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THE APPLICATION OF OZONE TO THE PURIFICATION OF SWIMMING POOLS.[1]

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Recirculation and disinfection of swimming pool water may now be accepted as standard and mutually interdependent procedures in the sanitary control of plunge baths. Experimental data[2] collected during the past several years have demonstrated beyond doubt the necessity of resorting to refiltration to aid in swimming pool purification unless fresh, warm, well-filtered water is constantly supplied to the pool. In the latter process the waste of water, and of coal for heating it, coupled with the difficulty of removing all suspended matter by an initial filtration are sufficient reasons for adopting refiltration of the pool water as a standard procedure. A clear water is essential not mainly because of esthetic reasons but for the reduction of the hazard of drowning. No method in actual practice measures up to refiltration.

Concerning the methods of disinfection, the writer has already set forth[3] the data and conclusions from a comparative study of all the chemicals hitherto applied to pool water purification. Ultraviolet light in actual operation was not considered a sufficiently powerful germicide. Copper sulphate was expensive in application and unreliable unless large quantities were employed, at which time the water became disagreeable to swim in. Furthermore, the transparency of the water was impaired and the tile lining of the pool stained, entailing additional labor in cleaning the pool.

Chlorine compounds, calcium hypochlorite, sodium hypochlorite, and gaseous chlorine, while effective to a marked degree as disinfectants, required, for satisfactory use in swimming pools, a type of technical control usually not available. A study of the practical application of these chemicals to swimming pool purification has demonstrated in the large majority of pools that either the quantity added was

[1] From the Research Laboratory of the Department of Health of New York City.

[2] Am. Phy. Ed. Rev., 1912, 17, p. 669; Jour. Inf. Dis., 1914, 15, p. 159; U. S. Pub. Health Rep., Sept. 17, 1915 (reprint No. 299); Jour. Inf. Dis., 1917, 20, p. 1; Jour. Am. Soc. Promote Hyg. & Pub. Baths, 1918, vol. 1, p. 19.

[3] Jour. Inf. Dis., 1917, vol. 20, No. 1, p. 1.

insufficient to effect proper bacterial reduction or that the water had a disagreeable odor and taste due to the pressure of an excess of the reagents. It is difficult to strike a nice balance between odor and taste on the one hand and bacterial purity on the other in the case of chemicals usable only in minimum quantities.

In consequence of the disadvantages attending the use of the common chemicals for water purification when applied in swimming pools the writer decided to attempt the application of ozone for this purpose.

The application of ozone to water purification presents no novelty. Vosmaer [1] in his comprehensive treatise gives no less than one hundred and fifty-one references to literature on this subject. According to Spaulding [2] there are forty-nine large ozone plants abroad, having a daily water delivery capacity of over 84,000,000 gallons. The plant in Petrograd alone, delivers 24,000,000 gallons a day and the plant at Paris over 12,000,000 gallons a day. Rosenau [3] in a summary of this question states: "Ozone is one of the most satisfactory methods of purifying water from a sanitary standpoint. As a germicide it is the most effective of all methods used, except boiling. A well-ozonized water is practically sterile and the organic matter is partially oxidized. It is true that a few resisting spores are not killed, but these are harmless when taken by the mouth."

The writer first applied ozone to the purification of a miniature pool. He concluded from his experiments [4] that ozone efficiently purifies water if proper contact of ozone and water be effected; that the application of ozone to pool water is automatic in its control and reliable in disinfecting pools. Furthermore, it can be added without objectionable result in any excess, since it is not very soluble in water. It oxidizes most of the organic matter in the water and is inexpensive in application.

As a result of these preliminary tests, the writer, in an effort to determine the applicability on a large scale, secured the installation of a large ozone plant at the Twenty-third Street Bath, New York. The following data have been gathered from tests on that installation.

Details of Installation.

