

Emerging Health Concerns Related to Water Treatment

Michael J. Plewa, Ph.D.
Elizabeth D. Wagner, Ph.D.

College of Agricultural, Consumer and Environmental Sciences
Department of Crop Sciences
University of Illinois at Urbana-Champaign

Executive Summary

Drinking water utilities provide an exceedingly important public health service through their generation of high quality, safe and palatable tap water. The disinfection of drinking water in public facilities primarily employs chemical disinfectants such as chlorine, chloramines, ozone and chlorine dioxide. These disinfectants are oxidants that convert naturally occurring and synthetic organic material, bromide, and iodide in the raw water into chemical disinfection by-products (DBPs). DBPs are an unintended consequence and were first discovered over 30 years ago. Each disinfection method generates a different spectrum and distribution of DBPs; to date over 600 DBPs have been identified. While reducing the public health risk of acute infection by waterborne pathogens, the unintended generation of DBPs poses a chronic health risk. DBPs represent an important class of environmentally hazardous chemicals that are regulated by the U.S. Environmental Protection Agency (U.S. EPA) and carry long-term human health implications. Epidemiological studies demonstrated that individuals who consume chlorinated drinking water have an elevated risk of cancer. DBPs have been linked to reproductive and developmental effects, including the induction of spontaneous abortions in humans.

Although chlorine has been used for over 100 years in the United States as a water disinfectant, the majority of DBPs present in drinking water have yet to be chemically characterized. With only approximately 30% of the total organic halide identified to specific DBP chemical classes, and a small fraction of these evaluated for their biological and toxicological effects, it is clear that a great deal of work remains in the characterization of DBPs.

A comparative, *in vitro* analysis measured chronic cytotoxicity and acute genomic DNA damage in Chinese hamster ovary (CHO) cells induced by three chemical classes of emerging DBPs. Haloacetonitriles and haloacetamides (nitrogen-containing DBPs) and haloacetaldehydes (carbon-based DBPs) were evaluated such that a rank order of their chronic cytotoxicity to CHO cells was generated. For the haloacetonitriles the cytotoxicity from most toxic to least toxic was dibromoacetonitrile > bromoacetonitrile > \approx iodoacetonitrile > bromochloroacetonitrile > dichloroacetonitrile > chloroacetonitrile > trichloroacetonitrile. The cytotoxicity order for the haloacetamides was diiodoacetamide > iodoacetamide > bromoacetamide > tribromoacetamide > bromoiodoacetamide > bromochloroacetamide \approx dibromochloroacetamide > chloroiodoacetamide > bromodichloroacetamide > dibromoacetamide > chloroacetamide > dichloroacetamide > trichloroacetamide. Finally the order of cytotoxicity for the haloacetaldehydes was tribromoacetaldehyde \approx chloroacetaldehyde > dibromoacetaldehyde > dichloroacetaldehyde >> trichloroacetaldehyde. The induction of genomic DNA damage by these DBPs was quantitatively measured using SCGE analysis. The rank order for the genotoxicity of the haloacetonitriles was iodoacetonitrile > bromoacetonitrile \approx dibromoacetonitrile > bromochloroacetonitrile > chloroacetonitrile > trichloroacetonitrile > dichloroacetonitrile. The

rank order for the genotoxicity of the haloacetamides was tribromoacetamide > diiodoacetamide \approx iodoacetamide > bromoacetamide > dibromochloroacetamide > bromoiodoacetamide > bromodichloroacetamide > chloroiodoacetamide > bromochloroacetamide > dibromoacetamide > chloroacetamide > trichloroacetamide with dichloroacetamide not genotoxic. The genotoxic rank order for the haloacetaldehydes was chloroacetaldehyde \approx dibromoacetaldehyde > tribromoacetaldehyde > dichloroacetaldehyde. Trichloroacetaldehyde was not genotoxic. These data demonstrate the wide range of responses by these emerging and important DBPs. The selection of these three DBP classes was based on information from recent U.S. EPA DBP priority and occurrence studies. Mammalian cell cytotoxicity and genotoxicity data provided a rank ordering of the relational toxicities of regulated and emerging DBPs and related agents both within an individual chemical class and among classes. The use of alternative disinfectants generates new DBP compounds and alters the distribution of DBP chemical classes. The water supply community will be able to consider these factors when employing alternatives to chlorine disinfection. In addition these data will be available to prioritize DBPs for future *in vivo* toxicological studies and risk assessment.