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THE LUDLOW FILTERS.

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[*Read March 10, 1909.*]

In order to understand the conditions which have existed in connection with the water supply of Springfield, Mass., it is necessary to go somewhat into history. Much of this is familiar to members of the Society, as it has been covered in different articles and reports which have been published from time to time. There is no account, however, which has covered the entire ground, and it will be easy in connection with such an account to understand the necessity for, and the success of, filtration as it has been adopted by Springfield on its Ludlow reservoir water. Few reservoirs have borne as bad a reputation as has Ludlow.

In 1872 the city took over the reservoirs and pipe lines of the Springfield Aqueduct Company. These reservoirs were small and located only slightly above the city proper, in a section which was lower than certain new parts of the city. It became necessary, immediately, to look for a new supply, both because the old was inadequate and because it could not be made to serve the entire city. There are several tributaries of the Connecticut River which are located within a radius of fifteen miles of Springfield, at an elevation sufficient to supply the city, and studies were made of different supplies which were available. It is interesting to know in this connection that the Westfield Little River was finally selected, but a more careful study of the cost proved that it could not be taken by the city as a cost of $1 000 000 was considered prohibitive for a city of 26 000 people. Further studies were made, and finally Mr. George Raymond, of Fitchburg, Mass., who had

THE POUGHKEEPSIE WATER WORKS.

BY DR. JOHN C. OTIS.

[*Read September 9, 1909.*]

The commissioners appointed by " an act to provide for a supply of water in the city of Poughkeepsie and for sewerage therein," in their report dated February 7, 1870, state that they called to their aid James P. Kirwood, Esq., well known for his abilities as a consulting hydraulic engineer, and that they also engaged the services of Theodore W. Davis, Esq., as resident engineer.

The investigation of a source of supply covered every available creek, including the Hudson River, Fallkill Creek, Crum Elbow, and the Wappingers Creek.

The report of Chief Engineer, Mr. J. B. G. Rand, on the river supply is quite interesting, especially his footnotes in reference to the word " sewage " in the text when speaking of the sewage contamination in the river. This I present here to show plainly what was in the mind of the engineer in 1870 and before.

" The evils resulting from the domestic use of water contaminated with sewage are too well known and of too disagreeable a character in contemplation to admit of much discussion. A regard for the decent taste of the people would prevent us from taking the water from any source which had received sewage, and might, therefore, contain the living germs of cholera, typhoid fever, dysentery, tape worm, etc., without using every reasonable means to guard against distributing them. It is true, the volume of water in the river is so large compared to the quantity of human excreta discharged into it that not much harm can come by this discharge at present. But who can say how much water and how much time is required to destroy these germs; or how much harm may come?—the ablest scientific minds are unable or unwilling to answer. It is, however, well settled that numerous cases of the above diseases have been directly traced to the use of water polluted by sewage, and that, in other cases, the type, though changed, is the effect of such water."

It was finally summed up that the advantages of the river system were a never failing supply and the securing of a better fire protection, while the objections were contamination by sewage, which would be a constantly increasing evil unless stopped by the enactment and enforcement of laws, the quantity of other foreign matter brought down the river, the saline matter at times, and the annual outlay for pumping.

It was finally decided to utilize the Hudson River as a source of supply and the water-works arrangement settled upon in 1871, and later installed, consisted of a pumping station at the river, a filter, a force main to a reservoir on College Hill, and a distribution system.

The pumping machinery, made by H. R. Worthington, of New York, consisted of two pumping engines with boilers. One engine, the smaller, a high or low pressure duplex steam pump working under a lift of 10 ft. and against a head of 20 ft., supplied water to the filters. The large engine, a compound duplex condensing pump, working against a lift of 9 ft. and a head of 270 ft., furnished filtered water at the College Hill distributing reservoir.

The contract for the purchase of these engines provided for a duty test of 500 000 ft. lb., and it is stated that their performance exceeded this specification.

The filtering works consisted of a raw-water basin 25 by 60 ft. and 12 ft. deep, in three compartments arranged in reference to the deposition of the heavier particles of mud. The two uncovered filter beds were each 200 by 73½ ft., giving 14 650 sq. ft. of filtering area with a depth of 6 ft. of filtering materials as follows:

24 in. of sand.
6 ,, ,, ¼-in. gravel.
6 ,, ,, ½ ,, ,,
6 ,, ,, 1 ,, ,,
6 ,, ,, 2 ,, broken stone.
24 ,, ,, 4 to 8 in. fragments.

This large open filter, with which filtration was started, continued as originally constructed to do the work for the city until 1895, in which year the question of enlargement of filtering area was agitated. It was set forth to the Common Council, from which body funds were sought, that in April, 1895, for four successive times in one month, the city's storage of water was exhausted, due to the heavy rains causing the raw water to be charged with an unusual supply of red mud and silt which clogged the beds, permitting only four and one-half day runs between cleanings. This, with the difficulties met in cleaning in the winter, brought the officials to the point of feeling the necessity of additional area.

The new filter bed consisted of a single basin having an area equal to that of both basins comprising the old bed, thus doubling the area.

