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DESCRIPTION OF METHODS OF OPERATION OF THE STERILIZATION PLANT OF THE JERSEY CITY WATER SUPPLY COMPANY AT BOONTON, N. J., AND DISCUSSION OF RESULTS OF ANALYSES OF RAW AND TREATED WATER, WITH NOTES ON THE COST OF THE TREATMENT.

BY GEORGE A. JOHNSON

The purpose of this paper is to describe the methods of operation followed during the first three months' operation of the sterilization plant of the Jersey City Water Supply Company at Boonton, N. J. The historical phases of the subject and a description of the process and the plant at Boonton have been given in the papers of Dr. Leal and Mr. Fuller. In this paper, therefore, only the methods of operation will be described, together with a discussion of the results of analysis of the raw reservoir water and the treated water made in the laboratory of the water company at Boonton and in the laboratories of Dr. George E. McLaughlin at Jersey City and Dr. Wm. H. Park in New York City.

Force Employed.—From September 26 to December 31, 1908, the operation of the sterilization plant at Boonton was under the direct charge of the writer. During that period Messrs. H. C. Stevens and Guy Britton were engineering assistants dividing the duties of the 24 hours of each day, and Mr. L. R. Whitcomb was analyst.

The duties of the engineering assistants were to superintend the preparation of chemical solutions and the application thereof to the water; to prepare accurate records of the rates of application of the sterilizing agent to the water; to collect and test at frequent intervals samples of the chemical solutions in order to ascertain the variation in strength of the same; and to prepare daily reports showing all necessary details of operation. Mr. Whitcomb's duties were to collect and analyze at least once a day samples of the raw reservoir water and of the water after treatment at a point on the aqueduct about one mile below the point of application of the sterilizing agent; and, also, to carry on incidental studies to show the effect of the treatment on particular forms of bacterial life.

CALIBRATION OF TANKS AND ORIFICES

In the beginning each of the tanks in which the chemical solutions were mixed and stored was carefully calibrated and tables prepared showing the content of each tank at different depths. The orifices whereby the flow of solution was regulated were also carefully calibrated and tables prepared showing the discharge through each orifice under a constant head with the orifice opened to a varying degree. With a knowledge of the amount of water which was being delivered into the aqueduct, it was possible by means of these tables to adjust at the orifice the dose of chemical solution with a great degree of accuracy in a moment's time.

PREPARATION OF SOLUTIONS

The bleaching powder was received at the plant in sheet-iron drums holding about 750 pounds, net. This powder was of a high degree of purity as ascertained by frequent analyses of it during the period of operation mentioned. Ordinarily the powder ran about 35 per cent in "available chlorine," equivalent to 7.9 per cent available oxygen. For the majority of the time solutions of 1 per cent strength were used. For a part of the time, as is the case now, ½ per cent solutions were used. By a ½ per cent solution is meant the addition of 5 pounds of dry bleaching powder to each 1000 pounds of water.

In making up a solution the amount of old solution remaining in the tank was first ascertained from the depth recorder and then it was decided to what height the tank was to be filled. By referring to the proper table showing the capacity of the tank between these two gage readings it was then possible to figure the amount of dry bleaching powder necessary to add to make up a solution of the desired strength. This amount of dry powder was then dumped into the dissolving compartment of the mixing tank, raw water turned on, and the agitators started. The solution rising in the dissolving compartment overflowed into the main solution tank, which was filled to the required height through this overflow.

APPLICATION OF SOLUTION

When it was desired to throw a tank into use the proper valves were opened, connecting the suction in this tank with the chemical feed pumps. The solution was tested by the Penot method for its strength in available oxygen by the so-called "available chlorine" method and the orifice on the orifice tank adjusted to give the required dose.

The chemical feed pumps were always operated so as to pump a quantity slightly in excess of that discharging through the orifice, and this excess escaped from the tank through an overflow pipe leading back into the main solution tank. In this manner it was possible to maintain at all times a constant head over the orifice and if, for any reason, the feed pumps stopped, the level of the solution in the orifice tank immediately began to fall, causing an alarm to be rung notifying the operator of the fact. Very little trouble was experienced from clogging at the orifice, and the variation in rate of application of the chemical solution was, therefore, exceedingly slight, being practically negligible.

