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A drinking water utility's perspective on bromide, bromate, and ozonation

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Abstract

Application of ozone in drinking water treatment plants in the US is growing because of ozone's multiple benefits. Ozone functions as a powerful oxidizing agent and disinfecting agent, it improves finished water quality by reducing turbidity, it reduces the formation of many halogenated disinfection by-products, and it is capable of treating chlorine resistant organisms like cryptosporidia. However, when bromide ion is present, e.g. from the geology, runoff, or sea water intrusion, ozone will convert some of the bromide to bromate depending upon the treatment reaction conditions. Bromate can also be introduced into drinking water as a contaminant in the chlorine used for disinfection. The current maximum contaminant level (MCL) in the USA is 0.010 mg/L, and the maximum contaminant level goal (MCLG) is zero, because of the possibility that bromate may function as a genotoxic carcinogen. The level of the MCL, especially if it is lowered, will significantly impact the ability of many water suppliers to utilize ozone in their water treatment processes and also raise the costs of those applications.

Keywords: Bromide; Bromate; Ozonation; Drinking water; Water utility; Water treatment plant

1. Introduction

The Fairfax County Water Authority (Fairfax Water) is the largest water purveyor in Virginia supplying 1.3 million people and the first utility in the state to utilize ozone in the drinking water treatment process. Located in Northern Virginia within the metropolitan area of Washington, DC, Fairfax Water supplies an average of 137 million gallons per day (MGD, =518.5 million liters per day) to Fairfax, Prince William and Loudoun counties, the Town of Vienna, the City of Alexandria and several large federal institutions within the metro area. Fairfax Water operates four potable drinking water plants with a combined capacity of 260 MGD (984.1 ML/d). The Corbalis Water Treatment Plant (WTP), located in Herndon, VA, is supplied by the Potomac River and has utilized the ozone/GAC process since 2001 with great success. A significant issue to Fairfax Water relative to the ozonation process is the potential to form bromate from bromide inherent in the source waters.

Ozone, in potable water treatment, acts as a very powerful oxidizing and disinfecting agent. It improves finished water quality by reducing filtered water turbidity, reduces the formation of many halogenated disinfection by-products and is capable of treating chlorine resistant organisms like cryptosporidia. However, a significant issue to Fairfax Water and other potable water suppliers relative to the ozonation process is the potential to form

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bromate from bromide inherent in source waters. The current maximum contaminant level (MCL) in the USA for bromate is 0.010 mg/L, and the maximum contaminant level goal (MCLG) is zero, because of the possibility that bromate may function as a genotoxic carcinogen. The level of the MCL, especially if lowered, will significantly impact the ability of many water suppliers to use ozone in their water treatment process.

2. Fairfax Water treatment process

In the FW treatment process coagulant, polymer, caustic soda, and sulfuric acid (for pH adjustment) are utilized, and powdered activated carbon can be added in rapid mix basins. Rapid mixing is followed by three levels of tapered flocculation and parallel sedimentation basins. The sedimentation basins are equipped with solids removal devices that transfer settled residuals to appropriate processing facilities. Ozone is added in ozone contactors prior to filtration through dual media (granular activated carbon (GAC)/sand) filters. After filtration, chlorine, fluoride and caustic soda are added in the filter clearwells and main clearwells. Aqueous ammonia and zinc orthophosphate are added for final treatment in the high lift pump suction wells. The treatment process is illustrated by Fig. 1 (Bonacquisti and Cronin, 2002).

3. Water quality enhancements with ozone

The application of ozone followed by biologically active carbon filtration using GAC at the Corbalis WTP has resulted in improved water quality and overall plant performance. Disinfection by-product (DBP) levels, including trihalomethanes (THMs) and haloacetic acids (HAAs) have been significantly reduced due to settled water ozonation followed by GAC filtration (Bonacquisti and Cronin, 2002). A DBP comparison of Corbalis finished waters was made for the years 2000 (non-ozonated) and 2001 as full-scale ozonation commenced in late December 2000. In every quarter of 2001, TTHMs were significantly reduced. The total yearly average of TTHMs for 2000 and 2001 were 36 and 23 μg/L, respectively. This constitutes a 36% reduction in ozonated distribution system water. Similar results were obtained for HAA5 levels. All quarterly averages are noticeably lower for HAA5s with a 43% reduction realized in 2001 (Bonacquisti and Cronin, 2002).

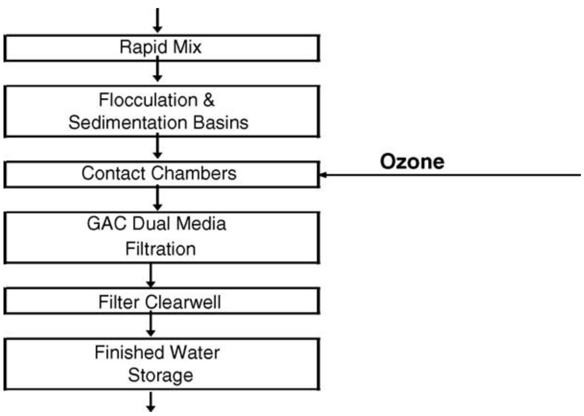

Fig. 1. Corbalis WTP plant flow diagram.

Another water quality enhancement that has been realized since the onset of ozonation at the Corbalis WTP has been the subtle beneficial changes in filter performance. When ozonation is discontinued due to power fluctuations, scheduled maintenance, etc., a noticeable increase in filter effluent turbidities of up to 0.05 NTU has been observed.

4. Bromide/bromate concerns

The presence of bromide in a drinking water source, even at relatively low levels of approximately 100 μg/L, is cause for concern from a drinking water regulatory compliance perspective (Gillogly et al., 2001). It is well known that ozonation of bromide-containing waters can oxidize the bromide ion (Br^-) to bromate (BrO_3^-) within normal water quality treatment parameters (Gillogly et al., 2001; Symons, 1999; Singer, 1999; Glaze and Weinberg, 1999; Jacangelo, 1997; Faust and Aly, 1998).

The U.S. Environmental Protection Agency has, in a negotiated rulemaking process, developed a primary MCL for bromate at 0.010 mg/L in the Stage I Disinfectants and Disinfection By-Products (D/DBP) Rule U.S. Environmental Protection Agency (1998). In addition, the Stage 1 D/DBP rule recommends a maximum contaminant level goal (MCLG) of zero. In recent negotiations for the Stage II D/DBP Rule U.S. Environmental Protection Agency (2003), a 0.005 mg/L bromate MCL was addressed but not adopted. It may be assumed that in future EPA rulemaking, a bromate MCL of 0.005 mg/L or less is a distinct possibility that should be anticipated.

5. Bromide/bromate chemistry with ozone

The bromide ion (Br^-) is defined as "an inorganic ion found in surface water and ground water and caused by (1) sea intrusion, (2) the impact of connate, or (3) industrial and oil-field brine discharge (Symons, 1999)." When oxidized by chlorine (Cl_2 or HOCl) or ozone