Drinking Water Contaminants and Miscarriages: Research Update

By Kelly A. Reynolds, MSPH, Ph.D.

For more than a decade, researchers have attempted to qualify the potential relationship between adverse health effects and by-products of chlorine disinfection used in water treatment. Results have been inconsistent and varied but a recent study has shed some new light on the issue, relieving some of the fears regarding unrecognized effects on unborn fetuses. Chlorine is the most widely used chemical drinking water disinfectant in the world and has played a primary role in the virtual elimination of typhoid, cholera and other bacterial scourges in the U.S. At question, however, is how to balance the benefits of chemical disinfection of drinking water to reduce infectious agents with the possible side effects of disinfectant use.

A necessary treatment

Chlorination is an inexpensive and highly effective disinfectant for controlling the presence of many microbial pathogens in drinking water, especially human viruses and pathogenic bacteria. Harmful microbes are commonly present in municipal source water supplies and thus a multi-barrier treatment process is necessary. As part of a multi-barrier approach, chlorine disinfection and other treatment practices (i.e., filtration) are largely credited with the 40 percent decline of death due to infectious diseases between the early 1900s and around 1940, when major U.S. cities were utilizing drinking water treatment technologies. Chlorination and filtration of water is estimated to have reduced total death rates (i.e., death by all causes) by an average of 13 percent and child mortality by 50 percent in U.S. cities.[1] Economic benefits of such a reduction in mortality have been calculated at more than $679 million annually relative to the treatment costs of about $30 million a year.

The problem with the use of drinking water disinfectants like chlorine is that they can react with other naturally-occurring compounds in water, forming by-products such as trihalomethanes (THM), haloacetic acids (HAA), chlorite and bromate. The U.S. Environmental Protection Agency (U.S. EPA) has set exposure limits to certain disinfectant by-products (DBPs), based on evidence that excess consumption is harmful to human health. Qualitatively and quantitatively defining exposure limits, however, has proved to be a difficult task.

New evidence

Moderate associations have been found with THM exposures and birth defects, reduced fetal size and spontaneous abortion.[2] Canadian researchers reported that women who drank tap water containing THM levels of ≥80 µg/L (the U.S. EPA's maximum contaminant level [MCL]) increased their risk of stillbirth by 2.2-times. One of the criticisms of the study is that the relationship between response and dose was non-linear, meaning that with increasing exposures, the expected increase in adverse effects was not seen.

Critical reviews of epidemiological evidence have been published that generally support a link between chlorinated drinking water supplies and adverse human health but the findings are inconsistent.[3] Most researchers agreed that additional studies were needed to determine the true risks.

A recent nationwide study, sponsored by the American Water Works Association and directed by scientists at the University of North Carolina School of Public Health, set out to answer these unknowns.[4] Utilizing a volunteer group of over 3,100 women who were either planning a pregnancy or already less than 12 weeks pregnant, fetal outcome was compared relative to consumption of DPBs in water, produced by properly functioning water treatment facilities in compliance with current federal standards. The study found that there was not significant evidence that THMs were harmful to developing infants at moderate contaminant levels (median concentration of 60.7 µg/L).

Other concerns

Although that study lessened the concern of THMs and their effect on pregnancy outcome, the researchers are quick to point out that there was a slightly positive association between brominated compounds and total organic halides at normal range levels in treated drinking water and miscarriages. In addition, a number of previous studies have suggested that exposure to disinfection by products in drinking water are related to an increase in bladder cancer, a topic not addressed in the Savitz study.

A miscarriage is defined as a pregnancy that is spontaneously aborted prior to 20 weeks, while a stillbirth is the delivery of a non-living fetus greater than 20 weeks in gestation. The number of stillbirths in the U.S. is approximately equal to the total number of infant deaths. According to the Centers for Disease Control (CDC), more than one in six pregnancies result in a miscarriage or stillbirth, equivalent to almost a million fetal deaths in 1996. Greater than half were after 28 gestational weeks and 20 percent were full-term. Although pregnancy loss may be due to genetic defects, maternal illness, or placental dysfunction, half of all stillbirths are due to unknown causes. Infectious agents have long been suggested as a possibility.

Reducing exposures

The vast majority of water treatment facilities in the U.S. use chlorine as their primary disinfectant. A still greater number add chlorine to the treated water as a residual disinfectant. It is this residual chlorine that reacts with naturally occurring organic matter in the raw water (i.e., humic and fulvic acids) to create the potentially harmful DBPs. Reducing the use of chlorine or the presence of organic matter aids in the reduction of associative THMs. Risk of exposure to patho-

gens, however, must not be increased. Some potential alternative methods of treatment include ozone, ultraviolet (UV) light and chloramines.

Although ozone and UV light are also effective primary disinfectants, they do not provide lasting residual effects to protect the water supply during distribution. A variety of other chemicals are available, each with their own list of pros and cons. Chloramine has been used as a residual disinfectant in the distribution system. The U.S. EPA estimates that 30 percent of surface water utilities will use chloramines as their secondary disinfectant to comply with current standards (i.e., *Stage 1 Disinfectants/Disinfection By Products Rule, {DBPR}*[5]), increasing to 60 percent for the newly promulgated Stage 2 DBPR. The use of alternative disinfection practices is being cautiously approached as any substitutive process may produce other by-products of unknown risk (i.e., chlorine dioxide by-product of chlorite and chlorate).

THMs were first recognized as potential human carcinogens in the 1970s, leading the U.S. EPA to set the first regulatory limits for the chemicals in 1979. *Stage 1 DBPR*, finalized in 1998, established an MCL for total THMs (80 ppb) and other DBPs (i.e., MCL of the sum of five HAAs is 60 ppb) while mandating the use of enhanced coagulation in the water treatment process to remove natural organic matter, a major contributor to DBP formation.

