

Science News - August 18, 2004

Chloramine complications

Alternatives to drinking-water chlorination, such as chloramines, may produce increased concentrations of disinfection byproducts (DBPs) with toxicities far more potent than those currently regulated, according to research just posted to *ES&T*'s website (es049971v).

The research was inspired by a 2002 drinking-water survey conducted by the U.S. EPA, which revealed that iodide-containing compounds were forming in some drinking water at concentrations on the order of 10 micrograms per liter ($F_{\mu\text{g/L}}$). The water came from a utility where source waters with high levels of bromide and organic matter were disinfected with chloramines. Finding the iodinated DBPs was "totally unexpected," says Susan Richardson, a chemist with EPA's Ecosystems Research Division lab in Athens, Ga., and head of the 2002 survey. Now, University of Illinois toxicologist and corresponding author Michael Plewa, together with Richardson and colleagues, has identified some of the specific iodinated DBPs and reports that one, iodoacetic acid (IA), is the most genotoxic to mammalian cells of any DBP ever identified.

The findings suggests that the switch in drinking-water disinfectants may cause increased adverse health effects in the U.S. population, says Plewa, who notes that current EPA regulations are based on limited toxicological and chemical knowledge. Water companies have been adopting chloramines and other chlorine-alternative disinfection strategies to comply with the first part, or stage, of EPA's 1998 DBP rule, because chloramines, a mixture of chlorine and ammonia, dramatically reduce levels of regulated DBPs. Part 2 of the DBP rule further encourages drinking water utilities to use chloramines and other alternatives to chlorine disinfection. But the new EPA study and other data indicate that alternative disinfectants may encourage the formation of new toxicologically significant DBPs, he says.

At least one organization, the National Rural Water Association (NRWA), is urging EPA to delay implementing the stage 2 DBP rule because these studies point to unforeseen consequences. "There is significant uncertainty around the health impacts of these iodinated DBPs—the changes initiated by stage 2 could actually make the health problem worse," says Mike Keegan, an NRWA analyst in Washington, D.C. The stage 2 rule is set to be finalized next year, and EPA does not intend to delay the rule, according to environmental engineer Stig Regli at EPA's Office of Water in Washington, D.C.

In mammalian cells, IA is by far the most potent DBP tested, says Plewa. The DBP most toxic to bacteria, dichloromethylhydroxyfuranone, a chlorinated furanone commonly known as MX, is 80 times more potent than IA as a mutagen in bacteria, as measured by the Ames test. But in mammalian cells, IA is 93 times more cytotoxic than MX and 28 times more mutagenic. Because mammalian cells are more indicative of effects in humans, Plewa concludes that IA is likely to be more hazardous to humans. IA is particularly toxic to mammalian cells because it inhibits cellular detoxification mechanisms, he says.

Drinking-water sources with high bromide concentrations often also contain iodide, since both

usually come from a saltwater source. The source of this saline water can be either saltwater intrusion into coastal fresh water or “connate water” locked away underground from a time in the geological past when ocean waters covered a region. For example, the high concentrations of iodinated DBPs in the national survey came from a source affected by connate waters.

Chloramination favors the formation of iodinated DBPs in such waters because chloramines, with less oxidizing power than chlorine, allow hypiodous acid to accumulate and react with organic matter to form them, according to Swiss Federal Institute for Environmental Science and Technology (EAWAG) chemist Urs von Gunten, who has studied the kinetics of these reactions (*Environ. Sci. Technol.* **1999**, *33*, 4040—4045).

Some of the iodinated DBPs may be significantly more toxic than those that we are currently aware of, agrees Regli. But it’s unlikely they pose a significant health risk, because it takes a rare set of conditions to produce them in significant quantities, he says. “The 2002 national study targeted extreme water—with extremely high levels of bromine and natural organic matter. As such, the finding is unlikely to affect a great number of people,” he says.

Epidemiological studies have linked chlorinated drinking water from surface sources with a higher risk of bladder and colorectal cancers, and DBPs are the most likely culprit. But to date, the particular DBP or mixture of DBPs responsible for the risk has yet to be identified, according to research chemist Stuart Krasner with the Metropolitan Water District of Southern California in LaVerne, Ca. It’s unlikely that iodinated DBPs could be the culprit, because epidemiological studies show that people who drink chloraminated waters have a lower risk for those cancers than those who drink chlorinated water, says Regli.

Krasner, a coauthor of the 2002 study, agrees with Regli. The iodinated DBPs typically occurred at submicrogram-per-liter levels, except for the one utility in the nationwide survey that had about 10 Fµg/L of iodinated trihalomethanes (THMs), he says. The utilities included in the survey were chosen to be representative and highlight the worst-case situations.

The stage 2 DBP rule is likely to prompt many surface water plants to switch to chloramines. But in many cases, utilities will be using chloramines for secondary disinfection during distribution, not for primary disinfection at the plant, says Krasner.

“Ultimately, it will be important to know the levels at which these iodo-acids occur, in order to assess the potential for adverse environmental and human health risks,” says Plewa. Richardson is currently working on a project to acquire those data.

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