grains free ammonia, 0.078 grain albuminoid ammonia, 0.253 grain nitrogen as nitrites, 0.353 grain nitrogen as nitrates, no suspended matter, and the absorbed oxygen from the potassium permanganate in four hours is only 0.388 grain per gallon.

"The great advantage of the septic tank process, if it does what it appears to do, is that so large an amount of suspended matter is removed from the sewage that there will be very much less trouble with the clogging up of the surface of filter beds in winter, and consequently an area that is large enough for the purification in summer will be more nearly, or possibly quite, sufficient for the work during the winter months.

"It is also claimed that a large amount of the organic matter in solution is removed in the septic tank; and if this is so, which appears probable from the analyses that have been made, it may not be too much to hope that future developments in this direction, taken in connection with the using of the cubical capacity of a bacteria filter, may so reduce the area required for purification that filter beds may, without too great expense, be protected from snow and ice."

Sailors are familiar with the fact that impure and even foul water, if barreled up, will in time "work itself clear," so that it makes excellent drinking water. The process which goes on in the water barrel is in its nature like what goes on in this septic tank.

The use of the septic tank is still in the experimental stage. We cannot regard the efficiency of the Dibden system of rapid filtration through coarse coke breeze or cinder as yet fully determined, but the accounts of its operation so far make it seem probable that it will greatly increase the working capacity of a given area of filter surface, and thus reduce the cost of sewage disposal by filtration for large cities.

The system of chemical precipitation has been fully tested, so that its possibilities and limitations are thoroughly understood.

Chemical precipitation, the septic tank, and Dibden's coke breeze filters dispose of most of the sludge, which greatly limits the filtering capacity of sand filters, but these systems, where full sewage purification is desired, must be regarded, not as independent, but rather as auxiliary to the system of sand filtration. It is possible that further study will prove that large sand areas can be economically replaced by more artificial construction and filtering material, which will make bacterial action more intense, and thus make it possible to handle a given quantity of sewage in less time, on a much smaller area, and at a smaller outlay than under the present system of sand filtration.

SUMMARY.

With four or five exceptions all the cities, towns, and boroughs in Connecticut which have public sewers discharge their sewage into streams or harbors. Many private sewers and drains from factories and dwellings discharge in the same way.

Considerably more than one-half of the inhabitants of the State live in sewered cities or towns, and the dwellings of a majority of these inhabitants contribute to the sewage discharge.

With the increase of population and its concentration in cities and large towns, the relative portion of population contributing to the pollution of our streams, as well as the total amount of pollution, is rapidly increasing.

Strongly polluted streams cannot sufficiently purify themselves.

All the larger streams in the State are so far polluted as to be non-portable and their waters can never be used for domestic water supply unless filtered through sand.

While the largest rivers are not so seriously polluted as to make them a public nuisance, other streams like the Naugatuck, Park River, and the Hockanum have either reached the limit of permissible pollution or have passed it, so that suits are being brought for nuisance and will probably be brought in increasing numbers.

The complaints made in these suits are chiefly of deposits of filth in mill ponds, injury to health by noxious odors and resulting damage to land values.

The courts have found for the plaintiffs in every case that has come to our knowledge, and have rendered decisions strongly upholding the rights of a single riparian owner as against the convenience and financial interests of a large community.

The evils which result from the present excessive pollution of our streams and harbors are (in addition to the invasion of legal rights of riparian owners) possible contamination of water and of ice supply, destruction of fish, general unsightly appearance of the streams, and damage to the public health.

There are only three methods of sewage disposal which are at all permissible as substitutes for water-carriage and dilution, viz.:

1. Chemical Precipitation.
2. Broad Irrigation.
3. Intermittent Filtration.

Of these the first cannot be regarded as in itself complete. It removes all suspended matter and from 30 to 50 per cent. of the putrescible matter of sewage and gives a clear or nearly clear effluent which may safely be discharged into streams under some conditions, but under other conditions filtration of the effluent will be necessary.

The second method, Broad Irrigation, requires a relatively large area of land and may profitably be combined in some cases with the third method, Intermittent Filtration.

This third method, properly managed, secures the almost complete destruction of the dangerous organic matters and bacteria of sewage, and having been in successful operation in this climate for a term of years may be regarded as no longer an experiment, but as a well established and most effective method of destroying sewage.

Unfortunately, some cities are so situated that their sewage can only be brought to land suitable for filters at very large expense.

