REPORT

ON

TORONTO SEWAGE

BY

G. R. STRACHAN, MEM. INST. C. E., ETC.

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9 VICTORIA STREET, WESTMINSTER, LONDON, S.W.,
8th August, 1906.

Emerson Coatsworth, Esq. (Mayor), and Members of the City Council of Toronto:

TORONTO SEWAGE DISPOSAL.

GENTLEMEN,—1. On the 6th ultimo Mr. C. H. Rust, your City Engineer, called at my chambers and entrusted me with the commission of reporting on this question generally, and in particular as to the schemes set out in his report dated July 8th, 1906, in the light of recent English experience.

2. Mr. Rust handed me several plans and papers, and the reports made on this question since the year 1873, all of which I have carefully examined and read. We have since had several conferences, and have fully discussed the Toronto issues of this very complex problem.

3. As I have not seen your City or visited Canada, my advice cannot be more than that of one who is in the thick of the water supply and sewage disposal questions here, and who has applied his mind by the aid of such experience to your case. I propose, therefore, to set out the facts as I have gathered them, and on which I have based my conclusions, and to give reasons in some detail for the advice I tender.

LOCAL CONDITIONS.

4. The City of Toronto is situate on the northern shore of the Lake of Ontario, and has a population of about 270,000 persons. The growth of the population has been continuously progressive as the following figures show:

Year.	Population.
1876	71,693
1881	76,934
1886	118,403
1891	188,904
1896	195,987
1901	235,000
1906	270,000

I accept the figure of 500,000 as being a proper provision for the future population in any scheme of disposal now considered.

5. The Lake of Ontario is filled with fresh water, has a length of 190 miles, a breadth of 55 miles, an area of 5,400 square miles, and a maximum depth of 738 feet. From the navigation chart first published in 1817, and amended as recently as 1891, I find that the deepest parts of the lake follow a line about 12 miles from the southern shore, and that the bottom slopes in opposite directions therefrom to the northern and southern shores without any undulations which could occasion or deflect currents. In summer the level of the lake is four feet higher than during the ice season, and this variation represents an accumulation of nearly four billions of gallons of water. Great as that volume is, it would not be likely to make currents, for its rise would be a swelling of the waters and its fall their slow dispersion into the river at its outlet.

6. The lake, in addition to the water draining directly from its own watershed, receives the flow of the Niagara River on its southern side nearly opposite to Toronto (which is 30 miles away), all of which pass into the St. Lawrence at its eastern end. One would not expect currents to be developed under the conditions of this lake, and this view is confirmed by float experiments made at and near Toronto, to which I refer in paragraph 13.

7. The water supply is obtained from the lake, outside the harbour, at a depth of 70 feet, and is distributed to the citizens without filtration or sedimentation gained by storage. To an English water engineer the quantity supplied is extraordinarily large, amounting as it does to 100 gallons per head per day.

8. At the present time the crude sewage of the City is discharged into the lake or the harbour, or the waters flowing directly thereto. From a very elaborate series of gaugings of the sewage taken in the early months of 1900, I find that out of a daily total of 20,745,473 gallons, nearly two-thirds of the flow goes into the harbour, and no less than 4,686,494 gallons (or twenty-three per cent. of the whole) are discharged at Garrison Creek at one point, in addition to smaller quantities at other points.

9. The rainfall on the average of the 65 years ended 1905, amounts to 27.042 inches per year, with a maximum of 43.555 inches in 1843, and a minimum of 17.574 inches in 1874. The maximum fall in any one day, occurred on 27th July, 1897, when 3.881 inches fell. These figures are similar to those I am familiar with here.

10. The average temperature of the 65 years ended 1905, has been 44.36 degrees Fah. The average for the warmest month has been 67.82 degrees Fah. and for the coldest month 22.18 degrees Fah. The highest temperature recorded was 92.2 degrees Fah. on the 24th August, 1854, and the lowest was 26.5 degrees below zero, on the 11th January, 1859. From an examination of the records as far back as 1872, I find that the temperature has been well below

zero each year. These figures are distinctly lower than those which obtain here, and the very cold periods introduce a factor in sewage disposal for which considerable allowance must be made.

