REPORT OF VICE-CHAIRMAN BOARD OF CONTROL (DR. W. S. HARRISON), THE MEDICAL HEALTH OFFICER AND DEPUTY CITY ENGINEER RE SEWAGE DISPOSAL AND WATER FILTRATION.

Toronto, May 18th, 1908.

To His Worship the Mayor and Board of Control:

GENTLEMEN,—In compliance with your instructions, we have visited various filtration works as ordered, the first plant which we carefully inspected being that of the City of Albany, New York, which was inspected by us on Thursday, May 7th, in the early morning. At this point we were fortunate in receiving admission to the plant with the workmen who were starting work for the day, and had the advantage during our visit of inspection of the assistance of Mr. Shields, the foreman in charge.

Albany, New York, was originally supplied by water taken from small streams lying west and northwest of the City. At times, with increasing consumption, the supply very often became unsatisfactory and inadequate, and an additional supply from the Hudson River was introduced. The water was obtained from the river through a tunnel along the bottom of and beneath the Erie Canal. A pumping station was erected to pump to reservoirs, which served as a distributing point for one of the gravity supplies. The intake was first used in 1873, and drew the water from the river opposite the heart of the City. As the City grew, some of the City sewers entered the river above the intake, although most of the sewage was delivered below. And thus, as time went on, the sewage of the City was present in a very considerable amount in its own water supply. In consequence of this and under these conditions, the typhoid death rate in Albany became excessive, and Professor Mason of Troy made a report in the year 1885 to the Water Board in which he stated, in unmistakable terms, that the water as then used was a source of disease and should be abandoned at the earliest practicable date.

Studies were then undertaken towards the purification of the water supply, the matter being studied by the Board of Water Commissioners and by its then Superintendent, Mr. George I. Bailey, member of the American Society of Civil Engineers, and Mr. Allen Hazen, of New York, who was engaged in January, 1897, to examine the studies which had been made and to report upon the projects. They reported that the Hudson River at the point of intake had a drainage area of about 8,240 square miles; of this 4,570 square miles was tributary to the Hudson above Troy; 3,542 square miles was tributary to the Mohawk River; and 168 was tributary to the Hudson below the Mohawk.

The main source of contamination then and up to the present has been the City of Troy, the approximate distance of which is four miles above the intake, with an estimated population in 1900 of 65,470. As a result of prolonged investigations, a filtration plant was decided upon, supplied with centrifugal pumps, reservoirs and distributing mains, in addition to a sedimentation basin.

We might here point out that this water is of marked turbidity, owing to contributions of clay and sand from the banks as well as the sewage con-

tributions of Troy, Little Falls, and adjacent municipalities, in consequence of which a sedimentation basin became an absolute necessity. This sedimentation basin, briefly, has an area of five acres, with a depth of nine feet and a capacity of 14,600,000 gallons, concrete lined, with its banks puddled and protected.

The filter plant is designed to filter 15,000,000 gallons per day. This does not supply the entire City of Albany, which at present is served with an additional gravity supply of 6,000,000 gallons; one section of the City of Albany being served by filtered water and one by unfiltered water. The consequence is that, at this time, we find the section supplied with unfiltered water is making strenuous efforts to have a filtered supply, and additions to the plant have thus become necessary. The typhoid rate before water filtration was 88 per 100,000, and at the present time it is 22 per 100,000, notwithstanding the fact of the partial distribution of unfiltered water besides outside contributions of typhoidal causes which are operative in every city—such as vacation typhoid, typhoid from milk supplies, typhoid from fish and oysters, typhoid from unwashed garden truck, etc.

The filtering medium used is sand and meshed gravel. The filters are of masonry, brick, and are covered to protect them against the winters, which, we were informed, were at times quite severe in Albany. The piers, cross-walls and linings of the outside walls, entrances, etc., are of vitrified brick; the depth of excavation for the filters was four feet to a clay bottom, the floors consisting of ingrained, groined concrete arches, properly arranged to distribute the weight of the walls, the bottoms being put in in alternate sections running diagonally with the pier outlines, the measures between the centres of the piers being 13 feet. The material for the under-drains for removing the filtered water are a vitrified pipe surrounded by concrete and entirely below the floors of the filters, which drains are put in before the construction of the filter was commenced, and the concrete surrounding them was brought to the plane of the bottom of the foundations, so that when the floors were built, they went over them continuously without breaking in any way the line of the inverted arches. The inverted arches below nearly correspond to the arches above, so that the entire contour of the filter, when empty of its material, is an ovoid, each end of the filter being a counterpart double ellipse.