In conclusion, the Commission offers the following expression of opinion, based on its study of sewage disposal in this State:

1. The disposal of sewage without nuisance is a duty which each community owes to the public.

It is a problem to be settled by each community for itself, with such State supervision and control as is necessary in the public interest.

In some cases, however, several communities, lying in the same topographical district, may profitably unite in the construction and operation of common outfall sewers or of disposal works.

2. No city, borough, or town, which has not now a sewerage system, should be allowed hereafter to build one which will discharge sewage or polluted water into any stream, whether such stream at the time is used by others for sewage disposal or not, nor should private corporations or individuals be allowed to discharge house sewage or excreta into any streams or rivers.

3. To insure sewerage construction and methods of sewage disposal which will be permanently satisfactory, the General Assembly should not grant to any corporation authority to issue bonds for building, or to condemn land for building, or to build any sewers, or system of sewers, until an accurate topographical survey of the region to be sewered has been made, and together with plans for effective sewage purification before discharging the effluent into any stream, has been submitted to, and approved by, some competent State authority.

4. Provision should also be made by which cities and boroughs now having sewage disposal works, or which may hereafter build them, may be compelled by the State to so manage them that the sewage shall at all times be effectively purified before its discharge into rivers.

The State is now at the parting of the ways.

It may leave the whole matter to drift as it will. Our smaller streams will then become more and more polluted, and at last will be so foul during the summer months that private individuals, plagued beyond endurance, will undertake the expense and wearisome delay of lawsuits, and after years of litigation, it may be, will at last succeed in holding up those cities which have most contributed to the defilement and force them to discontinue it and spend hundreds of thousands of dollars in changing their system of disposal. This is what is going on in this State to-day.

Or the State may take up the matter and seek, without unduly interfering with municipalities or manufacturing industry, to stop further pollution of our streams and reduce the present amount of it in the interest of public comfort and health.

Such a policy will need to be framed and executed with great judgment so as always to have behind it the force of public opinion, to be consistent and continuous in its operation, and to be administered with strict impartiality.

This course, we believe, the State should adopt.

RECOMMENDATIONS.

If this commends itself to the General Assembly, we recommend that an act be passed embodying the points covered by Sections 2, 3, and 4, just given. This will check the increase in the fouling of our streams, and will be an advance in the right direction.

We also recommend that the study of sewage disposal in this State be continued by a Sewage Commission. The foregoing report, as already intimated, is of necessity merely preliminary.

There are questions pressing for solution which cannot be immediately answered, but should have careful and intelligent study before any legislative action is taken. Ill-advised legislation, or injunctions of the courts, which will surely follow neglect of these questions by the public, are likely to inflict most serious injury on municipalities and on manufacturing interests.

As examples of these questions we may cite the following:

Are there any means, the value of which has been proved, by which the suspended matters in sewage may be separated and destroyed, by bacterial or other action, so as to greatly increase the quantitative efficiency of sand filtration, with a proportionately large reduction of the area and expense involved in sewage disposal? A most important question where suitable land is scarce or high in price.

Is it practicable or advisable to classify the rivers of our State, or to divide certain streams into sections, a part of which shall be given over to the carriage of sewage, in quantity not sufficient to create a nuisance, and a part of which shall be protected in every possible way from pollution?

Are there certain topographical sections of the State the inhabitants of which, in the interests of economy and public welfare, should be recommended or required to join in the construction of outfall sewers or disposal fields?

Are there factory wastes now discharged into streams which by proper treatment can be purified, made entirely unobjectionable, and the cost of the treatment largely, if not wholly, met by the value of products recovered from those wastes?

There are other equally important questions awaiting study and intelligent decision.

All which is respectfully submitted.

APPENDIX.

A

TWO REPORTS ON SEWAGE DISPOSAL.

As affording some idea of the serious nature of the burden which the necessity for sewage disposal, as at present understood and practiced, may impose upon Connecticut municipalities, we have made the following extracts from reports recently submitted to the cities of New Britain and Waterbury.

WATERBURY.

The report to Waterbury is dated August, 1896, and is made by Rudolph Hering, Esq., of New York, who is recognized as probably the leading sanitary engineer in this country. His finding of facts, discussion, and conclusions may be gathered from the following abstracts:

"The system of sewerage which has been built in your city collects the sewage and discharges it into the Naugatuck river. In the report accompanying the original design for the system (1882), it is stated that the river is sufficiently large to receive the sewage that would be discharged into it then 'without dangerous effects to the towns below. Yet it is not so large that this condition would not change within a reasonable number of years. As soon as the pollution of the river is objected to by other towns the city will be compelled to purify the sewage.' . . . .

