Tainted Water on Tap

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What to tell patients about preventing illness from drinking water.

OVERVIEW: Annual cases of waterborne illness in the United States are estimated to number about 900,000, but most experts believe the incidence to be much higher. The U.S. Environmental Protection Agency regulates the nation's drinking water supply, setting maximum allowable levels for 87 known natural and synthetic contaminants; but thousands more go unregulated. This article describes selected contaminants and their known health effects, which range from acute gastroenteritis to cancer and reproductive and developmental effects. It discusses which populations are more vulnerable, outlines assessment, and elucidates nurses' roles in patient education and as community advocates for safer drinking water.

When Hurricane Katrina roiled into New Orleans on August 29, it contaminated area water supplies with everything from gasoline to raw sewage. But what many people don't realize is that it doesn't take a category five storm to foul drinking water. In communities across the United States, local water supplies are threatened or have already been tainted by a range of synthetic and organic contaminants.

One morning in July 2003, I noticed a town highway department truck spraying herbicide on vegetation along a road near my home in Massachusetts. I asked the workers about the product's safety and was told that the chemicals were "perfectly safe" and approved for use by both the local board of health and the U.S. Environmental Protection Agency (EPA). But I remained concerned; my neighbors and I depend on private wells, which are susceptible to contamination through runoff and other routes, for drinking water.

Further investigation indicated that the local board of health apparently had not known about roadside spraying of the herbicide. I found several epidemiologic studies suggesting that herbicide exposure can have adverse health effects, including genetic mutations, cancer, and birth defects. Although most of these studies involved the agricultural use of herbicides, experts were voicing concern about the potential threat posed by chronic, low-dose exposure through drinking water. And contrary to what the high-

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Courtesy of the Western Pennsylvania Coalition for Abandoned Mine Reclamation

A headwater stream in the Allegheny–Monongahela watershed in western Pennsylvania is discolored by acid and heavy metals leaking from abandoned coal mines. The Allegheny–Monongahela river system ranked fifth on conservation organization American Rivers' 2004 "America's Most Endangered Rivers" list; with the Ohio, its waters serve 42 "public drinking water intakes" in the region.

way department workers had told me, the EPA does not have an approval process for herbicides and does not require testing for hormone or immune system damage and other health effects.

Eventually, I learned that in 2002 the Massachusetts Turnpike Authority had adopted a zero-use policy for herbicides as a result of scientific data and concerns that drinking water treatment processes do not adequately filter these chemicals. I presented my research to the local board of health. My perseverance paid off: four months later, responding to pressure from the board of health and community residents, the town's highway department adopted a zero-use policy in residential areas.

This article describes several types of known contaminants of drinking water in this country, discusses assessment when contamination is a suspected cause of illness, and describes the nurse's role in patient education and community advocacy. Although selected contaminants and their health effects are covered, a discussion of treatment is beyond its scope.

HOW SAFE IS THE WATER?

Americans drink a lot of water, "more than 1 billion glasses of tap water per day," according to the EPA; with the national population estimated to be just short of 300 million, that's at least three glasses per person daily.[1,2] But just how safe is the water we drink?

Americans no longer have much to fear from waterborne killers like cholera, dysentery, and typhus, diseases that were rampant 100 years ago. The use of chlorine to disinfect community water supplies, a practice that began in the early 1900s, has effectively eliminated many such diseases in this country.[3] But emerging resistant organisms and increasing environmental contamination continue to present significant challenges. The Safe Drinking Water Act (SDWA) of

Resources

Community Right-to-Know Hotline
(800) 424-9346
The hotline provides information on the uses and releases of chemicals by state.

Environmental Protection Agency
www.epa.gov
Recommended pages:
List of Drinking Water Contaminants and MCLs:
www.epa.gov/safewater/mcl.html
Local Drinking Water Information:
www.epa.gov/safewater/dwinfo/index.html
EPA Map of Radon Zones:
www.epa.gov/iaq/radon/zonemap.html
Ground Water and Drinking Water:
www.epa.gov/safewater/index.html
Recognizing Waterborne Disease and the Health Effects of Water Pollution:
www.waterhealthconnection.org

1974 and subsequent amendments charged the EPA with regulating the nation's drinking water supply, including setting maximum allowable levels for natural and synthetic contaminants. Yet despite these measures, about 900,000 cases of waterborne illness—and 900 deaths—occur in the United States annually, according to an often cited estimate attributed to the Centers for Disease Control and Prevention (CDC).[4] Most experts agree that such figures represent only a fraction of the actual occurrences. Extrapolated data from one intervention study suggest that annual cases of waterborne illness more likely number about 40 million.[5]

