Drinking Water and Women’s Health

Brenda M. Afzal, RN, MS

Primary health providers in the community must be able to field questions and guide vulnerable populations to informed decisions about drinking water quality and health. This article offers an overview of selected contaminants in drinking water and their possible effects on the health of women over the life span. Historical concerns for drinking water safety, which led to the development of current drinking water regulations, are briefly explored. Several chemical, microbial, and radionuclide contaminants of particular concern to women and children are discussed. Short- and long-term tap water alternatives are suggested for when tap water is deemed unsuitable for use. J Midwifery Womens Health 2006;51:12–18 © 2006 by the American College of Nurse-Midwives.

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**INTRODUCTION**

Early concern for drinking water quality centered on its aesthetic qualities: “is it cloudy; does it have an odor?” There was little understanding of the relationship between drinking water and disease until the mid-19th century, when Dr. John Snow, a British physician, correlated an outbreak of cholera in London to drinking water drawn from a contaminated source. Pasteur’s discovery of the germ theory later in the 19th century helped explain why water sometimes made people sick. Bacterial pathogens would remain the focus of concern during most of the 20th century.

After World War II, growth in agricultural and industrial development and the production of man-made chemicals provided an economic boom in the United States, but it also led to pollution of the nation’s waterways. Rachel Carson, in her book *Silent Spring*, reported on widespread poisoning of our nation’s waterways from toxic industrial chemicals and agricultural and sewage runoff.

**DRINKING WATER LAWS AND REGULATIONS**

Public concern in the 1960s and 1970s, related to the poor state of our nation’s waterways, compelled the federal government to investigate drinking water quality in the United States. The results found that public health standards were being met by only 60% of the water systems surveyed. One study of the Mississippi River showed that water taken from the river, which had passed through a water treatment facility, still contained 36 potentially hazardous chemicals. These concerns fostered debates in Congress that led to two landmark environmental acts of legislation: the Clean Water Act of 1972 and the Safe Drinking Water Act of 1974. The Environmental Protection Agency (EPA) administers both laws.

The purpose of the Clean Water Act was to restore and maintain the chemical, physical, and biological integrity of the nation’s waters. The Safe Drinking Water Act attempts to control drinking water contamination through the use of a multiple barrier approach. This includes source water and drinking water assessment and protection, wellhead protection, qualification of water system operators, ensuring the integrity of distribution systems, and public notification of drinking water quality.

There are primary and secondary national standards for drinking water. National Primary Drinking Water Standards (NPDWSs) are legally enforceable standards limiting the amount of contaminants detectable in drinking water. There are two types of enforceable NPDWS: Maximum Contaminant Levels and Treatment Techniques. Maximum Contaminant Levels indicate the highest level of a regulated contaminant that is allowed in finished drinking water. When there is no economically or technically achievable method to measure a contaminant, a Treatment Technique is set. This sets a specific procedure or technology that must be used by public water systems to control a regulated contaminant. For example, the action level for lead in drinking water is 15 parts per billion. If testing indicates the action level was exceeded in 10% of tap water samples taken, the water utility is required to take additional steps to reduce the corrosivity of the water by adding an alkaline chemical to the water.

**DRINKING WATER CONTAMINANTS**

The Safe Drinking Water Act directs the EPA to regulate contaminants in public drinking water that are known to, or are likely to, pose a risk to public health. The EPA does not have the authority to regulate private drinking water systems. The EPA regulates contaminants by setting standards for “finished” drinking water that flows from treatment facilities to customers. Currently, fewer than 100 contaminants are regulated.

Contaminants are classified as inorganic or organic chemicals, radionuclides, and microorganisms. Inorganic chemicals are mineral based and do not contain carbon. They may occur naturally or enter the watershed from farming or industrial discharge. Examples of inorganic...
contaminants are lead, nitrates, and arsenic. Organic chemicals contain carbon and access the watershed from agricultural and industrial run off. Volatile organic chemicals are persistent in the environment and have been associated with cancer and neurological and reproductive health effects. Examples include gasoline and degreasing and dry cleaning solvents. There are over 30 standards for synthetic organic chemicals, many of which are pesticides.