"In view of the progress that has been made in the art of sewage disposal since the above was written (1883), you desire that this question now be studied in detail. To do this has required the general inspection of the Naugatuck valley, from Waterbury to the Sound, the making of surveys as far down as Beacon Falls, the examination of sites and soil, where filtration was thought to be practicable, and the collection of other data. All known means of sewage treatment were considered more or less in detail with reference to their application to your city. . . . .

"The population of Waterbury is now estimated at about 35,000. Any works for the disposal of its sewage should now take into consideration a population of at least 75,000 persons.

"While it is proper, when considering the dilution of sewage in a stream, to use the population as a basis and not the quantity of sewage, it is not proper to use the same basis when considering other methods of sewage purification. When dealing with the sewage itself, the size of the sewers, the area of land, the tanks and whatever apparatus may be required, must all be large enough to take the actual quantity delivered, which consists usually of the waste water from houses, of the sub-soil water, and of some rainwater. The great length of an out-fall sewer for the Waterbury sewage renders it important that this quantity should be determined with care and also that it should be kept as small as possible.

"To resume, therefore, it is advisable to calculate at least for the sewage of 75,000 persons at 85 gallons per head, or 6,375,000 gallons per day. This quantity being the average per day, a suitable addition should be made for the maximum flow, which in the case of a long outfall sewer can be estimated at 25 per cent., and represents one-half of the daily sewage running off in about ten hours, or at the rate of 8,000,000 gallons per day. . . .

"I have assumed, further, that the subsoil water reaching the outfall sewer may be kept down to a flow of 500,000 gallons per day.

"Finally, the rain-water or flushing water which is allowed to enter, I have assumed as being equal to the maximum flow of sewage and sub-soil water combined, or at the rate of 8,500,000 gallons per day. . . .

"Therefore, the total maximum quantity of water to be provided for is assumed at 17,000,000 gallons per day, or 26.3 cubic feet per second. The outfall sewer must be large enough to carry at least this quantity. The disposal works must be sufficiently large to purify the daily flow of sewage, also to receive the ground water and a certain quantity of rain-water. The daily flow of sewage and ground water are together assumed at 6,875,000 gallons. The rain-water is a variable quantity and is contributed only occasionally.

Purification of Sewage.

"Besides the method of disposal in the Naugatuck river as used at present, there are in vogue two other practicable methods of rendering sewage inoffensive. One is filtration through porous soil, the other is precipitation and removal of the suspended and some of the dissolved organic matter contained in the sewage.

"There is, however, still another method, and in the distant future possibly the preferable one, and that is the collection of the sewage of the Naugatuck valley in a common outfall sewer, and its discharge into the Sound, in a manner to cause it to be diluted and dispersed by the tidal flow.

"A trip was made down the river, the line located in a general way, and an outlet found. The length of the outfall sewer would be about 31 miles and its cost, if large enough for Waterbury alone and on the economical assumptions made above, would not be less than $1,500,000. To make such a sewer a practicable undertaking would necessitate the co-operation of all the larger towns along the river, which it would be difficult to obtain. But even if it could be obtained, the cost for the city of Waterbury would not be proportioned much below the above figure, and therefore be too high to allow of a serious consideration of the project at the present time. In view of these facts, the details of the plan were not worked out.

"The importance of the problem led to the consideration of still other methods, tried and untried, in order to discover the best solution. But, either the great expense, or the undoubted failure of one or the other to provide the necessary relief to the city and the residents of the Naugatuck valley below, led to their abandonment.

. . . .

"In the present case it is not necessary to obtain a high degree of purity, as the Naugatuck river, into which the treated sewage would return, is not used for drinking or other potable purposes. .

. . .

"Among the two available tracts the one at Beacon Falls is alone sufficiently large to filter the crude sewage of a city of 75,000 persons. There are about 100 acres available, which happens to be the minimum area required.

" The Platt's Mills tract contains only 33 acres. It can therefore be utilized for the above population only after the sewage has been previously treated and freed of suspended matter, which allows a larger quantity to be discharged upon it per acre, than when in a crude state.

" The Beacon Falls tract requires an outfall sewer nine miles long and it (the sewer) will be high enough to deliver the sewage entirely by gravity. The Platt's Mills tract requires an outfall sewer 1.4 miles long, and a lifting of the sewage some 65 feet. . . . .