The form of construction is described in the report of 1896 as follows:

The length of this basin inside of wall is 260 ft.; width, 114 ft.; total area, 29 640 sq. ft. The clear depth of the basin from the top of the coping to the surface of the concrete bottom is 10.3 ft. The side walls, except along the old basin, consist of rubble masonry laid in Rosendale cement mortar, faced with a brick wall laid in Portland cement mortar. The inner faces of the walls are vertical. The bricks used for the facing were Catskill shale paving brick, of the best quality, absorbing not over 2 per cent. by weight of water after twenty-four hours' immersion. The thickness of these face walls for two thirds the height from the bottom is 18 in., and the remainder, 13½ in. On the west side, along the old basin, buttresses projecting from its walls necessitated filling between them with brick masonry. This was done with second-class bricks of the same kind, laid in Portland cement mortar. The whole was faced in the same way as the other walls, 13½ in. thick.

The bottom of the excavation varied from soft muck to solid rock. The rock was leveled and the muck excavated, the excavation being filled with fine cinders well rammed. The entire area was covered with concrete of Rosendale cement, 12 in. thick, put on in two layers.

A main drain, of brick masonry, sunken below the surface of the concrete, extends longitudinally along the center of the basin from south to north. Lateral drains of 6-in. tile pipes are laid on the concrete bottom at right angles to the main drain, and 10 ft. 3 in. apart between centers. These lateral drains are covered with 2-in. broken stone. The spaces between the laterals are filled to a depth of 10 in. with 2-in. broken stone and 1-in. gravel. Above this is a layer of ½-in. gravel 8 in. thick, and above this a layer of

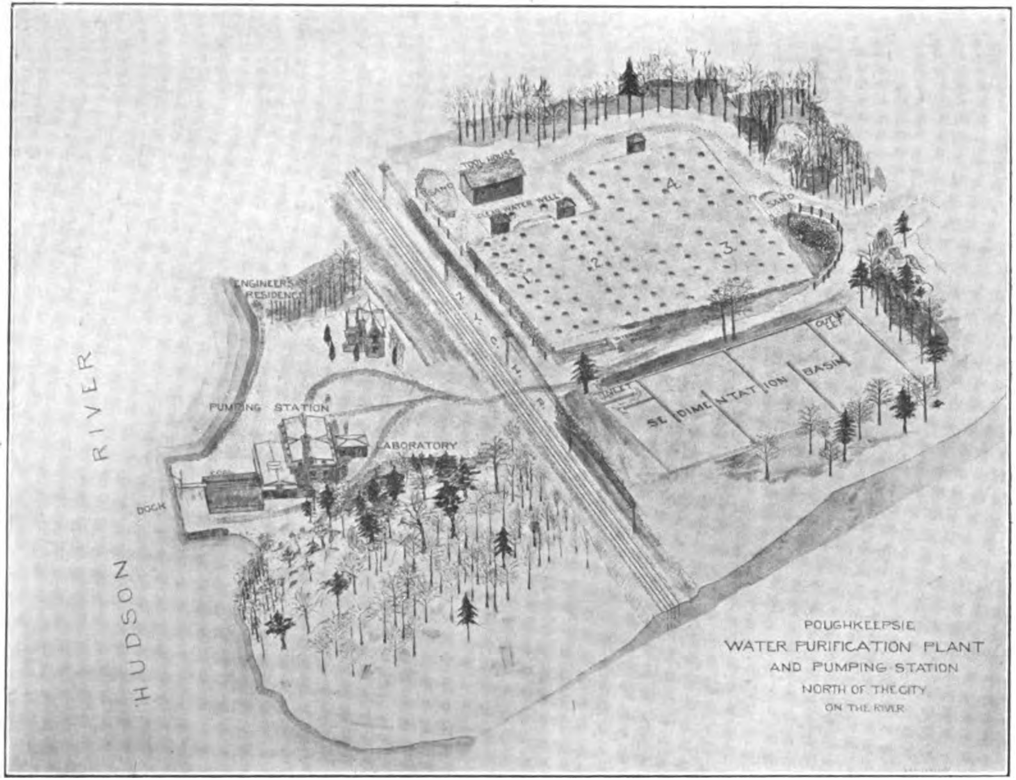
¼-in. gravel 6 in. thick, the total thickness of the gravel layers being 24 in. Above the gravel is the bed of filtering sand 31 in. thick. The water for this bed is taken from the inlet basin of the old filter bed, through an 18-in. supply pipe, entering the basin at the center of the south wall, and discharging into a distributing well 2 ft. wide, extending entirely across the south end of the basin. The top of the inner wall of this well is of the same height as the surface of the sand, and is perfectly horizontal, so that the water in entering the bed shall produce as little disturbance of the sand surface as possible.

The main drain discharges into a delivery well 6 ft. by 8 ft. on the outside of the north wall of the basin. In this well is a weir of cast iron sliding in vertical grooves, by means of which the working head may be regulated.

From the delivery well a 24-in. cast-iron pipe conveys the water westerly to a circular delivery pipe well, north of the clearwater basin of the old filter bed, at the bottom of which is a 6-in. valve opening into a short pipe connecting with a 20-in. drain. From this delivery pipe well an 18-in. cast-iron pipe conducts the water south to the clearwater basin of the old filter basin. In this last pipe is a valve, and also one in the supply pipe, by means of which the bed may be cut out of service at pleasure. The construction of the basin was done under contract by Charles Cook, of this city. The gravel and sand, comprising the filtering materials, were delivered under contract by John Sutcliffe, of this city, at the walls of the basin, and were placed in position by day labor. The gravel and sand were obtained by Mr. Sutcliffe at Heamstead Harbor, Long Island, and were thoroughly washed at the banks.