Microbial contaminants found in water may be bacterial, viral, or parasitic. Disinfection and filtration methods used by public water suppliers decrease the threat from these pathogens for healthy individuals. Disease outbreaks from these pathogens are usually a result of a water system treatment failure or drinking from a contaminated water source. The infectivity of these microbes is higher for individuals with weakened immune systems.

Radionuclides emit ionizing radiation, and long-term exposure to this type of radiation from a drinking water source results in an increased risk of cancer. The EPA currently has standards for four radionuclides.

ORGANIC CHEMICALS CONTAMINANTS

Chlorine Disinfection By-Products

Chlorine disinfection by-products are a family of contaminants of particular concern to women’s health and pregnancy outcomes. Chlorine disinfection of the nation’s drinking water in the 20th century was a major public health initiative, which led to a dramatic decrease in diseases caused by bacterial contamination. However, when chlorine is used to disinfect water, it can combine with organic material in the water distribution system, forming unintended organic chlorinated compounds, which have been associated in a variety of health outcomes, including bladder, rectal, and colon cancers, and poor reproductive and developmental end points. Health risks associated with chlorine disinfection by-products need to be taken seriously, because more than 200 million people drink water that has been disinfected.

Several epidemiologic studies have indicated that there may be an increased risk of reproductive and developmental effects to the fetuses of pregnant women exposed to high levels of chlorine disinfection by-products. Critics of these studies point to the difficulty of accurately assessing exposure. Although exposure assessment may be difficult, we know that there is potential for exposure because everyone uses water to drink, bathe, and cook, and the exposure occurs over the life span.

A 2003 in vitro study that examined the risk for spontaneous abortion related to bromodichloromethane, a chlorine disinfection by-product, concluded that exposure to this chemical could be associated with adverse pregnancy outcomes. The risk was attributed to the disruption of gonadotropin secretion by differentiated trophectoderm believed to target the placenta.

Several studies have examined associations between reproductive health and exposure to disinfection by-products in drinking water. One such study looking at pregnancy outcomes related to trichlorormethane (a disinfection by-product) exposure via drinking water ingestion indicated that increased exposure was associated with decreased menstrual cycle length. A recent case-control study looked at intrauterine growth restriction and exposure to disinfection by-products. The findings of the study suggested the fetal growth of genetically susceptible newborns exposed to the highest levels of trihalomethanes could be affected. The results of a meta-analysis of six case-control and two cohort studies indicated that there is a moderate increase in risk of bladder cancer for individuals, particularly men, who have consumed chlorinated drinking water long periods of time.

There is a need for further study of chlorine disinfection by-product exposure and possible adverse health outcomes. In the mean time, what can health care professionals do in response to the current state of knowledge? A good starting point is to access the local water utilities’ Consumer Confidence Report, which will indicate if there was an elevation in the level of disinfection by-products over the preceding year. Many Consumer Confidence Reports are published on the EPA website.

If disinfection by-product levels are elevated, consider a precautionary approach. Pregnant women and women who are considering pregnancy who consume drinking water from sources known to have elevated levels of chlorine disinfection by-products should access an alternative source of drinking water. There are water treatment devices that can remove disinfection by-products from the drinking water. In addition, allowing water to sit in an open container for an hour will reduce disinfection by-products. Reducing time spent showering or bathing, where inhalation and absorption may increase exposure, is advisable.