" Precipitation of the suspended matter contained in the sewage, or a clarification of the same, is a method of purification which has been frequently resorted to where sufficient land was not available for filtration. . . . .

" If the effluent sewage from these works can subsequently be filtered through land, the method is valuable, because, while an acre of porous soil under the conditions I have above assumed, may receive as much as 166,000 gallons of crude sewage per day, it may receive 500,000 gallons of clarified sewage per day, and thus require respectively a much smaller area of land for the same quantity of sewage. For a total flow of 17,000,000 gallons the area would be about 33 acres. . . . .

" The 33 acres of porous land west of Platt's Mills, above mentioned, are not sufficient to purify the crude sewage, even at the present time, by filtration alone. But they are quite sufficient to be used conjointly with the precipitation process, which first clarifies it, and may be sufficient until the assumed population of 75,000 is reached.

" It has been stated that the outfall sewer should be large enough to carry a maximum flow of at least 17,000,000 gallons per day, or 26.3 cubic feet per second. It is therefore assumed for purposes of estimate at 40 inches in diameter.

" If the additional expense for a larger outfall is not a serious objection to your community, it would be well at once to build it 48 inches in diameter, which would increase its capacity to 28,500,000 gallons per day, or 44 cubic feet per second. . . . .

Estimate of Cost and Conclusions.

" The investigation has narrowed the projects down to two that are practicable, and either would render the river free from nuisance. . . . .

" From a sanitary point of view, there is practically no difference between the two projects. A niusance need not occur in either case. The preference, therefore, must rest upon the question of economy.

. . . .

" I have given an estimate for the present as well as for the future needs, the former representing the immediate outlay. I have also given the present and future actual annual outlay, in the way of interest, repairs, renewals, and operation, because it furnishes the best means of making a comparison between the two projects.

" A condensed statement is as follows:

	I Beacon Falls.		II Platt's Mills.	
	Present.	Future.	Present.	Future.
Total investment,	$609,730	$767,580	$138,380	$336,270
Annual cost,	28,489	40,003	21,335	59,569
Average,	$34,246		$40,452	

. . . .

"In conclusion it may be recapitulated:

"That there are only two ways of solving the problem of sewage purification in your city, with the certain prospect of accomplishing satisfactory results, viz.: by land filtration alone, as, for instance, near Beacon Falls, and by combined chemical precipitation and land filtration, as, for instance, near Platt's Mills. Other known ways are either less efficient or more costly. Nor is any process that has been suggested, but is as yet untried, sufficiently promising in the light of modern knowledge, to warrant the expenditure for an experiment.

"On account of their expense, both of the available processes would require the prevention of waste in the use of water, a requirement that entails no real hardship nor evils of any kind. Both processes would also require a restriction regarding the free entrance of rain-water into the sewer system, a demand that is not difficult to enforce.

"Of the two processes, the one contemplating a preliminary precipitation, is not only more complicated, but also more costly to operate; *ceteris paribus*, it is not as advantageous as filtration alone. Unless other than engineering facts enter the problem, the latter process, with the fields at Beacon Falls, should therefore be preferred."

Thus we see that in the opinion of this very eminent engineer, the wisest plan for Waterbury to adopt, if compelled to dispose of its sewage otherwise than by discharging it into the Naugatuck river, would be to carry it to sand filtration fields at Beacon Falls, at a cost of from $600,000 to $770,000, and an annual burden beginning at $28,000 and growing to $40,000 by the year 1915. These figures for annual charges do not include any sinking fund payments.

NEW BRITAIN.

The New Britain report is dated January 25, 1898. It is written by Samuel M. Gray, Esq., of Providence, Rhode Island, formerly city engineer of that city, and author of an extensive report on European sewerage practice.

"New Britain is situated about eight miles west of the Connecticut river and covers an area of about 2,250 acres, and has a population approximating 26,000.

"On the north and east of the city, and also on the southwest, is additional territory, approximating 750 acres, which may and probably will, become a part of the city in the near future, making a total area of 3,000 acres.

"The topography of the city is considerably broken up into ridges and valleys. Its elevation is for the most part between 100 and 300 feet above tide-water, affording good surface drainage by two comparatively small water courses: Piper brook and Shuttle Meadow brook, the former flowing northeasterly through Newington to Hartford, where it empties into Park river; and the latter flowing southeasterly, emptying into the Sebethe river, and finally into the Connecticut river just above Middletown.