AMOUNTS OF CHEMICAL APPLIED

In the beginning, not having a thoroughly definite idea of the smallest quantities which could be used with satisfactory results, the amount of chemical applied was 1.4 parts per million of "available chlorine," corresponding to 0.3 part per million of potential oxygen, or 36 pounds of the dry bleaching powder per million gallons of water treated. Gradually the quantity of applied chemical has been decreased until at the present time about 0.2 part per million of "available chlorine" is being applied. This corresponds to 0.045 part per million of potential oxygen, or 5 pounds per million gallons of the bleaching powder.

There has been no striking evidence that the higher quantities were more efficacious in the destruction of bacterial life in the raw reservoir water than the small quantity last mentioned.

The composition and temperature of the raw water apparently affected not at all the rapidity and completeness of the sterilizing action.

A long series of analyses were made with a view to establishing if possible a relationship between the amount of carbonaceous organic matter in the raw water and the amount of sterilizing agent necessary to effect the desired degree of sterilization. The quantities of the sterilizing agent used were so small, however, that there was found to be no such relationship existing. In other places, where the amount of organic matter is much higher than in the raw Boonton water, it is possible that such a relationship may be found to exist.

RESULTS OBTAINED

In the following table are given records showing the amount of water treated each day, the amount of chemical agent applied expressed in parts per million of potential oxygen, the results of bacterial examinations to show numbers of bacteria in the raw and treated water, and of tests for B. coli communis carried on at Boonton and in the laboratories of Drs. Park and McLaughlin.

If there is an apparent disparity in the results of analyses of the treated water at the Romine gate house and at the point of delivery in Jersey City, 23 miles below, and if the numbers of bacteria at the latter point were higher than those at the Romine gate house, as they sometimes were, it shows either that bacteria were still being washed from the old deposits in the conduit, or that there was a slight multiplication among the harmless, forms of bacteria which successfully resisted the treatment. The completeness of the sterilizing action, so far as the destruction of objectionable forms is concerned, is apparent from the results presented. From October 10 to December 31, inclusive, the total number of bacteria in the treated water at the point of delivery in Jersey City averaged 15 per cubic centimeter, and only on one occasion out of 455 tests was B. coli positively isolated from the treated water at the point of delivery in Jersey City, namely, on November 1, 1908, when it was isolated by Dr. Park in 5 cc. of treated water collected at the Summit Avenue gate house in Jersey City.

Official Daily Record of the Results of Operation of the Oxidation and Sterilization Plant of the Jersey City Water Supply Company, at Boonton, N. J., for the Destruction of Objectionable Bacteria in the Raw Water Supply of Jersey City, N. J.