Methyl Tertiary Butyl Ether

Methyl tertiary butyl ether (MTBE) is an additive used in fuel to replace lead as an octane enhancer and to reduce carbon monoxide emissions from automobiles. This chemical has entered private and public drinking water systems through leaking underground storage tanks or pipes. There are insufficient data to estimate health risks associated with ingestion of drinking water containing low levels of MTBE, but it is a potential human carcinogen at high doses. After reviewing existing data, in 1997, the EPA released an advisory indicating there was little likelihood that negative health effects would be noted at levels between 20 and 40 ppb in drinking water. There have been widespread detections of MTBE at low levels, with only 1% of...
Nitrates

Nitrates are a family of compounds that can access shallow aquifers from agricultural (fertilizer and livestock manure) and industrial runoff. They are more often found in shallow groundwater of rural and agricultural regions, and therefore, are of particular concern to private drinking water supplies. The risk of groundwater contamination by nitrate is not the same everywhere. According to a US Geological Survey report: “High-risk areas occur primarily in the western, midwestern, and southeastern portions of the Nation.”

Infants who are exposed to elevated levels of nitrates in drinking water have an increased risk of developing methemoglobinemia, which develops when the immature infant gut converts nitrates to nitrites. Nitrites oxidize hemoglobin, thus reducing its ability to carry oxygen. Infants under the age of 4 months are at greatest risk.

Precautions should be taken in areas that are at risk for nitrate contamination. Never boil water for drinking or mixing formula; boiling the water will concentrate nitrates. Well water should be tested for nitrate levels with the understanding that there will be seasonal variations. If tap water is contaminated with nitrates, or if there is a possibility of contamination, drinking water should be obtained from an alternative source.

Pesticides

Pesticides are substances used to prevent, destroy, repel, or mitigate any pest ranging from insects, animals, and weeds to microorganisms, such as fungi, molds, bacteria, and viruses. Pesticides enter surface- and groundwater as runoff from crop application, suburban and urban landscape areas, golf courses, and applications sprayed along roadsides. Health effects due to acute occupational or environmental exposure to pesticides have been well studied. Although not as well studied, possible health effects associated with long-term exposure to drinking water containing low concentrations of pesticides include reproductive damage, birth defects, neurologic and endocrine abnormalities, effects on growth and development, cancer, and other adverse effects.

Pedersen reports that, “Approximately 50% of the U.S. population obtains its drinking water from groundwater sources and as much as 95% of the population in agricultural areas uses groundwater as its source of drinking water.” Farming families, farm workers, and individuals living in areas that are known to have pesticide contamination issues have an increased risk of exposure. Children, because they eat and drink more than adults in relation to body weight, and have hand to mouth behavior, may have an increased risk for exposure to pesticides.

INORGANIC CHEMICAL CONTAMINANTS

Lead

Lead is a powerful neurotoxin. According to the EPA, lead in drinking water can cause a variety of adverse health effects. Children should not be exposed to lead in drinking water known to be above the action level of 15 ppb. The US EPA reports that, “In babies and children, exposure can result in delays in physical and mental development, along with deficits in attention span and learning abilities.” Adult exposures may result in hypertension.

Although the primary source of lead exposure for children and pregnant women is from lead-based paint, a significant exposure can come from drinking water. Approximately 10% to 20% of background lead exposure in humans can come from drinking water, with as much as 40% to 60% for formula-fed infants (formula mixed with tap water). A 1986 amendment to the Safe Drinking Water Act prohibited use of lead solders and pipes in public water systems; thus, homes built before 1986 are more likely to have lead pipes, joints, and solder. However, new homes are also at risk as “lead-free” pipes and fixtures may legally contain up to 8% lead, which can leach into the tap water for several months after installation.

Arsenic

Arsenic is a poisonous heavy metal. Arsenic enters source water from erosion of natural deposits, industrial releases, agricultural runoff of arsenical pesticides, mining and smelting processes, and petroleum refining. In the United States, arsenic concentrations are higher in groundwater systems (wells) than in surface systems. Levels are lowest in the mid-Atlantic and Southeast, intermediate in New England, the Midwest, and the South-central and North-central regions, and the highest in the West. Several states have groundwater systems exceeding 50 mcg/L, including California, Nevada, and Texas. According to the US Geological Survey, “In 24% of the US counties where data were available, at least 10% of samples had arsenic concentrations exceeding 10 mcg/L.” The new EPA standard for arsenic in drinking water (currently set at 50 ppm) will be set at 10 ppm starting in 2006.