"At present there are said to be approximately forty-five miles of streets in the city, and 26.6 miles of sewers, including the southwest district now under construction, all of which, excepting the latter district, were constructed on the combined system. . . . .

"The discharging of the crude sewage into these small water courses and into Piper brook, has been the cause of considerable complaint and litigation against the city, resulting in the city having to pay more or less damages. . . . .

"In considering this question of sewage disposal it will be necessary to take into account the probable future requirements as well as the present needs. . . . .

"It has been thought best to allow for an area of 3,000 acres, and a population of 110,000 for future needs, or in the year 1925, and for the present needs, for a population of 30,000. . . . .

Methods of Sewage Disposal.

"The methods of sewage disposal commonly adopted, may be spoken of as Crude Disposal, Disposal by Irrigation or Filtration, and Disposal by Chemical Precipitation. . . . .

Crude Disposal Into Connecticut River.

"The estimate of cost for disposing of the sewage into the Connecticut river is as follows:

Sewers, rights of way, etc., necessary to take the sewage from New Britain to the Connecticut river, above Middletown. First cost for present and future needs,	$225,600.00
Annual cost of operating, exclusive of interest on the first cost, $3,356.00, capitalized at 5 per cent.,	$67,120.00
Added to the first cost makes,	$292,720.00
To discharge the sewage into the river below Middletown first cost for present and future needs,	$313,070.00
Annual cost of operating, exclusive of interest on first cost, $4,810.70, capitalized at 5 per cent.,	96,214.00
Added to the first cost makes,	$409,284.00

Filtration at Plainville.

"The estimate of cost for disposing of the sewage by filtration at Plainville is as follows:

Pumping station, force-main, land, right of way, construction of filter beds, etc., necessary to dispose of the sewage by filtration at Plainville. First cost for present needs,	$190,000.00
Annual cost of operating, exclusive of interest on first cost, $14,356.00, capitalized at 5 per cent.,	287,120.00
Added to first cost makes,	$477,120.00
That for future needs. First cost,	367,160.00
Annual cost of operating the same, $28,203.60, capitalized at 5 per cent.,	564,072.00
Added to first cost makes,	$931,232.00

Filtration on Artificial Beds.

"The estimated cost of disposing of the sewage by filtration on artificial beds, to be built near the city of New Britain, upon tracts of land before referred to, and indicated on the accompanying plan, are as follows:

For present needs. First cost,	$679,460.00
Annual cost of operating $8,994.60, capitalized at 5 per cent.,	179,892.00
Added to first cost makes,	$859,352.00

For future needs. First cost,	$1,698,650.00
Annual operating expenses $20,736.50, capitalized at 5 per cent.,	414,730.00
Added to first cost makes,	$2,113,380.00

"By these estimates it will be seen that the project of disposing of the sewage by filtration at Plainville is less expensive than to build filter beds near the city of New Britain.

Chemical Precipitation.

"The following is the estimated cost of chemical precipitation, without subsequent filtration of the effluent:

For present needs. First cost of work,	$78,967.00
Annual cost, including labor, cost of chemicals, etc., $14,161.67, capitalized at 5 per cent.,	283,233.00
Added to first cost makes,	$362,200.00
For future needs. First cost of works,	$180,332.00
Annual cost of operating as above, $31,609.37, capitalized at 5 per cent.,	632,187.00
Added to first cost makes,	$812,519.00

. . . . .

"The following is the estimated cost of chemical precipitation with subsequent filtration through sand:

For present needs. First cost of works,	$172,153.00
Annual cost maintenance $8,541.53, capitalized at 5 per cent.,	170,830.00
Added to first cost makes,	$342,983.00
For future needs. First cost of works,	$413,297.00
Annual cost of operating $22,456.37, capitalized at 5 per cent.,	449,127.00
Added to first cost makes,	$862,424.00

"By the estimates it will be seen that the first cost of the chemical precipitation project is less than any other method so far considered, but it will also be seen that the cost of operating capitalized makes it more expensive than the method of chemical precipitation and filtration combined.

"The reason for this is, that the chemical treatment will not need to be quite so thorough by this method as in the former, thereby reducing the annual cost of operating.

. . . . .

"Recapitulation of the estimates of cost of the projects thus far considered:

Crude Disposal Into Connecticut River.