Day of the Month.	Total quantity of water treated in million gallons.	Quantity of applied oxidizing agent expressed in parts per million in terms of potential oxygen.	BACTERIA PER CUBIC CENTIMETER: Raw reservoir water at lower Gate House.	BACTERIA PER CUBIC CENTIMETER: TREATED WATER AT: Romine Gate House.	BACTERIA PER CUBIC CENTIMETER: TREATED WATER AT: Summit Avenue Gate House. Dr. McLaughlin.	TESTS FOR B. COLI COMMUNIS: Raw reservoir water at Lower Gate House. 1.0 cc	TREATED WATER AT: Romine Gate House. 1.0 cc	Romine Gate House. 1.0 cc	Romine Gate House. 5.0 cc	Romine Gate House. 5.0 cc	Summit Ave. Gate House. By Dr. McLaughlin. 1.0 cc	Summit Ave. Gate House. 1.0 cc	Summit Ave. Gate House. 5.0 cc	Summit Ave. Gate House. 5.0 cc
1	40.0	0.097	....	....	....	–	–	–	–	–	–	–	–	–
2	40.0	0.095	....	....	....	–	–	–	–	–	–	–	–	–
3	40.5	0.088	....	....	....	–	–	–	–	–	–	–	–	–
4	41.0	0.085	....	....	....	–	–	–	–	–	–	–	–	–
5	41.0	0.088	....	....	....	–	–	–	–	–	–	–	–	–
6	41.0	0.108	....	....	....	–	–	–	–	–	–	–	–	–
7	41.0	0.129	....	....	....	–	–	–	–	–	–	–	–	–
8	41.0	0.111	180	1	1,400	+	–	0	–	–	–	0	0	0
9	41.0	0.099	240	2	190	+	–	0	–	–	–	0	0	0
10	41.0	0.104	200	11	70	+	–	?	–	–	–	0	0	0
11	41.0	0.106	160	7	....	+	–	0	–	–	–	0	0	0
12	41.0	0.147	190	3	24	+	–	0	–	–	–	0	0	0
13	41.0	0.162	275	3	28	?	–	?	–	–	–	0	0	0
14	41.0	0.151	220	5	48	?	–	0	–	–	–	0	0	0
15	40.3	0.144	180	6	42	+	–	0	–	–	–	0	0	0
16	40.6	0.151	275	8	30	+	–	0	–	–	–	0	0	0
17	42.4	0.158	220	6	....	+	–	0	–	–	–	0	0	0
18	43.3	0.144	250	4	12	?	–	0	–	–	–	0	0	0
19	42.0	0.156	170	7	12	+	–	0	–	–	–	0	0	0
20	41.3	0.160	190	6	5	+	–	0	–	–	–	0	0	0
21	38.5	0.147	350	10	3	?	–	0	–	–	–	0	0	0
22	39.2	0.147	220	8	4	?	–	0	–	–	–	0	0	0
23	41.0	0.160	275	5	275	?	–	0	–	–	–	0	0	0
24	41.0	0.156	170	4	....	+	–	0	–	–	–	0	0	0
25	41.0	0.151	180	6	8	+	–	?	–	–	–	0	0	0
26	41.0	0.142	375	5	8	?	–	0	–	–	–	0	0	0
27	40.3	0.135	425	4	6	?	–	0	–	–	–	0	0	0
28	40.0	0.142	275	8	9	0	–	0	–	–	–	0	0	0
29	40.0	0.149	600	20	14	+	–	0	–	–	–	0	0	0
30	40.0	0.149	1,400	12	12	+	–	+	–	–	–	0	0	0
31	39.4	0.142	650	12	....	0	–	?	–	–	–	0	0	0