The writer soon found out in his preliminary experimental work on ozone [4] that the engineering details connected with the application of ozone on a large scale are of paramount importance. The most important feature in the application of ozone to water is the securing of a thorough mix of ozonized air and water. No doubt the action of

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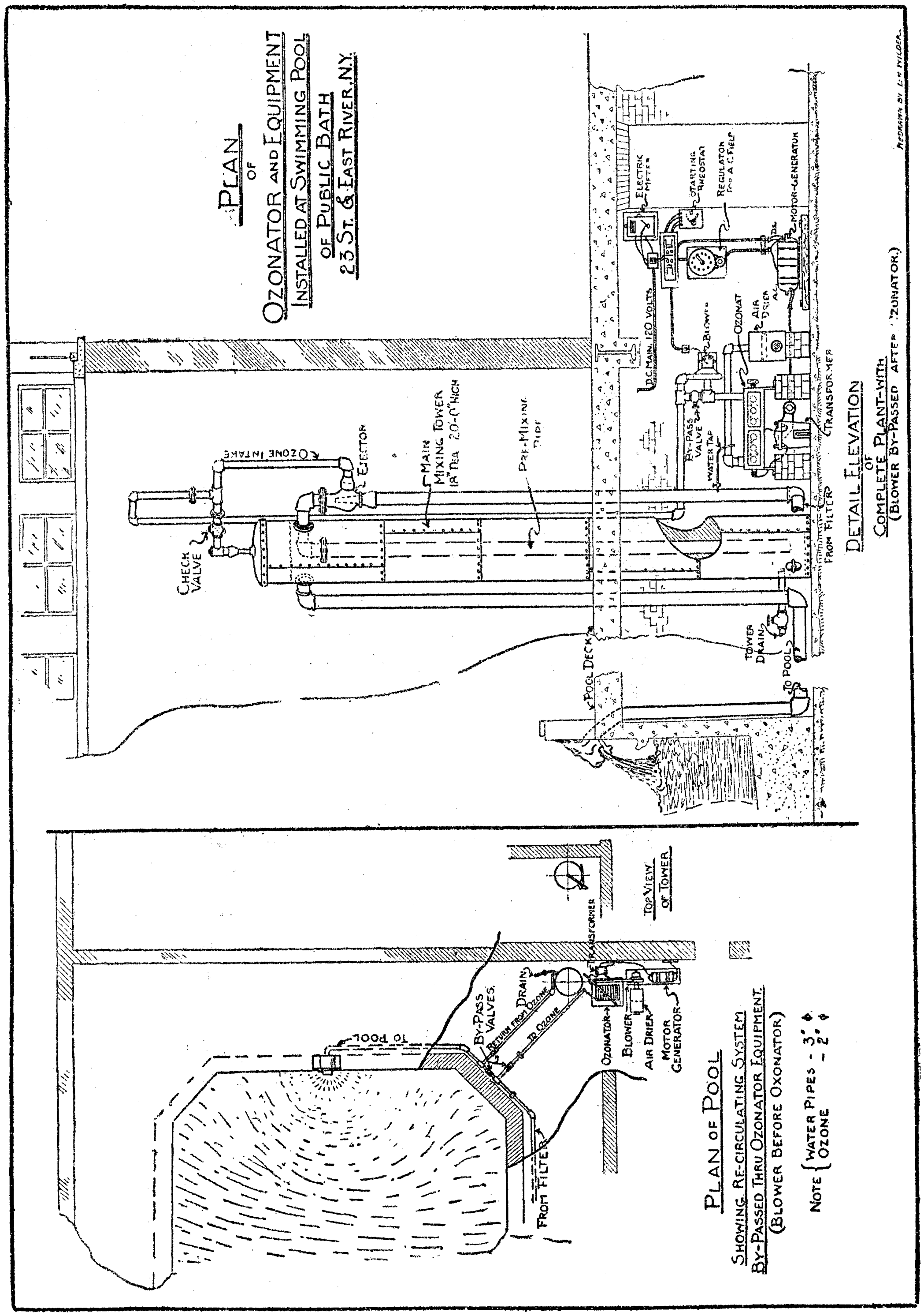
1 Vosmaer "Ozone" D. Van Nostrand Co., 1916.

2 Spaulding: "Report on Application of Ozone to Water Purification," N. Y. State Dept. of Health, 1913.

3 Preventive Medicine & Hygiene, D. Appleton, 1913, p. 794.

4 "Ozone Disinfection of Swimming Pools," Journal of the American Assn. for Promoting Hygiene & Public Baths, 1918, Vol. 1, No. 1, p. 19.