Above Middletown, present and future first cost, $225,600.00; capitalized cost, $292,720.00.

Below Middletown, present and future first cost, $313,070.00; capitalized cost, $409,284.00.

Filtration at Plainville.

Present needs, first cost, $190,000.00; capitalized cost, $477,120.00.

Future needs, first cost, $367,160.00; capitalized cost, $831,232.00.

. . . . .

Filtration on Artificial Beds.

Present needs, first cost, $679,460.00; capitalized cost, $859,352.00.

Future needs, first cost, $1,698,650.00; capitalized cost, $2,113,380.00.

Chemical Precipitation Without Subsequent Filtration.

Present needs, first cost, $78,967.00; capitalized cost, $362,200.00.

Future needs, first cost, $180,332.00; capitalized cost, $812,519.00.

Chemical Precipitation and Filtration Combined.

Present needs, first cost, $172,153.00; capitalized cost, $342,983.00.

Future needs, first cost, $413,297.00; capitalized cost, $862,424.00."

In further discussion of the subject Mr. Gray recommends either chemical precipitation, with subsequent rapid filtration, or filtration at Plainville, as being better adapted to that locality than any of the other of the well-established methods. The first he estimates, on the basis of works sufficient for the city needs at the present time, will cost over $172,000.00 to build and $17,150.00 annual charges. For 1925, $413,300.00 to build and $43,120.00 annual charges.

The second plan he estimates in a similar manner at $190,000.00 first cost and $23,856.00 annual charges for present needs, and $367,160.00 first cost and $46,560.00 annual charges for 1925. (Annual charges do not include any provision for a sinking fund to take up the bonds, but in all cases include interest at 5 per-cent. on the first cost.)

B

THE SEWERAGE SYSTEM AND DISPOSAL FIELDS OF MERIDEN.

In contrast with the very heavy financial burdens which will be imposed on Waterbury and New Britain by a change in their method of sewage disposal may be cited the experience of the city of Meriden, which arranged for sewage disposal by filtration at the same time that a sewerage system was introduced.

Being prevented by legislative action from adopting a plan which discharged the sewage into the Quinnipiac River, the city secured a tract of land of 145½ acres, its center being 17,500 feet from the center of the city, at a cost of $7,148, and built four beds, each having an area of one acre, for the intermittent filtration of sewage. The work was begun in 1891, and at present there are fourteen of these beds in operation. A following diagram shows the topography of the field and the arrangement of the beds.

The city has a population of about 30,000 and an area of 2,414 acres. A water supply was introduced in 1869. The sewer-pipe system is designed for a population of 70,000, discharging 100 gallons of sewage proper per capita daily, with a maximum hourly discharge of 5 gallons per capita. The daily capacity of the outfall is 11,016,000 gallons.

The soil of the disposal field consists of three feet of fine material, underlaid by sand and gravel of unknown depth, admirably suited for sand filtration. The ground water is 18 feet below the surface. It has been found advisable to remove most of the fine material from the surface. Underdrains to receive the effluent have proved to be unnecessary.

Each sewer outlet on the beds has a sort of low fence screen, shown in the pictures which follow. The screen is of galvanized iron wire netting, ¾-inch mesh.

This holds back the coarser part of the sludge, which is removed, and composted after each sewage discharge.

After removing the fine material from the surface of the beds first made, and providing for suitable supervision, the disposal field has worked very successfully, without nuisance, purifying the sewage perfectly.

At present about 391,600,000 gallons of sewage are annually treated at the field, or an average of 1,983,000 gallons per day.

The large beds receive from 900,000 to 1,000,000 gallons of sewage per day *on those days when they are in use.*

The accompanying pictures give a good idea of the appearance and equipment of the filtration beds.

