Safe drinking water: a public health challenge.

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Abstract

Disinfection of drinking water through processes including filtration and chlorination was one of the major achievements of public health, beginning in the late 1800s and the early 1900s. Chloroform and other chlorination disinfection by-products (CBPs) in drinking water were first reported in 1974. Chloroform and several other CBPs are known to cause cancer in experimental animals, and there is growing epidemiologic evidence of a causal role for CBPs in human cancer, particularly for bladder cancer. It has been estimated that 14 16% of bladder cancers in Ontario may be attributable to drinking water containing relatively high levels of CBPs; the US Environmental Protection Agency has estimated the attributable risk to be 2 17%. These estimates are based on the assumption that the associations observed between bladder cancer and CBP exposure reflect a cause-effect relation. An expert working group (see Workshop Report in this issue) concluded that it was possible (60% of the group) to probable (40% of the group) that CBPs pose a significant cancer risk, particularly of bladder cancer. The group concluded that the risk of bladder and possibly other types of cancer is a moderately important public health problem. There is an urgent need to resolve this and to consider actions based on the body of evidence which, at a minimum, suggests that lowering of CBP levels would prevent a significant fraction of bladder cancers. In fact, given the widespread and prolonged exposure to CBPs and the epidemiologic evidence of associations with several cancer sites, future research may establish CBPs as the most important environmental carcinogens in terms of the number of attributable cancers per year.

Case-control study of bladder cancer and chlorination by-products in treated water (Ontario, Canada).

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Abstract

Chlorine is by far the most commonly used chemical for the disinfection of water supplies in North America. However, chlorine reacts with organic material in the raw water producing a number of halogenated hydrocarbon by-products. This population-based case-control study in Ontario, Canada examined the relationship between bladder cancer and exposure to chlorination by-products in public water supplies. Residence and water source histories and data from municipal water supplies were used to estimate individual exposure according to water source, chlorination status, and by-product levels (represented by trihalomethane [THM] concentration). Exposures were estimated for the 40-year period prior to the interview, using 696 cases diagnosed with bladder cancer between 1 September 1992 and 1 May 1994 and 1,545 controls with at least 30 years of exposure information. Odds ratios (OR) adjusted for potential confounders were used to estimate relative risk. Those exposed to chlorinated surface water for 35 or more years had an increased risk of bladder cancer compared with those exposed for less than 10 years (OR = 1.41, 95 percent confidence interval [CI] = 1.10-1.81). Those exposed to an estimated THM level > or = 50 micrograms/liter for 35 or more years had 1.63 times the risk of those exposed for less than 10 years (CI = 1.08-2.46). These results indicate that the risk of bladder cancer increases with both duration and concentration of exposure to chlorination by-products, with population attributable risks of about 14 to 16 percent. Chlorination by-products represent a potentially important risk factor for bladder cancer.

Case-control study of colon and rectal cancers and chlorination by-products in treated water.

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Abstract

This population-based case-control study was conducted in southern Ontario, Canada from 1992 to 1994 to assess the relationship between chlorination by-products in public water supplies and cancers of the colon and rectum. Interviews providing residence and water source histories were completed by 76% of eligible cancer cases and 72% of eligible controls. Supplemental data from municipal water supplies were used to estimate individual exposure to water source, chlorination status, and by-product levels as represented by trihalomethanes (THMs) during the 40-year period before the interview. The analyses included 767 colon cases, 661 rectal cases, and 1545 controls with exposure information for at least 30 of these years (75% of subjects with completed interviews). Among males, colon cancer risk was associated with cumulative exposure to THMs, duration of exposure to chlorinated surface water, and duration of exposure to a THM level > or = 50 microg/liter and 75 microg/liter. Males exposed to chlorinated surface water for 35-40 years had an increased risk of colon cancer compared with those exposed for < 10 years (odds ratio, 1.53; 95% confidence interval, 1.13-2.09). Males exposed to an estimated THM level of 75 microg/liter for > or = 35 years had double the risk of those exposed for < 10 years (odds ratio, 2.10; 95% confidence interval, 1.21-3.66). In contrast, these relationships were not observed among females. No relationship was observed between rectal cancer risk and any of the measures of exposure to chlorination by-products. The results of this study should be interpreted with caution because they are only partially congruent with the limited amount of literature addressing this issue.

Disinfection of drinking water, disinfection by-products and cancer: what about Australia?

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Abstract

Chlorine, commonly used to disinfect drinking water, produces by-products known from animal studies to be carcinogenic and mutagenic. Most epidemiological studies into the possible association between chlorination by-products in drinking water and cancer have been ecological in nature, or have relied on case-control designs based on death certificates. Interpretation of results arising from these studies is limited. Individual levels of toxicant exposure and many potential confounders and effect modifiers are unable to be accounted for in the analyses. At best, these studies generate hypotheses that require more definitive investigation. Misclassification of individuals based on inaccurate assessment of the level of exposure is probable. The few analytic studies able to overcome or minimise these problems suggest a clear link between exposure to chlorinated drinking water and the development of urinary bladder cancer. They also suggest a possible link with rectal cancer. However, these studies have classified subjects by exposure to chlorinated drinking water, rather than to levels of chlorine and its by-products in drinking water. To date, the link between levels of chlorine and its by-products in water, levels of consumption and cancer has not been made. Information on the levels of chlorine and some by-products is available in many water jurisdictions in Australia. Further, epidemiological methods can be employed to quantify water consumption. Case-control studies linking these parameters would help us to understand the magnitude of the risk to human populations and provide a basis to investigate mechanisms for risk reduction.

