REPORTS

ON

SEWAGE DISPOSAL

OF THE

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REPORT OF THE MEDICAL HEALTH OFFICER

ON THE

DISPOSAL OF THE SEWAGE OF THE CITY OF TORONTO.

To the Chairman and Members of the Local Board of Health:

GENTLEMEN,—As various complaints have from time to time been made to the Health Department regarding the unsanitary condition of various localities along the water front, I have felt it my duty to call the attention of the Board to the wisdom of placing before the Council the need, in the immediate future, of deciding upon some definite plan for the treatment and ultimate disposal of the sewage of the City of Toronto.

I consider the present time opportune, as, in a few years, the water front will likely be rearranged, in accordance with the extension and enlargement of the wharves to the Windmill Line, and possibly some of the sewers extended and the ground prepared by filling, piling, etc.; and as year by year considerable expenditures are incurred for the purpose of dredging the harbor, and proposals entertained for the diverting of the Don, all of which are more or less tentative, I feel it would be a wiser policy for the Municipality, and one upon sanitary grounds much to be preferred, to definitely determine what the ultimate method of dealing with the sewage of the City of Toronto is to be, and to proceed with all subsequent work relating to the general improvement of the water front with due regard thereto.

I think it will be admitted by any one who has given thought to the subject that the water front requires attention, and is in need of being put in a more sanitary and systematic form. The first question which strongly urges itself is the care and disposal of the sewage. The old idea of putting it into water is one not in accordance with modern practices, and one which for many reasons is prejudicial.

The close association between the disposal of sewage and the water supply of the Municipality has been repeatedly brought before the notice of the public. The City of Toronto is the possessor of water facilities and a harbor second to no lake city on the North American Continent, and the continuous deposition of its yield of sludge in the Lake and Bay tends to materially detract from the natural advantages which the City should enjoy.

I do not call attention to the matter at this particular juncture because of the need for alarm, but with the object of urging the advisability of deliberately considering the task, not unassociated with difficulties, of sewage disposal, and with the belief that this can be better done at a time when the problem may be carefully and quietly studied rather than on some occasion when the Municipality may be forced into less independent action. The public generally should also be reminded that a serious and somewhat expensive work must sooner or later be undertaken, and that a careful housing of the resources of the Municipality will consequently be necessary.

In my report, necessarily more or less voluminous, I do not now propose to fully provide a solution of the difficulty, but rather to deal with the processes at present employed elsewhere, and by presenting as briefly as possible an outline of what has been done in other cities, both European and American, under somewhat similar conditions, to indicate the quarter from whence light is to be derived for the solution of our own problem.

The effects produced by the discharge of crude sewage into fresh water to a certain extent depend upon the relative volumes of sewage and clean water thus mixed. If the sewage is small in volume, and immediately diluted with clean water, travelling with a fair head, its removal thus might, under favorable circumstances, be tolerated, but, as a general principle, the discharging of crude sewage into water is fraught with so many evils and dangers that it cannot be too strongly condemned.

At the meeting of the British Association for the Advancement of Science, held at Montreal in 1884, a paper, entitled "Notes on Nitrification," was read by R. Warington, which throws so much light on the subject of sewage disposal that it is here in part reproduced:

"Up to the year 1877 it was supposed that the formation of nitrates from ammonia and from organic compounds containing nitrogen was the result of atmospheric oxidation. The belief had long existed, and had been a favorite one with Liebig and his followers, that the oxygen of the air contained in the soil was condensed on the surfaces of its particles and was renewed by the fresh access of air as rapidly as it was taken up by the process of oxidation, in which it was supposed to be especially active. In the year named, Schlœssing and Muntz showed that nitrification, as studied in the action of soils on sewage, is due to an organized ferment. Later experiments of these chemists and of others have fully sustained this theory.

"The process of nitrification goes on only within the range of temperature which permits the vital activity of living ferments. Near the freezing point it is very low. Its maximum is about 100 degrees, and it ceases at about 130 degrees. The process is dependent on the presence of plant food suitable for low organisms. Antiseptics are fatal to the process; so is a killing heat, whether applied to the soil or elsewhere. In sewage which has been sterilized by boiling, the process of nitrification can be re-established by the addition of a few particles of fresh soil. If protected against the approach of living ferments, it may be exposed to air containing oxygen without nitrification taking place. The organism here active is probably a micrococcus.

"Some important practical conclusions seem to follow from the limitation of the nitrifying organism to the upper layers of the soil. Thus it is evident that the oxidation of nitrogenous matter in soil will be confined to matter near the surface. The nitrates found in the subsoil, in subsoil-drainage waters, have really been produced in the surface soil, and have passed down by diffusion, or in a descending column of water. When we have reduced the filth of our sewage to a condition in which it may be washed out of the soil, or absorbed by roots, then, and not till then, have we destroyed it as filth; but then it is completely destroyed.

"In the place of a particle of meat-fibre we have carbonic acid and water and nitrates, all available for the nourishment of growing plants, and all reduced to what is probably the only form under which vegetation can take them up. The same action converts into plant food the other elements of the sewage. The result is no longer sewage, nor urine, nor fæcal matter, nor an animal or vegetation refuse, it is the renewed elementary condition of the substances, of which these various forms of filth were composed. If a crop be growing on the land, some or all of these resultant products of localized and disseminated putrefaction will enter on their new cycle as plant food. In the absence of such demand, they will, more or less, directly follow water descending through the soil. In either case their career as filth has ceased."

As long ago as 1876, Pasteur, in his studies on fermentation, indicated clearly the difference between decomposition taking place with full exposure in the air, and that going on in liquids from which the air was entirely or mainly excluded.

Waring, in referring to this subject, says: "It is well understood that the bacterium termo, on which we so largely depend for the destruction of organic matter in sewage, is not active except in the presence of air. In the experiments carried on in the laboratory of the Surgeon-General's Office in Washington, it was found that various specific germs planted in rows on gelatine plates can be identified and studied throughout their development so long as the growth of the bacterium termo could be excluded, but the germs of this taking root on the plate, it grew rapidly in all directions, and seemed entirely to destroy all of the special cultures. The inference, however, seems not unreasonable that, under suitable conditions of seeding, all pabulum, and all aeration, as in the surface-soil, the processes of nitrification will destroy germs which, if existing beyond the reach of these processess, that is in a position where atmospheric air is excluded, may remain unharmed, and may retain their power for mischief. This will explain the difference between the safe disposal of infected sewage by irrigation at or near the surface and its unsafe disposal in deep receptacles or by leaky, deep drains."

The Committee of the British Ass ciation, investigating the subject of sewage disposal, say in their report: "(1) Oxidation goes on in winter as well as in summer, and almost all nitrogen lost is lost in an oxidized and inoffensive form; and (2) this loss is very little greater in winter, with a very strong sewage, than in summer with a weaker one, so that sewaging in the winter would appear to entail no extra loss of manure.

"It was also observed that while in summer, sewage is cooled by percolation through the soil, and almost always heated (sometimes considerably so) by surface flow, as was observed both at Tunbridge Wells and Earlswood (the temperature of the effluent water in the latter case being actually five degrees higher than that of the sewage); in winter, on the other hand, the cooling which takes place is less with percolation through the soil than with surface-flow in both instances; so that these results are favorable to percolation through the soil as opposed to mere surface flow, both in summer and winter. Percolation causes a considerable cooling in summer, while in winter it does not cool the effluent water so much as surface-flow does.

"The distribution of bacteria in soil has been made the subject of microscopical investigation by Koch (*Jahresb. d'Agricultur Chemins*, 1881, p. 43). He states that the micro organisms in the soils he has examined diminish rapidly in number with an increasing depth, and at the depth of scarcely a metre the soil is nearly free from bacteria.

"The selection of an outlet, where alternative points are available, involves very full knowledge and sound judgment as to the whole subject of sewer alignment and sewer disposal.

"In inland towns, and often in others, we have to consider some artificial method of disposal. For low-lying towns we have to consider the question of pumping. For towns on the seashore there are questions of tidal rise and fall, tidal currents, the influence of wind, and the character of the shore. In towns on rivers, the influence of floods, of low stages of water, of currents at different stages, and the character of riparian population within a reasonable distance, and the possibility of affecting the interests of those depending on the stream for their water supply, etc., must all be duly weighed.

"In many of these things we have to consider not only, and often not chiefly, what are the facts and the scientific deductions from them which ought to control the work, but also what are the popular prejudices and notions, and what the private interests to be subserved or injured.

"In the execution of public works these conditions not seldom have a controlling influence. Another point relates to the future growth of the town, and how great this is likely to be within a given time, and also how its density is to fall. Whether future growth will follow the movement of past growth or take a new direction; whether proposed industries or probabilities of any sort indicate a material change in the character and location of future dense portions of the community; where the increasing manufactures of the town are to be located here or there, and are likely to produce much or little addition to the volume of the sewage to be removed.

" Having determined the question and character of the outlet in nearly all cases, the details can be worked out from the several ways feasible in which the system may be broken up into branches and laterals, and no absolute rule can be laid down according to which one method is to be selected more than another.

" It is in this part of the work especially that experience, judgment and natural aptitude for seeing all bearings of the question are important, and two points should be constantly kept in view.

" First,—The collection and most complete removal of all sewage.

" Secondly,—The accomplishment of this end in the most economical way.

" There are usually difficulties in the construction of sewage works, and often a great deal other than engineering experience and knoweldge are required in the requisition. To a degree that is not often realized, considerations which sometimes have nothing to do with the construction of the sewers are of paramount importance from the point of view of the public health interests, and the one who has to direct and determine the adoption of methods for the sewage disposal of a large city should have familiarity with the latest researches of physician, chemist, microscopist and biologist, and with the relation that these specialists have shown refuse and organic matter to hold to the health and life of human beings.

The Report of the Royal Commission on Metropolitan Sewage Discharge, 1884, contains the following most suggestive sentences:

" In the first place, no one denies that, by any chemical precipitation, the suspended matters may be almost entirely removed, or, in other words, the sewage may be practically clarified. It is proved that with well devised, not too deep, and abundant tanks so as to allow of complete subsidence (which may be well effected in a few hours), a clarified sewage may be prepared by precipitation, which will contain less than two or three grains of suspended solid matter per gallon. And as it is also admitted that the suspended matters are the worst causes of pollution and nuisance, it follows that the clarification must effect a great improvement.

" It seems also to be the general opinion that the chemical processes in their best form will also have some effect in removing noxious matters in solution. It is difficult to say how much effect will be so produced. The amount has been differently estimated by different persons, and probably it may vary at different times, with different kinds of sewage, and under different modes of treatment, but it cannot be very large. All agree that a considerable amount of polluting matter must be left in the effluent.

" Precipitating processes, though the same in principle as those of 30 years ago, have been greatly improved in detail, and, when well worked, are effectual where the quantity of sewage is not very great, where the sewage can be promptly treated, and where there is a running stream into which the effluent can be discharged in a proportion not exceeding five per cent. of the supply of fresh water.

"But the rationale of these processes has apparently been but little recognized; and, indeed, it is only within the last few years that scientific knowledge has sufficiently advanced to enable us to understand the matter."

PRECIPITATION OF SEWAGE.

With regard to the precipitation of sewage, Corfield and Parkes say:

"In some few towns at a former time attempts were made to strain the sewage by passing it through filters constructed of gravel, ashes or charcoal. The sewage was deprived of its suspended matters, but the filters very rapidly became choked, and had to be renewed at very great cost at frequent intervals. Although the sewage is clarified when the filtering medium is new, it was found that, when not renewed with sufficient frequency, it became possible for the effluent water to pass away with even more valuable elements than the raw sewage itself possessed. The manure, too, produced by the retention of the solid matters in the filter was only usefully employed, owing to its admixture with ashes or charcoal, to mix with and lighten stiff soils. It was not in itself a fertilizer of any but the slightest value. Owing to the great cost incurred in the frequent reconstruction of the filters, and to the fact that the sewage so treated was only clarified and in no degree deprived of its soluble polluting ingredients, these processes of straining or simple filtration have been everywhere now discontinued.

