perfecting disinfection

By Nathaniel Dunahee

Balancing ozone oxidation with disinfection byproduct mitigation strategies

Clean water is arguably the most important and undervalued commodity in the world. It fulfills the most basic of human services and is required in nearly every aspect of society. Drinking water facilities treat water from lakes, rivers, reservoirs, aquifers, oceans and other sources for human consumption. Multiple treatment processes are required that are customized to the raw water source to remove suspended and dissolved species, including chemicals, metals, natural organic matter and pathogens.

Drinking water disinfection is one of the major public health advances of the 20th century. One hundred years ago, typhoid and cholera epidemics were common throughout American cities. Disinfection was a major factor in reducing these epidemics and is an essential part of drinking water treatment today.

Disinfection Methods

The treatment process must satisfy primary and secondary disinfection requirements. The primary disinfection requirements state that a certain level of disinfectant concentration and contact time must be achieved to inactivate pathogens that may be present in the water. Ranked by ability to kill bacteria, primary disinfectants include ozone, ultraviolet (UV) light, chlorine dioxide, chlorine and monochloramine. The secondary disinfection requirements state that a disinfectant residual must be present in the finished water that leaves the plant to the customers. Water treatment plants provide secondary disinfection using either chlorine or monochloramine to proactively prevent the growth of dangerous bacteria and maintain water quality in the drinking water distribution system.

Most water treatment plants use traditional chlorine for disinfection because it is a low-cost option. Some drinking water plants are willing to consider a more expensive approach for several reasons, including disinfection of chlorine-resistant pathogens, oxidation of emerging contaminants and reduction of chlorine disinfection byproducts (DBPs), such as trihalomethanes and haloacetic acids.

Health officials are becoming increasingly alarmed about the public health impact from drinking water with emerging contaminants, including pharmaceuticals, personal care products, endocrine disrupting compounds, industrial chemicals, agricultural applications and medical products. A variety of pharmaceuticals are finding their way into the environment from flushing unused medication down toilets or from landfill leachate into drinking water supplies. These emerging contaminants are being discovered where they previously had not been detected. While most do not pose an immediate threat due to their low concentrations, some of these compounds were found to be toxic, persistent in the environment and accumulated in the food chain.

Disinfectants react with natural organic matter and inorganic contaminants during treatment to form harmful DBPs. A major challenge for many water suppliers is how to balance the risks between microbial pathogens and DBPs. It is important to provide protection from microbial pathogens while simultaneously decreasing the health risks to the population from DBPs that form during treatment. Many of these DBPs have been shown to cause cancer and reproductive and developmental effects in laboratory animals.

In lieu of traditional chlorine, other forms of disinfection could be used, including ozone, UV light or chlorine dioxide. Ozone typically has been used in water treatment for disinfection, process improvements, and the oxidation of color, taste and odor-causing compounds, industrial or agricultural chemicals and reduced metals. Ozone recently has gained attention for its ability to oxidize a wide variety of emerging contaminants, including endocrine disrupting compounds, pharmaceutical and personal care products, and algal toxins.

The presence of bromide in the raw water supply can complicate the benefits of using ozone and requires a study to determine if bromate formation will be problematic. Ozone can react with bromide to form bromate ions, a suspected human carcinogen that is regulated with a maximum concentration of 10 µg/L.

Bromate Mitigation

Bromate is formed through a series of interactions between bromide, ozone and hydroxyl radicals via three major pathways. Two of these pathways are initiated by a reaction between ozone and bromide to form hypobromite ions, which are in a pH-dependant equilibrium with hypobromous acid. Higher pH results in more hypobromite ions, which can then react with ozone or hydroxyl radicals to form bromate. The third pathway involves the conversion of bromide to bromate and is initiated by the hydroxyl radical, followed by a series of additional reactions. Understanding the primary bromate formation mechanism is required to implement a successful bromate control strategy.

Water with lower pH values will have less bromate formation for two primary reasons. First, at pH values less than 7, oxidized bromide will primarily be in the form of hypobromous acid instead of hypobromite ions, thus decreasing the first two bromate formation pathways. The second reason is that the generation of hydroxyl radicals is reduced, resulting in more stable ozone residuals, limiting the amount of bromate formed through the hydroxyl radical pathway. The increased ozone stability at lower pH values has the added benefit of requiring a lower initial ozone dose to achieve the same level of disinfection as compared to higher pH values.

The addition of ammonia has been shown to reduce bromate formation by reacting with hypobromous acid to form bromamines. The bromine sequestered in bromamines is no longer available to form bromate, thus reducing two of the three major pathways. Ammonia also can exert a free radical demand, thereby reducing the bromate formed through the chemical pathway initiated by hydroxyl radicals, thus reducing the third pathway as well.

The addition of hydrogen peroxide has been shown to be effective in the removal of taste and odor compounds during ozonation through the enhanced production of hydroxyl radicals. Hydrogen peroxide also dramatically increases ozone decay kinetics, thus acting as an effective quenching agent. Utilizing hydrogen peroxide has been shown to increase, decrease or not impact bromate formation depending on the water and treatment goals.

Recent studies by Burns & McDonnell were conducted to replace chlorine with ozone. Disinfection

and oxidation benefits were optimized while reducing bromate formation. Several bromate mitigation strategies were evaluated, including pH adjustment, ammonia addition, hydrogen peroxide, ozone dose and contact time, to achieve disinfection requirements, treatment process improvements, taste and odor reduction, and oxidation of emerging contaminants. The results from each study were used to develop a comprehensive plant expansion report specific to raw water quality and finished water goals. WWD

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