

## THE CHEMICAL STERILIZATION OF PUBLIC WATER SUPPLIES

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Probably 60 per cent of the population of the United States is enjoying the health protection which comes from the use of sterilized water supplies. Assuming an average per capita daily consumption of 100 gallons, it follows that there must be the collection, filtering, often the softening, the sterilization and distribution through an intricate system of underground conduits at a fairly constant pressure, of approximately seven and one-third billion gallons daily. Here is a triumph of science and engineering of which the consuming public is scarcely aware, and whose attention is called to the quality of the product only on those rare occasions when an unusual taste or odor is found in the supply. Its bacterial quality is such that over long periods of time not a single organism may be found in a ten cubic centimetre portion. This service is rendered at a cost of approximately one cent per day per person.

The wholesale sterilization of water supplies in the United States began about 1910. Nowhere is the efficacy of the process more evident than in the decline of deaths from typhoid fever which is so generally a water-borne disease. In 1910 the rate per 100,000 of population in the United States was 22.8, in 1920, 7.6, and in 1930, 5 (1).

In terms of human lives saved, these figures mean a yearly conservation of 21,894 and the number who have yearly escaped the disease is probably five times as great. That this saving in human life and suffering can largely be attributed to sterilized water supplies is shown in the case of the city of Milwaukee (2). In 1916, the sterilization of lake water with chlorine was discontinued for a period of eight hours. There resulted 50,000 or 60,000 cases of gastro-intestinal trouble and within the next few weeks 400 or 500 cases of typhoid fever with 40 to 50 deaths. Again, the city of Olean, New York (3), having a population of 21,600 had an outbreak of the disease in 1928, traceable to faulty operation of the city's water sterilization equipment, in which there were 248 cases and 25 deaths. The city was empowered to issue \$425,000 in bonds to cover its liability. Merchants estimated a loss of \$200,000 in business while \$125,000 was expended on improvements in the waterworks, making the total water bill for the city \$750,000, which is a per capita cost of \$34.80.

In Illinois where 52 per cent of the inhabitants use chlorinated water, it is clearly apparent that regions of high population have low rates, while rural areas have high rates.

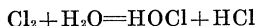
*Typhoid Fever in Illinois in 1931 (4)*

Part of State	Population	Cases	Deaths	Rates	
				Case	Death
Northern (33 counties)...	5,648,608	223	29	3.9	0.5
Central (35 counties)....	1,150,547	158	25	13.7	2.2
Southern (34 counties)...	985,485	423	73	42.8	7.4
Total.....	7,784,640	804	127	10.3	1.6

It is to be observed that 12.7 per cent of the population, that of the 34 southern counties, had 52.6 per cent of the cases and 57.5 per cent of the deaths from the disease in the state.

In 1896, G. W. Fuller (5) applied chloride of lime to the raw water supplying the city of Louisville, Kentucky. A similar treatment was given the water supply of Maidstone, England, in 1897, and similar experiments were started five years later in Belgium. The animals in the Union Stock Yards, Chicago, in 1908, were given water from Bubbly Creek containing chloride. Ten years later the city began the chlorination of the public supply. In the last two decades the process has been perfected and has been extended so rapidly that the world traveller need never be far beyond its protective influence.

At the present time liquid chlorine is almost universally used. The liquid gasifies and then is carried into the water at a predetermined rate dependent upon the degree of pollution of the raw water. The fundamental chemical reaction is believed to be that in which hypochlorous acid is produced.



The hypochlorous acid is believed to be the sterilizing agent. In addition to this function the chlorine may chlorinate such materials as amino acids, unsaturated compounds and phenol bodies, if present in the water, while oxidizable substances such as aldehydes, ferrous and manganous salts, and hydrogen sulfide may be acted upon by the hypochlorous acid. These reactions necessitate an increase in the dosage in order to insure a high degree of sterilization. This may mean the application of two or more parts per million in order to obtain a residual amount of 0.2 or 0.3 parts per million. With chlorine selling at four cents a pound a dosage of 5 parts per million represents a cost of but \$1.70 per million gallons, which means a per capita cost of about six cents yearly. In addition to its bactericidal value, chlorination prevents algae growths on filters and clarifying units at the water plant, thus increasing their usefulness.