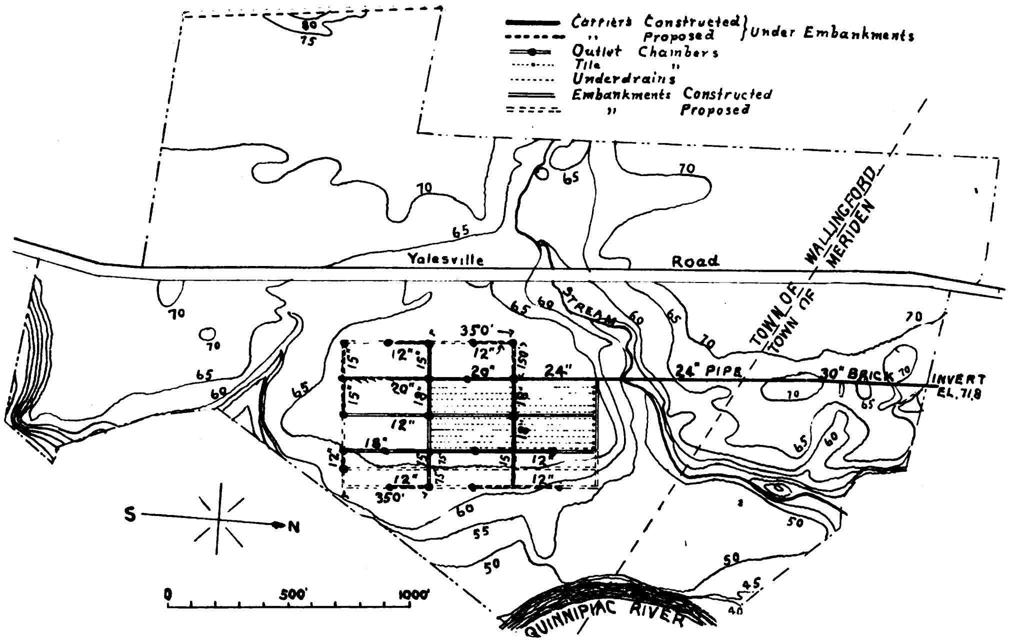
The annual burden for care and maintenance of the filtration beds and that portion of the sewer which is within the filtration field is $3,000, five men and one team being employed.

The following table gives the cost of the *whole sewerage system*, including the disposal field, from the time when the plans were first made:

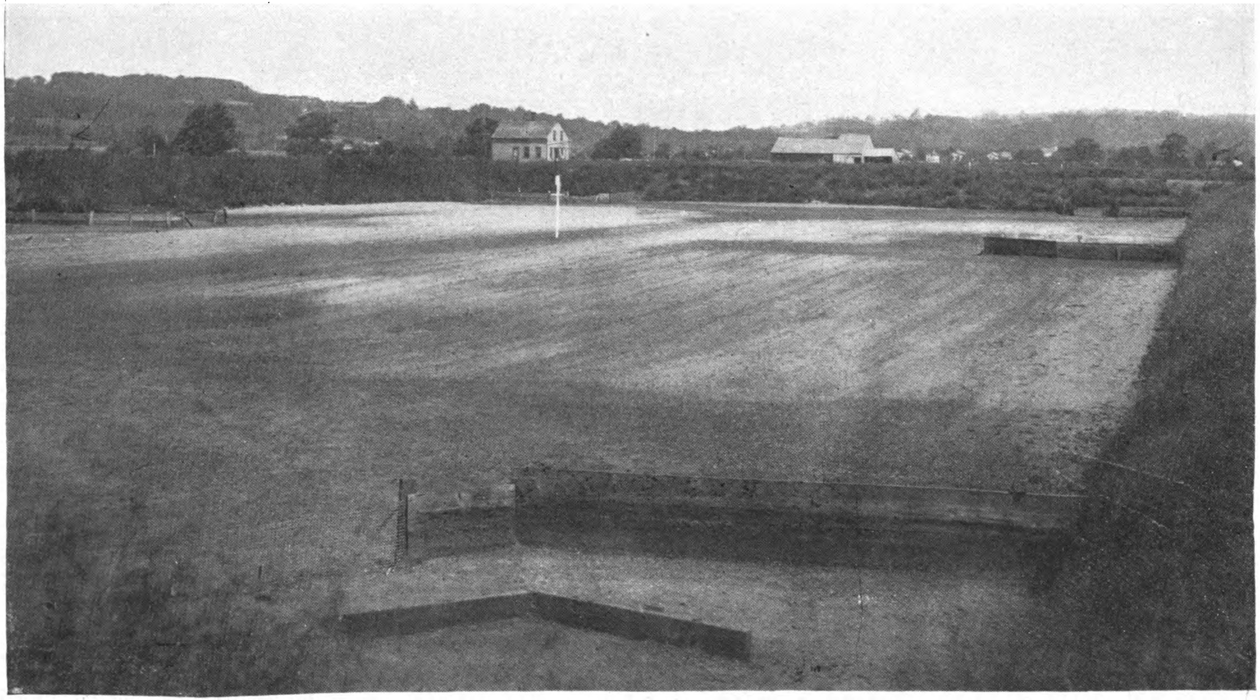
Appropriations.		Expenditures.		Realized from Bonds, Taxes, and Assessments.		
1890,	$500.00	....		1890,	Tax,	$500.00
1891,	95,000.00	1891,	$471.80	1891,	Bonds,	85,000.00
1892,	60,800.00	1892,	104,922.16	1892,	Bonds,	50,000 00
				1892,	Tax,	10,800.00
1893,	110,000.00	1893,	98,722.34	1893,	Tax,	5,000.00
				1893,	Assessment,	49,993.86
1894,	49,700.00	1894,	50,390.28	1894,	Tax,	9,700.00
				1894,	Assessment,	33,448 00
1895,	60,000.00	1895,	49,669.74	1895,	Tax,	10,000.00
				1895,	Assessment,	23,920.00
1896,	60,000.00	1896,	55,143.34	1896,	Tax,	10,000.00
				1896,	Assessment,	32,100.00
1897,	59,000.00	1897,	32,210.59	1897,	Tax,	9,000.00
				1897,	Assessment,	18,255.00
......	....	1898,	45,896.19	......		....
	$495,000.00		$437,426.44			$347,716.86