NOVEMBER. 1908

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Day of the month.	Total quantity of water treated in million gallons.	Quantity of applied oxidizing agent expressed in parts per million in terms of potential oxygen.	BACTERIA PER CUBIC CENTIMETER. Raw reservoir water at Lower Gate House.	BACTERIA PER CUBIC CENTIMETER. Treated water at: Romine Gate House.	Treated water at: Summit Avenue Gate House. By Dr. McLaughlin	Summit Avenue Gate House. Dr. Park.	TESTS FOR B. COLI COMMUNIS. Raw reservoir water at Lower Gate House. 1.0 cc	Treated water at: Romine Gate House. 1.0 cc	Romine Gate House. 1.0 cc	Romine Gate House. 5.0 cc	Romine Gate House. 5.0 cc	Summit Avenue Gate House. Dr. McLaughlin. 1.0 cc	Dr. McLaughlin. 1.0 cc	Dr. McLaughlin. 5.0 cc	Dr. McLaughlin. 5.0 cc	Dr. Park. 1.0 cc	Dr. Park. 1.0 cc	Dr. Park. 5.0 cc	Dr. Park. 5.0 cc
1	39.6	0.153	325	13	10	12	+	–	0	–	–	–	0	0	0	0	0	0	+
2	40.0	0.158	190	5	13	– –	+	–	0	–	–	–	0	0	0	–	–	–	–
3	40.0	0.151	150	2	8	35	+	–	0	–	–	–	0	0	0	0	0	0	0
4	39.6	0.151	100	3	10	35	+	–	0	–	–	–	0	0	0	0	0	0	0
5	39.0	0.167	190	8	9	40	+	–	0	–	–	–	0	0	0	0	0	?	?
6	39.0	0.165	275	12	5	39	+	–	0	–	–	–	0	0	0	0	0	0	0
7	39.0	0.167	130	5	– –	– –	+	–	0	–	–	–	–	–	–	–	–	–	–
8	39.0	0.162	70	6	10	10	+	–	?	0	0	0	0	0	0	0	0	0	0
9	39.3	0.158	130	5	5	16	+	–	0	–	–	–	0	0	0	0	0	0	0
10	40.0	0.167	90	8	11	10	+	–	?	–	–	–	0	0	0	0	0	0	0
11	39.3	0.155	90	10	2	15	+	–	0	–	–	–	0	0	0	0	0	0	0
12	39.0	0.155	75	10	7	3	+	–	?	–	–	–	0	0	0	0	0	0	0
13	39.0	0.153	200	10	12	3	+	–	0	–	–	–	0	0	0	0	0	0	0
14	39.6	0.153	350	11	– –	– –	+	0	–	–	–	–	–	–	–	–	–	–	–
15	39.4	0.149	210	10	8	6	+	0	0	0	0	–	0	0	0	0	0	0	0
16	39.0	0.138	325	8	3	3	?	0	0	0	0	–	0	0	0	0	0	?	?
17	39.0	0.133	130	5	12	17	?	0	0	0	0	–	0	0	0	0	0	0	0
18	39.4	0.155	200	6	3	2	+	0	0	0	0	–	0	0	0	0	0	0	0
19	40.6	0.167	100	6	2	3	+	0	0	0	0	–	0	0	0	0	0	0	0
20	41.0	0.167	–	2	7	3	?	0	0	0	0	–	0	0	0	0	0	0	0
21	41.0	0.158	85	7	–	– –	?	0	0	0	0	–	–	–	–	–	–	–	–
22	41.0	0.138	150	5	50	1	+	0	0	0	0	0	0	0	0	0	0	0	0
23	41.0	0.149	130	4	12	47	+	0	0	0	0	0	0	0	0	0	0	0	0
24	40.3	0.151	210	5	11	5	?	0	0	0	0	0	0	0	0	0	0	0	0
25	40.0	0.158	30	5	– –	– –	?	0	0	0	0	–	–	–	–	–	–	–	0
26	40.0	0.140	45	4	5	4	?	0	0	0	0	0	0	0	0	0	0	0	0
27	40.0	0.147	700	12	9	3	?	0	0	0	0	0	0	0	0	0	0	0	0
28	40.0	0.151	550	4	–	– –	0	0	0	0	0	–	–	–	–	–	–	–	–
29	40.0	0.158	325	5	11	16	0	0	0	0	0	0	0	0	0	0	0	0	0
30	40.6	0.158	350	2	6	19	0	0	0	0	0	0	0	0	0	0	0	0	0

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1	41.0	0.156	350	2	14	5	?	0	0	0	0	0	0	0	0	0	0	0	0
2	41.6	0.156	400	1	75	5	+	0	0	0	0	0	0	0	0	0	0	0	0
3	42.6	0.151	425	1	12	6	+	0	0	0	0	0	0	0	0	0	0	0	0
4	43.0	0.153	350	1	46	4	?	0	0	0	0	0	0	0	0	0	0	0	0
5	43.0	0.120	450	20	–	–	?	0	0	0	0	–	–	–	–	–	–	–	–
6	43.0	0.156	250	2	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0
7	41.6	0.126	350	7	13	2	0	0	0	0	0	0	0	0	0	0	0	0	0
8	41.0	0.142	325	1	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0
9	41.3	0.149	240	1	5	9	0	0	0	0	?	0	0	0	0	0	0	0	0
10	42.0	0.151	450	0	50	14	0	0	0	0	0	0	0	0	0	0	0	0	0
11	42.0	0.144	800	2	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0
12	41.3	0.151	1,100	1	–	6	+	0	0	0	0	–	–	–	–	0	0	0	0
13	41.0	0.151	550	0	15	–	0	0	0	0	0	0	0	0	0	0	0	0	0
14	41.0	0.149	1,400	0	24	8	+	0	0	0	0	0	0	0	0	0	0	0	0
15	41.0	0.153	1,100	0	5	8	0	0	0	0	0	0	0	0	0	0	0	0	0
16	41.0	0.158	800	0	8	6	?	0	0	0	0	0	0	0	0	0	0	0	0
17	41.0	0.151	900	0	8	9	+	0	0	0	0	0	0	0	0	0	0	0	0
18	40.0	0.158	1,600	0	37	16	0	0	0	0	0	0	0	0	0	0	0	0	0
19	39.0	0.156	600	0	–	–	0	0	0	0	0	–	–	–	–	–	–	–	–
20	39.0	0.167	700	0	17	6	0	0	0	0	0	0	0	0	0	0	0	0	0
21	39.0	0.165	450	5	16	2	0	0	0	0	0	0	0	0	0	0	0	0	0
22	39.0	0.144	250	0	21	6	?	0	0	0	0	0	0	0	0	0	0	0	0
23	39.7	0.074	700	30	12	8	0	0	0	0	0	0	0	0	0		0	0	0
24	40.2	0.081	450	0	–	–	0	0	0	0	0	–	–	–	–	–	–	–	–
25	41.0	0.086	350	0	12	5	0	0	0	0	0	0	0	0	0	0	0	0	0
26	40.3	0.086	290	2	–	–	0	0	0	0	0	–	–	–	–	–	–	–	–
27	40.0	0.086	280	2	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0
28	40.0	0.086	270	2	11	3	0	0	0	0	0	0	0	0	0	0	0	0	0
29	40.0	0.084	600	10	11	2	0	0	0	0	0	0	0	0	0	0	0	0	0
30	38.6	0.084	475	0	21	4	0	0	0	0	0	0	0	0	0	0	0	0	0
31	38.0	0.081	460	0	–	–	0	0	0	0	0	–	–	–	–	–	–	–	–