11. The average direction of the winds for the 35 years ended 1884, was N. 62 degrees W., and for the subsequent 21 years, N. 61 degrees W., that is to say, from the City towards the lake and its outlet.

12. The effects of the discharge of the sewage at Garrison Creek have been determined chemically and bacteriologically by Mr. McKenzie, Analyst to the Provincial Board of Health. The results obtained from samples collected on October 16th, 1891, are set out in Mr. Rust's report of the 23rd November, 1891, from which the following figures are taken:

ALBUMINOID AMMONIA AND ORGANIC IMPURITY IN PINTS PER MILLION.

Yards from sewer outlet.	Albuminoid ammonia.	Degree of organic impurity Muter's scale.
Near sewer mouth.	.80	2.44
720	.13	.25
2,350	.14	.29
3,170	.09	.17

BACTERIA PER CUBIC CENTIMETRE.

Yards from sewer outlet	Number of bacteria.
Near sewer mouth.	38,000
720	110
1,400	209
2,350	141
3,170	50
4,000 (at intake)	67

These tables indicate the very rapid manner in which the sewage pollutions are dispersed or destroyed.

13. The float experiments made in the lake to the east of the harbour, under very varying conditions, convey to the mind that the wind is the principal cause of the movements of the water, and from the anomaly of several of the floats moving against the wind when it is changing in direction, I infer that the water moves slowly in a mass in conformity to a steady blow and does not respond readily to a varying wind. These movements can scarcely be regarded as currents, but are rather the slow circulation of the waters due to wind and temperature, and it would appear from the experiments that their maximum velocity is probably about six-tenths of a mile per hour.

14. These appear to be the principal local facts affecting the question, and having set them out I now propose to discuss Mr. Rust's disposal schemes solely from the standpoint of the sewage issues in the first instance, and then as they bear on the water question.

SCHEME FOR DELIVERY OF CRUDE SEWAGE INTO LAKE ONTARIO.

15. Mr. Rust proposes in this scheme to construct a tunnel sewer to convey the whole of the sewage to a point under the cliff three miles east of the City limit, and nine miles to the east of the water intake, and to discharge it crude into the lake 750 yards from the shore at a depth of 25 feet.

16. The first question to be determined is the volume of sewage and rainwater to be conveyed to the outlet. In our best practice, as recognized by the local Government Board, provision is made in one form or other for dealing with sewage and rainwater up to the rate of six times the average dry weather flow, and we allow any flow in excess of the six volumes to spill itself untreated into the rivers or streams. The first three volumes always include the dry weather flow of sewage, and are subjected to thorough treatment to secure a high class effluent, but the treatment of the second three volumes is more in the nature of screening on a large scale through clinker beds and the effluent is of a secondary quality. This empirical method of dividing the flows is found to be satisfactory in practice, and it is obviously a common sense and practical arrangement. Hence in our best works for domestic sewage, when the dry weather flow is as much as 30 gallons per head per day, we deal thoroughly with all that reaches the outlet up to 90 gallons per head per day, and with the flow between 90 and 180 gallons per head per day, less thoroughly, while all above 180 gallons per head per day is allowed to overflow into the nearest water.

17. In the case of Toronto this standard would be inapplicable by reason of the high user of water, if applied numerically, but it can be applied in principle. The amount of pollution per head at Toronto cannot vary in any sensible degree from that which obtains here, and therefore your flow of 100 gallons per head can be regarded as the equivalent of our first three volumes, and an additional flow of 100 gallons per head per day as the equivalent of our second three volumes. Any flow in excess of 200 gallons per head per day may properly be allowed to go untreated into the nearest outlet into the lake or harbour without nuisance or sensible pollution.

18. The tunnel sewer should have an invert level 40 feet above datum at its outlet, which would bring it even with mean water level. I notice that the schemes before you give a gradient of 1 in 1,500 for the outfall sewer, with a diameter of 8 feet. According to my experience this gradient may be flattened to 1 in 3,000, and I suggest that it be so laid. It is of importance to command by gravitation as much of the sewage of the City as is consistent with the efficient working of the sewers, so as to reduce the amount to be pumped to its smallest dimensions. The flatter gradient however means an increased size, and I propose therefore, a diameter of 9 feet, and its invert will have an elevation of 50 feet above datum at Pape's Avenue. The minimum velocity in such a sewer during the night flow will be a self-cleansing one of 130 feet per minute.

