Drinking Water Disinfection: Options and Hazard Management

By Kelly A. Reynolds, MSPH, PhD

Drinking water disinfection is essential for the elimination of microbial contaminants. Several disinfectant options are available depending on the need for primary (typically stronger agents for initial water treatment) or secondary (agents with the ability to maintain a residual concentration) treatment to inactivate pathogens and inhibit growth in distribution systems, respectively. Consideration of treatment needs, target resistance and the production of harmful byproducts drives the need to balance disinfectant applications in municipal, bottled and POU water treatment.

Disinfection needs and options

Microbial contaminants in drinking water are estimated to cause 19 million infections in the US per year.[1] Federal regulations require that the quality of drinking water cause no greater risk than one infection per 10,000 persons per year. To better achieve this goal, disinfecting treatments are frequently used in the multi-barrier approach to water treatment. The most popular disinfectants for municipal water treatment include chlorine, chlorine dioxide and chloramines. At or near the point of use, ozone and ultraviolet are commonly used.

Chlorine is an effective disinfectant and powerful oxidizer. The first routine use in municipal drinking water treatment was in 1908. The process was largely responsible for the dramatic decrease in epidemic illnesses, such as typhoid, cholera and dysentery, and is considered one of the greatest public health achievements of the 20th century.[2] Benefits of low cost, easy availability and strong efficacy have sustained the use of chlorine in water treatment. Chlorine dioxide is a more effective microbial disinfectant compared to chlorine but levels rapidly decrease over time. This is problematic for municipalities, given that residual disinfectant does not persist to protect supplies during normal storage and distribution. Chlorine dioxide is also more expensive and more difficult to store and produce compared to chlorine.

Ozone gained popularity in water treatment in the 1970s when the discovery of potentially harmful chlorine DPBs surfaced. Later, ozone was also found to be more effective against generally chlorine-resistant protozoan pathogens, such as *Cryptosporidium*. Although not able to maintain a residual during storage and distribution, ozone was useful for the removal of organic and inorganic matter, pesticides, taste and odor constituents, and other water pollutants. When used as a precursor to chlorine, less chlorine disinfectant is needed. Chloramines have been increasingly used as a secondary disinfectant to maintain a residual concentration during piped distribution. Although not powerful enough to be used as a single, primary disinfectant, chloramine can help to reduce the concentration of primary disinfectant needed and is often used in combination with chlorine.

Health concerns

If not properly maintained, excessive amounts of chlorine and chloramines in drinking water (i.e., above regulated levels) can lead to irritation of eyes and mucous membranes and cause stomach upset. Further, exposure to chlorine dioxide or chlorite byproducts above regulated levels has resulted in respiratory problems and nervous-system effects in children, fetuses and pregnant women.

US EPA sets legally enforceable standards known as the maximum residual disinfectant level (MRDL) to guide facilities on acceptable levels of disinfectant concentrations in finished water supplies. Permissible levels of chlorine and chloramine are four ppm as an annual average. The chlorine dioxide MRDL is 800 ppb.[3] Utilities monitor supplies to ensure regulated maximum values are not exceeded and must report any violations to US EPA and consumers within a specified time (24 hours for chlorine dioxide and no more than 30 days for chloramine and chlorine). The more worrisome effect from chlorine exposures, however, follows the interaction between chlorine or chlorine dioxide and other naturally occurring compounds (such as organic matter) in water to produce harmful DPBs. One well known group of chlorine DPBs is total trihalomethanes, which may cause an increased risk of cancer and reproductive and development disorders.

Although ozone does not create trihalomethanes during drinking water treatment, it does form bromate and other DPBs that are thought to be harmful. Ozone-related DBP health effects and control strategies are not as well understood. Bromate formation, for example, can be influenced by bromide ion concentration, temperature and pH of the source water, concentration of ozone and disinfectant contact time. Increased cancer risks have been detected in laboratory animals but long-term effects in humans are uncertain. The maximum level of bromate permitted in drinking water is 10 ppb.

To address DBP concerns, US EPA's *Disinfectants and Disinfection Byproducts Rule* sets regulatory requirements for reducing DBP health risks in community water systems using disinfectants other than UV light. Regulated DBPs include total trihalomethanes (bromodichloromethane, bromoform, dibromochloromethane, chloroform), haloacetic acids (dichloroacetic acid, trichloroacetic acid, chloroacetic acid, bromoacetic acid, dibromoacetic acid), bromate and chlorite. According to US EPA, the most recent additions to the *Disinfectants and Disinfection Byproducts Rule (Stage 2)* will prevent an estimated 280 cases of bladder cancer each year, of which nearly 73 would have been fatal.[4]

Bottled water and bromate

Ozone is a common disinfectant for bottled water manufacturers and is highly effective for producing a quality product. Proper monitoring and controls, however, are required to ensure bromate concentrations remain below levels suspected to cause adverse health effects.

While DBPs are typcially more of a concern with municipal waters compared to bottled water, several high-profile recalls have occurred. One such event was in 2004 when Coca-Cola recalled ~500,000 bottles of Dansani purified water in the United Kingdom due to bromate levels ranging from 10 to 22 ppb.[5] In 2006, elevated levels of bromate were reported in water bottled by Mayer Bros. Co., distributed under a variety of private labels. Bromate was detected as high as 25 ppb.[6] Few studies have been published surveying the frequency of bromate detection in bottled water. In 2011, The Canadian Food Inspection Agency surveyed 288 bottled water domestic and imported samples, including spring, mineral and purified waters. The vast majority of samples (87 percent) did not contain detectable levels of bromate. Only two percent of the samples (n=6) exceeded the Canadian and US standard of 10 ppb.[7]

As a guidance for the bottled water industry, the US Food and Drug Administration (FDA) issued the *Bottled Water: Residual Disinfectants and Disinfectant Byproducts Small Entity Compliance Guide* in May 2009.[8] This document summarized ozone DBP concerns, acceptable levels and methods for monitoring and compliance assurance. Overall, the risk of bromate exposure in bottled water is thought to be very low.

DPB removal

Uncertainties around source-water quality, disinfectant use, DBP formation potentials and health risks continue to promote the need for better monitoring and control of drinking water, regardless of the source. Understanding the true public health risks is essential to setting meaningful standards for risk reduction. POU devices can be used to remove DBPs with variable efficacy, depending also on the contaminant type. Simple carbon filters installed at the tap or utilized in pour-through pitchers can remove more than 40 percent of DBP, including over 85 percent of THM and HAA contaminants. More research is needed, though, to evaluate DBP exposures and POU benefits.

References

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