PLAN OF OZONATOR AND EQUIPMENT INSTALLED AT SWIMMING POOL OF PUBLIC BATH 23 ST. & EAST RIVER, N.Y.
OZONE INTAKE
EJECTOR
CHECK VALVE
MAIN MIXING TOWER 18" DIA 20-0" HIGH
PRE-MIXING PIPE
D.C. MAIN, 120 VOLTS
ELECTRIC METER
STARTING RHEOSTAT
REGULATOR FOR A.C. FIELD
MOTOR-GENERATOR
BLOWER
OZONAT
AIR DRIER
BY-PASS VALVE
WATER TAP
TRANSFORMER
FROM FILTER
TOWER DRAIN
TO POOL
POOL DECK
DETAIL ELEVATION OF COMPLETE PLANT WITH (BLOWER BY-PASSED AFTER OZONATOR)
TO POOL
BY-PASS VALVES
DRAIN
RETURN FROM OZONE
TO OZONE
TRANSFORMER
OZONATOR
BLOWER
AIR DRIER
MOTOR GENERATOR
FROM FILTER
TOP VIEW OF TOWER
PLAN OF POOL
SHOWING RE-CIRCULATING SYSTEM BY-PASSED THRU OZONATOR EQUIPMENT (BLOWER BEFORE OXONATOR)
NOTE { WATER PIPES - 3" ϕ OZONE - 2" ϕ

ozone on bacteria and organic matter is exceedingly rapid, as was evidenced by the preliminary work, but if the time of exposure of the water to the ozonized air is short, three parts per million of ozone (which is at least three times the necessary quantity) are required to obtain satisfactory results. A mechanical mixer was designed to insure intimate contact of the gas with water, but this was abandoned for the simpler and surer method recommended by Vosmaer, namely, the use of a tall tower.

It was finally determined to install a 20-foot tower in the Twenty-third Street Bath and to pass the water of the swimming pool into the bottom of this tower after filtration. If this tower is constructed so that the top is on a level with the surface of the pool, there is practically no additional cost in the operation of the recirculation system.[1]

Two systems of introducing the ozone into the water were installed at the same time so as to ascertain their relative merits. One was the use of a common ejector (see diagram) and the other the use of a small centrifugal air blower. The ozonized air is introduced into the pipe leading down through the center of the tower, where both water and ozone are liberated. The ozone, of course, bubbles through the water quite rapidly, the water (in its slower upward passage) being thus brought continuously into contact with fresh ozone. The ozonized water is then drawn off from the top of the tower and returned to the shallow end of the pool.

It was found when the circulating pump was stopped that water backed down into the ozonator. The air in the pipe which carries both air and water into the bottom of the mixing tower rises and carries the water with it. By a special arrangement[2] of pipes and valves, the water and ozone from this pipe are returned to the mixing tower (see diagram).

Bacterial Data.

The bacterial counts in this pool were so low after continuous operation of the ozone machine, that it was deemed advisable to add a large number of *B. coli* to the water in order to observe the efficiency of ozone on heavily polluted water. Accordingly a mass culture of *B. coli* was emulsified in salt solution and thrown into the pool. In order to secure thorough mixing of the bacteria with the pool water and to keep the pollution high, the circulating pump was shut down between 10 a. m. and 2 p. m., a long-handled brush was used to stir the water, and this, together with the agitation produced by the bathers, resulted in a uniform mix. The pool was then operated as usual and 2 hours later the tests were made.

[1] The writer is indebted to Mr. S. Palmer for many practical suggestions and for the accompanying drawings which set forth the details of installation.

[2] I am indebted to Mr. Willard A. Kitts, jr., for the ingenious solution of this problem.

ONE PART OF OZONE PER MILLION OF WATER.

(NOTE.—All bacterial counts are averages of three or more determinations.)

Using ejector:

Bacterial count in the artificially infected pool, 3,700 per cubic centimeter.
After filtration and before ozonation, 1,850 per cubic centimeter.
After ozonation, no growth in 1 cubic centimeter.
After ozonation, no growth in 3 cubic centimeters.