19. It is not possible for me to trace the most advantageous line for the

gravitation intercepting sewer through the City, because of the lack of levels on the plans at my disposal, but it should be laid to catch as much sewage as possible, and its gradients should be such that when each section is running full, the velocity would be a little over 160 feet per minute.

20. The low level intercepting sewer for that part of the City not served by the gravitation system, should collect the sewage to a pumping station, from which it would be forced into the 9-feet sewer.

21. One effect of this division of the City into gravitation and pumping zones, is that those parts of the present outlet sewers which pass through the low level area will be needed hereafter to convey the overflow waters from the gravitation area, and cannot therefore be available for ordinary sewage purposes in the low level zone. This will necessitate the construction of short sewers alongside of the truncated sewers, correctly apportioned to the diminished volumes, with overflows into the truncated sewers. The combined arrangement of high and low level areas will give a serviceable and economical system of interception, for it fortunately happens that the future growth of the City will occur principally on the gravitation zone.

22. Before discharging the sewage into the lake it should be thoroughly freed from all floating solids by careful screening. This operation should take place preferably at the lake end of the tunnel sewer by a series of three sets of mechanically worked fixed screens with decreasing meshes, enclosed in a suitable structure. The solids would thus be effectually removed, and I suggest that they be burned. If, however, for local reasons it is advisable to place the screening house and destructor at the upper end of the tunnel sewer, the operations can be done there equally efficiently as at the outlet end. By this means the objection which might otherwise arise from solids floating on the lake after discharge will be avoided. A fall of 1 foot should be allowed in the invert of the sewer at the screens, and if they are placed at the outlet, the sewer invert should be 41 feet above datum instead of 40 feet, as stated in paragraph 18.

23. The question now arises as to the results which will follow the discharge of the screened crude sewage into the quiescent or slow moving waters of the lake. I do not doubt that for a few hundred yards near the submerged outlet the lake will be discoloured and objectionable, but so far as I can form an opinion, there will be no nuisance worth speaking about. Beyond this area of visible pollution there will be a larger one where adverse results will be distinguishable by the analyst and bacteriologist, and on the very important issue as to how far this adverse affection may extend, I now place before you some facts from our home experience.

24. The case of the London sewage is one in which the magnitude of the discharge is without parallel anywhere, and it fortunately happens that the facts have been critically determined. During the year 1902 the Royal Commission on Sewage Disposal now sitting, investigated the state of the Thames, and the results are set out in the third volume of their fourth report published in 1904. During that year a daily average of 232,000,000 gallons of

sewage effluent was sent into the River Thames at Barking and Crossness, being the liquid waste of a population of nearly 6,000,000 persons, after undergoing a meagre chemical treatment. The *b. coli* in the effluents were found to be 100,000 per cubic centimetre, and the spores of *b. enteritidis sporogenes* somewhere between 100 and 1,000 per cubic centimetre. The human mind is incapable of grasping the ultimate number of the organisms in the daily volume of the London effluent, yet the beneficent powers of nature deal with them so thoroughly that 25 miles lower down the *b. coli* and *b. enteritidis sporogenes* are reduced to one per cubic centimetre. On page 68 one of the conclusions is stated in these words: "That the waters of a tidal river grossly polluted in its lower esturial reaches, may, after a flow of some 25 miles become so far purified by sedimentation dilution and the operation presumably of bactericidal agencies, as to become seemingly as little objectionable, or in some respects less objectionable, bacteriologically, than certain of our water supplies." This is a very striking result, but not so significant as that relating to the sludge disposal. In the same year the liquid sludge resulting from the chemical processes at Barking and Crossness was conveyed by steamers and discharged neat into the open sea at Barrow Deeps, about 15 miles from the river mouth. The area of discharge is 10 miles long and 1 to 2 miles broad, and the depth is from 6 to 13 fathoms at low water of spring tides. The quantity of liquid sludge so disposed of amounted to 2,607,000 tons, or about 50,000 tons per week. The *b. coli* in the sludge varied between 1,000,000 to 10,000,000,000 per cubic centimetre, and the *b. enteritidis sporogenes* from 10,000 to 100,000 per cubic centimeter. The bacteriological determinations of the waters in Barrow Deep show that the *b. coli* numbered three per cubic centimetre and the *b. enteritidis sporogenes* four per cubic centimetre. On page 48 the Report says: "The ultimate fate of this vast horde of microbes is matter for conjecture, but the actual result is beyond question most satisfactory." I do not set out these facts as being parallel to the conditions at Toronto, for there are many points of difference, but when full allowance is made on the one hand for the tidal conditions in the River Thames and in the sea, and for the magnitude and foulness of the pollutions on the other, I personally feel reassured as to the speed and thoroughness with which the recuperative natural processes do their work in these matters.