The EPA regulates only 87 of the thousands of known contaminants of drinking water, although the potential health effects of many, including cancer, developmental effects, and various acute illnesses, are well documented.[6] The water systems in many large U.S. cities rely on an infrastructure of pipes more than 100 years old, and old pipes can rupture: in 2002 more than 200,000 water main breaks occurred nationwide.[7] They can also leach chemical contaminants such as lead or offer breeding ground for bacteria. The SDWA does not regulate private wells or community water suppliers that serve fewer than 25 people; in some states, as much as half the population drinks from unregulated water systems.[8]

RECENT OUTBREAKS AND VULNERABLE POPULATIONS

Since 1971 the CDC and other agencies have collected surveillance data on disease outbreaks in the United States associated with drinking water; in 1978 they also began gathering data on outbreaks linked to recreational water use. During the 2001–2002 surveillance period, the most recent for which data are available, 31 waterborne disease outbreaks associated with drinking water were reported in 19 states.[9] An estimated 1,020 people became ill; 51 were hospitalized and seven died. The cause of illness was identified in 24 outbreaks: 19 were associated with pathogens, including six involving *Legionella* species, and five were linked to chemical poisoning. Common microbial contaminants included parasites, bacteria, and viruses. Of the 25 outbreaks not attributed to *Legionella* species, 23 were linked to contaminated groundwater (water found in underground aquifers that is used for private and municipal wells), including nine that were associated with unregulated private or noncommunity wells.

During the same surveillance period, a record 65 outbreaks associated with recreational water were reported in 23 states; 2,536 people became ill, 61 were hospitalized, and eight died.[10] Of the 65 outbreaks, 30 involved gastroenteritis; among these, the most frequently identified contaminants were *Cryptosporidium* species, found at 50% of the treated water sites, and *Escherichia coli* and norovirus, each found at 25% of the freshwater sites.

Susceptibility to illness from exposure to contaminated water, as well as the magnitude of the toxic response, can be influenced by a number of factors, including older or younger age and fragile health. The most vulnerable populations—children, older adults, pregnant women, and people who are immunocompromised—may experience adverse effects at lower levels of exposure to contaminants than other populations.

Many environmental contaminants can have devastating effects. Prenatal exposure can produce teratogenesis and premature death. Exposure during infancy and childhood can damage developing organ systems. Children consume more water per unit of body weight, and they metabolize and excrete toxins less efficiently than adults do. Older adults are similarly at risk because diminished blood flow to the liver and kidneys can decrease their ability to eliminate environmental toxins; declining immune function and malnutrition can be factors as well. For example, a literature review by Gerba and colleagues found that nursing home residents who contract foodborne bacterial gastroenteritis are 10 times more likely to die than those in the general population who contract the same illness.[11]

Gerba and colleagues also found that pregnant women are similarly at increased risk.[11] They reported that two studies found that pregnant women are 10 times more likely to die during a waterborne hepatitis E outbreak than those in the

A 30-inch pipe spews out 27,000 gallons of blackened water per minute at the 17th Street Canal in New Orleans, Louisiana, on September 9. Contaminated water was pumped into Lake Pontchartrain. Some of the effects of Hurricane Katrina and the flooding in New Orleans may not be seen for years to come. Not the least of the problems is—and will continue to be—contaminated water. In the weeks after the disaster, EPA testing revealed greatly elevated levels of *E. coli* and other coliform bacteria associated with raw sewage, as well as many dangerous chemicals, including lead, concentrations of which are actually increased by boiling. The EPA warned both health care workers and the public to avoid contact with the polluted water and to avoid drinking it, if at all possible. According to the EPA, likely symptoms of ingestion are stomachache, fever, vomiting, and diarrhea. Infection at wound sites is also likely among those coming into contact with the filthy water; people with fever along with redness and swelling at wound sites are admonished to seek medical treatment. For links to information on the contaminants found in the floodwaters, go to http://sis.nlm.nih.gov/enviro/hurricane.html.

AP Photo/Steven Senne

general population. Altered immune response, hormonal changes associated with pregnancy, and malnutrition have been postulated as possible factors.

MICROBIAL CONTAMINANTS

Parasites. Common parasitic causes of recent drinking water–related disease outbreaks include *Cryptosporidium* species and *Giardia intestinalis*.[9] These organisms can readily infect humans when drinking water supplies are polluted by sewage or agricultural runoff. Transmission characteristically occurs by the fecal–oral route. Outbreaks are usually associated with contaminated well and surface water systems and water treatment failure.

