TREATMENT OF PUBLIC WATER SUPPLIES FROM LAKE MICHIGAN[1]

By Samuel A. Greeley[2]

Extent. Probably no bodies of water are used more extensively for water supply purposes than the Great Lakes. Of these, Lake Michigan ranks well to the front in the actual population which it supplies with water. From the large population centering about Chicago, amounting to about 3,000,000 people, down to the smaller villages of a few hundred people, all sizes and varieties of public and private water supplies are taken from the lake. A rough estimate of the total population supplied by water from Lake Michigan is 4,000,000 people. It is therefore of importance and interest to consider briefly the treatment of these public water supplies.

Source. The supply is drawn from the lake at varying depths of water and distances from shore. In the smaller intakes this is usually from a point near the bottom of the lake. In the larger intakes the water may be taken from mid-depth to the surface. The intakes farthest from shore are those at Chicago, the farthest out being 4 miles. The ports of the Chicago intakes are at a depth of about 33 feet. The intake at Milwaukee extends about 8000 feet from the shore to a crib in water 60 feet deep. The shallower intakes are those near the southern end of the lake. At East Chicago, Ind., the depth of water at the intake is only 20 feet. At Gary, Ind., an intake with a length of 17,000 feet reaches water 44 feet deep. Thus a considerable variation in the character of the water supply results from the location of the intakes.

Pollution. The near shore waters of Lake Michigan in the vicinity of the smaller cities are polluted by the sewage from over 1,000,000 people as well as from a large number of industries. Shipping also adds pollution. Only the sewage of Chicago and some of the adjacent towns within the Sanitary District of Chicago is now diverted from Lake Michigan. The balance of the sewage is discharged

[1] Read before the Illinois Section at Urbana on March 14, 1917.

[2] Hydraulic and Sanitary Engineer, 64 West Randolph Street, Chicago.

directly into the lake, for the most part without treatment. Where sewage treatment plants have been built, operation results chiefly in a reduction of the suspended matter and the oxygen requirement of the sewage rather than in bacterial purification.

This pollution, entering near the shore, is mixed with the lake water and carried considerable distances by natural agencies, principally the wind, which induces drifts in the lake. It is estimated by Judson and Evans that sewage pollution may be carried in this way as far as 20 miles. Where the volume of sewage is large, active pollution has been traced at Milwaukee a distance of about 5 miles from the main sewer outlet. Floating ice, wind driven, may also carry sewage pollution from points of greater intensity to points where the pollution is supposed to be slight. A moderate typhoid outbreak at Marquette, Mich., as well as one at Erie, Pa., were attributed by some to the movement of ice, carrying sewage pollution from the sewer outlet to the water supply intake. Actual chemical and bacterial analyses of the lake water by the Lake Michigan Water Commission and the Indiana State Board of Health have shown that sewage pollution at some points between Waukegan, Ill., and Gary, Ind., extends at times 5 miles from shore.

In addition to the sewage from the municipal sewer outlets and the industrial plants, a substantial amount of pollution comes from (1) private houses and clubs so located that they cannot enter a general sewer system, (2) from overflows on combined sewer systems, and (3) from surface run-off during times of storms. Moreover some pollution comes from ships and pleasure boats. This may be particularly dangerous where the course of vessels passes directly by the intakes, as at the entrance to the Chicago River.

The pollution varies in strength from season to season and even from day to day. Under certain directions of the wind, the pollution is greater at some points than at others, while a shift in the wind may entirely reverse the condition. During periods of calm some sedimentation occurs, particularly immediately near shore. During periods of storm, the sludge is stirred up from the lake bottom, increasing the pollution. The effect of ice in winter also bears important relation to the extent and strength of the pollution at particular points.