"When sewage is allowed to settle in tanks, the suspended matters, in course of time, subside to the bottom, and a more or less clarified liquid can be decanted from the top of the tanks. In this way, then, it is possible to attain quite as good a result as with the filters previously described, and without the inconvenience and cost arising from the periodical renewal of the filtering medium. But the subsidence of the suspended matters in sewage is a slow process, necessitating the provision of large tanks for the sewage to settle in, and the expenditure of large sums of money in their construction and in the acquisition of the requisite land.

"It soon came to be recognized that the addition of certain chemical substances to the sewage, when mixed with it prior to its entering the settling tanks, causes a more rapid and copious precipitation of the suspended matters than can be effected by subsidence alone. By such means it was found feasible to reduce the tank accommodation, and at the same time to obtain a more satisfactory effluent.

"The number of chemicals that have been used, or advocated, as precipitation agents is enormous. Many of them have proved worthless on practical trial, whilst others, like the various phosphate processes, though shown to be effectual as precipitating materials, depended on what is now known to be the wrong principle of introducing valuable substances into the sewage in the hope of recovering them in the deposited sludge in which they would give a certain fictitious value. Others, again, have been abandoned as being more expensive than certain cheaper substances, whilst not giving any better results. Even to enumerate all these various processes that have at one time or another been tried and then abandoned would be tedious in narration and unproductive in result, as we are more particularly concerned here with those methods that have stood the test of experience and are acknowledged to be, so far as at present known, the best and readiest means of attaining the end desired.

"The three chief substances on which at the present time, in a large majority of instances, is reliance alone placed are lime—as lime water or as milk of lime—sulphate of alumina, and protosulphate of iron.

"Lime exerts a precipitating effect upon sewage by combining with free carbonic acid in the water and with the partially combined carbonic acid of the bicarbonate of calcium, forming an insoluble carbonate of calcium (chalk), which is deposited; and this precipitate carries down with it most of the suspended organic matters of the sewage. These substances sink to the bottom of the settling tank, and form the so-called sludge of sewage. The clear supernatant liquid remains above, and is known as the effluent

"Lime has been longer in use as a precipitation material than any other substance. Leicester, Tottenham and Blackburn were among the first towns to adopt the lime treatment of sewage. Until recently it was generally used as cream or milk of lime (lime slaked and mixed with water) in the proportion of some 15 grains of the lime to the gallon of sewage. Within the last few years, lime water (lime dissolved in water) has been recommended as being equally efficacious with a proportionately less quantity to the gallon of sewage, viz.: five grains instead of fifteen.

"There can be no doubt that the lime process, when worked under the proper conditions of a sufficient quantity of the precipitant intimately mixed with the sewage and of adequate tank accommodation for settling, can be made to effect a very complete deposition of the suspended matters of the sewage, and that thereby it is possible to remove the grosser sewer odor from the effluent. The treatment has, however, very little, if any, effect in precipitating the organic matters in solution, and the ammonia likewise remains unaffected, so that the effluent water carries with it nearly all the valuable manurial ingredients of the sewage, and the sludge left at the bottom of the tanks is comparatively worthless. If the lime is used in too great a quantity, the sludge and effluent are rendered distinctly alkaline, and the tendency to secondary fermentation and decomposition is much promoted. It seems also that the use of an excessive quantity of lime, while affording a rapid settlement of the sludge and a very clear effluent, dissolves a considerable quantity of the offensive matters previously in suspension, and thus renders the effluent stronger and fouler than it need be. This constitutes the great drawback to the use of lime alone in the treatment of sewage, as it is of the greatest importance that the effluent should be discharged in as fresh a condition as possible, and that the sludge should not putrefy whilst collected in pits prior to pressing or drying. There is, besides a tendency when the sludge is alkaline for it to lose what little ammonia it may possess in the process of drying.

" The precipitation effected by sulphate of alumina is due to its combination with lime or carbonate of calcium, whilst the aluminium hydrate is precipitated in a flocculent state, entanging and carrying down much of the suspended organic matters, whilst some slight portion of the soluble organic matters is also thrown down. In some cases as much as five per cent. of these soluble matters may be deposited with the rest of the precipitate. In other respects the effect produced is very much the same as that resulting from the lime treatment; that is to say, the sewage is clarified but still contains the greater portion of its polluting and nearly all its valuable manurial ingredients. The crude sulphate of alumina, however, which is generally used, being somewhat acid, the sludge and e uent are neutral or even faintly acid. There is, therefore, less proneness to decomposition than is the case with the alkaline sewage sludge and effluent resulting from the lime process, and in this important respect sulphate of alumina is undoubtedly superior to lime. But there is the drawback that an acid effluent is harmful to vegetation, and therefore is less suitable as an irrigating liquid for land than an alkaline effluent; and, as we shall presently see, inasmuch as the clarified sewage from a precipitation process can be very effectually purified on a very small area of land, this is a practice which is coming very much into favor.

" Lime and sulphate of alumina have been used together at various towns in England, for instance, at Coventry and Hertford, to cite well-known examples, and, on the whole, these two agents are still generally recognized as practically the best precipitation agents when used in combination. The proportions in which they are employed should be such as to render the effluent as nearly neutral as possible. Where sewage of medium strength is to be treated, the quantity of lime used may be from five to seven grains per gallon of sewage. It is, perhaps, hardly necessary to add that when used in combination the effect of these salts upon the sewage does not very materially differ from the effect that would be produced by an equal quantity of either. The matters in solution in the sewage are but little affected by any chemical precipitant, or combination of precipitants yet discovered. The special advantage of the combination of lime and sulphate of alumina is the production of a neutral effluent and sludge.

" Protosulphate of iron is used as a precipitating material by itself or as an adjunct to lime. It is essential that the sewage with which it is mixed should be alkaline; hence its frequent use in combination with lime. When so used, it forms a highly flocculent hydrated protoxide of iron, which, in falling to the bottom of the settling tank, carries the suspended matters of the sewage with it. According to Dr. Stevenson, this protoxide of iron acts as a carrier of oxygen, absorbing free oxygen and again giving it up to organic matters, just as the red blood pigments absorb oxygen to again give it to the effete tissues. It therefore has a distinct purifying action on sewage by oxidation of organic matters when used in sufficient quantities. It also has considerable antisepic properties, and tends to prevent the occurrence of putrefactive processes in the sludge and effluent. By the use of protosulphate of iron, however, the mud banks of the stream into which the effluent is discharged become blackened, owing to the formation of sulphide of iron. This is a disadvantage from a sentimental, but not from a sanitary point of view.

" Protosulphate of iron has been but little used alone as a precipitating agent. When used as an adjunct to the lime treatment, it should be employed in about the proportion of from three to five grains per gallon of sewage. Mr. Dibdin, in the course of some experiments on the metropolitan sewage, found that on some occasions, especially on Saturdays, lime would not precipitate the sewage completely, a heavy scum rising to the surface, which was carried down on adding a little iron. This result he attributed to the unusually large amount of soap used on Saturdays for washing purposes.

" The effect of the precipitants used on the sludge must be considered, as well as their ability to produce a well-clarified effluent. Sulphate of alumina is said to increase the bulk of the sludge, owing to the fact that alumina carries down with it a good deal of water, but the sludge is more easily pressed into cakes than when lime and iron are used. Precipitation by lime and iron, however, is more rapid than by any other process, and the iron tends to produce a dense sludge. It is very often the practice to add some lime to the wet sludge before pressing, even when lime is used to precipitate the sewage, in order to secure a coherent cake. What should be aimed at is to procure rapid precipitation of a sludge of but little bulk, which can be subsequently easily pressed into cakes.

" It is probable that a combination of the three materials considered is capable of producing the most highly clarified effluent, and, at the same time, a sludge which is most easily dealt with. The lime and sulphate of alumina should be used in about equal proportions, viz.: About four or five grains to the gallon of sewage, whilst the iron may be less (about two or three grains to the gallon). It is certainly advisable that the whole quantity of chemicals used should not exceed fifteen grains to the gallon. The question of cost is, however, of much importance in considering this matter, for, inasmuch as the best chemical process cannot purify sewage, but only clarify it, it is almost always highly desirable that the effluent from a precipitation process should be further purified by filtration through specially prepared areas of land or other suitable filtering material. In such cases all that is required of the precipitation process is that it should precipitate the suspended matters of the sewage in a fairly effectual manner, and should do this at the least possible cost. The removal of the suspended matters is essential for the proper working of the filter beds, but the precipitation of organic matters in solution is not required, as these will be purified in the subsequent process of filtration.

"The lime process is especially adapted for the preliminary treatment of the sewage of those maufacturing towns where free acids and acid salts or metals in solution are discharged into the sewers with the waste waters of factories. If lime is used, these matters are, to a great extent, precipitated. the acidity is neutralized, and the e uent sewage can be used to irrigate land growing crops. This is the process adopted at Birmingham, where the sewage contains immense quantities of "pickling liquor"; milk of lime, in the proportion of 15 grains to the gallon, is mixed with the sewage prior to its entering the settling tanks.

"To ensure the most complete clarification of the sewage, the following conditions must be fulfilled: The sewage to be treated must be fresh and undecomposed, and the larger solid matters should be removed from it by means of a Latham's extractor before the admixture of the chemicals, or by straining the sewage through a metallic sieve with fine meshes. The chemicals must be added to the sewage before it arrives at the tanks, and at a spot a short distance from them, so that in its flow along the channel the sewage and chemicals become well mixed together. The admixture may also be accomplished by stirring up the liquid with rotary beaters. There must be sufficient tank accommodation. The tanks are best arranged in series, so that the sewage may pass through two, three, or four tanks, according to circumstances. A double set should be provided, in order that the treatment of the sewage may continue at all times. The sludge must be removed frequently, but, of course, sufficient time must be given it to settle in the tanks. If allowed to remain too long, it will putrefy and give rise to nuisance. When emptied, the tanks must be thoroughly cleansed before being refilled When the clarified effluent is discharged direct into a stream, it should be made to flow in a broad but thin stream down a rapid incline, and fall over a weir so as to secure its aeration; and with the same view the effluent channel should be at least a quarter of a mile in length, and kept scrupulously clean.

"In most modern works the tanks are constructed and managed somewhat as follows: Each tank is from four to six feet in depth, and is divided nearly into two by a vertical brick partition parallel to its longest sides, round which partition the sewage flows. At the outlet of such tank should be built a weir, not more than half an inch below the surface of the sewage, over which the effluent flows into the next tank of the series, or into the effluent channel. Intermittent precipitation, *i. e.*, allowing the sewage a short period of complete rest in the tanks, has been tried, but does not seem to produce a better effluent than can be obtained by continuous working; and it requires besides, greater care in management. After from one to ten days of continuous working, the flow of sewage through the series should be discontinued, and the sludge allowed to settle, the clear liquid above being drawn off through the open mouths of float valves into the effluent channel. The residuum of sludge is then allowed to settle, and finally pumped into a sludge well, from which it can be forced up in pipes to the filter presses.

"This sludge contains from 90 to 95 per cent. of moisture. It was formerly the custom to allow it to dry by exposure to the air in pits, but this method was productive of much nuisance during the process of drying, so that it is now the usual practice to press part of the moisture out of the sludge in filter presses actuated by compressed air by which a solid cake containing from 50 to 60 per cent. of moisture is produced.

"Johnson's filter press, or that made by Manlove, Alliott, Fryer & Co., may be taken as a type of these machines. It consists of a number of grooved discs arranged in series, each disc having a central perforation, and separated from the disc on each side of it by a filtering cloth. The liquid sludge is forced between the discs by compressed air at a pressure of 100 to 120 pounds per square inch; the liquid, being forced through the filter cloths and along the grooves on the discs, escapes, whilst the solid portions remain behind between the discs, to be subsequently removed as solid cakes. The expressed liquid is clear, but exceedingly rich in dissolved organic matters, and very offensive, and is therefore passed back into the outfall sewer to undergo treatment with the crude sewage, or, better, again separately treated.