In addition to plating one cubic centimeter of the water delivered from the ozone tower, three cubic centimeter samples were plated as well. In the majority of cases no growths were obtained.

Using blower:

Pool water in the artificially infected pool, 3,500 per cubic centimeter.
After filtration and before ozonation, 1,540 per cubic centimeter.
After ozonation, no growth in 1 cubic centimeter.
After ozonation, no growth in 3 cubic centimeters.

The results, using the blower, are identical with the foregoing. We conclude therefore that when one part per million of ozone is used, either with an ejector or with a centrifugal blower (which delivers more air) the pool water artificially contaminated with *B. coli* is sterilized.

USING 0.5 PART OZONE PER MILLION OF WATER.

The foregoing results were so striking that it was determined to cut down the amount of ozone supplied to the pool to ascertain the safety factor allowed when supplying one part of ozone per million of water. For this purpose the output of the ozonator was reduced to one-half by removing three of the six tubes.

Using ejector:

Count from pool (artificially infected), 2,700 per cubic centimeter.
After filtration and before ozonation, 1,580 per cubic centimeter.
After ozonation, 1⅓ colonies per cubic centimeter.
After ozonation, 1 to 3 colonies in 3 cubic centimeter samples.

When using half part of ozone per million of water and introducing the ozone by means of the ejector, the contaminated pool water was delivered in a relatively pure condition. A pool operated in this way, using half the quantity designed, while not delivering entirely sterile water, would be sufficiently pure for all practical purposes.

Using blower:

Count from pool (artificially infected), 3,020 per cubic centimeter.
After filtration and before ozonation, 1,150 per cubic centimeter.
After ozonation, 130 per cubic centimeter.

When the blower was used a larger number of bacteria escaped destruction. This was due, in the writer's opinion, to the larger quantity of air introduced into the ozonator, resulting in a dilution of the ozone, and to the more rapid escape of the gas from the water.

A noticeable odor of ozone is observed when the blower is used, indicating that the ozone escapes without a sufficient opportunity of mixing with the water. The conclusion is reached, therefore, that the use of a turbine blower is inferior to that of an ejector, and that a great dilution of ozone in air is a disadvantage.

Cost Data.[1]

The installation cost in normal times would probably be at the rate of about 3 cents a gallon of capacity of the swimming pool. This cost will naturally vary from time to time with the cost of labor and materials. The electrical current consumption when using alternating current is 2 kilowatts per day, which amounts to from 10 to 14 cents if the cost of current varies between 5 and 7 cents per kilowatt. To this should be added 1 cent a day for the maximum cost of replacing the calcium chloride in the air dryer. The total daily cost of operation with alternating current for 60,000 gallons of water is between 11 and 15 cents. If direct current is supplied, a motor generator must be used, increasing the cost by from 10 to 15 cents a day (2 kilowatts). These figures are based upon local prices of electrical current. In plants where electrical current is generated on the premises, the cost, already very low, will be brought down still more.

The plant when once installed and adjusted is automatic and requires practically no care. The water is bleached, gradually assuming a transparent blue color, enhancing the appearance of the pool and decreasing the hazard from drowning. There is no occasion for renewal of the water, which can be retained for an indefinite period in a pure state.

The cost of water in New York City is at the rate of $1 per 1,000 cubic feet; thus, to fill the pool costs $8 for water alone. To heat the water during the cold season from the temperature in the main to that of the pool requires an average expenditure of 3 tons of coal, costing about $18. The cost of labor for cleaning the pool is about $4.[2] The total cost is about $30. By using the ozone system the saving in the course of a short time will make up for the cost of the installation, while maintaining a clean and safe pool.

The above operating and installation costs are estimated on the basis of one part of ozone per million parts of water, which under the average conditions that obtain in swimming pools allows 100 per cent safety factor in water sterilization.

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[1] The writer is indebted to Mr. G. S. Eble, engineer in charge of baths of the borough of Manhattan, for many of the figures on cost.

[2] In municipal pools, while there would probably be no reduction of the pay roll on account of other duties to which the attendants could be assigned, nevertheless a labor saving of at least $4 is effected. Three attendants are occupied for about two and one-half hours in scrubbing out the pool.