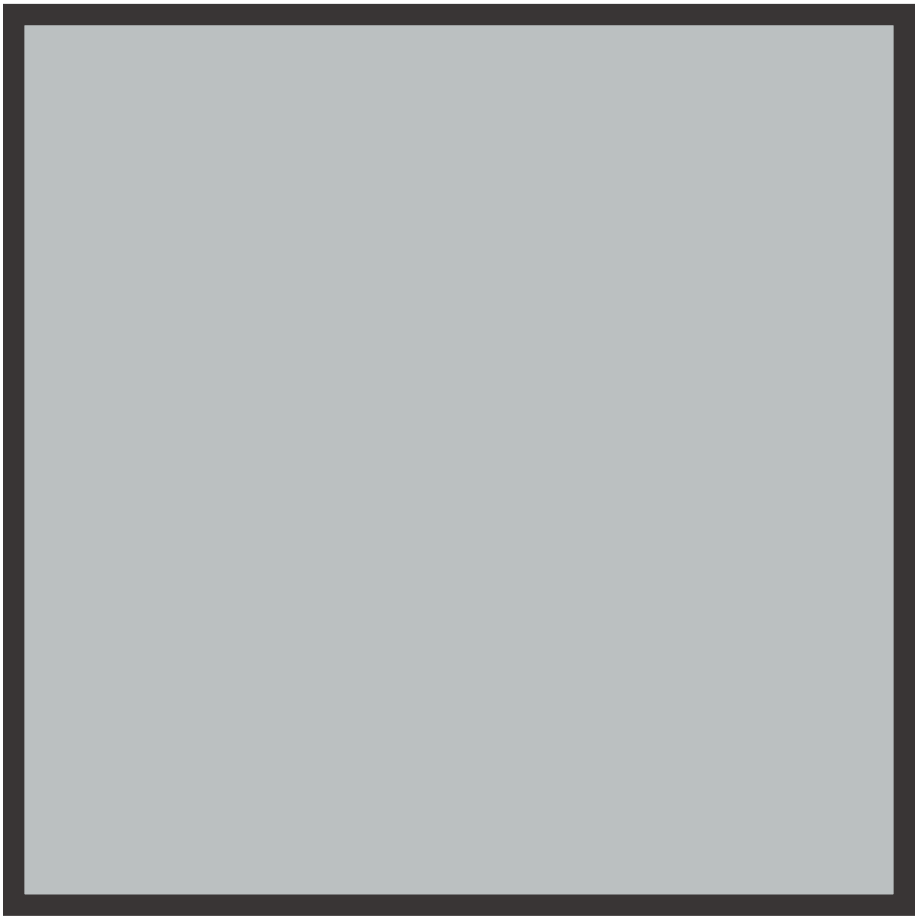
The U.S. EPA estimates that more than 260 million individuals are exposed to DPBs. Since the *Stage 1 DBPR*, human epidemiology and animal toxicology studies have continued to show associations between chlorinated drinking water and adverse birth outcomes, as well as bladder and rectal cancers. Therefore, with the *Stage 2 DBPR*, the U.S. EPA is showing an increased commitment to lowering DBP exposures, beyond the compliance levels required in the *Stage 1 DBPR*.

Stage 2 DBPR is aimed at reducing the level of exposure from disinfectants and DBPs, using a risk-based approach and identifying monitoring sites where exposure levels are highest. This rule is projected to prevent some 280 bladder cases per year providing a monetary benefit of $1.5 billion relative to the average cost of $79 million per year.[5]

Conclusion

A major concern in the process of reducing exposure to DBPs in drinking water is that the substantial benefits of pathogen reduction, realized by chlorine disinfection, are not compromised. With the uncertainty of risks and the cost effectiveness of alternative disinfectants, the EPA is focusing largely on removal of the organic precursors to control the formation of DBPs.

Although the most recent research shows that disinfectant by-products play a lesser role in miscarriages than previously expected, other risks are still present, such as bladder cancer. Consumers can, however, control the quality of their drinking water at, or near, the tap with POU and POE devices. Although one must carefully evaluate their individual needs and the capabilities of various systems, there is a wide selection of brands and models of water treatment devices on the market. Generally speaking, activated carbon or reverse osmosis filters are considered the most effective for removing THMs. POE devices offer protection from cumulative exposures (i.e., dermal or inhalation routes). Regardless of the system chosen, careful adherence to manufactures maintenance schedules is imperative to maximize the benefits of any water treatment system.



Footnotes

1. Cutler and Miller. 2005. The role of public health improvements in health advances: the twentieth-century United States. *Demography*. 42: 1-22.

2. On Tap. *Water Conditioning and Purification*. June 2004

3. Nieuwenhuijsen et al., 2000. Chlorination disinfection byproducts in water and their association with adverse reproductive outcomes: A review. *Occupational and Environmental Medicine*. 57(2):73-85.

4. Savitz et al., 2005. Drinking water disinfectant by-products and pregnancy outcome. AWWARF. Available online: http://www.awwarf.org/research/TopicsAndProjects/execSum/2579.as

5. U.S. EPA. *Stage 2 Disinfectants and Disinfection Byproduct Rule*. www.epa.gov/safewater/disinfection/stage2. June, 2006.

Additional reference

Bove et al., 2002. Drinking water contaminants and adverse pregnancy outcomes: A review. *Environmental Health Perspectives*. 110 (Suppl. 1):61-74.

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