ELECTROLYTIC METHOD

Some time after the sterilization plant was put into service studies were inaugurated to demonstrate the efficiency of electrolytically-prepared hypochlorite of sodium. An electrolyzer was obtained from the National Laundry Machinery Company, of Dayton, Ohio, and this machine was set up in the gate house at Boonton and studies began. This electrolytic cell is of porcelain-lined pottery clay containing carbon electrodes and glass and carbon baffles. A solution of common salt of about 4.5 per cent strength and having an initial temperature of about 65 deg. Fahr. was run through this cell at a rate of about 2 cubic feet per hour in the presence of a direct electric current of 110 volts and 22 ampères. The yield of a single cell was about 0.6 pound of available chlorine per hour.

RESULTS OBTAINED DURING A SPECIAL TEST

Between the dates March 20 and 24, 1909, a comparative test was made on the raw water to determine the relative efficiency of hypochlorite of lime in the form of bleaching powder and sodium hypochlorite electrolytically prepared. A considerable number of determinations of the bacterial quality of the raw and treated water before, during and after the use of the sodium hypochlorite solution showed that when equal quantities of the germicide in these two forms were added to the raw reservoir water the efficiency, so far as the destruction of bacterial life was concerned, was the same. The following table shows the results obtained during this test:

Results Obtained During a Special Test Run at Boonton, N. J., to Determine the Relative Efficiency of Calcium Hypochlorite (from Bleaching Powder) and Sodium Hypochlorite (Produced Electrolytically from Common Salt at Boonton).
(The Daily Flow of Water was 40,000,000 Gallons.)

Date, 1909.	HOUR. (Upper figure — hour of collection of raw water sample. Lower figure — treated water sample.	Quantity of applied oxidizing agent expressed in parts per million in terms of potential oxygen.	BACTERIA PER CUBIC CENTIMETER. Raw water.	Treated water at Summit Avenue Gate House, Jersey City.	RESULTS OF TESTS FOR B. COLI IN 1 CC. OF RAW RESERVOIR WATER AT BOONTON, N. J., AND IN 10 CC. OF TREATED WATER AT SUMMIT AVENUE GATE HOUSE, JERSEY CITY, N. J. Raw water. (Presumptive test.)	Treated water. (Determinative Test.)	REMARKS.
March 20	3:00 p.m	0.044	3,200	19	0	0	Calc. hypo. in use.
" 20	3:30 "						
" 20	4:00 "	0.044	2,300	18	0	0	" " " "
" 20	4:30 "						
" 20	5:00 "	0.044	2,900	15	0	0	" " " "
" 20	5:30 "						
" 20	6:00 "	0.044	2,700	20	0	0	" " " "
" 20	6:30 "						
" 21	8:00 a.m.	0.052	2,800	19	0	0	Sodium hypo. started 9:30 p.m., Mar. 20.
" 21	8:30 "						
" 21	9:00 "	0.052	2,600	18	0	0	
" 21	9:30 "						
" 21	10:00 "	0.052	2,800	15	+	0	
" 21	10:30 "						
" 21	11:00 "	0.052	2,800	15	0	0	
" 21	11:30 "						
" 21	12:00 "	0.052	1,800	15	0	0	
" 21	12:30 p.m.						
" 21	2:00 "	0.052	2,000	11	?	0	
" 21	2:30 "						
" 21	3:00 "	0.052	Lost	17	0	0	
" 21	3:30 "						
" 21	4:00 "	0.052	1,800	10	+	0	
" 21	4:30 "						
" 21	5:00 "	0.052	6,100	21	0	0	
" 21	5:30 "						
" 21	6:00 "	0.052	4,600	10	0	0	
" 21	6:30 "						