"The cakes taken from the filter press can be stored without causing any nuisance, until they can be removed from the works. Or they can be further dried in steam-drying cylinders, and then ground into a powder containing about 20 per cent. of moisture. In this dried granular condition the manure is far more suitable to application to land than in the form of the moist and coherent cakes which issue from the filter presses."

Ferozone and Polarite Process.

In this process, which is of somewhat recent origin, the introduction of the precipitating material, ferozone, is followed by filtration of the effluent through a filter containing polarite.

The following descripton of the process is by Dr. Arthur Angell, Ph. D, F. I. C.:

"Ferozone contains a large proportion of ferrous iron salts, and for that reason alone cannot fail to be a powerful chemical disinfectant; further than this, however, it contains salts of alumina, and of magnesia, both of which assist as decolorants and precipitants. The remaining part of ferozone is made up principally of very finely divided porous magnetic oxide of iron, and this serves both as an oxidizing agent and as a weighting material, which accelerates the subsidence of the suspended matter and keeps the sludge down as it accumulates at the bottom of the tank.

"The insoluable portion of the ferozone is composed of finely powdered polarite, the newly invented material, to which the filter beds containing it owe their very remarkable oxidizing powers; this powder, therefore, keeps the sludge sweet during subsequent disposal, either by pressing or drying, or by both, and thus a part of the process, which is so offensive at sewage works where lime forms one of the ingredients used, is carried on without committing a nuisance."

LAND FILTRATION.

The following outline of the requirements for land filtration is by Prof. Corfield:

"The first experiments of the filtration of sewage through the soil were made by the Rivers' Pollution Commissioners, about twenty years ago. It was then shown that sewage was capable of being very efficiently purified in its passage through a few feet of porous soil, but that, to secure the best results, the filtration must be from above downwards, and must be intermittent, in order that the pores of the soil may be aerated during the periods of rest.

"The purification of sewage by soil is, to a certain extent, due to the soil acting as a mechanical filter, separating and retaining the suspended matters in the sewage. But the principal agent is the oxidizing power of the soil, by which ammonia and organic matters in the sewage are converted into nitrates, nitrites and carbonates. This oxidizing power is partly dependent upon the porosity of the soil, by which the particles of sewage are brought into contact with oxygen from the air retained in its pores, but chiefly upon the presence of nitrifying organisms belonging to the family of bacteria. These organisms are found in sewage itself, and are abundantly present in most soils, but chiefly in those rich surface soils of mould or loam which contain an abundance of organic matters.

"In the choice of a soil for the reception and purification of sewage, the following conditions should, if possible, be fulfilled: The soil should be of a rich loamy character, and therefore well supplied with the nutrifying organisms. it should be porous and composed of small fragments, both to allow of free aeration and oxidation, and also that it may present an immense surface, covered with the organisms to the sewage while percolating through it. Pure sandy soils are not efficient purifiers until their particles have become coated with the nitrifying organisms present in the sewage, and then they act well.

"The surface of the land must then be carefully levelled, to admit of the sewage flowing evenly over every part of it, and it should be under drained with porous agricultural tile drains, laid at a distance of 10 to 50 feet apart, according to the porosty of the soil, and at a depth of 4 to 10 feet from the surface. To lay these under drains at a greater depth from the surface than

4 or 5 feet is thought by some to be unnecessary, as the nitrifying organisms are not usually found at a greater distance from the surface than 4 feet, and are almost invariably present in greatest numbers in the first 18 inches of soil. The filteration area should then be laid out in plots, each plot to receive sewage for six hours only every day, so that it may have eighteen hours out of the twenty-four for necessary rest and aeration.

"Where the sewage of a large number of people has to be applied to a small area of land, it is generally advisable to precipitate the suspended matters of the sewage by chemicals, as a preliminary process, and to irrigate the land with the clarified sewage effluent only. As a general rule—which, however, must not be applied too strictly—it may be stated that where the sewage of more than 1,000 people must be applied to each acre of land, the sewage should undergo a preliminary precipitation; but if the proportion is less than 1,000 to an acre, and the land is of suitably quality, the sewage should be allowed to flow on to it as it comes, or after a mere simple straining, to remove the larger solid bodies. If the raw sewage is applied in too large volumes to a small area of land, the surface of the soil tends to become rapidly clogged with a thin layer of suspended matters and slime, and a coating is formed which prevents the percolation of the sewage and the penetration of air into the interstices of the soil. The slimy matters in sewage are derived from the grease of kitchen waste waters, the fats of soap, the mucus from the urinary and intestinal mucous membranes, and from macerated paper. The land has, therefore, to be constantly raked over, and the surface layers dug up and incorporated with those beneath with some labor and expense; if this is not done, the sewage stagnates and forms ponds on the surface and gives rise to nuisances as soon as decomposition commences.

"This difficulty is entirely avoided by irrigation with clarified sewage only. There are other advantages besides this in adopting precipitation as a preliminary. Most of the bacterial organisms and their spores, the active agents in putrefaction, are carried down in the precipitate, and therefore removed from the effluent, which is consequently less prone to putrefy, and readier to undergo nitrification in the soil, for putrefaction and nitrification are antagonistic processes, as are also putrefaction and oxidation. It would seem that, as a preliminary to land treatment, lime is the best precipitating material that can be used, as it introduces into the sewage effluent the requisite base for combination with the nitric and nitrous acids formed by nitrification. Lime is also the best material to neutralize the acids and acid salts contained in sewage which has received the waste waters of manufactories and chemical works, this kind of refuse proving a great hindrance to the purification of sewage by soil. The presence of antiseptics in the sewage also prevents nitrification, so that such deodorizing agents as carbolic acid and perchloride of iron, which have been used as adjuncts to the lime process, must not be employed where the clarified sewage is to be applied to the land. Whether black-ash waste or herring-brine are sufficiently strong antiseptics to prevent nitrification in the soil has not yet been determined."

BRIEF SYNOPSIS OF FACTS RELATING TO SEWAGE WORKS IN OPERATION IN ENGLAND AND UNITED STATES.

SEWAGE OF LEEDS IN 1887.

The population of Leeds is estimated at 318,000, and the daily quantity of sewage dealt with is 10,000,000 gallons, which is the dry weather flow.

The precipitation works have been constructed upon the continuous flow system, and have been in full working operation for the past 11 years.

The sewage is conveyed by a culvert 8 feet wide by 7 feet 9 inches high, with a gradient of 1 in 1,634, and is carried for a distance of 4½ miles beyond the town.

For the precipitation of the sludge, 12 tanks have been constructed, 6 upon either side of a central channel; each tank is 100 feet long, 60 feet wide, and 6 feet deep, being equal to a water area of 72,000 superficial feet, or 1¾ acres, with a holding capacity of 2½ million gallons. Each tank is 2½ inches lower than the preceding one, and a regular and continuous flow is thus maintained over the whole of the 12 tanks. When the sewage leaves the last tank a good clear effluent is produced.

In order to provide for the cleansing of any one of the tanks, sluices have been fixed across the top of the division walls, so that any one of the tanks can be stopped independently of the others.

The first tank into which the crude sewage and precipitant are allowed to flow requires cleansing every third day; the next three every fifth day; and the fifth and sixth every seventh day. The remaining six tanks receive little or no deposit, and only require cleansing two or three times a year.

The sludge is conveyed by under-ground pipes to a well, and is then pumped into open drying pits. It is, however, passed off to the well with considerably less quantity of water in it than is the case at Sheffield, owing to the tanks running for a longer period.

When the works were first commenced, various chemicals were used, the effect of which was to introduce into the sludge materials which had a deleterious effect upon vegetation, and the farmers in the neighborhood would not use it, consequently large quantities accumulated; but since lime only has been used the greater portion has been removed by farmers and others without any expense to the corporation.

Thirty-one men are engaged at the Leeds works, as compared with twenty-eight men at Sheffield, but nine of the thirty-one men are engaged in the removal of the sludge, which, in the case of Sheffield, is allowed to accumulate.

The average quantity of lime used is about one ton for every million gallons of sewage.

The total area of the site of the sewage works is twenty-six acres, of which nine acres remain for future extensions.

SEWAGE OF SHEFFIELD IN 1887.

The population of Sheffield was about 300,000, but the works have been constructed and are calculated to provide for a population of 450,000.

Ten million gallons of sewage are treated daily, this being the calculated dry-weather flow.

The precipitation works have been in operation since June, 1886; they are upon the intermittent system, and consist of 30 tanks, arranged in two sets of 15, each tank measuring 40 feet by 36 feet by 6 feet deep, with a capacity of 50,000 gallons each.

The main outfall sewer, with a gradient of 1 in 1,700, is carried for a distance of about 6 miles from the town, and at its termination at the works measures 6 feet 6 inches diameter.

Before the sewage is allowed to flow into the tanks, it passes over a series of catch-pits, which intercept the bulk of the solid matter previous to receiving the admixture of lime. These catch-pits, four in number, are arranged in two sets, and are emptied alternately by means of miniature dredgers.

The sewage, after leaving the catch-pits, flows under the floor of the mixing house (where the lime is converted into milk of lime, and where it is mixed with the sewage), and then flows forward into an outer channel, which runs round three sides of the tanks. The tanks are fitted with penstocks for the purpose of regulating the flow of sewage.

In filling any one of the tanks a penstock or sluice is opened to allow the mixture of lime and sewage to pass from the outer channel, and in about four or five minutes the tank is filled, the penstock is again closed, and the mixture is allowed to remain in the tank in a quiescent state for about 30 minutes, after which a self-floating automatic valve empties the tank, and the effluent is run off on to a series of low weirs, having slight falls, for the purpose of exposing the effluent to the air. It is then passed through a downward and upward filter bed, composed of coke from the gas works. It is estimated that about 700 tons of coke will be required annually, but after it has been used in the filter beds it is mixed with coal and used as fuel for the boilers.

The sludge which is deposited in the settling tank is carried forward along the sludge channel to pits, where it is pumped into open-air drying ponds, and is allowed to remain until it is sufficiently dry to permit of its being removed and prepared for other treatment. It is calculated that there will be about 10,000 tons of sludge to be dealt with annually, but no system has as yet been adopted for its disposal.

The works are in operation 18 hours daily, from 6 a.m. until midnight. There are at present 28 men employed, 14 men working a shift of 9 hours, but, when dealing with the sludge, the employment of a larger staff will be necessary.

It is stated that, owing to improvements in the construction of the works, the quantity of lime has been reduced from one ton to 15 cwt. for every million gallons of sewage treated.

Land has been purchased to the extent of 22½ acres, 7½ acres being covered with tanks and buildings.

The land cost £12,000, and the plant, tanks and buildings £33,000, making a total of £45,000.

SEWAGE OF BIRMINGHAM.

The works at Birmingham are chiefly remarkable for their magnitude and for the extreme simplicity of detail.

The history and details of the works are admirably set out by Mr. Till, M. Inst. C. E.

The borough of Birmingham, together with the towns of Walsall, West Bromwich, Wednesbury, part of Wolverhampton, and a number of other urban or rural sanitary districts, forming the major part of what is known as the "Black Country" is situated near the summit of one of the great watersheds of England, that of the Trent, being drained by the River Tame, which, with its various feeders, forms a small stream discharging into the Trent, about midway between Tamworth and Burton.

The corporation of Birmingham constructed, as far back as 1853, main intercepting sewers whereby the sewage from those portions of the borough draining to the River Rea and Hockley Brook was conveyed to the general outlet at Saltley, where subsequently a system of tank purification had been adopted, and which was developed from time to time until at the period when the drainage Board was formed, the corporation possessed land and works thoroughly capable of purifying so as precipitation by lime could purify, the sewage of the borough.

