Use of Chlorine as a Drinking Water Disinfectant

Water sometimes contains **microbial contaminants**, mud, silt, and dissolved minerals that must be removed before human consumption. Water suppliers remove those and other impurities using a variety of treatment and filtration processes before providing water to consumers. To ensure that the water is safe to drink, water treatment plants usually disinfect it with a chemical agent or ultraviolet light. Because **chlorine** is very effective and relatively inexpensive, it is the most commonly used disinfecting agent (98 percent of U.S. water utilities that disinfect drinking water use chlorine). In addition, only chlorine-related disinfectants leave a **residue** that protects the water from recontamination as it travels from the treatment plant to the consumers' tap. This protection is particularly important in older U.S. cities where drinking water distribution pipes are corroded and damaged.

How Does Chlorine Disinfect Drinking Water?

Chlorine dissolves when mixed with water and forms hypochlorous acid:

$Cl_2 + H_2O \rightarrow \mathbf{HOCl} + H^+ + Cl^-$

Hypochlorous acid (HOCl) is the agent responsible for killing disease-causing organisms in water.

The treatment of drinking water with chlorine has been a common practice in the United States since about 1908, when it was first added to public drinking water in Jersey City, New Jersey. As the use of chlorine as a water disinfectant spread across the United States and Canada, there was a dramatic decrease in the number of deaths caused by cholera and typhoid. To illustrate this change, the death rate from typhoid fever was 44.2 deaths per 10,000 people in Toronto before chlorination was introduced in 1910. By 1928, the death rate had dropped to 0.9 deaths per 10,000 people. By the mid-20th century, the incidence of many waterborne diseases had dropped to almost zero.

As a result of such advances, most people in the United States and Canada take safe drinking water for granted. However, around the world, some 25,000 people die every day as a result of diseases associated with unsafe water. Many of those deaths could be avoided with better protection in drinking water. The World Health Organization, in its *Guidelines for Drinking Water Quality*, notes that "disinfection is unquestionably the most important step in the treatment of water for public supply."

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Use of Chlorine as a Drinking Water Disinfectant

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In the early 1970s, scientists discovered the formation of **disinfection by-products** (DBPs). Disinfection by-products form as a result of the combination of a chemical disinfectant and organic matter present in the water. The pH, temperature, and concentration of chlorine, bromine, and organic nitrogen in the water influence the concentration of DBPs formed. Most of the research conducted so far has focused on by-products formed from chlorination (including trihalomethanes, haloacetates, and aldehydes) that may be **carcinogenic.** In 1979, under the Safe Drinking Water Act, the U.S. Environmental Protection Agency (EPA) set a maximum contaminant level for total trihalomethanes (THMs) at 100 parts per billion (ppb) for surface water systems serving more than 10,000 people. Since then, it has been recognized that THMs are not the only potentially carcinogenic disinfection by-products. Consequently, the EPA is revising disinfection by-product regulations to include compounds other than THMs. At the same time, however, the EPA is paying careful attention to be sure the new regulations maintain control of microbial contaminants.

Formation of Disinfection By-Products (DBPs) From Chlorination

$HOCl + NOM \rightarrow$ THMs and other DBPs

NOM = natural organic matter, THM = trihalomethanes

Because of the great variability in the concentration of organic material and chlorine in any given water supply, direct correlation between those factors and any health effect is difficult. In addition, a large number of factors have an impact on the health of any individual. **Epidemiological data** *suggest*, but do not *prove*, that chlorine and chlorine disinfection by-products may increase the incidence of certain cancers in humans. Additionally, there is no conclusive evidence that disinfection by-products cause adverse health effects at the concentrations found in drinking water supplies.

Despite the inconclusive results regarding the health effects of chlorination, alternative disinfection methods have been examined. However, when one considers the different disinfection options, it is important to remember that all chemical disinfectants (including chlorine, chlorine dioxide, and ozone) are reactive and produce reaction by-products. For example, the principal by-products that occur from ozonation of drinking water include aldehydes, acids, and brominated by-products such as bromate, which may also be carcinogenic. Additional factors to consider include the cost of implementing an alternative method, its effectiveness at controlling microbial disease, and its technical feasibility.

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Use of Chlorine as a Drinking Water Disinfectant

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