The small size and unique structure of *Cryptosporidium* species make them resistant to standard methods of water filtration and disinfection. The organisms have an outer shell that protects them outside the human body and also makes them resistant to chlorine treatment. Cryptosporidiosis, the resulting illness, is particularly dangerous for immunocompromised patients, young children, and the elderly. In 1993 the largest waterborne-disease outbreak of the late 20th century occurred when more than 400,000 people in Milwaukee became ill with diarrhea after drinking *Cryptosporidium*-contaminated water.[12] More than 50 fatalities, most of them in people with AIDS, resulted.

The incubation period is about one to two days; symptoms, which include dehydration, weight loss, abdominal cramps or pain, fever, nausea, and vomiting, begin one to 12 days after infection. Some patients are asymptomatic.

Giardia intestinalis lives in the intestines of infected animals and humans and can be found in soil, food, water, or any site contaminated with their feces. Symptoms, which usually appear between three and 25 days after infection, include diarrhea, steatorrhea, abdominal pain, bloating, nausea, and vomiting. The disease can be transmitted as long as the patient remains infected, which can be as long as a few months. In cases of chronic giardiasis, recurring symptoms can be debilitating and can cause malabsorption.

Bacteria. *E. coli* O157:H7, a particularly toxic strain of the bacterium, causes severe bloody diarrhea and abdominal cramps; there is usually little or no fever and some people are asymptomatic. The incubation period is typically two to eight days but may be longer. The illness usually resolves in five to 10 days without antibiotic treatment. However, in susceptible populations, particularly children younger than five years and older adults, the infection can cause hemolytic uremic syndrome, a life-threatening illness. In the digestive tract, *E. coli* O157:H7 produces toxins that enter the circulation, attacking erythrocytes. As the damaged cells accumulate in the

TABLE 1. Keeping it Clean

Water Treatment Method*	How It Works	Some Contaminants Treated
Adsorption	Particles in the water adhere to the surface or pores of adsorbent mediums, such as carbon or charcoal. A filter contains the carbon or charcoal; when water is passed through it, the contaminants are removed.	Volatile organic chemicals (VOCs), pesticides, trihalomethanes
Water softeners	Water softeners use a cation-exchange resin, regenerated with sodium chloride or potassium chloride, to reduce the "hardness" of the water. Calcium and magnesium ions are replaced with sodium or potassium ions.	Calcium and magnesium
Ultraviolet (UV) light	Water is passed through a tube that is exposed to UV light, which is a microbicide.	Bacteria and viruses (some systems treat only heterotrophic bacteria)
Reverse osmosis	Water molecules are forced through a membrane that blocks larger inorganic particles from passing through.	Pesticides, dioxins, and VOCs
Distillation	Water is heated to the boiling point in one chamber; the steam is collected in a separate chamber. When the water is completely vaporized, many contaminants, including nitrates, bacteria, heavy metals, and radionuclides, are left behind. The cooling steam condenses into purified water. Household distillers are generally used for drinking or cooking water.	Arsenic, barium, cadmium, chromium, and lead

*For a complete list of water treatment technologies and products that reduce specific contaminants and are certified by the National Sanitation Foundation, see www.nsf.org/consumer/drinking_water/dw_treatment.asp?program=WaterTre.

National Sanitation Foundation International. *Home water treatment devices: drinking water treatment technologies.* 2004. http://www.nsf.org/consumer/drinking_water/dw_treatment.asp?program=WaterTre#technologies.

kidneys, waste filtration is impaired. The resulting buildup of excess fluid can cause hypertension and swelling of the hands and feet; in some cases, the illness can progress to acute kidney failure.

Campylobacter jejuni causes campylobacteriosis; the illness has an incubation period of between two and five days after exposure and can last as long as a week. Symptoms include diarrhea, abdominal cramping or pain, malaise, nausea, and vomiting. Long-term complications can include reactive arthritis or Guillain–Barré syndrome (it's believed that as many as 40% of cases of Guillain–Barré are triggered by campylobacteriosis[13]).

Salmonella enterica typhimurium infection usually resolves in five to seven days; treatment isn't required unless the patient becomes severely dehydrated or the infection spreads from the intestines. Symptoms include diarrhea, fever, abdominal cramps, nausea, and vomiting. Infection may also present as septicemia, an abscess, reactive arthritis, or cholecystitis.