The nature of the land is very favorable for the purification of sewage, the natural surface of the ground being as a rule even and unbroken, and the level such as to admit of the irrigation of the whole by gravitation, with the exception of about 100 acres. The sub-soil is of gravel and sand, varying from 6 ft. to 10 ft. in thickness. Provision was made to reduce the risk of flooding from the river. For conveying the sewage to the land a conduit 8 ft. in diameter and about 2¾ miles long has been constructed, capable of discharging 38 million gals. per day when running half full, or double that quantity when running full, the fall being two feet per mile. This conduit commences at the outlet end of the large tanks at Saltley, and terminates at Tyburn, valves being placed at suitable intervals for discharging the sewage on to the land passed through. Below Tyburn the capacity of the conduit has been reduced, a conduit 3 ft. 6 inches in diameter being sufficient for the remainder of the farm. The sewage is drawn from these conduits into open brick carriers, which again discharge into secondary carriers of earth, and thence into flooding carriers. The brick carriers are constructed with a slight fall, ramps being provided in the inverts at suitable intervals for drawing down the water. The land is drained to a minimum depth of 4 feet 6 inches, but in many cases, owing to the level nature of some of the land, a greater depth has been found necessary at the lower ends of the drains. The sub-soil drainage consists of three-inch and four-inch agricultural drain pipes placed from half to three-quarters of a chain apart and discharging into main drains of 9-inch, 12-inch, 15-inch, and 18-inch stoneware socket pipes, which in turn discharge into the outfall channels. Roads generally 12 feet wide, with passing places at intervals, have been laid out with the view of meeting the requirements of the steam-cultivating operations, as well as for the conveyance of produce.

The total cost of the land and works to the present has been £403,695, of which the purchase of original land and works is £170,544; new land, £110,800; new works, £113,299; farming stock and implements for new land, £9,052.

The method of treating the sewage, as now carried on, is as follows:

The sewage, on arriving near the liming sheds, at the upper end of the works, is mixed with lime, both to neutralize the acids (present to an unusual extent in Birmingham sewage) and also to assist precipitation, which, however, is not now necessary to so great an extent as formerly; the sewage then passes through the large or roughing tanks, where the grosser impurities are precipitated, and from thence it is conveyed by the main conduit to the land, and disposed of by ordinary irrigation. The sixteen small tanks required at one time for completing the precipitation process are still used under certain circumstances, and are a valuable auxiliary when rainfall has increased the normal quantity of sewage.

The sludge from the tanks is elevated by bucket-dredgers and pumps into movable wooden carriers and flows into beds formed in the land at the Saltley or western end of the farm. The sludge contains about 90 per cent. of water as it comes from the tanks, but after lying on the ground for about 14 days much of this water drains away or is evaporated, leaving the sludge in a layer about 10 inches thick and of a consistency that admits of its being trenched into the land. Crops are then planted, and after a time the sludge becomes pulverized and the land with which it has been incorporated is capable of being irrigated. About 50 acres of land is required for the sludge.

Practically, the whole of the sewage of the draining district, amounting to 16,000,000 gallons per day, flows by gravitation to the outfall works. Only a very small area requires its sewage lifted by pumping, the cost of such pumping being £104 per annum.

Sewage of Manchester.

The sewage system of the City of Manchester was designed by the City Engineer, Mr. Allison, about the year 1887. The population at that time was 434,261, and it provided for an anticipated population of 648,000, the average amount of sewage furnished being 20 gallons per head.

Intercepting sewers were constructed at that time, and connecting sewers, so as to make the entire system operative. The outfall works consisted of precipitation tanks, constructed upon the same principle as those of the Leeds Corporation, and filtration beds, with land fitted for the digging in of the sludge after removing it from the tanks. The quantity of land amounted to about 146 acres. The tanks, of which Mr. Allison prepared plans and details, were designed on the plan of those of Leeds, and they are intended for the continuous flow system.

The system consisted of 20 tanks, each 100 feet long by 60 feet wide, and an average depth of 6 feet, so arranged that each succeeding tank would be two inches lower than the one immediately above it. Thus with 20 tanks the out-flow from the last or lowest tank would be 3 feet 4 inches lower than the in-flow into the first or highest tank.

Manchester is favored by having at command land in proximity to its tanks, which, in character of soil, height of surface, and capability of drainage, offers excellent facilities for intermittent filtration through soil.

Of the total 146 acres, 110 are devoted to filtration, 10 acres to tanks and buildings attached thereto, and 26 acres to the digging in and treatment of the sludge.

Data of Sewage Works of some English Cities and Towns, Tabulated to Year 1890.

Name of Town.	Population.	Daily Volume of Sewage.	Mode of Disposal.	Years in Operation.	Acreage of Land.	Chemicals Used.	Annual Yield of Sludge.	Tanks Continuous or Intermittent.
		Gals.						
Ealing	7,500	400,000	Precipitation and Filtration.	20	3¼	Lime and Sulph. Alumina.	11,000	Continuous.
Coventry	50,000	2,000,000	Precipitation and Filtration.	15	13	Lime and Sulph. Alumina.	5,720	Continuous.
Wimbledon.....	46,000	780,000	Precipit'n, Irrigation and Filtr'n	14	74	Lime, Sulph. Alumina, Ozo, etc.	....	Continuous and Intermittent.
Bradford	200,000	8,450,000	Precipitation and Filtration.	12	7½	Lime	6,000	Intermittent.
Birmingham	619,693	16,000,000	Precipitation and Irrigation.	10	136	Lime	....	Continuous.
Portsmouth	130,000	4,500,000	Precipitation ...	6	3¼	....	....	Continuous.
Chiswick	21,000	550,000	Precipitation ...	4	6	Lime and Sulph. Alumina.	2,600	Continuous.
Doncaster	26,000	800,000	Irrigation and Filtration.	....	264	....	....	....
Salford........	176,233	4,000,000	Precipitation	4	....	Lime	....	Continuous.

WORCESTER, MASS.

Population 110,000. Gallons of sewage per day 17,000,000. The effluent passes into the Blackstone River. The sewage contains protosulphate of iron derived from the Wire Works, and lime is therefore the only chemical added. The sewage is acid in character. It is estimated that 5,000,000 gallons of surface and sub-soil water pass into the sewers, in addition to the sewage proper of the town. They are at present using 10 tons of lime per day, and operating 16 tanks, with a capacity of 5,000,000 gallons. The tanks are 100 x 66⅔ x 7, also 143 x 43½ x 7. The tanks are cleaned every three days. The sewage is treated day and night. Fifteen men are employed, the cost for labor being $30,000 per annum. One hundred acres of land are provided. The out-fall sewer cost $60,000, and the whole plant is estimated at about $275,000. The sludge is at present deposited on the ground, where it has accumulated, and it is therefore proposed to operate filter presses, of which four are being put in. These presses cost $5,000 each, and were made by the Bushnell Press Company of Thompsonville, Conn.

BROCKTON, MASS.

Population 35,000. Average amount of sewage 580,000 gallons per day. The sewage is pumped 30 feet high and passes by a conduit three miles in length to the filter beds. A separate system is operative in Brockton, and storm water does not find its way into the sewers proper.

The municipality of Brockton has 30 acres of ground in its possession, 15 acres of which are made ready for the treatment of sewage either by filtration or broad irrigation, 7½ acres being under-drained. The under-drains are made of 5-inch bell pipe, laid at a depth of 10 feet, 50 feet apart, and connected with two main openings, one 12 and the other 15 inches in diameter. The filter beds are each of the area of an acre. Twenty miles of new sewers have been constructed as part of the general sewage system. The land damages paid in connection with the pumping station, and filter beds, were $40,000. The cost of the ground for filter beds was $300 per acre. The capacity of the receiving reservoir is 6,000,000 gallons. They are at present pumping 5,000,000 gallons per day. Their engines are a double system, with a capacity of 7,000,000 gallons per day each.

The aggregate cost of the force main and filter beds is $250,000, and the plant is operated at an annual cost of $10,000, about 30 cents per capita. The ground upon which the filter beds are laid varies in character from fine sand to coarse gravel. It is native land. Two to four men are employed upon the filter beds, and two men at the pumping station. 100,000 gallons of sewage are placed as the dose for each bed, and the bed is used every alternate day.

Considering the question of the disposal and treatment of the sewage of the City of Toronto in the light of the facts here submitted, and the experience of other cities and towns, it may be assumed:

Firstly—That some form of intercepting or trunk sewer will undoubtedly be required to conduct the sewage to outfall works.

Secondly—The drainage of the greater part of the City of Toronto is generally southward and eastward, and the character of the land in the eastern portion of the City appears to be better suited for sewage treatment than that of the western portion.

Thirdly—Pumping of the sewage either in whole or in part will apparently be required.

Fourthly—Chemical treatment of sewage, while it may produce a clarified effluent, will not accomplish complete purification. Precipitation and filtration of the effluent, or filtration of the sewage in its entirety, by properly constructed filter beds, or broad irrigation, appear to give the best results.

Fifthly—In addition to the original cost of sewage works, including intercepting sewers, additional cost for maintenance will be necessary, which, in the various cities and towns where sewage disposal works are operative, is between 30 and 40 cents per capita.

Whether the treatment of the city sewage can be carried to completion in one operation, or whether it should be accomplished by degrees, but still as part of a systematized plan, are questions which are largely controlled by financial and engineering considerations.

All of which is respectfully submitted,

CHARLES SHEARD, M.D.,
Medical Health Officer.

REPORT

ON

SEWAGE DISPOSAL OF THE CITY OF TORONTO.

CITY ENGINEER'S OFFICE,
Toronto, October 12th, 1898.

To His Worship Mayor Shaw and the Corporation of the City of Toronto:

GENTLEMEN:—In compliance with two resolutions of the City Council, one dated October 11th, 1897, and the other May 3rd, 1898, as follows:

> "Moved by Mr. Ald. Saunders, that the City Engineer take into his consideration, and report to this Committee, the best method to be adopted for the disposal of sewage by purification or otherwise, from the Eastern, Western and Rosedale Sewers."

> "Moved by Ald. McMurrich, seconded by Ald. Leslie, that whereas it is of the utmost importance that early action be taken by this Council in reference to the disposal of the sewage now being discharged into the Bay, and creating a cess-pool thereof, be it resolved: that the City Engineer report to this Council at the earliest opportunity as to the cost of chemically treating the sewage from that portion of the City extending from the water-front northward to the City limits, and westward from Bathurst Street to the City limits, concentrating the same at some point on the Garrison Creek Sewer, where the same can be chemically treated and all solids intercepted, while the effluent may be so purified as to materially improve the waters of the Bay and Lake in front of our City."

I beg to submit the following report:

Dr. Sheard, Medical Health Officer, has in his report to the Local Board of Health on Sewage Disposal, called the attention of the Board to the unsanitary condition of the various localities along the water-front, and to the necessity of deciding upon some definite plan for the object of disposing of our sewage." Dr. Sheard also deals in a very exhaustive and thorough manner with sewage disposal by chemical treatment, filtration and other methods. I will, therefore, not proceed to discuss this matter, but would refer you to the Medical Health Officer's report.

In August of this year, in company with Mr. Ald. Saunders, Chairman of the Board of Works; Mr. Ald. Crane, Chairman of the Local Board of

Health, and Dr. Sheard, I visited a few cities and towns in the United States for the purpose of investigating this important question of sewage disposal, and a great deal of valuable information was obtained. Visits were paid to the following places:

Worcester, Mass.

Worcester, which has a population of 110,000, treats its sewage by chemical precipitation, using lime and sulphate of alumina. The actual quantity of sewage is about 5,000,000 gallons per day, but they also have to deal occasionally with between 4,000,000 and 5,000,000 gallons of subsoil and surface water. There are 16 tanks at present in use, with a capacity of 5,000,000 gallons, the tanks being cleaned every three days. At these works there are 12 to 15 men employed on eight-hour shifts, and the annual cost is from $30,000 to $35,000. The cost of the tanks, buildings, etc., were $190,000. They are now spending $40,000 in erecting a new building with machinery for pressing the sludge, and have also purchased 100 acres of land at a cost of $40,000. The disposal of the sludge has been a very difficult matter to deal with. To give an instance, it is only necessary to mention that in November of last year they had 8,000 cub. yds. of sludge in 306 hours. The present cost is only about 27c. per head per annum. This is low on account of having to use very little sulphate of alumina, owing to the salts of iron contained in the drainage from the Wire Works. The sewage flows to the works by gravity.