Results obtained during a Special Test Run at Boonton, N. J., to Determine the Relative Efficiency of Calcium Hypochlorite (from Bleaching Powder) and Sodium Hypochlorite (Produced Electrolytically from Common Salt at Boonton). (The Daily Flow of Water was 40,000,000 Gallons).

Date, 1909.	HOUR. (Upper figure — hour of collection of raw water sample. Lower figure — treated water sample.	Quantity of applied oxidizing agent expressed in parts per million in terms of potential oxygen.	BACTERIA PER CUBIC CENTIMETER. Raw water.	Treated water at Summit Avenue Gate House, Jersey City.	RESULTS OF TESTS FOR B. COLI IN 1 CC. OF RAW RESERVOIR WATER AT BOONTON, N. J., AND IN 10 CC. OF TREATED WATER AT SUMMIT AVENUE GATE HOUSE, JERSEY CITY, N. J. Raw water. (Presumptive test.)	Treated water. (Determinative test.)	REMARKS.
March 22	8:00 a.m.	0.051	5,100	9	?	0	
" 22	8:30 "						
" 22	9:00 "	0.051	3,000	12	+	0	
" 22	9:30 "						
" 22	10:00 "	0.051	3,800	7	+	0	
" 22	10:30 "						
" 22	11:00 "	0.051	4,400	13	0	0	
" 22	11:30 "						
" 22	12:00 m.	0.051	6,400	6	0	0	
" 22	12:30 p.m.						
" 22	1:00 "	0.051	5,000	1	0	0	
" 22	1:30 "						
" 22	2:00 "	0.051	2,000	3	?	0	
" 22	2:30 "						
" 22	3:00 "	0.051	4,500	2	0	0	
" 22	3:30 "						
" 22	4:00 "	0.051	4,900	2	0	0	
" 22	4:30 "						
" 22	5:00 "	0.089	3,900	3	0	0	Dose increased 4:20 p.m., March 22.
" 22	5:30 "						
" 22	6:00 "	0.074	5,200	9	0	0	Dose diminished 5:15 p.m., March 22.
" 22	6:30 "						
" 23	8:00 a.m.	0.079	2,200	6	0	0	Sodium hypo. discontinued and use of calc. hypo. resumed 11:00 p.m., March 22.
" 23	8:30 "						
" 23	9:00 "	0.079	2,700	2	?	0	
" 23	9:50 "						

Under the existing circumstances the total cost which can be charged against the process when using bleaching powder was found to be $0.14 per million gallons of water treated, this figure being divided up substantially as follows, basing the figures on an average daily treatment of 40,000,000 gallons of water:

One extra operator	$0.065
Bleaching Powder	0.065
Coal for heating the plant, miscellaneous laboratory and other supplies	0.010
	$0.14

It may be well to point out that power costs nothing at this plant for the reason that it is obtained from a water wheel actuated by the water flowing through the pipes which deliver the water from the dam to the aqueduct leading to Jersey City.