Enteric viruses include noroviruses, rotaviruses, adenoviruses, astroviruses, and hepatitis A.[9] Viruses are much more resistant to chlorine disinfection than bacteria are. Symptoms of infection include watery diarrhea, vomiting, headache, fever, and abdominal cramps; such symptoms usually appear one to two days after infection and can last as long as 10 days. It can be especially difficult to identify enteric viral infections; nurses are more likely to be aware of parasitic and bacterial causes of these symptoms and may not consider viral causes. It's likely that many outbreaks of "stomach flu" with resulting vomiting or diarrhea are actually caused by enteric viruses.[14]

CHEMICAL CONTAMINANTS

More than 70,000 chemicals are produced annually in the United States.[15] Hundreds of these chemicals may be found in drinking water supplies nationally, although many have never been tested regarding their toxicity for humans or the environ-

ment.[16] According to the Institute of Medicine, recent data released by the United States Geological Survey show that "new contaminants and contaminant mixtures"—such as natural and synthetic hormones and pharmaceuticals—are "appearing in our surface waters."[17] Surface water is water found on the surface of the earth, such as in lakes, rivers, or streams—about half of all Americans get their drinking water from a surface water supply; half obtain it from groundwater.[18]

Water becomes polluted through "point sources," easily identified sources that discharge chemicals into the environment, such as factories, or through "nonpoint sources," less easily discernible sources carrying agricultural or industrial runoff, such as melting snow or paved roads. Chemicals can enter surface water reservoirs directly or seep into underground aquifers to contaminate groundwater. Inorganic chemicals (such as arsenic, beryllium, cyanide [as free cyanide], and nitrites), synthetic organic chemicals (such as vinyl chloride, toluene, benzene, and dioxin), pesticides, and herbicides are found in low concentrations in many drinking water systems. Many pesticides that were once widely used, such as dichlorodiphenyltrichloroethane (DDT) and other chlorinated hydrocarbons, have been banned for decades but are resistant to degradation; such chemicals are known as persistent organic pollutants.

There is concern about the risks of drinking water that contains even very low levels of known or suspected carcinogens or of chemicals with documented adverse neurologic, reproductive, or teratogenic effects. For example, halogenated hydrocarbons (such as trichloroethylene, a solvent and an ingredient in adhesives and in paint and spot removers) are among the most common water supply contaminants in this country. Low-level exposure to trichloroethylene has been associated with immune system impairment, kidney and liver damage, and impaired fetal development.[19] Selected chemical contaminants found in drinking water and some of their potential health effects are discussed below; for a more complete listing of all types of drinking water contaminants, go to www.epa.gov/safewater/mcl.html#mcls. It's also important for patients to realize that exposure to chemical contaminants isn't confined to ingestion; volatile chemicals, such as benzene, are easily absorbed through the skin or inhaled from heated or aerosolized water, which means that bathing is another potential source of exposure.

Disinfectant byproducts. Water treatment with disinfectants such as chlorine, ozone, chloramines, and chlorine dioxide reduces the levels of microbial contaminants. But these disinfectants can react with organic matter such as decaying vegetation to create byproducts, including trihalomethanes (THMs), haloacetic acids, bromate, and chlorite. Some studies have demonstrated associations between exposure to disinfectant byproducts in drinking water and various adverse health effects. For example, epidemiologic and toxicologic studies have shown a link between such exposure and bladder and rectal cancers.[20, 21] Studies have also found associations between chlorinated drinking water and reproductive and developmental outcomes such as stillbirth, congenital cardiac defects, intrauterine growth retardation, and low birth weight.[22, 23] Pregnant women exposed to water with increased levels of THMs appear to be at higher risk for pregnancy-related complications, including birth defects, stillbirth, spontaneous abortion, and fetal growth retardation.[22, 24] However, other studies have found no such associations between exposure to disinfectant byproducts and adverse health effects, and the debate is ongoing.

Two studies found that pregnant women are 10 times more likely to die during a waterborne hepatitis E outbreak than those in the general population.

The EPA has stated that it considers disinfectant byproducts "a potential hazard concern" and has supported regulatory action.[25] In 1998 the EPA's Stage 1 Disinfectants and Disinfection Byproducts Rule set goals for maximum allowable levels of disinfectants and disinfectant byproducts in water systems. Large surface water systems were required to comply by 2002; groundwater systems, by 2004. However, with the exception of the District of Columbia and Wyoming, all other states have "primacy," which means that the states, not the EPA, have primary enforcement authority. Compliance data can be accessed only through state databases; no federal database exists. A proposed Stage 2 Disinfectants and Disinfection Byproducts Rule, aimed at further reducing exposure levels and health risks, is slated for review in December.[26]

Lead. Lead-contaminated drinking water may account for as much as 20% of a person's total exposure to lead, and that percentage may be higher in infants drinking formula prepared with lead-contaminated water, according to the EPA.[27]

Even though in 1986 Congress banned the use of lead solder with more than 0.2% lead and limited the

Drinking Water Choices: Filters, Bottles, and Beyond

In their pursuit of safer drinking water, many people consider adding household filtration or treatment devices or drinking bottled water. Nurses can help patients to make informed decisions by knowing which contaminants may be affecting local drinking water and by understanding the potential benefits and risks of alternative sources. If the household is served by a public water utility, basic drinking water information is available through a consumer confidence report (see *The Consumer Confidence Report*, page 49).