Lawrence, Mass.

Our next visit was to the Experimental Station of the State Board of Health of Massachusetts, which is situated at Lawrence, about one hour's run from Boston. A most exhaustive series of experiments have been made at this station, which have been of great value to municipalities and engineers. These tests have extended over a period of eight or nine years. They had 10 experimental filters, each filter representing 1/200 part of an acre. The experiments have been made on filters consisting of different sizes of sand, gravel and coke. These various filters are estimated to remove about 89 per cent. of the organic matter, and about 97 per cent. of bacterial growth.

Brockton, Mass.

Brockton, which treats its sewage by intermittent filtration, has a population of about 35,000. The average amount of sewage per day is about 580,000 gallons. The sewage is pumped to a height of thirty feet, the main being three miles in length. The separate system is in use. The municipality have thirty acres of ground, fifteen acres of which are for the treatment of sewage either by filters or broad irrigation, of which seven and a half acres are underdrained. The size of the filter beds are one acre each, the land for the filter beds costing $300 per acre. The force main, filter-beds, etc., were constructed at a cost of about $250,000, and are being operated at an annual cost of $10,000. From two to four men are employed upon the filter beds; 100,000 gallons of sewage per day is placed on each bed, and is dosed every other day.

PROVIDENCE, R. I.

At Providence during the past few years they have spent a very large amount in constructing a system of intercepting sewers, discharging the crude sewage into Providence River at Field's Point, but the City is now engaged in constructing the necessary works for the treatment of their sewage by chemical precipitation. The cost of the necessary tanks, etc., will be about $250,000, and the pumping station with the necessary machinery cost $207,000.

READING, PA.

The system pursued at Reading, Pa., is an entirely new one, being a rapid, double filtration system. The population of the town is 95,000, and about 2,000 houses are connected with the system at present, or about one-half the population. The sewage is run into wells at the pumping station, where it is strained through twelve inches of coke. The coke, after being used a week is dried and used in the boilers for generating steam. The sewage, after being strained is then pumped to the filter beds, a distance of nearly 7,000 feet from the pumping station. The filter beds are constructed on plate girders resting on iron columns. The upper filter consists of about one foot of broken stone and 15 inches of sand on top of this. The lower filter, which is about ten feet from the upper one, consists of three feet of sand. Both filters are divided into ten compartments, twenty-five feet by fifty feet. The effluent appeared to be very good. The beds, I understand, were designed to filter 5,000,000 gallons of sewage per day. This is at the rate of 400 gallons per square foot per day, or something over 17½ million gallons per acre through each bed, or taking into account the double filter, the rate is about 8½ millions per acre per day. There are eleven men employed continuously, eight labourers and three foremen, the foremen being on for eight hours each. At present they are treating about 1,500,000 gallons of sewage in twenty-four hours. The whole cost of the work, including pumping station, force main, filter-beds, and all the necessary land and right of way was about $200,000. The filter beds complete cost $100,000. The works were erected by the Pennsylvania Sanitary Sewage Company, who, I understand, have various patents covering the different works. We were informed that care had to be exercised in the winter time, watching the beds, especially in very cold weather.

The question of diverting the sewage of this City from the waters of the Bay has been before the citizens of Toronto for a number of years. As early as 1857, Mr. Thomas H. Harrison, then City Engineer, reported to the Council on a system of drainage. In 1873 Messrs. Wadsworth and Unwin presented to your Council a report on "A scheme for a general system of main drainage for the City of Toronto, and an estimate of the value of the resultant sewage," the report being prepared for them by Mr. John Dickenson, C.E. Mr. Dickenson refers to Toronto as having a population of 70,000, and estimates that in thirty years the population would be doubled, and bases his plan on a poulation of 150,000. The writer proposed constructing an intercepting sewer, commencing at the intersection of the West City Limits (Dufferin Street) with Queen Street, along Queen to Bathurst, down Bathurst to Front, and along Front eastwardly to a point of discharge in Lake Ontario, east of the Gap. Mr. Dickenson also suggested that the sewage should be utilized for the purpose of irrigating a portion of the Island, and further recommended that some of the marsh should be reclaimed by depositing "the dredgings of the Harbour and the scrapings of the streets, and fertilizing it also by sewage irrigation." The writer, however, does not give the cost of his proposed scheme.

In March, 1876, Mr. Frank Shanly, then City Engineer, submitted to Council a report on the proposed intercepting sewer along Front Street, discharging it into the Don River, which it was proposed to divert into Ashbridges Bay. Mr. Shanly estimated that the work would cost $190,000. This scheme did not provide for the drainage of the City west of the Garrison Creek. Mr. Shanly stated that west of that he was prepared with a scheme, but "for the present it will, I suggest, be sufficient to confine your attention to the work above named."

In the Annual Report of the City Engineer for 1882, Mr. Redmond J. Brough touched upon the importance of an intercepting sewer, and proposed to discharge the sewage of the City into the Lake opposite Scarboro' Heights, at an estimated cost of $1,127,000. In 1886 Messrs. W. J. McAlpine and Kivas Tully, Consulting Engineer, and Mr. C. Sproatt, City Engineer, presented a report to your Council upon the subject. Messrs. McAlpine and Kivas Tully proposed to discharge the sewage into the Lake a short distance east of the Eastern Gap, at an estimated cost of $1,115,100. Mr. Sproatt did not agree with these Engineers as to the point of discharge, and recommended that it be taken further east, to avoid any danger of polluting the water supply, and proposed to discharge the sewage opposite Victoria Park; the estimated cost of his scheme being $1,418,355, and an annual expenditure of $43,455 for pumping a portion of the sewage.

In 1889 Messrs. Hering and Gray were appointed by the City Council "to report their conclusions as to the best means to be adopted to increase the water supply, and to dispose of the sewage." These gentlemen made a very valuable report dealing with both these questions. They recommended that the sewage be discharged into deep water in the Lake opposite Victoria Park, at an estimated cost of $1,471,448.

In August, 1890, Mr. W. T. Jennings, City Engineer, presented a report to your Council in connection with the proposed trunk sewer, recommending two outlets, the high-level sewer discharging its sewage into the Lake near Victoria Park, and the low-level into the Lake a short distance west of Woodbine Avenue, the cost of the proposed scheme being $1,632,538. In 1892 Mr E. H. Keating, City Engineer, also presented a report on the proposed main intercepting sewer, agreeing substantially with the suggestions of Messrs. Hering and Gray, and estimated the cost to be $1,150,000, and the annual cost of pumping $8,000.

Since these reports were prepared a considerable change has taken place in the vicinity of the proposd outlet. The land in the vicinity of the Lake in the summer is largely occupied as summer residences, and no doubt the fact of discharging the crude sewage into the Lake opposite these resorts would have a very detrimental effect upon their value, and might involve the City in an expensive litigation. In addition to the above, there is a very strong feeling that the discharge of crude sewage should never be permitted into a body of fresh water, which is the source of our water supply, if there is the slightest danger of contamination taking place. I would also call the attention of your Council to Mr. J. Mansergh's remarks upon the sewage of this City, taken from his report to the Council upon the Water Supply of this City. They are as follows:

"I cannot close this report without saying a few words upon the sewage question, although it does not come within the terms of my instruction.

"To justify this instruction, I may say that for over thirty years I have been constantly engaged in the designing and carrying out of important works of sewage collection, interception and treatment, or I would not have ventured without invitation to make any observation on the subject; and such as I do make will be of quite a general character.

"During my stay in Toronto I did not meet a single individual who had a word to say in justification of the existing state of things, excepting that it would cost a very large sum of money to remedy it.

"To discharge all the sewage of 175,000 people in its crude state into a tideless and practically stagnant harbour is obviously a very wrong thing to do, and every rational man must condemn it.

"If Toronto is ever to take the high position as a residential City, which its climate and other natural advantages would justify, this blot must be wiped out. All the world over people are becoming more alive to the importance of safe sanitary surroundings, and more critical in fixing upon a place of permanent residence; and a common enough question to be asked nowadays is: Where does the sewage go to, and where does the water come from?

"I am quite prepared for adverse criticism upon my advice respecting the water, on account of the bald answer which could be given at Toronto to this question. I am quite satisfied however, that if what I have recommended is carried out, there is no risk whatever of harmful pollution of the water to be supplied; but, at the same time, every one must admit that if the sewage were removed right away there would not remain a ground even for the slightest sentimental objection.

" The offence arising fom the stiring up of the foul mud in front of the wharves by the steamboats in hot weather is, I know, very great, and the discomfort caused to the people carrying on their business on the water-side, must at times be almost intolerable, not to speak of injury to their health.

" But I know there is no necessity whatever to argue the question, and that it is merely the cost which stands in the way of a remedy being found On this I would say: If you determine to indulge in the luxury of Simcoe water, I fear the diversion of the sewage from the harbour will be relegated to the dim future.

" If you adhere to Ontario, several good things will follow, viz:—

" 1st. You will be better able to undertake the sewage work;

" 2nd. You will see the desirability of stopping the waste of water, in order to save money to spend upon that work, and to reduce the cost of its execution, by diminishing the volume of sewage; and

3rd. You will desire to remove entirely the last trace of uneasiness with regard to the intake."

I will therefore not further consider the matter of turning crude sewage into the Lake, but proceed to discuss the question of disposing of the sewage by some other means.

There are several methods of purifying sewage by means of one or more chemical agents. Since the commencement of the present century nearly 500 patents have been issued in connection with this matter. The latest system, and one which is exciting much interest amongst Engineers, is called the Septic System, and it may perhaps be of interest to your Council if I were to give a short account of this system, condensed from the Engineering News.

" This system, which was invented and patented by Mr. Cameron, City Engineer of Exeter, is at present attracting much attention from Municipalities and others interested in sewage disposal. A small plant has been in operation in Exeter since 1896, and is treating sewage from about 1,500 people. The plant consists of two parts, the septic tank in which the anaerobic bacteria act upon the sewage and prepares it for the second part, which consists of five filter beds made water tight and filled with coke breeze and crushed cinders, in which the anaerobic bacteria complete the purification. The septic tanks is a reservoir, made of concrete, built in the ground, arched over and covered with sods and dark and air tight."

The Local Government Board have recently given the City of Exeter permission to borrow about $195,000 to instal this new system, but have insisted upon land treatment in connection with the Septic Tank System. As this method is at present only in its experimental stages I will not further discuss it, but proceed to deal with two other well known means of sewage disposal, namely, Land and Chemical Treatment.

Discussing first the question of Land Treatment; this system has been very largely used in Europe, and is carried out in Paris, Berlin, Dantzic, Birmingham, Bedford, and various other towns which have had sewage farms in operation for several years. Coming to this country, however, there are at present only a few small places that get rid of their sewage by this method. There are two means of disposing of sewage on the land, viz., Broad Irrigation and Intermittent Filtration. Broad Irrigation means "Sewage being utilized over a large surface of land for the production of vegetation, consistent with suitable purification of the sewage."

Intermittent Filtration means, "Sewage applied intermittently in as great a volume, and at as short interval as can be properly absorbed, and purified by the land, and while not excluding vegetation, yet making produce of secondary importance."