The gravels surrounding the under-drains are of three grades. This material was obtained from the river bed by dredging, this dredging materially adding to the cost of the construction at that time, the gravel being used after it was separated, cleansed and screened. The sand used in connection with the filter was obtained from the river at various places by dredging, and was brought in scows to a point a little north of the filtering plant, the cost of the cartage of the sand and the handling of it being an important consideration in the primary cost of the filter construction. Coarse sand of proper character, carefully selected, being an essential to the proper operation of the plant, and when such is available and close at hand, necessarily reduces materially the cost, whilst, if it has to be conveyed, as was the case in connection with the Washington filter, from a distance of from ten to

twenty miles, it can easily be seen the cost will be largely increased. The requirements of a sand for such work is that it shall be clean, not too fine, containing sharp and rounded grains, and entirely free from clay.

After the filter is carefully prepared water is admitted to each filter through a 20-inch pipe from a piping system connected with the sedimentation basin. Before being filled, the greatest care is required to allow of proper saturation of the filter and a rise of water of about two inches or more before the valve of the distributing main is opened to allow further flooding; the idea of this being to secure a uniform pressure throughout the filter bed, and to avoid a stream being directed from the main upon any one point upon the bed, which would tend to destroy or to disturb it. Each filter bed is also provided with an overflow, so arranged that it can be closed, and thus the water level is prevented from exceeding a fixed limit. These filters are then allowed to run and do their work. They are carefully watched and their work scientifically gauged, and when the filtering activity becomes reduced below what is considered proper, arrangements are made for the cleaning of the filters. The number of times such filters are required to be cleaned will vary according to the character of the water which they are called upon to filter. Thus, we found upon examining the statistics of the Albany works, this period would run out in nineteen days and sometimes ninety, the average being about twenty-nine or thirty days.

Most of the suspended matters in the filtered water are held by a top layer of sand, and this layer requires to be removed from time to time so as to prevent the filter being clogged. The dirty sand removed is washed and eventually replaced again in the filters. Ejector sand washing machines are placed at convenient places between the filters and handle this sand in them; the dirty sand is mixed with the water and thrown up by the ejector into which it runs through a chute into a receptacle, from which it is again lifted by another ejector.

It might be here explained, and this will apply to all filter beds of this material, that the cleansing is not a matter of reconstruction, but is comparatively simple, from one to two inches of sand being removed at each cleansing, washed, and returned to the bed. This bed is then gone over and any further sand which is found not to be of sufficient purity is removed by workmen with ordinary shovels.

At Albany, consequent upon the marked difference in the typhoid rate between the section supplied with filtered water and that supplied with unfiltered water, further additions to the filter plant were demanded, and whilst it was originally intended that the filter plant at Albany should filter about 3,000,000 gallons of water daily per acre, it was ascertained that this capacity could safely be increased if some process of preliminary rough filtration was employed.

In consequence, they are at present constructing a preliminary filter plant made of reinforced concrete, capable of filtering upwards of 20,000,000

gallons per day at a very high rate. Thus it is proposed to operate the plant by a process of rough preliminary filtration, and a high rate of subsequent filtration before the finished product is delivered.

Tests have been made at Albany during the year 1906 as to the value of preliminary filtration. These works have shown that after twelve hours sedimentation of raw water, it has been found feasible to filter the same through a preliminary filter at a rate of 85,000,000 gallons per acre per twenty-four hours, without the use of any chemical or coagulant, and then filter the effluent through a slow sand filter at the rate of 6,000,000 gallons per acre per day. This means that by first passing the water through preliminary filtration, which can be washed by reversing the current of the water, the capacity of the plant can be doubled.

Emphasizing the fact that one of the central thoughts, more particularly with reference to the cost of construction, is the high rate of filtration obtainable with perfect safety, and we have found not only in Albany but everywhere, that the increased rate of filtration is contemplated, so much so that Mr. Hazen remarked to us upon this question that in his judgment, with an ordinary water, he would think 5,000,000 gallons a reasonable rate, and in an ordinary case absolutely safe.