Health impacts of long-term exposure to disinfection by-products in drinking water in Europe: HIWATE.

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Abstract

There appears to be very good epidemiological evidence for a relationship between chlorination by-products, as measured by trihalomethanes (THMs), in drinking water and bladder cancer, but the evidence for other cancers, including colorectal cancer appears to be inconclusive and inconsistent. There appears to be some evidence for a relationship between chlorination by-products, as measured by THMs, and small for gestational age (SGA)/intrauterine growth retardation (IUGR) and preterm delivery, but evidence for other outcomes such as low birth weight (LBW), stillbirth, congenital anomalies and semen quality appears to be inconclusive and inconsistent.The overall aim of the HIWATE study is to investigate potential human health risks (e.g. bladder and colorectal cancer, premature births, SGA, semen quality, stillbirth, congenital anomalies) associated with long-term exposure to low levels of disinfectants (such as chlorine) and DBPs occurring in water for human consumption and use in the food industry. The study will comprise risk-benefit analyses including quantitative assessments of risk associated with microbial contamination of drinking water versus chemical risk and will compare alternative treatment options. The outcome will be improved risk assessment and better information for risk management. The work is divided into different topics (exposure assessment, epidemiology, risk assessment and management) and studies.

Occurrence, genotoxicity, and carcinogenicity of regulated and emerging disinfection by-products in drinking water: a review and roadmap for research.

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Abstract

Disinfection by-products (DBPs) are formed when disinfectants (chlorine, ozone, chlorine dioxide, or chloramines) react with naturally occurring organic matter, anthropogenic contaminants, bromide, and iodide during the production of drinking water. Here we review 30 years of research on the occurrence, genotoxicity, and carcinogenicity of 85 DBPs, 11 of which are currently regulated by the U.S., and 74 of which are considered emerging DBPs due to their moderate occurrence levels and/or toxicological properties. These 74 include halonitromethanes, iodo-acids and other unregulated halo-acids, iodo-trihalomethanes (THMs), and other unregulated halomethanes, halofuranones (MX [3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone] and brominated MX DBPs), haloamides, haloacetonitriles, tribromopyrrole, aldehydes, and N-nitrosodimethylamine (NDMA) and other nitrosamines. Alternative disinfection practices result in drinking water from which extracted organic material is less mutagenic than extracts of chlorinated water. However, the levels of many emerging DBPs are increased by alternative disinfectants (primarily ozone or chloramines) compared to chlorination, and many emerging DBPs are more genotoxic than some of the regulated DBPs. Our analysis identified three categories of DBPs of particular interest. Category 1 contains eight DBPs with some or all of the toxicologic characteristics of human carcinogens: four regulated (bromodichloromethane, dichloroacetic acid, dibromoacetic acid, and bromate) and four unregulated DBPs (formaldehyde, acetaldehyde, MX, and NDMA). Categories 2 and 3 contain 43 emerging DBPs that are present at moderate levels (sub- to low-mug/L): category 2 contains 29

of these that are genotoxic (including chloral hydrate and chloroacetaldehyde, which are also a rodent carcinogens); category 3 contains the remaining 14 for which little or no toxicological data are available. In general, the brominated DBPs are both more genotoxic and carcinogenic than are chlorinated compounds, and iodinated DBPs were the most genotoxic of all but have not been tested for carcinogenicity. There were toxicological data gaps for even some of the 11 regulated DBPs, as well as for most of the 74 emerging DBPs. A systematic assessment of DBPs for genotoxicity has been performed for approximately 60 DBPs for DNA damage in mammalian cells and 16 for mutagenicity in Salmonella. A recent epidemiologic study found that much of the risk for bladder cancer associated with drinking water was associated with three factors: THM levels, showering/bathing/swimming (i.e., dermal/inhalation exposure), and genotype (having the GSTT1-1 gene). This finding, along with mechanistic studies, highlights the emerging importance of dermal/inhalation exposure to the THMs, or possibly other DBPs, and the role of genotype for risk for drinking-water-associated bladder cancer. More than 50% of the total organic halogen (TOX) formed by chlorination and more than 50% of the assimilable organic carbon (AOC) formed by ozonation has not been identified chemically. The potential interactions among the 600 identified DBPs in the complex mixture of drinking water to which we are exposed by various routes is not reflected in any of the toxicology studies of individual DBPs. The categories of DBPs described here, the identified data gaps, and the emerging role of dermal/inhalation exposure provide guidance for drinking water and public health research.

Drinking water chlorination by-products and cancer.

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Abstract

This review discusses the relation between by-products of drinking water chlorination and cancer in the light of present toxicological and epidemiologic evidence. During the chlorination of drinking water, a complex mixture of by-products forms from chlorine and the organic and inorganic compounds present in raw water. The quality and quantity of such compounds depend on the specific nature of the organic material in raw waters, the inorganic material in raw water, pH, temperature, other water treatment practices, and the chlorine timing and dose added. Chlorination by-products are important mainly when surface water is used for drinking water as more organic compounds are present in surface waters than in ground waters. The gastrointestinal and urinary tract are the cancer sites that are most often associated with the use of chlorinated surface water or with the quantity of chlorination by-products in the water-supply network. Yet the microbial quality of drinking water should not be compromised by excessive caution over the potential long-term effects of disinfection by-products because the risk of illness and death resulting from exposure to pathogens in untreated drinking water may be several orders of magnitude greater than the cancer risks from chlorination by-products.