Chronic ingestion of arsenic in contaminated drinking water is known to cause skin cancer and may increase risk for bladder, lung, kidney, liver, colon, and prostate cancers. There is also evidence that supports an association between arsenic ingestion and cardiac and cerebrovascular disease and diabetes mellitus.

Little research has been directed at examining associations between arsenic and reproductive health outcomes. However, one retrospective study that investigated the
trends in infant mortality between two geographic locations in Chile, one area known to have a history of an exposure to drinking water from contaminated water and one with low exposure, indicated a possible role for arsenic exposure in increasing the risk of late fetal and infant mortality.  

Drinking water quality can be determined by accessing the most recent Consumer Confidence Report from the water utility or by calling the local department of the environment or health department. If the water source is a private well and arsenic contamination is suspected, the water should be tested. Patients suspected to have been exposed to high levels of arsenic should be screened by a 24-hour urine test. Patients with elevated arsenic levels should use an alternative source of drinking water, such as distilled or bottled water, or they should use a water treatment device that will remove the contaminant. Consultation with an occupational medicine specialist is advisable. Infant formula should never be prepared with water known or suspected to contain arsenic.

**MICROBIAL CONTAMINATION**

Agricultural runoff is an enormous source of pollution; 70% of rivers and streams are affected by nutrient and animal waste runoff. Waste generated from concentrated animal feeding operations, sometimes referred to as factory farms, is estimated to be 130 times more than the waste generated by humans each year in the United States. Waterborne disease outbreaks are tracked by using voluntary, passive surveillance techniques. Thus, estimates vary on the incidence of waterborne microbial disease in the United States, probably because not all outbreaks are recognized, investigated, or reported. CDC surveillance for 2001 to 2002 indicates that 79% of the 31 waterborne disease outbreaks reported by 19 states were associated with pathogens.

Bacterial contaminants are fairly well controlled by conventional water treatment techniques. However, private water systems, particularly in agricultural areas, have an increased risk of bacterial contamination from coliform bacteria. Private wells drawing from shallow aquifers can be contaminated by agricultural runoff. Of particular concern for young children and frail or immune-compromised individuals is contamination from *E. coli* 0157:H7. Hemolytic uremic syndrome is a serious complication that can result after exposure to *E. coli* 0157:H7. About 2% to 7% of elderly and children younger than 5 years of age will develop the syndrome if infected. Three identified drinking water outbreaks, in 1998, 1999, and 2000 in North America, affected thousands of individuals and led to several deaths.

**Cryptosporidium Parvum**

Cryptosporidium parvum is a parasite that contaminates up to 97% of surface water in the United States. Surface water becomes contaminated with Cryptosporidium primarily from runoff of animal waste and from human waste in contaminated wastewater runoff from sewage overflows. The organism is resistant to chlorination and filtration, and thus, can pass through conventional water treatment systems into drinking water sources. Infection, although unpleasant, is usually self-limiting in healthy individuals. However, individuals with compromised immune systems may experience severe, even life-threatening complications. A 1993 waterborne disease outbreak in Milwaukee was estimated to cause gastrointestinal signs and symptoms in over 400,000 people with over 50 deaths.

**RADIONUCLIDES**

There are four radionuclide contaminants currently regulated by the EPA. They include alpha particles, beta and photon emitters, Radium 226 and 228 (combined), and uranium. Radionuclide presence in drinking water is usually due to erosion of naturally occurring radioactive material. Potential health effects from exposure above the maximum contaminant level include an increased risk of cancer. Radon, a known carcinogen and the second leading cause of lung cancer, can be found in drinking water. An estimated 170 people a year die from cancer due to radon in their tap water, and many more suffer from nonfatal cancers. According to a report from the National Academies, “National data on radon distribution across the United States indicates that the northern United States and some areas in southern states tend to have higher than average indoor radon, while New England states and some areas in the Southwest have higher concentrations of radon in water. The Appalachian and Rocky Mountain states and some areas in the Great Plains have higher than average radon in both water and indoor air.” The EPA has not set a standard for radon, although they have been mandated to do so.