25. In order that the full meaning of the remarkable results obtained in the Thames may be realized, I set out the results of the analyses of daily samples of the crude sewage and effluent taken every two hours, day and night, for the whole year 1904.

NORTHERN OUTFALL AT BARKING.

	Grains per gallon.	
	Sewage.	Effluent.
Total suspended matters	29.8	7.1
Total dissolved solids	60.2	63.2
Chlorine	11.1	10.8
Oxygen absorbed in 4 hours	3.124	3.225
Free Ammonia	3.027	3.137
Albuminoid Ammonia	0.353	0.356

SOUTHERN OUTFALL AT CROSSNESS.

	Grains per gallon.	
	Sewage.	Effluent.
Total suspended matters	31.5	6.2
Total dissolved solids	90.8	99.2
Chlorine	24.8	28.4
Oxygen absorbed in 4 hours.....	3.709	3.115
Free Ammonia	2.963	2.460
Albuminoid Ammonia	0.420	0.331

It is obvious from these figures that with the exception of the reduced amount of suspended matters, the effluent is practically as foul as the crude sewage itself, and that it contains the whole of the dissolved organic impurities. Yet the river digests this enormous pollution with practically no resulting inconvenience.

26. Having given much thought to this scheme I advise you that the screened crude sewage of Toronto may be discharged at the point selected three miles east of the City limits without nuisance or offence (save very locally), and that in my judgment the lake will digest the pollution with the aid of the bacterial life brought into being by the discharge. In expressing this opinion I am influenced by the facts recorded in paragraph 12 relating to the sewage at Garrison Creek sewer, as well as by my experience here.

27. I do not attempt an estimate of the cost of the scheme by reason of the lack of details already named, and also because one feels diffident at putting prices to work to be done under conditions with which one is unfamiliar. I have, however, subject to your leave, arranged that Mr. Rust shall work out the scheme in detail, on lines we have agreed, and send it to me, with his estimate of cost, for consideration.

SCHEME FOR DISPOSAL ON LAND.

28. This is a scheme for septicising the sewage in covered tanks near Ashbridge's Bay, then pumping it to 600 acres of land in the vicinity of Woodbine Avenue for eight months of the year, and passing the effluent into the Don or the streams leading to Ashbridge's Bay, and of turning the septicised effluent direct into the lake during the four very cold months.

29. It is my duty to advise that this proposal will not be satisfactory, and particularly so, as to the discharge of the septicised effluent.

30. In 1901, when the scheme was conceived, there was a very substantial body of opinion in England that sludge was disposed of by septicising sewage, that the tanks need not be covered, and that the effluent from the tanks was fit to put on land.

31. It is now known, and not disputed, that there is with sewage of the strength we have here, a very foul residue from the septic process, which,

when the tanks hold one day's dry weather flow, amounts each year to one-sixth of the contents of the tank or thereabouts.