Washington, D.C. The sand filtration plant for the purification of the water supply of Washington, D.C., has been recently put into service, and at present 70,000,000 gallons of water per day are being treated. For the last fifty years the water supply of Washington has been obtained from the Potomac River at Great Falls, about fourteen miles above the City; the water being retained in three reservoirs, these reservoirs being known as the Dalecarlia Reservoir, the Georgetown Reservoir and the Washington Reservoir, their total capacity being estimated at about 150,000,000 gallons.

The plans for the water filtration plant at Washington were undertaken by Colonel Miller, assisted by Lieutenant George H. Hoffman and Mr. Hardy, the latter being at present in charge of the plant, which plant was constructed after consultation, revision and association with Mr. Allen Hazen. These plans and specifications were practically completed in December, 1902, and adopted in January, 1903. The filters are adjacent to the Washington City Reservoir, located upon an elevation, water being elevated from the reservoirs to the filters, the lift ranging about 20 feet when the reservoir is full to about 30 or more when the water is drawn off. These filters present a most enviable and magnificent appearance. They are constructed of concrete, and the general design follows closely upon the lines of the Albany filters, with this difference, that the plant is many times larger, and designed with that regard for ornamentation and cleanliness which characterizes all the city buildings and undertakings of Washington. So that, as you enter upon the works, with their concrete sand bins, with their beautiful filters covered with grass and carefully kept, traversed by roads for the delivery of sand, with their ornamented buildings, pumping station, laboratories, gauging room, etc., one is forcibly impressed; and this has been devoted to

and constructed for the purification of a water supply which, in many respects, at the start, is closely similar to the present supply of the City of Toronto.

As already stated, the design and construction of the work is, to a large extent, a reduplication upon a large scale of the Albany works. The masonry structures are of concrete; the floors are all inverted groined arches carrying piers; the walls are of concrete built in sections not exceeding 30 feet long, the joints being tongued and grooved, and the details, with minor differences, practically the same as given in connection with the Albany plant, the under-drains, however, being operated upon a much cheaper plan and apparently with equal satisfaction. In this connection we might, however, point out that the sand used in the Washington filter was furnished from a bank at Laurel, Md., on the line of the B. & O. Railroad half way to Baltimore, the bank consisting of layers of clay and sand. This necessitated the conveyance of the sand a distance of twenty miles, increasing largely the primary cost of construction.

The most important point which appeared to us in connection with the Washington plant was the construction and operation of the sand ejectors. The water for bringing the sand into use for suspension is introduced generally at the bottom of the ejectors, and slowly rises as the sand is shoveled into it. The mixture of water and sand thus produced containing more sand in proportion to the water, the ejectors therefore throw more sand and less water. The discharge ends of the ejectors, beyond the throats, are made with a very flat batter; the ejectors are operated entirely by water, which is not the case in Albany, and which is a great labor-saving device. So far as we could learn, this filtration plant was designed for the purpose of being operated at the lowest rate of water filtration, viz., 3,000,000 gallons per acre per day, and it was stated by Mr. Hardy that in his opinion it could be operated at double this capacity. It was constructed in its entirety at a cost of $3,356,300, divided as follows:

Pumping Station, including intake, Ventroni Metres electric light generating apparatus	$ 183,600
Twenty-nine filters, with excavations, grading, concrete work, piping, electrical hoist, shelter house, laboratory and office, electric light wiring, sand washing apparatus, sand bins, etc.	2,197,000
Filtered water reservoir, including excavation, concrete work, gate house, electrical apparatus, etc., complete	150,000
Lower gate house and pipe line	24,300
Land	619,000
Engineering and clerical work	181,500
Total cost of work	$3,356,300

The 29 filters are divided off in acre beds and are to-day filtering 70,000,000 gallons daily. Pleasing as was the impression which your deputation received upon entering the water plant, still more striking were the results

which sustained the enterprise, after the most careful, exhaustive, and crucial scientific tests applied in the well-equipped laboratory. We found that careful and separate records were kept of the various waters in the reservoir before and after filtration, both as to turbidity and biological conditions. The turbidity of a water relates largely and mainly to gross impurities, such as an admixture of clay, suspended matter, etc., so annoying and so uncomfortable to the water consumer. Thus upon stormy days and under storm conditions what annoys an ordinary citizen as he tries water from his house-tap is that the water is exceedingly turbid, murky and dirty. This at Washington is totalized under the term turbidity and set to the standard adopted by the United States Geological Department, and is kept altogether apart, so far as records are concerned, from the bacteria in the water supply.

