Identification and Occurrence of Ozonation By-Products in Drinking Water [Project #510]

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BACKGROUND

Interest in the use of ozone in drinking water treatment plants continues to grow with the imminent prospect of new regulations for disinfection by-products (DBPs). Many utilities employing chlorine as their only oxidant and disinfectant have discovered concentrations of DBPs that may not meet new or future regulations. These DBPs can most easily be removed by pretreatment of the water to remove the by-product precursors before the application of chlorine or by the use of alternative oxidant combinations such as ozone and chloramines.

When ozone is used as a pretreatment prior to final disinfection, especially as a preoxidant in conjunction with chloramines (as the final disinfectant), it produces its own array of by-products. Although ozone by-products are considered less of a potential health hazard than the DBPs produced by chlorine and other disinfectants, there are still questions to be answered. Relatively little is known about the identity of by-products formed by the interaction of ozone with natural water components, and even less has been learned about the occurrence of such by-products in treatment plants employing ozone.

APPROACH

This project consisted of two interconnected components: (1) a laboratory phase, in which methods to analyze targeted ozonation by-products were developed or optimized, and (2) a survey phase, in which ozonation by-products were analyzed in water samples taken from selected treatment plants that utilized ozone.

In the laboratory-scale research, studies were carried out to determine what factors affected the levels of specific classes of ozone by-products. These studies primarily used a local water source (University Lake, Orange County, N.C.) and, in some cases, waters from other supplies in North America. The specific classes of by-products targeted were aldehydes, ketones, carboxylic acids, mixed aldo or keto acids, organic and inorganic brominated by-products, hydrogen peroxide and organic peroxides, and epoxides. Existing analytical methods were improved or new methods were developed to aid in identification and quantitation of these compounds.

The analytical methods developed in this study together with existing methods for analyzing halogenated DBPs were applied in a survey of selected treatment plants in the United States and Canada that use ozone. The selection of the plants was based partially on the variety of the treatment trains and raw water qualities they represented; this variety provided a wide input into the data base on the formation and fate of ozonation by-products.

RESULTS

The plant surveys indicated that the most significant aldehydes formed were formaldehyde, acetaldehyde, the dialdehyde glyoxal, and the keto aldehyde methyl glyoxal. The formation of organic peroxides and hydrogen peroxide was demonstrated for the first time in treatment plants using ozonation. The surveys also provided new data on the formation of bromate and brominated organic compounds when ozone is applied to waters that contain bromide ion. A new group of brominated organic compounds (bromohydrins) was discovered, but the factors that

determine the quantities and fate of these compounds, as well as of other brominated DBPs in distributed water, are not clear.

At selected utilities, this study was also able to monitor the effect of treatment with and without ozone on the formation of chlorination by-products currently regulated or under consideration for regulation. In most of the cases evaluated in this study, the use of ozone reduced the levels of halogenated by-products formed by subsequent chlorination or chloramination and, at the same time, lowered the disinfectant demand. The oxidation by-products of ozone identified in this study can be controlled to some extent by the application of appropriate physical and biological treatment.