In 1904, there was an agitation to reconstruct and cover the filters. The reasons given for making the change were, low purification efficiencies, expense of removing ice, leakage in old filters, and growth of algæ on the beds. The work was started, and is described as follows:

The work done consisted in removing all the filtering materials from both filters; and, for the old or west filter, placing a puddle filling in the bottom of both sections; placing a concrete floor in the form of inverted arches on this puddle; lining the side walls with concrete; setting concrete piers; covering the whole with groined



AN ISOMETRIC VIEW OF THE PURIFICATION PLANT.

arches of concrete, with 2 ft. of earth cover; and providing and placing new under drains. In the new or east filter the work consisted in covering the old concrete bottom with a waterproof coat of asphalt, laid on hemp burlap; laying upon this asphalt coat a concrete course, in the form of inverted arches; building a central transverse wall of concrete; placing concrete piers, and covering the whole with groined arches of concrete with 2 ft. of earth cover; modifying the main drain and replacing old laterals. The sides and bottom of the clearwater basin were also lined with concrete, and concrete piers and arches with earth cover were placed. This system as completed in 1905 consisted of four units of ⅓ acre each.

The period from the construction of the filters to 1880 was one of absolutely no particular control and no regularity of operation. It was not unusual to allow the filters to remain out of commission for a whole winter season. The typhoid death-rate statistics check out these periods very nicely.

The period from 1880 to date has been one of more intelligent control, during which time no unfiltered water has been served to the consumers, but without doubt there have been times when it has been hard to draw the line between the filtering of water and the screening of it.

TABLE 1.

TYPHOID FEVER STATISTICS.

Year.	Total Deaths.		No. of Cases.	Per Cent. of Typhoid Deaths to Cases.
	Typhoid.	Malarial.		
1893	21	10	61	33.0
1894	14	6	28	50.0
1895	10	8	27	37.0
1896	5	4	32	15.6
1897	10	5	19	52.5
1898	5	2	20	25.0
1899	6	3	52	11.5
1900	11	3	51	21.5
1901	10	1	63	16.2
1902	5	3	33	15.1
1903	11	2	39	31.0
1904	15	2	93	16.1
1905	9	2	78	11.5
1906	9	3	66	13.6
1907	30	3	168	18.0
1908	11	..	42	26.2

Typhoid and intestinal diseases have been prevalent in the city, and the statistics from our health department do not begin to show what has happened. Table 1 shows the number of deaths from typhoid and malarial diseases for each year, from 1892 to date; also the number of cases reported by the health department, and the per cent. of deaths to cases. This percentage varies from 52 per cent. to 11.5 per cent., showing clearly the very low average ability of the physicians or great lack of accuracy in reporting. The table shows that while malarial diseases are beginning to disappear, the typhoid cases have increased, as we become more enlightened in the management of filters and their design. Such inconsistent results must be due to erroneous statistics. Just a few years ago, the health department would accept no case as typhoid unless a positive Widal reaction was obtained, while at this time any fever or intestinal disease is reported as typhoid.

The Hudson River water in its raw condition is most variable. This great river comes to us and by us at the salt line, and in about every twenty years the taste of salt is perceptible in the filtered water. In the fall of 1908, it was so salty that it was most unpleasant to drink. This of course occurs during seasons of extreme droughts. The water varies in color, in turbidity, and in purity with the change of the tide, with the weather, and with the time of day; it may be heavily laden with silt or entirely free from it; it may be very impure when filled with silt or it may be a fairly good water; it may be perfectly clear and yet be so polluted that it is suicide to touch it to your lips.

A sedimentation basin was added to the plant, being finished in December, 1907. This basin started in operation on December 29, 1907, and continued until June 11, 1908, when it was emptied, the water being clear enough without its use, and also to do away with the growth of algæ.

Coagulation with alum was used, with the exception of three weeks, until May 22. This interruption, from January 27 to February 18, was due to the clogging of beds owing to inexperience in operation. The alum was added to the raw water through the suction pipe of the low lift pump from an alum tank in the chemical laboratory, the amounts varying with the turbidity from $\frac{7}{8}$ grains per gallon with a turbidity of 25, to $2\frac{1}{2}$ grains per gallon with a

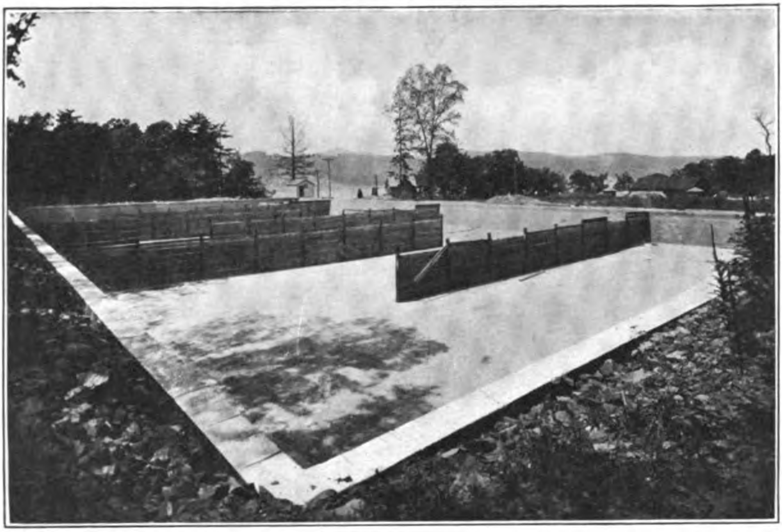


FIG. 1. THIS COAGULATING BASIN HAS A CAPACITY OF 3 MILLION GALLONS. THE DISINFECTANT HOUSE CAN BE SEEN AT THE FARTHER CORNER. THE TOP BOARDS OF THE BAFFLES WERE REMOVED BY ICE.