32. There can be little doubt that the processes of septicising go on as efficiently in an uncovered tank as in one that is covered, when once the scum has formed and remains intact. The Toronto tanks were to be covered for climatic reasons, and therefore the issue does not, strictly speaking, arise in this case, but it may be well to state that the odors from open septic tanks have been abominable in several cases of nuisance I have investigated. There are open tanks without offence such as those at Birmingham, but the sewage there is much mixed with trade wastes, which seem to give it an impunity in this respect. In every case of open tanks I know of, where the sewage is domestic, offence is present and often in a pronounced form. The trouble arises in three ways. There is first and continuously the ebullition of new septic sludge through vents in the scum, which give off putrid odors when drying in the air and sun. There is second, and frequently, the wetting of the scum by rain and the subsequent bad smells during evaporation and absorption. Then a third and less frequent offence is caused by the wind compressing the scum into a more solid mass and leaving part of the septicised sewage exposed. It happened that at the time of Mr. Rust's visit I was investigating a case where these evils were the cause of nuisance. We visited the works and he experienced for himself the offences I have indicated.

33. There is now no serious contention here that septicised effluents should have their putrescence corrected by ærobic bacterial treatment before being applied to land. Quite recently two cases on a small scale have passed through my hands where the uncorrected septic effluent was put on land, and in both cases the offence of putrid sewage was very marked. This must be the result when the conditions are realized. A septic effluent is one in which the anærobic organisms have turned the sewage into a putrid condition, and when such a liquid is applied to land in a thin film the exposure must and does produce ærial nuisance. In my practice, septicised effluents are conducted in covered pipes and channels to the ærobic beds to avoid the nuisance of even so short an exposure. I have been engaged in most of the cases of nuisance from septicised sewage which have been in the Courts here, and in every one the exposure of the liquid has been a main contributor to the offence. I have no doubt that ærial nuisance would ensue if the proposal now under discussion is carried out.

34. The scheme can, however, be modified to meet this objection. I suggest that the tanks be reduced in volume to hold three or four hours' flow, which will enable the heavier suspended particles to subside, and will not give time for the sewage to be septicised. The sludge would have to be removed from the tanks twice a week, and should be pressed into cake or dug in. The clarified sewage could then be applied to the land without nuisance. I know of no case where sewage is disposed of at a greater rate than 30,000 gallons per acre per day, and even when one allows for the dilute character of your sewage I do not think the ultimate flow of 50,000,000 gallons per day can be properly dealt with on less than 1,200 or 1,500 acres, and even more land might be necessary.

35. It is to be borne in mind that 30,000 gallons per acre per day is the equivalent of 480 inches of rain per year. Purification at such a high rate cannot be obtained by flowing the liquid over the land; it must be passed slowly through the subsoil if the sewage is to be properly cleansed. With the area I have suggested for Toronto, the sewage would equal more than 500 inches of rain per year, and it is possible that such a burden would tax the powers of even very good land somewhat severely. I advise you, however, that with careful manipulation this scheme would be a successful one for many years, and I have no fear that the cold weather would render it inoperative.

36. When standards for effluents were based on chemical analyses and were judged according to the effects produced by the discharge, it was held that land treatment was completely successful in dealing with sewage. Now, however, the bacteriologist has revealed results from the land effluents not previously thought of. I propose to briefly set out these modern features in the cases of Croydon and Nottingham, as determined by the Royal Commission on Sewage now sitting.

37. At Beddington, Croydon, the sewage farm has an area of 673½ acres, of which 420 acres are used for broad irrigation. The sewage after screening is applied to the land at the rate of 9,500 gallons per acre per day, and it is a domestic sewage without trade wastes. The subsoil is a free open one of sand and gravel, but it is not underdrained save at a few places. The average results of several determinations are given below.

TOTAL NUMBERS OF BACTERIA PER C. C.

	Gelatine at 20° C.	Agar at 37° C.
Crude sewage	29,000,000	5,315,000
Effluent	2,972,509	321,600

The effluent also contained between 10,000 and 100,000 *b. coli* per C. C., and spores of *b. enteritidis sporogenes* were present in small numbers. About two years after this investigation was made I was commissioned by the Croydon County Borough to examine and report upon the farm in consequence of complaints of aerial and river pollution, and was thus brought into intimate acquaintance with the facts. I found that the land was then slightly overtaxed and that there was some basis for the complaints made. On examining the river, the effects of an insufficiently purified effluent were to be noticed in the growth of small fungus weed and by a slight odor arising from the water. At the same time, there was no substantial pollution, notwithstanding that the river is a small one fed from chalk springs and receives the effluent containing the vast numbers of bacteria named. This case may be considered as an example of broad irrigation where the sewage is spread over the surface and not through the subsoil, and where the efficiency was declining from overwork.