Based upon the above standard, the turbidity at Washington ran from five to three thousand; after filtration it averaged one to zero, the result being practically the entire removal of turbidity and the reduction of albuminoid ammonia from 2.2 to .001 parts per million. Equally striking were the results in connection with the removal of bacilli and bacteria. Thus in one of the reservoirs, before filtration, daily tests of coli communi throughout the month of April, tested by triplicated amounts of 10 c. c. s., 1 c. c. and 1-10th c. c., showed the presence of coli communi before filtration in 7 per cent. of the days, and after filtration none. Nevertheless, the bacteriologist in charge of the filtration laboratory freely admitted that such magnificent returns would not invariably occur, and at certain times, when the water was subjected to certain seasonable influences, and owing to conditions operating upon the unfiltered water at the source of supply, an occasional appearance of coli communi in the finished product might occur, but so seldom that the results were in importance practically equal to the above.

We cannot better sustain the above statement than by giving the investigations of Theodore Horton, Esq., Member of the American Society of Civil Engineers, in a paper discussing the water filtration of Washington, as follows:

———	Bacteria per cubic centimeter. Average of months Jan. to Oct., 1906.	Percentage removal due to each separate reservoir, etc.	Percentage removal compared with raw Potomac River water.
Great Falls	4,900		
Outlet to Dalecarlia Reservoir	1,480	70.0	70
Outlet to Georgetown Reservoir	700	52	86
Outlet to Washington City Reservoir (as it passes upon the filters)	300	57	93
Effluent from filters	18	94	99.6

We also desire to submit a summary of the results of tests for bacillis coli extending from February 1st, 1906, to October 31st, as furnished by Mr. Francis F. Longley, as follows:

		Total Samples Examined.	Number positive.	Percentage positive.
Great Falls or Dalecarlia Inlet. ..	10 c.c.	164	71	43
	1 c.c.	164	45	27
	1-10 c.c.	164	27	17
Dalecarlia Outlet...	10 c.c.	211	97	46
	1 c.c.	211	55	26
	1-10 c.c.	211	20	9
Georgetown Reservoir	10 c.c.	177	58	33
	1 c c.	177	34	19
	1-10 c.c.	177	9	5
Washington City Reservoir (applied water)	10 c.c.	242	66	27
	1 c.c.	242	26	11
	1-10 c.c.	242	3	1
	100 c.c.	148	26	18
Filtered water Reservoir . .	10 c.c.	244	11	4
	1 c.c.	244	5	2
	1-10 c.c.	93	0	0
Tap water from various parts of City	10 c.c.	171	8	5
	1 c.c.	171	3	2
	1-10 c.c.	59	0	0

New York City. The most important work done by us in New York City was our interview and discussion of the whole subject with Mr. Allen Hazen and his office staff. We might state that Mr. Hazen is not only the distinguished author of works upon water filtration, but he is, in our judgment, the most distinguished Civil Engineer in connection with water purification works upon this continent, having been retained by all the leading cities in the United States in connection with similar work, and has only recently returned from a three months' trip to Australia, where he was engaged in constructing and planning similar works in that colony. He has been the engineer of the water systems of Washington, Albany and Springfield, and has been the consultant in connection with the filtration works of Philadelphia, and in connection with the Water Commission appointed to consider the advisability of establishing and constructing a water filtration plant in Jerome Park for the City of New York, wherein it is proposed to filter upwards of 500,000,000 gallons of water per day.

In discussing the question of water filtration, and going over numerous plans at present in course of preparation in the office of Messrs. Hazen & Whipple, the discussion with Mr. Hazen centred principally upon the following points:

First.—In view of the character of the City of Toronto's water, as represented in the reports and details submitted, the question was asked, "If in his opinion filtration was a necessity for the City of Toronto?" We considered Mr. Hazen's answer conclusive. We give it verbatim: "If I lived in Toronto I should want that water filtered."