#### THE PROBLEM OF TASTES AND ODORS

Chlorination of water containing organic materials frequently produces derivatives that have marked and disagreeable tastes and odors. Chlorinous tastes are produced by an excess of free chlorine, and chlorophenolic tastes result from the chlorination of phenolic bodies. The latter tastes and odors are much more pronounced and are, therefore, a more frequent cause of trouble. Thus, chlorinated ortho hydroxy benzaldehyde can be detected by taste to the extent of one part (6) to 1000 million parts of water, while the product arising from ordinary phenol is detectable one part to 100,000 million. The chlorophenolic tastes in the water of the south side of the city of Chicago are attributed to phenolic wastes poured into the lake at South Chicago and adjacent points. Phenols in stored water may also arise from decomposition of organic materials.

*Taste prevention by use of chloramines.*—In order to prevent the action of chlorine on organic substances present in the water, the practice has arisen of feeding both chlorine and ammonia to the water thus producing chloramines which are odorless, tasteless, and non-toxic to human beings, but more effective as germicides than chlorine, although somewhat slower in action.

The reactions involved are as follows:

- (1)  $\text{Cl}_2 + \text{H}_2\text{O} = \text{HOCl} + \text{HCl}$
- (2)  $\text{NH}_3 + \text{H}_2\text{CO}_3 = \text{NH}_4\text{HCO}_3$
- (3)  $\text{HOCl} + \text{NH}_4\text{HCO}_3 = \text{NH}_2\text{Cl} + 2 \text{H}_2\text{O} + \text{CO}_2$
- (4)  $2 \text{HOCl} + \text{NH}_4\text{HCO}_3 = \text{NHCl}_2 + 3 \text{H}_2\text{O} + \text{CO}_2$
- (5)  $3 \text{HOCl} + \text{NH}_4\text{HCO}_3 = \text{NCl}_3 + 4 \text{H}_2\text{O} + \text{CO}_2$

According to Chapin (7), the predominating reaction is determined by the hydrogen-ion concentration of the solution. Thus at a pH of 8.5 (1) the product is 100 per cent monochloramine (reaction (3)), while at 4.4 it is entirely dichloramine, (reaction (4)). Below 4.4, seldom met in water practice, reaction (5) sets in.

The formation of the mono- and di-chloramines through the use of ammonia saves the chlorine used in the treatment from being consumed by the organic matter, thereby preventing undesirable tastes and odors, and permits the carrying of a desirable chlorine residual of 0.2 or 0.3 parts per million for a longer time in the distributing system. In practice the ammonia dose is about one-half the chlorine. Recently the use of ammonium sulfate instead of ammonia has been adopted at certain plants.

*Taste and odor removal by active carbon.*—Charcoal has long been supposed to be highly efficacious when used as a filtering agent for the improvement of water. Ordinary, or non-active carbon has been found to have a phenol absorptive capacity of but one per cent of that of highly active carbon. For water treatment the carbon is finely powdered and of great absorptive surface. Garner, McKie and Knight (9) report that one cubic foot of active carbon, weighing 10 pounds, has a surface area of 3,000,000 square feet. It is fed into the water by means of a dry feed mechanism at the rate of about five parts per million parts of water or 42 pounds per million gallons at a cost of \$2.10. The carbon is applied, of course, ahead of the filters. Such material furnishes inexpensive insurance against undesirable tastes and odors, while the application is so elastic that seasonal trouble may be taken care of. Such treatment is also of high value because the quality of the water holds the confidence of the public. Sterilization, accompanied by undesirable tastes and odors, in a considerable measure defeats its own purpose, but with the undesirable qualities removed it becomes a great human blessing.

Thus, through the combined efforts of science and engineering, one of the essentials of human existence, water, is practically no longer a vehicle for the spread of contagious diseases. The value of this in promoting public health is immeasurable.

#### BIBLIOGRAPHY

- (1) U. S. Public Health Reports.
- (2) TURNEAURE and RUSSELL, Public Water Supplies, 3rd Ed. p. 169. John Wiley and Sons.
- (3) DEAN, A. S., The Olean City Epidemic of Typhoid Fever in 1928. Am. J. P. H. and Nation's Health, 21:390 (1931).
- (4) Report from the State of Illinois, Department of Public Health.
- (5) COHN, Chlorination of Water. Municipal Sanitation, 2:333 (1931).
- (6) ADAMS, B. A. Substances Producing Taste in Chlorinated Water. Water and Water Engr., 33:109 (1931).
- (7) CHAPIN, J. Am. Chem. Society, 51:2112 (1922).
- (8) BAKER and SCHMELKES, Research Publication 305 p. 4, Wallace and Tiernan Co. Inc. Newark, N. J.
- (9) GARNER, W. E., MCKIE, D. and KNIGHT, B. C.. The Area of the Internal Surface of Charcoal as Determined by the Absorption of the Normal Aliphatic Alcohols from Aqueous Solution. J. of Physical Chem. 31:641 (1927).