38. The Nottingham farm, however, is one where the land is underdrained and the sewage goes through the subsoil. The total area is 907 acres, of which 651 acres are used for the sewage. The crude sewage contains about 43 per cent. of trade wastes and is applied to the area watered at an average rate of 10,750 gallons per acre per day. The subsoil is river alluvium of sand and gravel covered with a free soil.

TOTAL NUMBERS OF BACTERIA PER C. C.

	Gelatine at 20° C.	Agar at 37° C.
Crude sewage	23,350,000	5,146,666
Effluent	304,770	101,157

B. coli and *b. enteritidis sporogenes* were practically absent in the effluent. This is a highly creditable result and is one of our best examples of land filtration.

39. It is to be noted that the sewage at Nottingham is applied at the average rate of 10,750 gallons per acre per day. Such a rate at Toronto would mean an area of nearly 5,000 acres for the ultimate flow, to secure the like biological results. With the more limited area suggested herein a good effluent will be produced, but it will be much fuller of life than the Nottingham one.

40. As regards the estimate I have arranged with Mr. Rust to work out the details and cost. It will be best to place the tanks on the land instead of at the pumping station, and they should be on the highest parts or above the general level, so as to allow of the insertion of bacterial works hereafter if need be. The sewage of course would have to be pumped and dealt with all the year round.

SCHEME FOR BACTERIAL TREATMENT.

41. Before discussing this proposal in detail, it will be best to describe the developments in the bacterial processes since Mr. Rust's visit in 1901.

42. The use of the septic tank as a preliminary treatment has proved very helpful, but there is a growing tendency to reduce the capacity of the tanks from 24 hours' to 20 or even 18 hours' flow.

43. The contact bed, however, has rather fallen into the second place. This is not due to any lack in producing good effluents, but rather to considerations of expense and difficulties of manipulation. In my view the contact beds hold the first place for steadiness of results all the year round, for in winter the cold does not affect the processes therein to the same extent as in the sprinkling beds which will be referred to later.

44. The expense of the beds, however, has become a serious one. The tanks containing the clinker have to be water-tight, and this makes their construction

a costly matter. It has been found that the idea of three fillings per day as the normal rate of working, has to be modified to one and a half or two fillings per day. Difficulty has also been experienced in thoroughly emptying the beds, which is principally due to the liquid hanging back in the interstices of the clinker, and only draining off in a slow manner. There is a growing opinion that the clinker will have to be taken out and washed from time to time to remove the accumulations of solids. Notwithstanding all these drawbacks, however, the contact bed has proved itself a very useful and reliable instrument in sewage purification.

45. The present trend of thought and practice is in the direction of sprinkling beds. These consist of clinker, on which the sewage is distributed, and through which it percolates to the floor, where it is conducted to the outside. The structures are not made water-tight, and the beds depend for their vitality on the current of air which flows from the false bottom through the clinker to the surface. The means of distribution are various. A common form is the revolving arm after the manner of Hero's engine, or a lawn sprinkler. In that case the arms revolve continuously under the pressure of a few inches of sewage, and in their rotation the liquid is dropped intermittently on the clinker. This for small volumes is a useful and efficacious machine. Another form of distribution is the tumbling bay, which fills and tips automatically. One or two mechanically driven distributors are also in use. There is also the fixed type from which the sewage is sprayed or dripped continuously over the clinker. In the moving distributors a depth of 18 inches is enough to work them automatically, but with the fixed spraying jets the head has to be from 3 to 6 feet. The rival patentees claim that the purification results are best obtained by their particular distributor, but the fact is that the whole problem depends on even distribution, and the machines have no influence on the bacterial operations.