Intakes. The relation of intakes to the purity of the water supplies from Lake Michigan is a factor which has long been recognized. This has been the case in Chicago where intakes have been

extended from year to year as the population has increased. It is undoubtedly true that for most of the time, intakes farther from shore tap a less polluted water, and particularly a water which varies less in quality from day to day. The relative importance of new or extended intakes as compared with water filtration and other methods of treatment has been frequently discussed. The tendency at present leans toward the water filtration plant. In this connection two points should be emphasized. In the first place in actual operation it is found that anchor ice frequently clogs the outer end of the intakes, thus forcing the use of emergency near-shore intakes. This has occurred at East Chicago, Ind., North Chicago, Evanston and Waukegan, Ill., and elsewhere. When this is done, an additional load of pollution results which may seriously disturb the operation of a chlorinating plant if used alone and thus remove the safeguard relied upon by the consumers.

In the second place, breaks and leaks in the intake may occur near shore without the knowledge of the water works superintendent. Thus a sudden and unexpected pollution results which is more likely to dangerously upset the routine treatment of the water. This occurred at Evanston, Ill., in 1912, causing an outbreak of typhoid. It has also occurred at Gladstone, Mich. Thus the value of intakes, particularly on the smaller installations, must be viewed with certain definite qualifications.

Need for treatment. The need for treating public water supplies taken from Lake Michigan is obvious and is recognized at practically all places. The most popular treatment is with calcium hypochlorite or liquid chlorine. This of course is a cheap method which can be quickly installed, and is of great value as an emergency project. A more certain method of treatment is by rapid filtration, a method which is now being used extensively. Rapid sand filter plants are in successful operation at Escanaba, Mich., South Milwaukee, Wis., Evanston, Ill., and probably at one or two other towns. Filters of the closed pressure type are used at Lake Forest, Kennilworth and Rogers Park, Ill. A slow sand filter has been in use at the U. S. Naval Training Station but is now being changed to a rapid filter.

By far the largest amount of water, however, is treated with hypochlorite of lime or liquid chlorine alone. The cities of Chicago, Milwaukee, Waukegan, Whiting, Hammond, East Chicago, Michigan City, etc., treat all of their public water supplies from Lake Michigan in this way.

Chlorine treatment. Treatment of water supplies from Lake Michigan with hypochlorite of lime or liquid chlorine has the distinct advantages of low first cost, low cost of operation and the rapidity of installation. These advantages are all characteristics of an emergency treatment. There are a number of disadvantages which it is worth while to note. As already stated, the quality of Lake Michigan water is subject to frequent and rapid variations as regards the content of suspended organic matter and the strength of bacterial pollution. Thus it is necessary at frequent intervals to adjust the amount of chlorine added to the water.

TABLE 1

Pounds of calcium hypochlorite used per million gallons at Waukegan, Ill.

DATE, 1916	12 TO 4 A. M.	4 TO. 7 A. M.	7 TO 12 NOON	12 TO 3 P. M.	3 TO 8 P. M.	8 TO 12 NIGHT
February 6.....	9.45	10.96	22.37	9.65	14.60	16.71
February 3.....	7.89	7.55	7.07	7.50	8.07	6.30
February 7.....	24.23	11.66	22.20	20.11	10.08	10.71
February 8.....	7.90	5.55	13.49	9.69	13.20	13.08
February 9.....	7.88	7.58	13.67	17.58	9.16	5.60
February 28.....	15.07	13.04	16.66	15.03	15.19	12.85
March 18.....	11.77	10.00	10.11	9.10	9.84	9.27
March 20.....	8.24	7.57	7.44	7.54	7.90	7.65
March 22.....	8.29	8.35	8.13	8.20	9.59	8.20
March 23.....	6.48	8.74	8.35	7.74	7.62	7.27

Table 1 indicates variations in the amount of calcium hypochlorite added to the water supply at Waukegan. The water is tested at intervals of approximately four hours by the starch iodine test under the supervision of W. J. Allen, superintendent of the water works. It appears from this table, that between the morning of February 6, 1916, and the afternoon of the same day, the required amount of hypochlorite changed from 22.37 to 9.55 pounds per million gallons. The required amount then increased in the late afternoon to 14.6 pounds per million gallons. It is apparent that if the amount of chlorine added to the water were not adjusted to the need, an under-dose or over-dose would result. The under-dose would probably not thoroughly disinfect the water and an overdose would produce objectionable tastes and odors.