In Broad Irrigation we are informed that it will take about one acre for every 100 of a population, but with intermittent filtration the sewage of 1,000 persons may be satisfactorily disposed of upon the same area. We are also told by authorities that efficient filtration will probably remove 99 per cent. of the bacteria, and it is this system combined with perhaps Broad Irrigation, to some extent, that I suggest to your Council as being suitable to this City. The only land available in sufficient quantities for this purpose is situated in the Township of York, east of Leslie Street, and north of Danforth Avenue, extending eastwardly almost to East Toronto, and northerly to a branch of the Don. There is about 1,100 acres in this section and is admirably fitted for the purpose. A great portion of this area has to-day no value for agriculture, the soil being sand, running down to a great depth. I would recommend, providing this land can be purchased at a reasonable figure, and if this system of sewage disposal is adopted by the Council, that about 600 acres be purchased, and that at present about 300 acres of it be laid out for filter beds. There is no doubt that arrangements could be made with a number of the owners and tenants of some of the land in this district so that they would only be too glad to receive a portion of the sewage upon their properties during a part of the year. The remaining portion of the sewage could be turned upon the filter beds, and the effluent conducted to the nearest water course. The soil is of such a porous character that there could be no difficulty in disposing of 50 or 60 thousand gallons of sewage upon an acre. The question of the efficient working of the filter beds during our severe winter may be considered by some as an objection, but from the results obtained in the New England States, where the winter is almost as severe as ours, I do not anticipate any serious difficulty. In connection with the question of the efficient working of the filter beds during the winter months, I wrote to Messrs. R. Hering and S. M. Gray, the well-known Consulting Engineers of New York and Providence, and received the following replies:—

100 William Street, New York,
October 3rd, 1898.

C. H. Rust, Esq., City Engineer, Toronto, Ont.

My Dear Mr. Rust:—Your favor of September 28th is just received, on my return from Ottawa. Had your letter arrived a day or two before, I would have received it in Ottawa, and might have returned by way of Toronto, so as to have a talk with you, as that would have been much more satisfactory. I was very sorry to have missed you in New York last month.

Regarding the disposal of the sewage of Toronto by a prior purification, I am very glad that the matter is taking this shape, because I should at this time recommend some method of treatment, had I to report once more. When Mr. Gray and I made our report, the subject of purification was less well known than it is to-day. To have made a recommendation then would have compelled the assumption of an expense, which, together with the expense necessary for the intercepting sewers, would have made the adoption of the scheme a hopeless one. As it was, the expense was already very great, and but little, if anything, has been done in the construction of any intercepting sewers.

To-day it is much safer to estimate the cost of chemical precipitation, and also the cost of operating filter beds. Such estimates would be less to-day than they would have been formerly.

So far as I can judge, and this was the opinion held by me when writing the report, a chemical precipitation with subsequent filtration could have been accomplished near Victoria Park, and to adopt a system of intermittent filtration, it would have been necessary to pump the sewage on to the sandy area you speak of, north-east of the City.

I am quite satisfied that there would be no trouble whatever as to the working of the system of intermittent filtration during your severe winter weather. The winters in Berlin and in Dantzic are more severe, I believe, than the winters in Toronto. Yet they dispose of their sewage by intermittent filtration without trouble.

I could not give you, off hand, an idea as to the probable annual expense involved in working a farm of about five hundred acres. This estimate would depend on a number of points; for instance, do you intend to have a farm upon which to raise crops, and, if so, what kind of crops. If suitable land is scarce, and you wish to adopt the intermittent system for the purification of sewage, irrespective of the raising of crops, the cost would be again different. In the latter case, much less land would be required, because the sewage could be put upon the land irrespective of any danger to crops. A greater amount could be put upon the land, and also with greater regularity in time.

You, no doubt, will study up the various results obtained on different farms and different disposal works in general.

Where the raising of crops is an item, one might roughly say, irrespective of the cost of land and of preparing the filter beds, the income from the crops might, with very good management, pay for the expense of raising such crops, including the work of irrigating. In some cases, such crops have barely paid for the working; in others, they have even paid a good profit.

With very kind regards, I am,

Yours truly,

RUDOLPH HERING.

October 1. 1898.

C. H. Rust, Esq., C.E., City Engineer, Toronto, Canada.

MY DEAR MR. RUST:—Your favor of the 28th ult. is just received. I was very sorry not to have seen you when you called here last August. Should have been pleased to talk about Sewage Disposal with you.

In regard to the operating of a sewage farm in your climate, I should say from what experience we have had in and around New England with this method, you need have no fear but it would work successfully in your locality; especially if the soil is very sandy and porous. I should expect that the filtration areas would be thoroughly underdrained.

It would doubtless be more expensive to operate a sewage-farm in your locality in the winter time than in our country, owing to the difference in the climate.

In our Report to the City of Baltimore we estimated that the annual expense attending the care of filtration fields would amount to about $30 per acre on the basis of using 1,900 acres. This expense was made up of labourers, horses and the necessary superintendence for the proper working of these fields: it did not include any depreciation or interest on the first cost; but did include the maintenance and care of the main carriers from the pumping station to the filter-fields.

This estimated cost per acre may be too high for your conditions, but I do not think it is far from a reasonable estimate.

Hoping this may be of some service to you, I remain,

Yours truly,

SAMUEL M. GRAY.

As an illustration of the disposal of sewage upon land during severe weather, I give an extract from Rafter and Baker's work on Sewage Disposal, as to what actually took place at South Framingham during the winter of 1893.

" A filter bed with an area of seven-eighths of an acre received no sewage from some time in September until January 9. On this date there were 18 inches of frost in the bed and 10 inches of snow upon it, the thermeter reaching 6° F. below zero. Jan. 9, 300,000 gallons of sewage were applied to the bed, and on Jan. 10, 150,000 gallons. It is said that the effluent appeared in the underdrain in six hours after the application of the sewage. On Jan. 11 the frost was, in places, out of the bed for its whole depth, and on Jan. 12 it was nearly all gone and the sewage had disappeared from the surface. The temprature of the applied sewage was 50° F.

" On Jan. 16, 17, and 18, observations were made on another bed, with an area of one acre. The frost in this bed was from twenty to thirty inches deep, and there were fifteen inches of snow upon it. On Jan. 16 the thermometer indicated 6°; on Jan. 17, 20°, and on Jan. 18, 4° below zero. On Jan. 16, 500,000 gallons of sewage at a temperature of 49° F. were pumped upon this bed, and on Jan. 17, 175,000 gallons. The underdrain started in seven hours after beginning the application of sewage. On Jan. 18, the frost was out of the ground in places, and on Jan. 19 nearly all out, while the sewage had entirely disappeared from the surface."

The following is the approximate cost of the disposal of sewage by intermittent filtration:—

600 acres of land and preparing 300 acres for filter beds	$240,000
Buildings, etc.	25,000
Force main	115,000
Pumping station	65,000
Pumping engines, boilers, machinery, etc.	275,000
Land for Pumping Station	10,000
	$730,000
Sewer outlet to Lake	$ 80,000
Total	810,000

Contingencies	$100,000
Total	$910,000
Add cost of intercepting sewers	$820,000
Total	$1,730,000

The above estimated provides for sufficient land to accommodate a population of 400,000, but the area ample for a population of 600,000 could no doubt be obtained. The annual cost of pumping the sewage and maintaining the farm for the present population would be about $70,000.

I have not considered in the annual cost the question of any revenue that may be derived from the sale of the produce. While there is no doubt that in a number of towns in England, sewage farming on the intermittent filtration system has resulted in a revenue sufficient to meet the cost of operation, yet in the case of Toronto, where, owing to the climate, no crops can be produced for at least six months in the year, I have, as just mentioned, not estimated upon any revenue, yet there is no doubt that the cost of management of the farm should be partly met by the revenue to be derived from the sale of its products.

The description of the following farms in England have been taken from Mr. W. Santo Crimp's work on Sewage Disposal, which was published in 1890.

Doncaster.

"The sewage farm at Doncaster is 264 acres in extent, and the dry-weather flow is about 800,000 gallons per day. The Corporation, however, are the owners of a large estate of 700 acres, and a portion of this estate forms the sewage farm, viz., 264 acres. The capital expended upon the farm to prepare it for sewage disposal has been about $25,000. This, of course, does not include the cost of the land. The pumping station, machinery and rising-main cost about $90,000. The farm was let for the first fourteen years at a yearly rental of $4,000. It is now let at an inclusive annual rental of $2,700.

Croydon.

"Beddington Irrigation Farm, Borough of Croydon. The population draining to the farm is about 73,000; the dry weather flow being about 3½ million gallons in twenty-four hours. The sewage flows to the farm by gravitation. The farm contains 525 acres; 420 acres are laid down for Broad Irrigation. Irrigation upon part of the farm was begun in 1860, and has since been continuous. During the past three years the working expenses have been about $20,000 per year, and the sales of produce have averaged about $22,000. The cost of the whole has been about $690,000.

Dewsbury.

"Dewsbury, where the sewage is treated by intermittent filtration, has a populatien of 30,000. The sewage farm consists of about seventy acres, fifty of which are laid out as filter area, while some ten or twelve acres of higher ground serve for surface irrigation. The sewage has to be pumped. The crops grown are principally roots and rye grass, which succeed very well, and have in dry summers proved of great value. The Farm Manager writes, 'The crops are doing well, some of the land being cropped four times, while the effluent is always good! Indeed, many mill-hands came down to bathe at the outlet, it being the only clear water for miles that they can bathe in.' This fact is striking, because it was from this part of the River Calder that the Rivers' Pollution Commissioners took the water wherewith to write their 'memorandum,' in lieu of ink, showing the condition of the river."

The following descriptions of the Paris, Berlin and Dantzic Sewage Farms are condensed from a report of the City Engineer of Worcester, Mass., on the result of his visit to Europe in 1886.

Paris.

"The Paris Farm has an area of 1,482 acres, about one-quarter of the sewage of the City, viz., 16,500,000 gallons, is used upon the Irrigation Fields daily. The cost of the works, including Pumping Station and conduits was 4,445,579.39 frs. The cost to the City annually is about 400,000 fr., gross revenue from the letting is about 10,000 francs.

Berlin.

"Berlin has now two immense sewage farms, consisting of about 13,000 acres, the sewage being pumped to a height of sixty-five feet. The ground is frozen to a greater or less extent from the 1st January to 1st March. The odor from the sewage on this farm is very marked. The effluent is quite clear in appearance, but not so clear as that of Paris. It is estimated that the sewage of 899,000 people is collected and distributed upon the farms.

Dantzic.

"Dantzic, Germany has a population of 100,000. The flow of sewage to the farm is about 2,500,000 gallons per day. The ground is frozen to a depth of about one foot in winter, in some extreme cases to a depth of nearly three feet. The sewage is all turned upon the irrigation fields during the winter, and is allowed to stand until the ground is sufficiently clear of frost to allow of its absorption. The effluent, however, is not as good as during warm weather, especially during the severest portion of the winter. The land for this farm cost nothing. It is in fact a plain of waste sand thrown up by the sea. The cost of preparing the land for the irrigation was $57,600, or about $146 per acre. The pumping cost $3,400 per year. It is claimed that the farm pays a profit of about $4,000 per year over and above running expenses, but labor is extremely low. Common laborers, forty-eight cents per day; mechanics, ninety-six cents per day; farm laborers, thirty-seven cents per day. At times, portions of the land is rented to farmers, and the sewage supplied to them without cost."

The above are descriptions of these farms as they existed some years ago, and no doubt several changes have since taken place.

Chemical Precipitation.

The next method of disposal to be considered is that of chemical precipitation. This system, which a number of your Council have seen in operation in Hamilton, is carried out by turning the sewage into large tanks after it has been treated by the chemicals. The sewage is then passed very slowly through the tanks to enable the suspended matter to settle to the bottom. It is necessary of course to have sufficient tank capacity to permit of a sufficient number to be out of use while the sludge is being removed. Disposal of the sludge is the most difficult part of the sewage precipitation, the sludge being used on land as manure, or got rid of by filling in low land or by burning. Authorities inform us that precipitation removes from fifty to sixty per cent. of the organic matter. American Engineers assume that for every 1,000 people, fifty-four cubic feet of sludge may be expected. The disposal of the sewage by precipitation is carried out in a large number of the principal cities in England, notably London, Leeds, Manchester and Bradford. In America, there are several plants in operation, the largest of which is at Worcester, Mass. Providence, R.I., is now engaged in constructing works of this character.