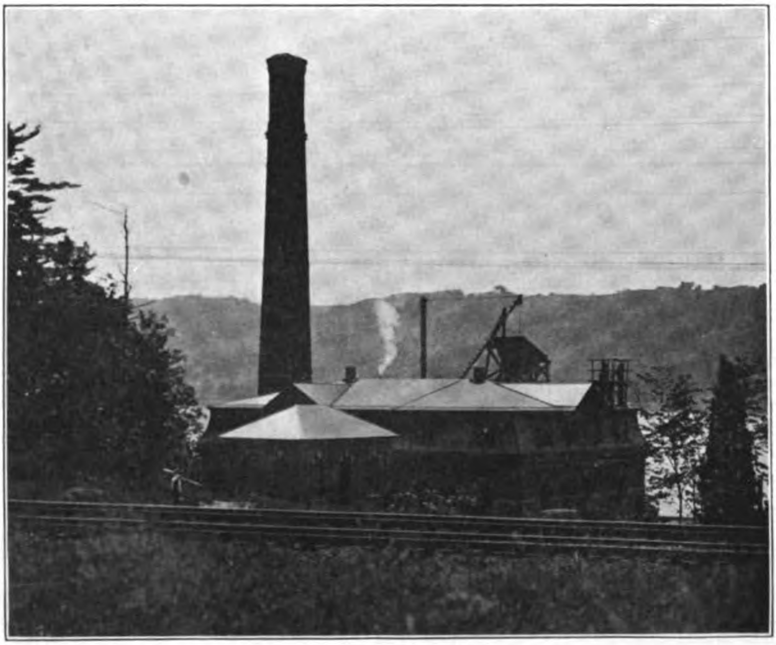


FIG. 2. PUMPING STATION AND CHEMICAL LABORATORY.

TABLE 2.

General Summary of Bacteriological Results. Monthly Averages.

Month.	Raw Water.		Settled Water.				Effluent Filter No. 1.				Effluent Filter No. 2.				Effluent Filter No. 3.				Effluent Filter No. 4.				Remarks.
	20°	37°	20°	Per Cent. Rem.	37°	Per Cent. Rem.	20°	Per Cent. Rem.	37°	Per Cent. Rem.	20°	Per Cent. Rem.	37°	Per Cent. Rem.	20°	Per Cent. Rem.	37°	Per Cent. Rem.	20°	Per Cent. Rem.	37°	Per Cent. Rem.	
1907.																							
December	11 400	.....	.....	.....	...	.....	108	99.1	...	....	119	99.0	...	....	89	99.2	...	....	82	99.3	...	....	Cd. basin not completed.
1908.																							
January	9 200	.....	6 920	24.8	...	.....	88	99.0	...	....	104	98.9	...	....	69	99.3	...	....	63	99.3	...	....	
February	19 520	.....	16 300	16.5	...	.....	130	99.3	...	....	96	99.5	...	....	142	99.3	...	....	106	99.5	...	....	Coagulant not used.
March	20 600	.....	5 440	73.6	...	.....	104	99.5	...	....	125	99.4	...	....	76	99.6	...	....	94	99.5	...	....	
April	16 420	.....	6 560	60.0	...	.....	47	99.7	...	....	47	99.7	...	....	44	99.7	...	....	57	99.7	...	....	Coagulant in large quantities.
May	9 790	1 110	5 390	44.9	750	32.4	26	99.7	22	98.0	30	99.7	18	98.4	36	99.6	30	97.3	38	99.6	22	98.0	
June	3 290	385	2 970	09.7	230	40.3	28	99.1	17	95.6	27	99.1	16	95.8	28	99.1	12	96.1	50	98.5	14	96.4	No coagulant.
July	2 120	445	.....	.....	...	.....	25	98.8	18	96.0	70	96.7	23	94.8	17	99.2	11	97.5	25	98.8	41	90.8	Basin not operated.
August	2 000	730	.....	.....	...	.....	21	99.0	9	98.8	22	98.9	12	98.4	27	98.7	14	98.1	29	98.6	19	97.4	
September	2 090	780	1 080	48.3	535	31.4	18	99.1	8	99.0	42	98,0	30	96.2	16	99.2	15	98.1	18	99.1	16	98.0	No coagulant.
October	2 160	870	1 250	42.1	450	48.3	24	98.9	13	98.5	12	99.5	11	98.7	20	99.1	12	98.6	31	98.6	28	96.9	No coagulant.
November	2 060	705	1 400	32.0	405	42.4	16	99.2	11	98.3	14	99.3	10	98.4	24	98.8	10	98.4	25	98.8	41	94.0	Coagulant used 3 weeks.
Average	8 390	720	5 260	*40.6	475	*38.3	53	99.4	14	98.1	59	99.3	17	97.6	49	99.4	15	97.9	52	99.4	26	96.4	
December	8 070	454	7 040	12.8	248	45.4	94	98.7	7	97.3	108	98.5	10	96.0	86	98.8	9	96.5	107	98.5	9	96.5	
1909.																							
January	11 690	399	5 690	51.4	135	66.2	177	97.1	16	88.1	218	96.4	21	84.5	171	97.1	19	85.9	164	97.2	16	88.2	
February	32 640	709	1 210	85.2	107	84.9	114	90.6	15	86.1	149	87.8	17	74.6	109	91.1	15	86.0	96	92.1	11	89.7	
March	30 000	539	497	98.3	84	84.5	69	86.2	11	86.9	47	90.5	15	82.1	37	92.5	9	89.3	48	90.4	10	88.2	
April	13 520	331	70	99.7	49	85.2	16	77.2	10	79.7	14	80.1	16	67.4	14	80.1	11	77.5	22	68.5	12	75.6	
May	3 222	179	118	96.3	25	86.1	38	67.8	15	60.5	19	74.3	13	48.0	18	84.8	11	56.0	22	81.4	11	56.0	
June	1 953	326	413	89.2	85	74.0	25	94.0	12	85.9	17	96.0	9	89.5	15	96.5	8	90.7	14	96.7	7	91.9	
July	1 475	475	393	80.1	209	56.1	16	96.0	8	50.0	17	95.7	9	95.7	13	96.7	7	96.7	17	95.8	8	96.3	