To obviate the undesirable effects of an over-dose, a few water works superintendents have resorted to the use of sodium thio-

sulphate, which neutralizes the excess amount of chlorine. This has been tried at Milwaukee, Wis., and at East Chicago, Ind. The danger of this method is that the thiosulphate may be applied at too short a time interval after the application of the chlorine, thus neutralizing the chlorine before it has accomplished the disinfection. It appears unsafe under ordinary circumstances to add both chemicals in the same well. The experience at both Milwaukee and East Chicago would indicate that the use of the thiosulphate should be undertaken only as a last resort under the most favorable conditions where time intervals of the magnitude of an hour or more are available.

Other disadvantages of the chlorine treatment are its inability to cope with sudden unsuspected increases in the load of pollution, resulting from the use of emergency intakes near shore or from breaks in the intake pipe. It is also true that occasionally water works plants run out of hypochlorite, particularly under present market conditions, as happened recently at Whiting. Another disadvantage of the hypochlorite treatment is the fact that it is less efficient in cold weather and that consequently over-doses are needed at times during the winter months. The possibility of tastes resulting from the chlorine treatment is, of course, familiar.

Treatment by filtration. The treatment of water supplies by filtration has the decided advantage that it is able to cope with marked variations in the quality of the raw water without reducing the bacterial efficiency. In other words the filtration plant is always on the job, delivering a water of reasonably uniform quality substantially free from pathogenic bacteria. If the filtered water be, in addition, treated with liquid chlorine the greatest safeguard to the consumers results. Small doses of chlorine can then be used, and better results obtained than in treating the raw water. In addition, a filtration plant removes turbidity, microscopic organisms and other impurities. The only disadvantage is, of course, the higher first cost and annual cost for operation. However, the failure of the chlorine treatment to afford thorough protection against typhoid, as demonstrated particularly in the smaller towns around Lake Michigan, has resulted in a wholesome trend towards filtration. Filtration plants have been recommended for East Chicago, Ind., and Wilmette, Winnetka, North Chicago and Waukegan, Ill. A plant is under construction at Kenosha, Wis., and plans are in preparation for a plant at Whiting, Ind.

In the design and construction of filtration plants there are several points which require careful consideration. These are due chiefly to the changes in the quality of the lake water at different points along the shore, and to the effect upon the water of the length of intake and the depth at point of intake. Thus there is a marked variation in the amount of turbidity present requiring removal. It has also been found in practice that at certain points along the lake, substantial growths of microscopic organisms develop, which materially affect the length of runs between washings of rapid sand filters. This point can be handled in properly designed plants by efficient operation.

Of particular importance, however, are the amount and character of pollution from industrial plants. Thus at Whiting, where the author's firm is now making investigations preparatory to the preparation of plans for a filtration plant, the waste from the Standard Oil refineries, though small in amount, imparts a decided oily taste to the water. The purified water should be free from this taste, if popular faith in water filtration is to be maintained. In the same vicinity, also, is the waste from a glucose factory and steel mills. At the steel mills the quench water from the coke ovens imparts a so-called creosote taste to the water which resembles the taste resulting from an over-dose of chlorine. Further north along the shore, the discharge from tanneries and other industries is important. Thus each particular water supply along Lake Michigan requires special consideration if satisfactory results are to be obtained.

Result of treatment. It is particularly pertinent at the present time to record a few results of these two methods of treating public water supplies from Lake Michigan. At present there is an outbreak of typhoid at North Chicago and Waukegan, Ill. Investigations by the State Board of Health indicate that the typhoid at North Chicago has resulted because the liquid chlorine apparatus failed to operate for a period during December, 1916. It is uncertain yet as to whether the typhoid at Waukegan did not result from an overload on the hypochlorite plant, due to the use of the near-shore intake during anchor ice troubles at the regular intake. At East Chicago, Ind., during the winter of 1916 something like 100 cases of typhoid fever occurred in a population of less than 30,000. The water supply was treated with liquid chlorine followed almost immediately by the addition of sodium thiosulphate. A less extensive outbreak occurred during the present winter, although the treat-

ment with liquid chlorine continued and the addition of thiosulphate was stopped. The engineering press has reported an outbreak of typhoid fever and intestinal diseases which occurred in Milwaukee during February and March, 1916. This water supply was treated with liquid chlorine. A special investigation was made by the epidemiologist of the Milwaukee Health Department. The author quotes as follows from his report to the Health Commissioner, Dr. Geo. C. Ruhland:

> It is our opinion that this outbreak of typhoid fever was caused by two factors.
>
> The first factor was the unusual concentration of sewage about the water intake during the week of January 19–26, due to the coincident warm weather resulting in an unusual flow of surface washing, combined with the usual sewage discharge from the city, and which was driven across the intake by prevailing southerly winds, thus resulting in an increased sewage concentration of the city water.
>
> The second factor was the failure of the chlorination process to care for this increased pollution with the same efficiency that had been the case previously. It was, therefore, in our opinion a water-borne infection, based on the following reasons:
>
> *First.* The explosive outbreak of diarrheal disease, followed in from three to four weeks by a tremendous increase in the typhoid morbidity.
>
> *Second.* The distribution of the cases in all portions of the city reached by the general water supply, and their absence in the community lacking this supply.
>
> *Third.* Its distribution regardless of the sanitary condition of the homes, location of toilets, or general sanitation.
>
> *Fourth.* The absence of any evidence pointing to occupation, or age. It affected all ages, and the distribution among the sexes was approximately equal. It was more frequent in small than in large families.
>
> *Fifth.* Contact cases could not be traced until the outbreak was at its height or was on the decline.
>
> *Sixth.* Absolutely no evidence was discovered pointing to infected milk or other food supplies which were in common use by the entire population of the city, or even by those infected.
>
> *Seventh.* The prompt subsidence of the outbreak as soon as boiling of the water began to be generally practiced.

Tendencies. The facts and experiences outlined point strongly to the desirability of installing water filtration plants for the treatment of the various water supplies derived from Lake Michigan. This tendency has developed into definite recommendation wherever the matter has been taken up along engineering lines, particularly in the smaller communities. Thus, Alvord, Eddy and Ful-

ler in their report to the Trustees of the North Shore Sanitary District, make the following statement:

Purity of water supplies. As has already been pointed out, Lake Michigan is year by year becoming less reliable as a source of pure water supply, from causes both within and without the district. While this is due in part to the discharge of untreated sewage, in part to the discharge of incompletely purified effluents, and in part to the natural run-off of storm water from the more or less thickly populated drainage area within and without the District, and while much may be accomplished in preventing contamination by untreated and partially treated sewage, it is not practicable to prevent all contamination due to storm water.

The District must therefore rely upon purification to assure the purity of supplies taken from the Lake. Such purification plants must be carefully and skillfully operated.

As the burden of contamination increases, sewage treatment can be relied upon to reduce the load upon the water purification plants sufficiently to assure their ability to produce a safe water. Such sewage treatment plants, however, must be carefully and skillfully operated. With such operation of both sewage and water purification plants, two barriers to the contamination of the water supply will be established.

Dabney H. Maury in reporting upon the water supply at Wilmette advised the installation of a rapid sand filter plant as the best means of securing safe and wholesome water. The author's firm, in work at East Chicago and Whiting, Ind., and at Evanston, Winnetka, and North Chicago, Ill., advised the installation of water filtration plants. At Evanston, the filter plant has been in operation since 1914, with the result that there were only 7 cases of typhoid in 1914, 7 in 1915 and no cases in 1916. At Whiting, Ind., plans for a filtration plant are now being prepared. At East Chicago, the installation of a filtration plant by the private water company is up before the Public Service Commission of Indiana. The plans are also being prepared by Metcalf and Eddy.

Summary. In the opinion of the author, eventually all public water supplies from Lake Michigan will be filtered. In the meantime, where reliance must be placed on treatment with chlorine, careful, expert supervision should be provided and routine analyses made at frequent intervals during the day to regulate the amount of chlorine applied to the varying conditions.