It is a question whether the removal of about half the organic matter from our sewage would permit of its being turned into the Lake without creating a nuisance, and I therefore considered in connection with chemical precipitation that the effluent should be afterwards further purified by filtration, either by turning it upon the natural soil, or if sufficient land cannot be procured at a reasonable price for this purpose, artificial filters could be constructed. It may perhaps be found during the winter months and after a strong wind has been blowing from a westerly direction, that it would not be necessary to further purify the sewage by putting it on the filter beds, but after treatment with the chemicals it could be permitted to discharge into the Lake. In connection with this matter the Local Government Board of England is now compelling nearly all the cities using this system alone to supplement it by further filtration. I have in my estimate assumed that the most economical and satisfactory chemicals to be employed would be lime and either sulphate of alumina or copperas. Messrs. Hering and Gray in a report upon the Baltimore Sewage Scheme, state that 8,000 grains of lime and 2,000 grains of sulphate of alumina are employed to properly clarify 1,000 gallons of American sewage. Assuming that our present sewage amounts to 16,000,000 gallons per day, this would take for Toronto between nine and ten tons of lime and nearly three tons of sulphate of alumina in twenty-four hours, the cost of which would be at the present price of lime and alumina $115 per day. The quantity of lime and alumina to be used varies hourly, depending of course upon the quality of the sewage. If it should be decided to dispose of our sewage by

this means, these works could be located in the vicinity of Woodbine Avenue and Queen Street, where a sufficient amount of land could in all probability he purchased. To carry out this scheme involves the necessity of procuring a large block of land so as to provide for the necessary buildings, tanks, filter beds, etc. The cost of the Disposal Works would be as follows.

Purchase of land and preparing filter beds ....$	115,000
Tanks, buildings, sludge press, etc	250,000
Pumping station, machinery, boilers, screens, etc	190,000
Outlet to Lake	75,000
Total ....$	630,000
Contingencies	90,000
Total ....$	720,000
The cost of intercepting sewers ....$	820,000
Total	$1,540,000

The annual cost of treating the sewage, including the pumping, would amount approximately to $105,000. This of course is for the present population. The above estimate of the cost of the work is ample to dispose of the sewage from a population of 300,000, but sufficient land is provided to accommodate ultimately a population of 500,000.

In the matter of the disposal of the sewage by chemical means, we have a great deal more information available, and, as I have previously mentioned, this system is carried out in a very large number of the principal cities, and I will now proceed to give you a description of some cities who use this system, taken from reports and works on sewage.

Glasgow, Scotland.

" Glasgow disposes of its sewage by chemical precipitation, the present main sewer draining a population of 215,000. The sewage first empties into a large chamber in which all the bulky, floating matter in the raw sewage is caught on the wrought-iron gird bef ı· it passes eastward into the machinery building by three channels, and the floating matter thus caught is taken into the destructor furnace. After the sewage has been sifted, as it were, it flows into two catch-pits where the heavy suspended matter falls to the bottom, which is in each catch-pit formed of three V shaped ridges and channels, and along these channels continuously work an endless compressed steel-chain scraper, which pushes forward the deposited matter to the sunk elevator troughs, from which it is raised by elevating buckets, and tipped into a railway waggon on the floor level. The sewage is now free from floating detritus, and heavy suspended matter. From these catch-pits, or settling tanks, the sewage flows to the pump wells, where by means of four centrifugal pumps it is raised into the mixing pit, in which the chemical precipitants are introduced. These consist of a solution of sulphate of alumina and lime. The amount of these ingredients required for the thorough purification of the sewage varies widely with the varying conditions of the liquid dealt with. From the mixing tank it passes to the precipitation tanks, of which there are two sets of twelve, each tank having a capacity of 81,000 gallons. The precipitation tanks are worked on the intermittent system, one set at a time being charged; and each tank occupies about seven minutes in filling. The operation of precipitation occupies about three-quarters of an hour, and when completed the floating arms are lowered and the clear water flows off over the aerating beds, leaving in the bottom the sludge. Over the stepped bottom of the aerating beds the water flows in thin sheets so as to expose a great and constantly changing surface to the atmosphere, and then by three syphon pipes, it passes under Swanton Street to the filter beds on the west side. From a 20-ft. main channel the water is distributed into the coke filters, of which there are twenty, each 40 ft. by 10 ft. and 3 ft. 6 inches deep. Through these it passes, and thence it goes to be distributed over forty sand filters, each 40 ft. by 38 ft. and 2 feet 3 inches deep. From the sand filters the water is taken through the effluent channel into the Clyde. The sludge is carried through from the tanks back into the machinery room, is received into a large tank under the floor of the mixing room. From this it is raised by a centrifugal sludge pump into a range of three sludge settling tanks, in which a further separation of sludge and liquid takes place to the extent of about 50 per cent. The supernatant fluid is run off into the pump well containing the untreated sewage, and the sludgy mass left is drawn into a tank under the lime room. The sludge is no longer in a condition to be lifted by pumping and, to get it from the tank into the two sludge mixers, a sludge ram worked by compressed air is employed. In the mixers there is added to the sludge, hot lime to facilitate the subsequent pressing. From these mixers the sludge runs by gravitation into a range of four high-pressure rams by which it is shot to the upper floor, on which there is a series of seven filter presses, each capable of delivering 25 cwts. of pressed sludge cake. The filter presses are of the ordinary form, a range of quadrangular corrugated plates 3 ft. 6 inches square, canvas covered on each side. Between these the sludge is pressed with a power equal to ninety pounds per square inch, and the water which exudes is caught in a trough and carried into the mixing pit. The pressed cake is dropped through shoots into the railway waggons placed below, and mixed with ashes and street sweepings; it is disposed of as farm manure. The amount of sewage treated at present is about 8,000,000 gallons per day. From a total of 2,942,000,000 gallons, which passed through the works up to the end of the 31st October, there was extracted by precipitation 156,864 tons of crude sludge, which was reduced by filter pressing to 12,921 tons. In addition to that quantity, 1,749 tons of sludge were raised from the catch-pits by the elevators. These two quantities make a total of 14,670 tons of sludge, which was handed over to the Cleansing Department for disposal. By that Department there were sold as manure 6,074 tons, and deposited by rail as unsaleable refuse 8,596 tons. The quantity of sewage dealt with, and the working expenses per million gallons during each three months, August to October, 1894, and 1895, were as follows:

	Aug. to Oct., 1894.	Aug. to Oct., 1895.
Total sewage dealt with	551,785,000 gallons.	828,942,000 gallons.
Average daily quantity	5,997,663 "	9,010,239 "
Average daily weight	26,775 tons.	40,224 tons.
Pumping	£0 15s. $0\frac{3}{10}$d.	£0 11s. $6\frac{3}{10}$d.
Precipitation, including Chemicals	1 14 $2\frac{6}{10}$	1 7 $4\frac{3}{10}$
Filtering	0 7 11	0 7 $4\frac{8}{10}$
Pressed Sludge	0 14 $1\frac{3}{10}$	0 10 $1\frac{3}{10}$

"The total capital expenditure on the works and machinery up to the 31st May, 1896, amounted to £111,400, the land acquired cost £37,800; £2,340 were charged against the Cleansing Department for accommodation it obtained. On the works and machinery there was spent £81,170, but this amount again is subject to a deduction of £5,220 paid by the Cleansing Department. The ordinary expenditure for the year ended 31st May, 1896, amounted to £18,282, in which amount is included £3,333 paid to the sinking fund in redemption of debt, and £2,949 of interest. There remains £12,000 as expenditure connected with the working establishment, of which sum salaries and wages absorb £3,879. The account for sulphate of alumina and lime amounted to £4,382, and filter materials cost £664, and the remainder is made up of minor charges. The sludge yields no revenue; indeed there is a charge of £295 for the removal of 8,876 tons, which was not considered worth its own carriage, and the whole expenditure is met by an assessment at the rate of 1 3/16d. per pound, which produced in the year in question £18,858. The experience of sewage purification is completely satisfactory."

The above account of the works in Glasgow has been taken from "Glasgow, its Municipal Organization and Administration," by Sir James

Bell, Bart., Lord Provost of Glasgow, and Mr. James Paton, and is the most recent and complete account of large sewage disposal works. The volume was kindly lent to me by Mr. James D. Allan of this city.

MANCHESTER.

"Manchester has recently constructed very extensive outfall works where the sewage is treated with lime and green copperas. The corporation of Manchester have purchased 165 acres, of which about fifty acres are occupied by tanks, buildings and filter beds. The cost of these works up to the present have been about $900,000, and owing to the difficulty of getting rid of the sludge the corporation have recently constructed a sludge steamer, similar to those used on the Thames for the disposal of the London sludge. The cost of this steamer was about $120,000. The steamer carries the sludge out and deposits it in the ocean. The cost of sewage treatment for 1897 was about $100,000, and the population contributing to the sewage system was about 500,000. The total flow of sewage was about 20,400,000 gallons. The cost of the sewage treated per million gallons for 1897 was about $12.50. The average amount of wet sludge precipitated has been 21.16 tons per million gallons, yielding 7 tons 12 cwt. of pressed cake per million gallons. The amount of sludge removed by farmers was 14,233 tons, equal to an average of about 39 tons per day, and the balance 41,875 tons have been deposited in the old bed of the river."

The above account is taken from the last annual report of the City Engineer of Manchester.

The account of the following works is taken from the report of the City Engineer of Worcester, Mass., who, in 1886, was sent to Europe to report on the different systems:

BRADFORD.

"Bradford has a population of 200,000, and treats its sewage with milk of lime, about 8,000,000 gallons being treated per day. The works cost $300,000, including outfall sewer, and the cost of operation is $20,000, exclusive of interest on the outlay. The lime costs $2.50 per ton, delivered at the works; about twenty-five men are employed. The amount of water used averages about thirty gallons per day per person."

LEEDS.

"Leeds has a population of 343,000. The sewage is treated with milk of lime. The quantity of sewage treated per day is about 10,000,000. The sewage has to be pumped, the lift being 18 feet. There are thirty-one men employed on the works constantly. Lime costs $3.16 per ton. The cost of operating, outside of interest on the outlay, is $25,000 per year. The works cost about $300,000. This includes outfall sewer. The sludge is given away to farmers."

In the resolution of your Council, dated May 3rd, 1898, I am requested to report as to the cost of chemically treating the sewage from that portion of the City west of Bathurst Street. However, I cannot recommend your Council making a separate system for the treatment of the sewage west of Bathurst, as the works would cost a great deal of money, owing to the difficulty of procuring suitable land. I understand, however, that the portion of the City more particularly referred to is that west of Dufferin Street, the shores of the Lake in this locality being very much polluted, owing to the discharge of the sewage at the foot of Dufferin and Fort Rouille Streets. If your Council, however, take up the question of dealing with the whole question of this City, this nuisance would be prevented, as the sewage from this section of the City could be pumped into an intercepting sewer and carried east to the Disposal Works at a small annual expense. If, however, it should be considered advisable not to proceed with the large and general scheme of the disposal of the sewage, but you should decide to get rid of the nuisance at South Parkdale, I would recommend that Disposal Works be erected on the Lake front, and the old Parkdale Water Works property could be utilized for this purpose. It would be necessary to procure additional land, which could be carried out by cribbing and filling with sand from the Lake. It would also be necessary to construct a small intercepting sewer along the Lake front, so as to carry the sewage to this point. I am recommending this place as the sewage could flow to the proposed works by gravity. If the works were located at the foot of Dufferin Street it would be necessary to pump the sewage, and land in this neighborhood would be much more valuable, if it was required to purchase it. There is no doubt that when the sewers of Parkdale were constructed, if it had not been for the fact that Parkdale was then procuring its water supply from the Lake opposite Sunnyside Avenue, that the sewage, owing to the natural drainage of the ground, would have been discharged at this point. Although West Toronto Junction procures its water supply a short distance west of the proposed sewage works, there should be no danger of contamination if the sewage is properly treated. The cost of works, including the intercepting sewer, necessary to treat this section of the City would be approximately $60,000, and the annual cost of operating the same for the present population would be about $4,000.

If your Council, in view of the fact that at no distant time the question of the disposal of the sewage of this City must be considered, and are not prepared to expend this amount, I would recommend as a temporary means of abating the nuisance at South Parkdale, that the sewer be extended, at the foot of Dufferin Street, into deep water. The cost of this will be approximately, $6,500.