COST OF THE PROCESS WHEN USING ELECTROLYTICALLY PREPARED SODIUM HYPOCHLORITE

With power costing nothing, the charge for electric current in this process is nil. It has been found that to produce a pound of available chlorine in the electrolytic cell requires about 8.5 pounds of common salt. This salt, delivered at the plant, costs about one-third of a cent per pound; therefore, the cost for salt amounts to 4¼ cents per 1,000,000 gallons of water treated. The other figures previously given remain the same, making the total cost by the electrolytic process 11¾ cents per 1,000,000 gallons of water treated. In neither case has interest on the investment been included nor charges for depreciation in the plant. If this were added the total cost of the process would be between 20 cents and 25 cents per 1,000,000 gallons of water treated.

DEPRECIATION OF PLANT

As to depreciation in either process, it may be well to point out that, although the plant has now been in operation over seven months it has not been necessary to replace any of the piping, pumps or valves, and such repairs as have been made are not worthy of mention.

EFFECT OF THE TREATMENT ON THE CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE RAW BOONTON WATER

In general terms when hypochlorite of lime or soda is added to water the chemical and physical characteristics of the water are changed to some extent. Through the action of carbonic acid, either free or half bound, hypochlorous acid is released from the hypochlorite, and this acid, although very weak, is an active oxidizing agent. In the presence of organic matter its oxygen is released and this attacks the organic matter and oxidizes it. As hypochlorite of lime is a mixed compound, composed of calcium chloride and calcium hypochlorite, it follows that the former will add to the hardness of the water. In the electrolytic process where sodium hypochlorite is produced, the resultant solution contains in addition a slight amount of caustic soda and some sodium chloride, and the hardness of the water would, therefore, not be increased by its addition to it. In both cases the total solids in the water would be increased, and the color, if an organic stain, would be reduced. The carbonic acid in the water would be reduced, since it is essential for the liberation of hypochlorous acid from the hypochlorite.

In more concise terms it may be said that by adding hypochlorite of lime or soda to a water, the organic color thereof will be reduced; there will be an oxidation of organic matter; the carbonic acid will be reduced; the total solid matter in the water will be increased and, in the case of hypochlorite of lime, the total hardness of the water will be increased. With hypochlorite of soda this is not the case. All of the above changes were noted in a series of chemical analyses of the raw reservoir and treated waters. The amounts of chemical applied were so small, however, that the differences in the physical and chemical characteristics of the water before and after treatment were so slight as to be barely noticeable and were well within the limits of accuracy of the methods of analysis.

The most important chemical change which is brought about in this process is the reduction of carbonic acid. This has considerable practical significance from a standpoint of the incrusting and corrosive action of water on iron and steel pipe brought about by the action of carbonic acid.

The claim has been made that free chlorine is liberated in this process, and that it may persist in water treated with hypochlorite of lime. This is in no sense true for the reason that free chlorine cannot be liberated from hypochlorite of lime or soda in a natural water. To do so it would first be necessary to decompose all the alkaline constituents in the water with an excess of strong mineral acid. Again, even if free chlorine could be liberated from hypochlorite of lime in a natural water, the chlorine would immediately combine with the hydrogen of the water and liberate atomic oxygen.

DISCUSSION

PROF. H. B. CORNWALL: *Mr. President and Gentlemen:* When Dr. Leal called on me sometime ago to speak about this process which he has just described to you, and which it appears to have been his notion to put into regular effect as a means of sterilizing a water suitable for treatment, he asked me two or three questions. One was whether I thought that water could be sterilized in this way. I told him that I thought that it could. He asked whether I thought there would be any objectionable results from the process? I told him that I thought there would not; but I must confess that when I was giving him these answers, although there was not any doubt in my mind upon first looking into it that they were correct enough answers, I was basing them all on a somewhat different assumption, than what has turned out to be the truth. He told me they were going to use bleaching powder. Of course, the first idea that occurs to anyone in connection with bleaching powder is that it is a very powerful sort of substance. All the manufacturers of bleaching powder and the people who are using bleaching powder invariably refer to its strength in terms of what they call "available chlorine;" and every chemist working in a laboratory knows what happens when some of his chlorine gets beyond the bounds that he has set for chlorine. He knows that it is not a pleasant neighbor to have in a laboratory.

But on looking the subject up afterwards more thoroughly I found that under the conditions in which this agent is used, whether as a solution of calcium hypochlorite made from bleaching powder, or obtained electrically as a solution of hypochlorite of sodium from common salt, it was not a question of free chlorine at all.