* Per cent. removal in basin computed from average of months when in operation.

Average bacteria in effluent for 1908, 20°—53, 37°—18.

Average per cent. removal for 1908, 20°—99.4, 37°—97.5.

turbidity of 500. This method of sedimentation and coagulation in connection with the Hudson River water is simple and efficient when the water is bad and heavily laden with silt. The basin in its first run gave efficiencies good enough to give a uniform water to the filter, and the alkalinity permitted large amounts of alum. The maximum bacteriological efficiency obtained was 98 per cent.

Table 2 shows the record of operation of the purification plant. This table gives the monthly averages of raw, settled, and filtered water for the 20° and 37° counts and are averaged from daily examinations with two plates to each count with an incubation of sixty-five hours.

As shown in Table 1, the operation of this plant reduced the typhoid cases from 168 in 1907 to 42 in 1908.

Table 3 gives the quantities of alum used, the amount of water treated, and the percentage monthly removal of turbidity with alum during the last winter.

TABLE 3.

COAGULATION RECORD.

	No. Days.	Average Lbs. Used per Day.	Average Million Gallons of Water Pumped per Day.	Grains per Gallon.	Tur-bidity.	Tur-bidity after 24 Hours.	Per Cent. Rem.
1908–1909.							
December........	18	393	3.199	1.11	20.0	13.5	32.5
January..........	30	767	2.728	1.61	32.5	18.5	43.
February.........	9	631	2.88	1.77	163.3	25.5	78.2
March............	12	748	2.94	1.81	98.6	28.1	71.5
April.............	16	589	2.72	1.53	55.5	23.7	57.3
May..............	2	551	2.97	1.31	17.0	13.0	24.7

The summer of 1908 was extremely dry for New York state, and the Hudson River became very low, the salt water reached Poughkeepsie in the fall and was noticeable in the drinking water from the middle of October to the middle of November, for the drought continued into the winter. The river froze over and the water came to us concentrated with sewage, but with no turbidity. As there was nothing in suspension, no results were obtained from the sedimentation basin nor from the alum. To add to this condition the filters failed to respond to any treatment, and as a result, there were bacterial counts in the filtered water.

Mr. G. C. Whipple was called in consultation and he suggested that "chloride of lime" be applied instead of coagulant.

This was done at once with most satisfactory results. The application was begun February 1, using the coagulant apparatus, which introduces the chemical into the low lift pump suction line. By February 12, a temporary dosing appliance (consisting of two barrels with a suitable "regulating box") was constructed to apply the chloride at the inlet of the sedimentation basin, and the permanent apparatus was put in operation on March 17. This consists of two wooden tanks of about 1 100 gallons capacity each, and a regulating box, one tank being used while the other is being filled. The regulating box is a lead-lined chamber 18 in. by 18 in. by 12 in. with a ball-cock on the inlet and a small hand valve on the outlet. Lead and bronze are used throughout in the piping and valves. The tanks are hand stirred at frequent intervals, but this does not insure absolute uniformity of applied solution, the variation amounting to 10 per cent. or 15 per cent. at different times. Other means of stirring are being considered. The strength of solution is 20 to 35 lb. of chloride to a tank (about a 20 per cent. to 35 per cent. suspension). A much stronger liquor, about 25 per cent., was used in the barrel apparatus described before, but much trouble was experienced by reason of clogging of valves and consequent interruption. Electrolytically prepared bleaching powder is used, analyses of which show from 37 to 39 per cent. by weight of available chlorine. The average amount applied has been about 0.4 parts of chlorine per million.

Amounts less than 0.2 parts have been tried experimentally, but with marked decrease in per cent. of bacteria removed.

The following table shows the bacteria removal obtained.

Applied Chlorine. Parts per Million.	Bacteria in Raw Water.	Bacteria in Settled Water.	Per Cent. Removed.
.25	12 600	1 160	90.8
.25–.40	41 200	1 100	97.3
.40–.50	18 700	165	99.1
.50	50 400	234	99.5

These results are not entirely conclusive evidence that somewhat smaller doses applied carefully would not do the work. The reliability of the results of earlier experiments with small amounts was impaired by annoying interruptions incident to starting new and unfamiliar apparatus, and because coagulant was used part of the time to treat the turbidity and color. Experiments using quantities up to .80 parts per million did not show a material increase in percentage removed.