The EPA recommends radon testing for all homes, as the primary exposure is via indoor air, which should be tested before testing drinking water. If the level exceeds the EPA recommendation of 4 pCi/L, remediation by a qualified professional is recommended. Individuals with private wells, who live in areas that are known to have elevated radon levels, should have their tap water tested. There is a National Radon Hotline that can offer guidance on testing and remediation (Appendix A). In addition, water treatment technologies can remove radon and other radionuclides from water. NSF International, an independent, not-for-profit organization, provides an online service that offers information about effective treatment units.
ure to a small dose of some microbes may be very serious for vulnerable individuals, so individuals known to be immunocompromised should err on the side of safety and seek an alternative source of drinking water that is pure. If there is a long-term need for an alternative source of tap water that is pure (98%), a home distilling filtration unit should be considered. Water utilities will issue a “boil water advisory” via media (television, radio, and newspapers) when there is an indication that the water they deliver to the tap may have a risk of microbial contamination. All individuals, not just the immunocompromised, should use an alternative source of drinking water during a water advisory.

Boiling water is an inexpensive, short-term method used for microbial disinfection. Bringing water to a rolling boil for 1 minute will kill most microbes. Patients should be cautioned to use boiled water for everything including food preparation and for brushing teeth. However, boiling water can concentrate metals such as lead and nitrates and may vaporize volatile chemicals, creating an additional route of absorption by contaminating the indoor air.

Bottled Water
A 4-year study evaluating the quality of bottled water determined that current regulations are inadequate to assure consumers of safety. At least one third of the bottled waters tested violated a state standard or guideline for microorganisms.40 NSF International tests and verifies that bottled water products meet specified standards for microbial, heavy metal, and mineral reduction. Consumers who choose bottled water as an alternative to tap water should check the label for either a certification from NSF or for an indication that the bottler has attempted a purification process such as reverse osmosis or submicrobial filtration for less than 1 micron.

Water Treatment Units
Many people who are concerned with the aesthetic qualities and/or the possible contamination of their water are turning to water treatment units. There is no single unit that removes all contaminants completely.

CONCLUSION
Drinking water safety should not be assumed. It may depend on an individual’s vulnerability. It may depend on where one lives and the water utility’s ability to mediate the source water. It may depend on funding allocations to research current and emerging water quality issues. In the end, an individual’s risk may partly depend on their primary health provider being able to field questions and guide them to informed decisions about drinking water quality and health.

REFERENCES


## Appendix A. Resources for Water Safety

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| **Environmental Protection Agency** | [http://www.epa.gov/safewater/dwinfo/index.html](http://www.epa.gov/safewater/dwinfo/index.html)  
The EPA Web site has water quality reports (Consumer Confidence Reports) for all water systems in the United States. These reports can also be obtained from the local water utility or library. |
| **The National Safety Council’s Radon Hotline** | 1-800-SOS-RADON [1-800-767-7236]  
The hotline has an informational recording available 24 hours per day. Callers can order a brochure that describes a low-cost test kit.  
1-800-55-RADON [1-800-557-2366]  
Information specialists are available to answer questions during daytime hours. |
A nonprofit organization provides an online service that offers information about effective treatment units for radon. |

### HAZARDOUS LEVELS OF MERCURY: FACTS ABOUT FISH
- Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, Pollock, and catfish.
- Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna. Patient recommendations should highlight two meals of fish and shellfish per week. It is safe to eat up to 6 ounces (one average meal) of albacore tuna per week.
- Pregnant women should not eat shark, swordfish, king mackerel, or tilefish because they contain high levels of mercury.