Second.—The point was taken up as to the possibility of Lake Ontario water being purified by a high rate of filtration, and how high, in Mr. Hazen's opinion, would be efficient? His statement to us was that, under the circumstances, he thought he could assume a 5,000,000-gallon rate. Upon being asked what percentage of bacteria would be removed by filtration, his answer was from ninety-eight to ninety-nine per cent., and even more.

The question of sewage disposal for the City was also discussed with Mr. Hazen at length, and he was asked to give an opinion as to the safety of discharging the City's sewage (which is now being discharged into the Bay) at a point four and a half miles east by trunk sewer, and there to be treated by septic tank treatment with effluent drains discharging into the water of Lake Ontario. He stated that if the proposal was to discharge such sewage without water filtration, having regard only to the building of a trunk sewer with outlet as indicated with septic tank treatment, he was not prepared, from present information, to say that it would constitute an improvement. Coupled, however, with water filtration, he would consider the water supply would be safeguarded in the event of such point of discharge being resolved upon.

In discussing the question as to the relative cheapness and safety of filtering the sewage by sand filtration at point of delivery, or by treating the sewage at point of delivery by septic tank treatment coupled with water filtration, he stated most positively that it would be far cheaper and better to filter the water and adopt the septic tank treatment of sewage.

After a careful survey and thorough discussion of the whole situation, studying the records both as to typhoid and bacterial counts as to water, Mr. Hazen, without wishing to be regarded as committing himself as to cost upon such representation, frankly admitted that he would think that the filter plant could be easily built for a million dollars or much less. More particularly was this view forcibly presented to your Committee, as he was already constructing, in Springfield, Mass., a filter plant to serve a population of 80,000 people, to deliver 15,000,000 gallons per day, at a cost of $201,000, apart from the cost of constructing the main and dam, and which above included the formation of temporary reservoirs or artificial lakes.

Philadelphia. The filtration plant of Philadelphia supplies only a portion of the city, consequently extensions have been made from time to time

of the filtration plants of the city, and preliminary filters have been and are being constructed, with the object of securing more rapid filtration of the water through the sand filter beds. At present there are three separate filtration plants: "The Roxborough," filtering about twenty million gallons per day, on the Schuylkill River; "The Belmont Filter," filtering about thirty million gallons per day for West Philadelphia, from the Schuylkill River; and the largest, and the main one, the "Torresdale," located on a site on the Delaware River.

At the Belmont filtering plant they are subjecting the water to preliminary filtration through coke breeze before throwing it upon the sand filter. The Belmont filter includes 13½ acres. Two days' sedimentation is permitted in the reservoir, when it is submitted to the preliminary filter at a rate of about 50,000,000 gallons per acre, and passed on to the sand filter beds, which beds are 7-10 of an acre in size, made of sand and gravel, sixteen inches of gravel, and from twenty inches to forty-two inches of sand, under-drained by perforated tile under-drains surrounded by the gravel, graded in five grades.

The "Torresdale" filter, filtering Delaware water, consists of 65 beds, three-quarters of an acre each, filtering upwards of 190,000,000 gallons per day. The water is stored in a 50,000,000-gallon reservoir before being put upon the beds, the construction of which is practically the same as the other filter plant mentioned, the under-drains being however somewhat different, consisting of perforated eight-inch tile, and the average run of the filter bed, without cleansing, is about thirty-five days. The sand used in the beds was drawn from New Jersey.

The water filters of the City of Philadelphia have given most satisfactory results, and the introduction of filtered water into the various sections of the city has resulted in a marked decrease of the typhoid fever rates in sections heretofore affected, and Philadelphia furnishes a very striking instance of the benefits of water filtration, and proves conclusively that when the entire city receives the benefit of filtered water, typhoid will be practically obliterated so far as it is caused by water.