The bacterial content of the filtered water averaged by weeks was as follows:

Week Ending	Bacteria per Ccm.	Week Ending	Bacteria per Ccm.
February 6	185	March 20	80
„ 13	100	„ 27	32
„ 20	120	April 3	23
„ 27	75	„ 10	16
March 6	30	„ 17	16
„ 13	60		

showing a progressive decrease of bacteria in the filtered water. On several occasions in the first weeks the bacteria content of the filtered water was higher than in the settled water applied to the beds.

The following tables show the results of tests for B. coli:

RAW WATER.

Quantity Ccm.	Number of Tests.	Number of Positive Tests.
.01	4	2
.1	4	1
.5	5	3
1.0	3	3

SETTLED WATER.

Quantity. Ccm.	Number of Tests.	Number of Positive Tests.
1	16	2

FILTERED WATER.

Quantity. Ccm.	Number of Tests.	Number of Positive Tests.
2	4	0
3	55	3
5	8	0

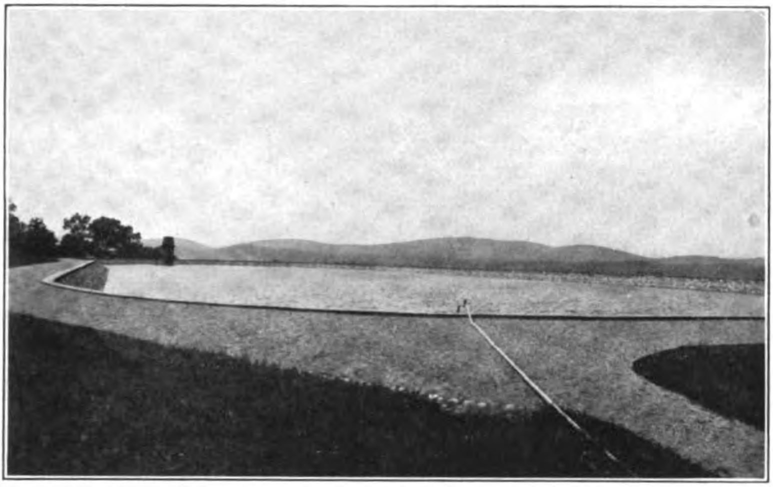


FIG. 1. COLLEGE HILL RESERVOIR. — 12 MILLION GALLONS CAPACITY.

FIG. 2. GENERAL VIEW OF THE PURIFICATION PLANT.

The presence of free chlorine in the settled and filtered water was determined by the tolidine test recently invented by Professor Phelps of the Massachusetts Institute of Technology. This is the most sensitive test for free chlorine known. The distinctive color resulting when free chlorine and this reagent are brought in contact has been observed at the laboratory of the Poughkeepsie plant when the amount of chlorine was known not to exceed .025 parts per million. The test has frequently given positive results in the settled water, but never has there been the slightest trace in the filter effluent. A slight musty odor has been noticed in the filtered water when the test was made on a hot sample, but no taste or odor can be detected in the cold. There are no records of odor before the use of chlorine, so it is impossible to say whether or not the condition is due to its use.

The cost of treatment by this process is insignificant. The building and tanks cost $275 and are of a substantial nature. No extra employees are required, so the cost is reduced to interest and depreciation on the plant and cost of chemicals. The former is difficult to estimate but should not amount to over two or three cents per million gallons. The cost of the bleaching power is 1.4 cents per pound, bringing the total cost up to 14 or 15 cents per million gallons.

CONCLUSIONS.

It is seems safe to conclude from the experience at this plant during two and a half months operation:

1. That amounts of free chlorine from .35 to .45 parts per million will reduce the bacteria in the sedimentation basin more than 99 per cent. and will practically eliminate the B. coli and presumably the typhoid germs.

2. That free chlorine persists for at least twenty-four hours in the unfiltered water, though very much reduced in quantity.

3. That no free chlorine remains in the water after filtration.

4. That no tastes or odors are developed to such an extent that the consumer notices them.

Table 4 shows quite plainly, when peculiar local conditions are considered, that 0.5 parts per million will give percentages of removal of nearly 100 per cent., when used in connection with alum

TABLE 4.

CHLORIDE OF LIME.

Month.	Hypochlorite. Lb. Used per Day.	Lb. Free Chlorine Used per Day.	Million Gallons Pumped per Day.	Chlorine. Parts per Million per Day.	Bacteria. Per Cent. of Removal.
1909.					
‡February	31.4	11.6	2.88	.46	85.2
†March	28.8	11.0	2.94	.45	98.2
†April	32.1	12.4	2.97	.49	99.7
†May	23.1	8.8	2.81	.34	96.3
*June	20.0	7.1	2.60	.34	89.2
*July	31.4	11.1	2.60	.51	80.1

‡ Method of applying not satisfactory.
†Twenty-four hours' storage before taking samples.
* Six hours' chlorination.

