Chlorine Chemistry: Safer Water for Over 100 Years

On a mild, early fall day in September, 1908, a water treatment operator at New Jersey's Boonton Reservoir performed a task that would become routine for the next 100 years. He added a chlorine disinfectant to the Jersey City water supply to destroy waterborne germs. It was the first time chlorine chemistry would be used to disinfect the drinking water of an American city. A public health revolution was about to begin.

Gate Houses and Chlorination Plant at Boonton Reservoir *circa* 1908 (The chlorination plant is the building at the center.) *Photo courtesy of Keith Wood, Watershed Superintendent, United Water Jersey City*

By the 1920s, most U.S. city dwellers were drawing chlorinated water from their taps, and rates of waterborne diseases, such as typhoid fever and cholera, were plummeting. It is no wonder that 100 years after its first use in Jersey City, the U.S. Centers for Disease Control and Prevention calls drinking water chlorination one of the most significant public health advances in U.S. history.

Smart Chemistry in Action

Drinking water chlorination represents a smart use of chemistry in our everyday lives. Small amounts of chlorine disinfectants added to comparatively huge volumes of water help destroy germs, including bacteria and viruses that once killed thousands of people every year. Historians include Alexander the Great, ruler of most of the known world 1,000 years ago, and Willie Lincoln, the beloved 11-year old son of President Abraham Lincoln, among the millions of victims of waterborne diseases.

According to the American Water Works Association (AWWA), 98 percent of modern U.S. water treatment facilities use chlorine disinfectants to disinfect drinking water. Chlorine disinfectants are enormously popular not only because they destroy most waterborne germs, but because they are the only disinfectants that provide protection from recontamination as water flows from the treatment plant to consumers' taps. That is why the U.S. Environmental Protection Agency requires that all water systems that treat drinking water maintain a residual level of chlorine throughout their water distribution systems.

Click Here to View a Chart on U.S. Typhoid Fever Rates (1920-1960)

Chlorine Disinfection Chemistry

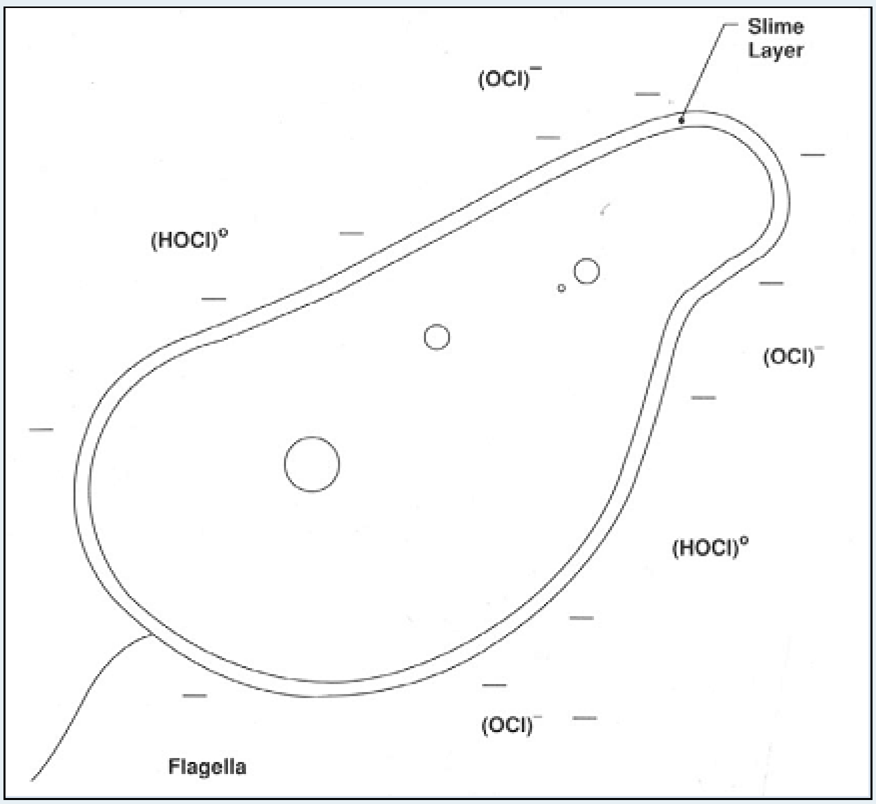
Chlorine can be added to drinking water in any one of three states of matter: solid, liquid or gas. "Chloride of lime," a solid called calcium hypochlorite, was the first chlorine disinfectant used to treat Jersey City drinking water. Sodium hypochlorite, the active ingredient in chlorine bleach, is a liquid and elemental chlorine is a gas. When each of these substances is added to water, a great germ-buster, known as "free chlorine," is released.

How Does Drinking Water Chlorination Work?

When chlorine disinfectants are added to water, “free chlorine” is formed—a combination of hypochlorous acid and hypochlorite ion. While hypochlorous acid carries no electrical charge, hypochlorite ion carries a negative one. Of the two substances, hypochlorous acid is the more potent disinfectant.

The pH, or the relative acidity of water, determines the ratio of hypochlorous acid to hypochlorite ion. Water treatment operators can adjust the pH during water treatment to make hypochlorous acid levels dominate hypochlorite levels.

Another reason to maintain a predominance of hypochlorous acid during water treatment has to do with the fact that germ surfaces carry a natural negative electrical charge. For that reason, hypochlorite ion is repelled in the vicinity of germ surfaces, while hypochlorous acid can easily penetrate those surfaces. Favored by lower pH conditions, and its own electrical neutrality, hypochlorous acid pierces the barriers of germ slime coatings and resistant layers, destroying these microscopic agents of disease.



A typical bacterium with a negatively charged slime coating can be penetrated by hypochlorous acid $(HOCl)^o$, but not by the negatively charged hypochlorite ion $(OCl)^-$.