No better illustration can be furnished of the beneficial results of water filtration than to submit the following table taken from the official report of the Bureau of Water Filtration for the year ending December 31st, 1906, issued by the City of Philadelphia, as follows:

	Per cent.
Average reductions, turbidity	99.52
Average reductions, bacteria	99.81
Maximum reductions, turbidity	100.00
Maximum reductions, bacteria	99.98
Minimum reductions, turbidity	97.06
Minimum reductions, bacteria	98.75

These statistics are also confirmed in the annual report of Dr. Abbott, the Chief of the Bureau of Health of the City of Philadelphia for the year 1906, which contains a table showing the comparison of typhoid fever reductions in the filtered water districts as compared to that of the entire city:

Cases per 100,000 population of the entire city	13.3
Cases per 100,000 population in Roxborough filtered water district.	5.0
Cases per 100,000 population filtered water district, West Philadelphia.	3.9
Reduction in Roxborough as compared to that of the entire city.....	62.4
Reduction in West Philadelphia as compared to that of the entire city	70.7

Pittsburg. The City of Pittsburg takes its supply from the Alleghany River, some distance up the river from the city, the water of which is polluted with sewage from towns higher up, and at times shows very considerable turbidity. With a desire to improve the condition of the water, the city has erected upon the right bank of the river filter beds consisting of forty-six one-acre beds, similar, so far as construction of the beds is concerned, to those of the cities above referred to in this report.

The water is lifted from the Alleghany River to a height of about sixty feet, and there discharged into three sedimentation basins, the middle one containing 20,000,000 gallons, and into which the water from the pumping station is discharged; from there it passes into two sedimentation basins, one on each side, containing 55,000,000 gallons. After traversing the entire length of the sedimentation basins, in which it is given forty-eight hours' sedimentation, resulting in a reduction of bacteria to the amount of 50 per cent.; from this basin it passes into the filters, and after passing the filters into the clear water basin containing 50,000,000 gallons; from there it is piped across the Alleghany River to the Brilliant Pumping Station, from which station the City of Pittsburg is supplied. The consumption for the city is 75,000,000 gallons, but at present only 22 acres of filters are in operation, filtering about 50,000,000 gallons of the water used. Owing to the taking in of Alleghany City, they are about constructing ten more filters of an acre each.

The construction of the filters is very similar to those above referred to; the arrangement for operation is novel and differs very materially from that of Albany, Washington or Philadelphia, no courts being provided for washing operations or buildings erected for the manipulation and control of the filters, instead of which galleries are constructed underground practically of the same construction as the arches and work for the filters, in which is contained the sand washing apparatus and all the pipes and plant necessary for the operation of the work, all of which are in clear view instead of being buried as in the others. The method also of cleansing and replacing the sand is entirely novel and original, a special machine having been designed and constructed for cleaning the filters, which can be made to remove any depth of sand necessary, and this sand is then conveyed through pipes by hydraulic pressure to the sand washing apparatus, where it is washed and is then ejected through other pipes and conveyed to the filter requiring renewal,

where it is deposited in the most perfect manner by another machine. These machines are operated from rails suspended from the sides of the piers of the filters. They have some eighteen scraping machines and sixteen sand laying machines in operation, the work being done much more satisfactorily by means of these machines than by hand.

All of the filters are, of course, lighted by electricity, as in the other plants, and the effluent fully as satisfactory. The removal of bacteria amounts to 99 per cent.

In presenting this report we desire to emphasize the fact that cities of the United States of any size, who are drawing their water from a source which is liable to sewage pollution, are adopting sand filtration.

Secondly, that this process of purifying water supplies and removing sewage contamination therefrom has been most satisfactory, and the cities which have operated filters have demonstrated the fact that water filtration can be safely conducted at a much more rapid rate than was at first considered safe, more particularly when preliminary filtration is provided for, which would invariably be done where an entirely new plant was being built.

We also desire to point out that in the City of Toronto we begin with a water which, in its character, is better than that of many cities after their preliminary filtration and sedimentation, and in the face of the interview and the encouraging statements of Mr. Allen Hazen, we consider $750,000 will amply provide for filtering 40,000,000 gallons of Lake Ontario water daily, supplying the City of Toronto's present needs, and placing forever beyond question the purity of the City's drinking water; and if the By-law submitted to the people be carried, we would suggest the wisdom of placing in the hands of Messrs. Hazen & Whipple the preparations of the plans, specifications, and details necessary for the construction of the plant.

All of which is respectfully submitted.

CHARLES SHEARD, M.D.,
Health Officer.

C. L. FELLOWES,
Deputy City Engineer.

W. S. HARRISON, M.D.,
Representative Board of Control.