In order to bring out more forcibly the necessity for some radical action, it may be seen by referring to bacteriological records for 1908 (Table 2) that the summer and fall averages were very low, and that, of course, there was no typhoid fever. In December, the counts in the filtered water ran higher, reaching to 450, causing unusual alarm, although throughout the entire month of December no typhoid was reported. Table 5 shows the daily average number of bacteria for four filters for each month, beginning with December, 1908, together with the number of typhoid cases reported, every one of which was specially investigated. The third column shows the number of cases which may have been caused by the city water, which checks out with the condition of the water in December, January, and February, and which condition was remedied by chlorination.

The total number of cases of typhoid for nine of the twelve months is 23 for 1909 to 41 for the corresponding months of 1908.

TABLE 5.

TYPHOID TABLE.

Months.	Average Number Bacteria in Filtered Water.	Number of Cases of Typhoid Reported.	Number of Cases Possibly Caused by City Water.	Number of Cases for which Definite Cause was Found.	Number of Cases which from General Conditions or Peculiar Circumstances may be from Some Other Source than Water.
1908.					
December	99	0	0	0	0
1909.					
January	182	7	3	3	1
February	117	7	3	3	1
March	50	3	2	1	..
April	16	2	1	1	..
May	24	1	..	..	1
June	18	1	..	..	..
July	16	2	1	..	1

We have recently established a price for water which, with our thoroughly metered service, will furnish income to meet all obligations and care for the interest and liquidate the bonded debt in thirty years.

The total receipts from the sale of water from 1873 to 1908 inclusive amount to $1 077 643, ranging in amounts yearly of from $9 000 to $50 000. The operating expenses during this same period amount to $866 536.04.

The additions to the distribution system have amounted to $94 550.53; the renewals and changes as follows: For new pumps in 1893, $35 689.95; filter improvement, $80 830.27; new intake, $6 135.41; and $40 407.37 in the construction of a new sedimentation basin, amounting in new construction, including the extension of the distribution system, to $257 613.53. The original bonded indebtedness of the city for its water works was $550 000, which was the original cost. These bonds were 7 per cent., interest bearing. During thirty-seven years, $35 000 worth of bonds have been paid, although many have been refunded at lower rates of interest. Forty thousand dollars was added in 1907, leaving the present bonded indebtedness at $555 000. A rough computation shows that there has been paid about $1 080 000 in interest, all of which came out of the general city fund.

There were delivered in this thirty-seven years 22 000 million gallons of water at an average cost for operating expenses of 3.5 cents per thousand gallons.

The cost per thousand gallons for new construction amounted to 1.1 cents.

The city has been paying for the use of money at the rate of 4.8 cents per thousand gallons.

The total cost of the city to provide water amounts then to 9.5 cents per thousand gallons.

The total receipts per thousand gallons amount to 4.8 cents, showing that the receipts have been about one half the cost.

DISCUSSION.

A Member. I should like to ask Dr. Otis what the present population of Poughkeepsie is.

Dr. Otis. The present population is about 30 000. It has gone up from 18 000 to 30 000 since the installation of our water works, and the Board of Trade will tell you that we expect soon to have 50 000.

Mr. Alexander Potter.* May I ask Dr. Otis if he has any special reason for his conclusion or his suggestion as to the abandonment of the sand filter as the matter has been worked out in Poughkeepsie.

Dr. Otis. I should like to have it distinctly understood that that is a suggestion coming from a layman, and, therefore, is not one that carries any special weight. I base my conclusions simply on a study of the statistics of our filter plant. So long as we were using sand filtration alone we did not produce a good water. Our water for most of the time was really much worse than our records show, from the fact that when we awoke to the necessity of a change we found that we had been using in our bacterial analyses a gelatine which was not correct, so that undoubtedly our counts should have been at times much higher than our records show. I simply put it as a suggestion from an ignorant layman, upon a

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study of the statistics, that we possibly would have just as good water simply by the use of our settling basin and our coagulant. I assume that sooner or later we will know more about the chemical treatment of water, and I believe it is only a matter of a short time when we shall know a chemical substance that will take out all these growths, not only the algæ, but every other growth that is likely to contaminate a reservoir.

MR. EARLE B. PHELPS.* I have been much interested in Dr. Otis's remarks about disinfection, as I have made that particular point of water purification a special study for the past few years. I fully agree with what Dr. Otis has said as to the experimental stage with regard to water disinfection. I have the firmest belief in the great possibilities of some such method, but whether bleaching powder or some other similar oxidizing agent is more efficient remains for the future to determine.

There are some points in connection with this matter, however, which I think cannot be overstated. The chief of these is that I believe we should insist continually on the fact that disinfection is not a substitute for filtration. It is an adjunct, apparently, which permits us to filter the water at higher rates, and which gives us a greater margin of safety and greater security against a breakdown of filtration.

But there are constituents in a polluted water which disinfection does not remove, things other than germs which it is undesirable for many reasons to drink, which common sense tells us not to drink, and which, whatever may be the scientific aspects of the case, we simply do not want to drink. Personally, I am firmly convinced that the studies of Mr. Allen Hazen and Professor Sedgwick have shown us that there is an actual danger in these polluting substances. Aside from the bacteriological diseases carried by water, I believe that there is a detriment in polluting material which probably acts indirectly by lowering the general vitality. Observations show that we have from this cause an increased deathrate among diseases which we cannot ascribe to actual bacteriological infection.