In both schemes that I have brought before your Council pumping would be necessary, although in connection with the Precipitation Works the annual cost would be small.

It has occurred to me that, if it were not that the shores of the Lake in the eastern section of the City had not within the last few years become so popular as a summer resort, that it might have been cheaper to have turned the crude sewage into the Lake and filter our water supply.

In conclusion, I would recommend to your Council the adoption of the system of intercepting sewers, as recommended by Messrs. Hering and Gray, with some slight modifications. But I am of the opinion that if either of the methods of sewage disposal, as suggested in this report, are adopted, as both of them involve pumping, it may be found upon further investigation that one large intercepting sewer along Front Street may be sufficient to answer all the requirements for many years, and a saving of about $125,000 in the cost of the intercepting sewer would be effected. My estimate of the cost of the system of intercepting sewers is based upon present prices for this class of work, and is liberal.

Dealing next with the more important question of the best method of getting rid of our sewage, I am of the opinion that either of the schemes suggested will meet the requirements of the City. But I consider it would be advisable, before your Council incurs such heavy expenditure, that the opinion of a Consulting Engineer, who has made a specialty of sewage disposal, should be obtained. In the matter of first cost it will be seen that the Precipitation Works are the lowest, yet the annual cost is in favour of Intermittent Filtration:

Intermittent Filtration—	
Total cost	$1,730,000
Annual cost of maintenance	70,000
Precipitation Works—	
Total cost	$1,540,000
Annual cost of maintenance	105,000

Respectfully submitted.

C. H. RUST,
City Engineer.

SEWAGE DISPOSAL.

CITY ENGINEER'S OFFICE,
Toronto, November 3rd, 1899.

To the Chairman and Members of the Committee on Works:

GENTLEMEN,—Referring to a communication from the Committee of September 23rd last, forwarding the following resolution :

"Moved by Ald. J. J. Graham, seconded by Ald. Score, that whereas the question of the best method of sewage disposal for the City of Toronto has been from time to time reported upon by various engineers at considerable expense, and more recently by the City Engineer and Medical Health Officer, in the opinion of this Board the present time is opportune for taking up the construction and carrying out of the trunk sewer and sewage disposal works for the City of Toronto. Be it therefore resolved, that the City Engineer at once present a report, stating what system he recommends, and the amount of money required for same."

I beg to call the attention of the Committee to my Report on the Disposal of Sewage, submitted to the City Council in October of last year, which deals very fully with this question.

Since this report was written, Messrs. Ald. Saunders, Ald. Lynd, Dr. Sheard and myself visited the Sewage Disposal Works at Madison, Wis., and I also visited the septic tank in use at Champaign, Ill., and made a further inspection of the Hamilton Sewage Disposal Works.

The Madison works were visited last August, at which time the works had not been taken over by the city. They were erected by the American Sanitary Engineering Company, of Detroit, the Manager of which is Mr. McDougall, who some time ago addressed the Committee upon the question of sewage disposal. At the time of our visit, ferrozone was used as a precipitant, although I have recently ascertained that they are now using lime with satisfactory results. Polarite, with sand, is used for filtering purposes. At present, about 700,000 gallons of sewage is treated per day. There are four tanks, twenty-five feet in diameter and fifteen feet deep. After the sewage leaves the tanks it flows on to filtering beds, of which there are three, with an area of five thousand five hundred square feet. There is about four feet of filtering material in each bed. The total cost of the works was $50,000. The Company claim that by the use of Polarite they are able to filter at the rate of nine million gallons per acre. The population of the town is about 20,000. The tanks used are of an improved form and fitted with an ingenious method of removing the sludge, which operates without emptying the tank or throwing it out of use, as is ordinarily the case. One advantage of this system is the small area of land required. The whole system, however, is a proprietary process, the rights of which have been acquired for this country by the Company who erected the works.

At Champaign, Ill., which I visited on the 19th of October, a septic tank is used for getting rid of the sewage. This is probably the first erected in the United States, and was constructed under the direction of Professor Talbot, of the University of Illinois. For the information of the Committee, it may be proper to describe what this system is, the material for which was kindly furnished me by Professor A. N. Talbot.

There are two masonry tanks, eight feet wide, thirty-seven feet long and having a depth of five feet of water. The sewage flows into each through a diverging channel, which is arranged to discharge well over the cross section of the tank, and flows out of the opposite end over a weir, the full width of the tank. Across the tank at intervals are partitions which reach two or three feet below the surface, trapping the floating solids and preventing surface currents. These tanks are enclosed in a brick building, which is dark and without ventilation. A light, floating mat covers the surface of these tanks. Both this and the sludge at the bottom contain little organic matter. The action of the tank is continuous and no attendance is necessary. A fairly good effluent is produced, which is discharged into a small creek which, during the summer months, is nearly dry. The population of Champaign is between 9,000 and 10,000, and at present they are treating about 300,000 gallons daily. Analysis show that from seventy to ninety-five per cent. of organic matter in suspension is removed. The effluent, as before mentioned, is sufficiently pure to permit its discharge into the creek, and I understand no objectionable results have been noticed. There is an odor to be noticed inside the building, which is not specially objectionable. When the sludge, however, is pumped out, the odor, of course, is much stronger. This tank has been in operation since 1897.

The action of the tank seems to involve the following operations :

1. The mechanical separation of suspended solids, the solid matter settling and the lighter floating.

2. The reduction of the retained organic matter by bacterial action, the gases being given off and the ash settling, leaving some inorganic compounds to be carried off in the effluent.

3. The similar reduction in organic matter in solution, though to a smaller degree.

4. The breaking down of the compounds, so that a further purification is made in the stream after leaving the tank much faster than would otherwise be effected.

The bacterial processes of sewage purification are now receiving a great deal of attention in England, and I have gathered the following information from technical papers and reports :

At the present time there are two systems which are receiving a great deal of attention from engineers and municipalities—the septic tank method of treating sewage and the bacteria tank. The septic tank is a process of removing most of the suspended organic matter, and some which is in solution, and giving an effluent which, although not chemically pure, is inoffensive to the sight or smell and is pure enough to be turned into large streams or bodies of pure water without doing appreciable harm. This system differs from the other processes in that it attempts to bring an entirely new and different class of bacteria into operation—the anærobic. These bacteria thrive in the absence of oxygen and are the organisms that give rise to putrefaction. The operation consists in running the sewage steadily into closed darkened chambers, where it is acted upon by anærobic bacteria, and the effluent is drawn off below the surface, at a rate falling from 1,800,000 gallons per acre per day in Exeter, England, to 17,000,000 gallons per acre per day in Champaign, Ill. The sludge produce is estimated at only about one-seventh of that produced by chemical precipitation. The effluent may, as with other preliminary processes, be again treated by passing through fine sand filters, which gives, of course, a much purer effluent. The annual cost of operation is very small, as compared with chemical precipitation, and from experiments it is found that there is no danger of the operation becoming gradually less efficient by choking up, as in bacteria beds.

The first experiment made in England with septic tanks was at Exeter, where they aroused a great deal of interest. Some of the leading scientists of the country seemed to be greatly impressed with the work done by the tanks and the recognition of the fact that the only destruction of waste organic matter is effected solely through the agency of living organisms, is quite modern.

There is a great deal of difference between the tanks at Exeter and those at Champaign, Ill., where the sewage is not held more than four hours. The wide interest which has been taken in this system in England, and the high standing of the gentlemen who have examined its workings and pronounced favorably upon it, warrant us in considering it in connection with our Toronto problem. Enough data has been published to enable us to understand in a general way the principles which govern its use.

One objection to the septic tank for large cities is the constructiion of a reservoir of sufficient storage capacity to hold a large quantity of sewage, and the one which would be required for Toronto would be quite expensive.

The first cost of the septic tank system would probably be somewhat greater than that for chemical precipitation or intermittent filtration, but the annual expense would be comparatively light.

The bacteria tank method of treating sewage consists in passing sewage first through a fine meshed screen, extracting the coarser particles of paper, etc., and then allowing it to stand a few hours on a coarser filter bed or tank, open to air and light which is acted upon by a class of bacteria which thrive in the presence of air and light, and the greater portion of the organic matter is removed or changed into harmless compounds. These beds are about three and one-half feet deep, composed of coke breeze, sand, burnt clay ballast, etc. The dangerous point not yet fully demonstrated is that the beds may have a tendency to gradually get choked and thereby become less efficient. The effluent appears to be purer than that of the septic tank, but the process requires a great deal more land. The cost of operation and construction is not reported as being fully determined. This process is considered preliminary also to the effluent being again filtered through finer material, to give a pure final effluent.

The London County Council have instituted a series of experiments at the Outfall Sewer Works, at Barking Creek, and the results have been, I understand, satisfactory. From a few experiments made in this country it does not appear that there is danger of the temperature of the bacteria beds falling to a point sufficiently low to destroy the vitality of the organisms.

The disposal of sewage by means of bacteria tanks is in operation at Suttou, Surrey, and the results are, I understand, very satisfactory. So far I have not been able to ascertain any facts about the cost of construction or annual maintenance of any of these works.

In addition to these places there are a number of cities and towns in England which are experimenting on these lines, notably, Manchester, Leeds and Sheffield.

The sewage disposal works at Manchester are at present not working satisfactorily, and they are making some very extensive experiments with bacteria beds and are now constructing beds upon thirty-seven acres of land. In December of last year the Manchester Corporation approved of the preliminary report of the Experts appointed by the Council, recommending the bacteriological system of sewage disposal, and recommending that further experiments be made as to the precise form and details of the method which can be most successfully carried out on such a large scale, so as to make the proposed works a complete success.

Leeds and Sheffield have already spent from $30,000 to $40,000 each in experimental works, and the results so far have been satisfactory. Both these cities had been using lime as a precipitant and in Sheffield they called in Mr. Mansergh to advise them. I understand that his report was, that the present system is obsolete and it will be necessary to instal an entirely new system. There are now about two hundred cities or towns in England where they are experimenting or considering the adoption of either the septic or bacteria tank.

In conclusion, it is a question whether your Committee think it advisable to instal a small experimental station on the septic tank plan, or await further results from the experiments which are now being made in England, probably in a more thorough and exhaustive manner than could be done here. An experiment on a small scale could be made in this City, at a probable cost of $3,000.

I believe that some members of the Council arc very desirous of having the sewage from Parkdale and the Garrison Creek sewer treated at a separate point, if possible, and not carried eastwardly, as proposed in my former report. I am, however, not in favor of this plan, as it would be more economical to treat the whole sewage of the City at one station. There would also be considerable difficulty in obtaining a sufficient area of land (probably thirty acres would be required) in the west end of the City, whereas, if the sewage is disposed of in the locality suggested in my report of last year, there would be no difficulty in obtaining the necessary seventy-five to one hundred acres of land required. It might, on further investigation, be found that the east end of Ashbridge's Marsh could be filled in and made available for these works.

If, however, your Committee are desirous of commencing these works at once, I recommend that a By-law be submitted to a vote of the ratepayers to provide the sum of $2,000,000 for this purpose. This is somewhat in excess of my estimate of last year, for precipitation works, but if the septic tank method of disposing of the sewage is adopted, the cost of installation will be somewhat in excess of the cost of constructing precipitation works. It must also be borne in mind that there is a tendency at present towards an increase in the price of both labor and material. If the proposed By-law is submitted to and carried by the ratepayers, the intercepting sewers, which will require to be constructed in any event, could be commenced. It would probably take three or four years to construct these sewers, and by that time we would, no doubt, be in a better position to decide which system it would be advisable to adopt for the disposal of the sewage of the City.

I am, however, of the opinion that either of the systems outlined in my report of last year, would satisfactorily dispose of the sewage; but considering the large annual saving in the cost of operation which would be effected if either the septic or bacteria tank method were adopted, it might be advisable, before coming to a final decision in the matter, as already suggested, to further investigate these systems.

I would, however, recommend that during the coming winter complete plans of the intercepting sewers be prepared.

Respectfully submitted.

C. H. RUST,
City Engineer.