46. I find that with a revolving arm operating on coarse clinker six feet deep, the filtrate can be depended on having 60 per cent. of purification, and with fine clinker, the purification will reach 80 per cent. to 90 per cent. There passes out with the filtrate a number of small black pieces, which are voided by the beds, and these have to be taken out by shallow filters or subsiding tanks. In cold weather the vitality of this type of bed is reduced, probably from the chilling of the interior by the passage of air. Some of the beds have been enclosed in structures and fed with warmed air, and the winter results then have equalled those obtained in summer.

47. There can be no doubt that such beds would have to be enclosed at Toronto to protect the operating and distributing parts from freezing and to maintain the vitality of the bacterial life in winter, and probably the air might have to be warmed. The details of the beds are somewhat complicated, and I have therefore sent to Mr. Rust a complete copy of my Maidstone contact drawings (which embody all I know) for his guidance, if sprinkling beds are adopted.

48. The local government board insist on the same cubical capacity of

clinker for sprinkling beds as for contact beds, but I think this regulation puts the easier duty on the sprinkling beds. The rule is that the clinker capacity must be such that when contact beds are used one filling of the dry weather sewage per day with 33 per cent. interstitial space will be provided for. When the flow is increased by rain there are three fillings for the three volumes dealt with by these beds, but as this extra burden is intermittent, the average of the fillings runs out to about two per day all the year round.

49. In your case the normal flow represents our first three volumes and the average would therefore work out three fillings per day all the year round. Having regard to the very dilute character of the sewage I should expect the contact beds to do their work at this high rate of user, and I have no doubt the sprinkling beds would do it. The calculations therefore for the contact beds or sprinkling beds should be based on a cubic content of clinker equal to the daily volume of the dry weather flow of sewage.

50. As an instance of the results obtained from the septic tank and single contact process, I select the case of Exeter. The filtrate from the contact bed may be described as clear, practically inodorous and non-putrescible, but as regards bacterial life, it is not much better than the crude sewage itself. This is shown by the following determination made by Dr. Sims Woodhead, F.R.S., etc.

NUMBERS OF ÆROBIC ORGANISMS IN EXETER SEWAGE PER C. C.

	Liquefying Organisms.	Non-liquefying Organisms.
Crude sewage	300,000 to 500,000	3 to 5 millions.
Septicised sewage	150,000 to 200,000	3 to 5 millions.
Filtrate—		
After running 3 minutes ..	30,000	3 to 5 millions.
At end of filtration.. ..	100,000	900,000

NUMBER OF ANAEROBIC ORGANISMS IN EXETER SEWAGE PER C. C.

	Liquefying Organisms.	Non-liquefying Organisms.
Crude sewage	300,000	600,000 to 700,000
Septicised sewage	200,000 to 300,000	300,000 to 400,000
Filtrate—		
After running 3 minutes	70,000	500,000
At end of filtration ..	100,000	300,000

There are two deductions to be derived from these figures for our present purpose. The first is that the septicised sewage as delivered from the tanks is teeming with microbal life, and the other that the contact filtrate swarms with life when the discharge is running freely, but improves at the last drainings of the bed.

51. I have practically no direct criticism to make on the engineering

features of the tank and contact scheme as proposed by Mr. Rust, but I suggest that it would be well to determine whether it is economical to provide an intercepting sewer to discharge the sewage from the higher lands by gravitation into the works rather than to pump it all. The top water level in the tanks need not be higher than 54 feet above datum, and I think a large volume of sewage could be commanded at that level. In my opinion, contact beds will be more suitable than sprinkling beds for reasons of temperature. The effluent is to be discharged into the lake about one mile from the inlet at Ashbridge's Bay and about 4½ miles to the east of the water intake, where it will cause no nuisance or visible pollution. There ought to be no aerial pollution at the works from the process save perhaps an occasional smell when the sludge is being removed from the tanks. Mr. Rust will go into this proposal again and send the figures to me, with those for the other two schemes.

Costs of the Three Sewage Disposal Schemes.

52. Although I have not worked out the estimates, yet I venture the opinion that both in capital cost and operating expenses the scheme for discharging the sewage into the lake will be the most economical of the three, that the filtration scheme will come next, and the bacterial scheme will prove the most costly. The maintenance expenses for up-keep of the plant and works will also follow the same order.