In any discussion of disinfection methods, I think we should not

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lose sight of the possibilities of ozone. Ozone has a poor record at present, but it must be remembered that ozone has successfully passed through the experimental stage through which these newer compounds are now passing. Ozone has hitherto failed not from any inability to purify water, but for mechanical reasons. We cannot produce ozone at a sufficiently low price. As it is a matter of mechanical and electrical engineering, there is no reason to believe that ozone must always be as high in price as it is to-day. There is every reason, on the contrary, to expect that ozone machines will be developed, and I believe they are being developed, which will make ozone a practical disinfectant; and once given ozone at sufficiently low cost to make it possible to be used, it is certainly the ideal disinfectant. As ozone reduces to ordinary oxygen, there are absolutely no after effects, so there can be no objection to its use. This is a very practical matter to be considered.

There are certain objections to the use of chloride of lime which seem to have some weight. It has been observed in some places, and I was interested to note that Dr. Otis referred to the matter, that the odor of the water is slightly altered and made a little unpleasant by the addition of bleaching powder. I have studied that point and am convinced that it is not due to the oxidizing action of the chlorine but to "chlorination," as the chemists call it; that is, to the action of the chlorine upon the organic material accumulated in the sand. The sand is there to accumulate the organic material, and if we get these odors when we pass the chlorine through it, then some other procedure is necessary. Adding the chlorine after filtration may be the solution of this problem.

There are certain other objections to the use of chlorine compounds for which there may be no real scientific reason, but which are nevertheless forcible in the public mind. For this reason, while we have in the case of bleaching powder a disinfectant of very great value, and while the use of this disinfectant probably works no harm so far as we know, it would be highly desirable to substitute some other disinfectant which might at least have a better sounding name. In this connection I have been investigating for some time the disinfecting properties of the various peroxides, including the peroxides of sodium, calcium, and magnesium. At the present market prices of these substances none of them are practical for water disinfection. The magnesium peroxide is the most advantageous for use, since this forms in the water hydroxide of magnesium, which appears to be fully as efficient as the aluminum compound as a coagulant. The magnesium salt is also sufficiently soluble for use. The calcium peroxide, on the other hand, is very slightly soluble and could only be used in conjunction with sand filters, in which case a layer of the undissolved peroxide would accumulate on the sand. The water in passing through this layer is efficiently disinfected. Peroxide of sodium acts too violently with the organic matter to be economical. In the presence of any considerable amount of organic matter it is rapidly decomposed and is a most efficient oxidizing agent, but larger quantities are necessary to produce bacterial results than of the other compounds mentioned.

Since the cost of production of all of these substances is largely a mechanical question and depends also, in some degree, upon the market demand, it is not at all improbable that, given sufficient incentive, the manufacturers may be able to produce them in large quantities at a price which would make their use possible. It is believed that in some of these compounds, particularly the magnesium peroxide, we have a most valuable adjunct to filtration.

In my opinion, the chief line of development of the disinfection methods lies in connection with rapid mechanical filtration. Slow sand filters reach their limiting rates when color and turbidity as well as bacteria begin to come through, and in most cases the passage of bacteria through the filter is coincident with the passage of other impurities. On the other hand, with mechanical filters using coagulants the rate is only limited by the necessity for bacterial removals. If such removals can be accomplished in the final disinfecting treatment, the present rates of mechanical filters can undoubtedly be doubled without sacrificing efficiency in other lines.

In brief, then, I regard these recent developments in the disinfections of water as most important in the sense that they will make it possible to operate mechanical filters at high rates, to relieve the burden of many filters which are now overworked, and to reduce by nearly 50 per cent. the cost of new works. If such proves to be the case, we may expect to see plants built where polluted raw water is now being used, and a general improvement in the quality of water delivered by many plants which are now greatly overworked.

A MEMBER. Bleaching powder sterilizes and practically embalms the bacteria, doesn't it?

MR. PHELPS. I cannot call it embalming; it kills them.

A MEMBER. Have you tried any tests to determine whether they are actually killed or whether they would come back again after a length of time.

MR. PHELPS. Those germs which are actually killed do not come back, but if I catch the point of the question it refers to the secondary increase in bacteria which is often observed after disinfection. The few residual germs which are present may grow, and often do grow, so we get an increased count of a secondary kind. From a sanitary point of view, however, that does not mean anything. We have become accustomed to considering high counts as an indication of pollution; but after we have killed out the disease germs it does not make any difference if the other germs grow, so we pay particular attention to the disease germs, using the B. coli as an index, and if we get those down we are not worried by any subsequent growth which may occur in the reservoir.

MR. EDWARD BARTOW.* I should like to ask either Dr. Otis or Mr. Phelps whether they have any definite knowledge of detrimental results from the use of the amount of bleaching powder ordinarily used. Mr. Phelps suggests other disinfectants, and I thought possibly he had in mind some definite detrimental effects of bleaching powder. He suggests also the possibility of a controversy, perhaps something like the alum in baking powder controversy, which may arise concerning bleaching powder, and I should like to know whether there is any ground for any such a controversy.

DR. OTIS. I should like to say, in regard to the Poughkeepsie filters, that we have had no subsequent bad results. In fact, we have never found any chlorine in our filtered water.

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Mr. Phelps. I regard the possible ill effects as imaginary rather than real, but there seems to be in this respect a wide gap between the practical water-works men and the people who consume the water, and we all know how easy it is for a line of kicks to get started at the water-works office when some suggested change has been published before the change has been brought about. The kind of thing I have in mind is merely that popular clamor which we all know the force of, however ill founded it may be.