It appears that up to December, 1898, the total cost had been $437,426.44, which had been raised by:

Bonds, ...	$135,000.00
Assessments, . . .	157,716.86
Taxation, . . .	144,709.58
Total, . . .	$437,426.44

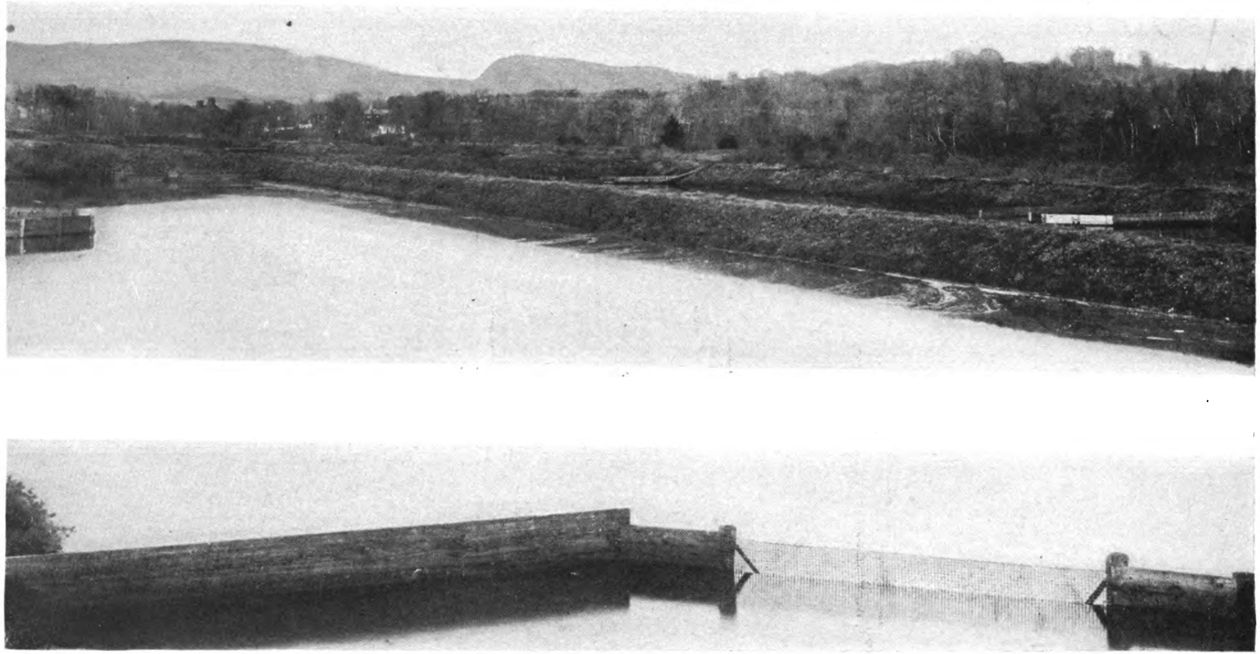


SEWAGE DISPOSAL AREA AT MERIDEN, CONN.



FILTRATION BED, MERIDEN.
Ready to receive sewage.

FILTRATION BED, MERIDEN.
Discharging sewage on the filter.



FILTRATION BED, MERIDEN.
Bed flooded with sewage.