The Schemes as Affecting the Water Supply.

53. I now come to the crux of this question, and that is, the effect the schemes may have upon the water supply of the City. Before addressing myself to that issue I desire to make a preliminary observation as to the position of expert advice on questions involving considerations of taste and sentiment. In my view the function of an expert is to lay before his clients in as clear language as he can command the facts on which his special knowledge and training presumably fit him to draw the proper deductions, and to tender his advice thereon. But it is equally the privilege and the duty of the clients, after assimilating the issues as the expert sees them, to elect which of the conclusions are to be acted on, if any. If for instance the reason is convinced by a particular report, one's taste may with propriety prevent one acting on it if the conclusion is repugnant.

54. While reading and digesting the reports presented to you on the sewage disposal at Toronto, an impression has formed in my mind that they all assume an immunity from risk to the water supply, if the sewage is dealt with bacterially or by land treatment. It is, however, by no means self-evident that the discharge of septicised sewage into the lake 4½ miles east of the intake during the four cold months is safe when regard is had to the figures as to the organisms in that liquid set out in paragraph 50, or that the effluent from the filtration area would be absolutely free from menace to the water supply, even if the excellent results at Nottingham, set out in paragraph 38, are secured, or that first contact filtrate would be harmless when attention is paid to the figures for the final effluent given in paragraph

50. I suggest, on the contrary, that all the schemes must be enquired into as to whether they offer a more or less remote menace to the water supply.

55. In my judgment the discharge of crude screened sewage nine miles east of the intake contains so remote a risk to the water supply as to make the scheme a reasonable and proper one. It is to be remembered that the movement of the water in the lake is slow, that the suspended matters soon settle, that the bacterial life is rapidly reduced by exposure to light and air and by the bactericidal agencies, and that the microbes undergo a loss of vitality in water. I cannot bring my mind to the conclusion that either suspended matters or bacteria from the sewage will reach the zone feeding the intake.

56. The effect of the effluent from the land filtration scheme is very difficult to gauge. It may all go into the Don and so into the harbour, or into streams leading to Ashbridge's Bay. This scheme, however, is one for dealing with the dry weather sewage only, and it does not provide in any way for the increased flow from the rainfall, which would continue to be discharged as now. In my opinion there is less risk from the effluent considered by itself than in the crude sewage scheme, but when the smaller volume dealt with is considered, and the consequent greater pollution of the water by more frequent overflow is brought into the account, I hesitate to put it as the safer of the two. At the same time I can describe it as a reasonable and proper scheme.

57. As regards the tank and contact scheme, I feel bound to say that while the risk to the water is remote, yet it is, in my view, more real than in the other schemes. It, too, deals only with the dry weather flow, and consequently there is more pollution from overflow than in the first proposition. Seeing that this scheme is the most costly, it may be regarded as the least favourable of the three, although it is a good proposal in itself.

58. The choice seems to lie between the crude sewage discharge and the land filtration scheme, and having as an expert discharged my task, in advising that the cost of the first is less than that of the second, that the remote risks to the water supply are on a parity, and in indicating my preference for the former scheme, I leave the selection to the Council and the citizens without further comment.

59. I cannot, however, close this report with comfort, without a digression to the water question. I know that voluntary advice generally meets with short shrift, yet I must express anxiety at the absence of filtration. With us filtration is so much used, even for our upland schemes, that its omission in the circumstances at Toronto has the effect of a shock on one's mind. The huge user of water undoubtedly operates as a hindrance to the adoption of filtration, by reason of the enhanced cost of the very large area of sand for filtering 100 gallons per head per day, but notwithstanding that exaggerated burden I commend filtration as a prudent safeguard. Should the undue cost

of the filters lead to the prevention of the waste now going on, so as to bring the financial burden within the usual limits, that would be a double advantage gained by filtration.

60. It may also be allowed me to express my sense of the courtesy shown by Mr. Rust in meeting my convenience as to interviews and visits, and of his readiness to give me the information I required.

I have the honour to be, gentlemen,

Your obedient servant,

GEO. R. STRACHAN.