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When chlorine + antimicrobials = unintended consequences

Washing dishes by hand with an antibacterial dishwashing liquid can do more than just ensure that the plates, glasses, and silverware are free from grease and germs, according to Peter Vikesland of the Virginia Polytechnic Institute and State University. In research published this week on *ES&T's* Research ASAP website ([es048943+](#)), he and his colleagues show that the triclosan antimicrobial agent used in household dishwashing soaps reacts with chlorinated water to produce significant quantities of chloroform. The research also suggests that the reaction of triclosan with chlorine could be producing highly chlorinated dioxins in the presence of sunlight.



Paul Thacker

New research shows that the triclosan in anti-bacteria dishwashing soaps may react with chlorinated drinking water to produce levels of chloroform that exceed EPA regulations.

Because of its antibacterial, antifungal, and antiviral properties, triclosan is found in toothpastes, acne creams, deodorants, lotions, and hand soaps. It is also incorporated into a wide range of consumer goods, including kitchen tiles, children's toys, cutting boards, toothbrush handles, hot tubs, and athletic clothing. As triclosan flows down drains, it is making its way into surface waters and sewage treatment plants, the bile of fish, and breast milk, according to the Alliance for the Prudent Use of Antibiotics, a consumer group. Since 2000, the American Medical Association has been urging the U.S. Food and Drug Administration to closely monitor and possibly regulate the home use of antimicrobials such as triclosan.

The formation of chloroform from triclosan is of concern because the U.S. EPA classifies the compound as a probable human carcinogen. Moreover, the presence of trihalomethanes such as chloroform in drinking water has been linked with human bladder cancers and miscarriages.

The reaction of phenols such as triclosan with free chlorine is well known, but Vikesland's research is important because "it ties the use of a household product [to] increased exposure to a disinfection byproduct," says David Sedlak, a professor in the civil and environmental engineering department at the University of California, Berkeley. "This research is important for demonstrating that the chlorination of triclosan can occur under environmentally relevant conditions," says Kristopher McNeill of the University of Minnesota's department of chemistry. "The fact that you can chlorinate triclosan [under] pretty mild conditions is troubling," he adds.

Since writing the paper, Vikesland's team has conducted follow-up research under conditions that more closely mimic those found during home dishwashing. The new experiments used EPA's maximum allowable residual disinfectant concentration of 4 milligrams per liter in tap water and were conducted at 40 °C, which fits well with the cleaning recommendations of the Soap and Detergent Association. (The association's website says that dishwater temperatures of less than 33 °C, even with sufficient detergent, are likely to leave a greasy film, while the hottest water most people's hands can tolerate is about 43 °C.)

Under these conditions, triclosan reacts with free chlorine to generate more than 50 parts per billion (ppb) of chloroform in the dishwater. When combined with the other trihalomethanes in the water, the additional chloroform could easily ratchet up the concentration of total trihalomethanes to 80 ppb, which is EPA's maximum allowable amount, or higher, Vikesland says.

"Since chloroform and other trihalomethanes and disinfection byproducts are already likely to be present in the tap water, and since chloroform, the other THMs, and many other [disinfection byproducts] are highly volatile, there is a very real likelihood that washing dishes with triclosan-containing liquid could cause additional and troubling significant exposure to these volatiles through inhalation and potentially through dermal absorption," says Erik D. Olson, senior attorney for the Natural Resources Defense Council, a nonprofit environmental group. Olson calls the research "significant."

Water treatment plants are working hard to keep the levels of trihalomethanes in tap water below 80 ppb, Vikesland says, noting that the admissible level has recently decreased from 100 ppb. If there is any bromide in the water, the level of trihalomethanes produced during dishwashing is likely to shoot up even higher, he says.

The research makes clear that it is always wise to wear gloves when dishwashing, says Doris Day, M.D., an assistant professor of dermatology at New York University Medical Center. In light of previous studies showing that the levels of trihalomethanes in people's blood increase when they shower, the research raises questions about exposures to

chloroform when antimicrobial soaps are used. At this point, however, no one knows what risk they may pose.

Vikesland's research also shows that triclosan's reaction with free chlorine produces a number of chlorinated triclosan intermediates, including 2,4 dichlorophenol. In the presence of sunlight, these chlorinated intermediates could be producing dioxins, say McNeill and his colleague, William Arnold of the University of Minnesota's department of civil engineering. The two have recently demonstrated that sunlight readily converts triclosan in river water to produce dioxins (*Environ. Toxicol. Chem.* **2005**, *24*, 517–525). But the more highly chlorinated dioxins that could be generated photochemically from chlorinated triclosan intermediates could be far more toxic, says McNeill.

It is unlikely that such dioxins would be generated during dishwashing even near a window on a sunny day because the glass would screen out most of the ultraviolet light necessary to produce the dioxin. But the research suggests that dioxins could be forming near swimming pools in some situations. "There's triclosan in hand soaps and moisturizers. [If] someone who has triclosan-containing moisturizer [on jumps] into the pool ... they're a potential source for chloroform [and chlorinated dioxin] formation," Vikesland says. The same is true for a child using an antimicrobial soap before getting into the pool, McNeill and Arnold agree. "You could produce a dioxin on the surface of your skin [that] gets absorbed through the skin," Sedlak adds.

McNeill and Arnold say that the research also calls for more detailed studies of whether chlorinated triclosans are being released from wastewater treatment plants. Because triclosan is widely found in the environment, chlorinated triclosan could be a source of toxic dioxins in the environment, says Arnold. Research has already shown that the presence of triclosan can affect algae populations (*Environ. Sci. Technol.* **2003**, *37*, [162A–164A](#)). —KELLYN BETTS