Courtesy of Brita

Household water treatment and filtration systems have become increasingly popular in recent years. According to *Consumer Reports*, Americans spend more than $1 billion on household water filtration annually.[1] Various treatment technologies are available. Point-of-use systems treat water at a single tap and may be installed at the faucet, on a counter, or under a sink. Point-of-entry systems are installed where the water line enters the house and treat water used throughout the house.

Filters differ in their capacity to reduce chemical and microbiologic contaminant levels, such as disinfectant byproducts, lead, and parasites. Not all filters can remove all types of contaminants. Moreover, any filtration system must be maintained or it will eventually become ineffective and, if accumulated contaminants are released back into the drinking water, a health hazard. Although the U.S. Environmental Protection Agency (EPA) does not test or certify water filtration devices, it recommends that such devices meet the standards of the Water Quality Association (www.wqa.org) or the National Sanitation Foundation International (www.nsf.org).[2]

Bottled water. Americans drink an estimated 6 billion gallons of bottled water annually.[3] But bottled water is not necessarily safer than tap water; indeed, an estimated 25% or more of bottled water sold in the United States may be tap water.[4] Moreover, a four-year study by the Natural Resources Defense Council found synthetic organic chemicals, bacteria, and arsenic in water samples representing 103 brands of bottled water.[4] One-third of the samples violated established industry or state limits on contaminant levels.

There are important differences between regulations governing tap water and bottled water. The EPA sets standards for tap water, but nationally sold bottled water falls under the jurisdiction of the U.S. Food and Drug Administration (FDA)—and water bottled and sold within the same state is exempt from both EPA and FDA regulations. Moreover, many states lack state regulations regarding water bottled and sold within the state, and these unregulated bottles account for 60% to 70% of bottled water.[4] The FDA also exempts carbonated water and seltzer from the oversight process.

Each time the EPA establishes a standard for a chemical or a microbial contaminant, the FDA is free to adopt it or not.[5] For example, EPA rules prohibit tap water from containing any coliform bacteria, including *E. coli*, but the FDA stipulates a maximum allowable limit for coliform bacteria. Municipal water systems *must* test tap water for coliform bacteria at least 100 times per month, while FDA regulations for bottled water plants require weekly coliform bacteria testing. The less rigorous requirements for some microbial contaminants are of greater concern for populations at higher risk of infection, such as people with a compromised immune system, older adults, and infants. Only bottled water that's labeled "filtered through an absolute 1-micron or smaller filter," "one micron absolute," "distilled," or "reverse-osmosis treated" has been processed by methods effective against *Cryptosporidium* species.[6]

Some parents may buy more costly bottled water marketed and labeled as being "for use in preparing infant formula." They should be cautioned that such products are only required to meet EPA standards for tap water.[7]

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lead content of faucets, pipes, and other plumbing materials to eight, older homes may still have lead-based plumbing.[28] In many large cities, lead piping still connects municipal water mains to homes. Drinking water—especially water that is acidic (has below-neutral pH) or soft (has low mineral content)—can cause lead to leach from lead-soldered joints and lead connector pipes, as well as from brass fixtures.

Lead has long been recognized as neurotoxic; in children the effects of exposure can be devastating. Clinical manifestations vary somewhat, depending on blood lead levels, which are determined, in part, by duration and intensity of exposure. Some effects of exposure may be latent. Overt clinical symptoms and health effects produced by high exposure levels can differ from person to person; however, a lack of symptoms doesn't mean that lead poisoning has not occurred. Lower levels of exposure may cause numerous subtle health effects, including decrements in IQ scores and changes in peripheral nerve function. In infants and young children, continuous exposure to high environmental levels can result in delayed physical and cognitive development and learning disabilities. Lead exposure in adults can result in kidney problems or hypertension.[27]

Assessment of blood lead levels is best accomplished by the collection of a venous blood sample. The CDC, stating that "there is no apparent threshold at which the adverse effects of lead do not occur,"[29] defines a blood lead level of 10 micrograms per deciliter or greater in children as elevated. Children with blood lead levels greater than 60 micrograms per deciliter can experience abdominal pain, a loss of appetite, constipation, headaches, agitation, clumsiness, decreased activity, or somnolence.

Nurses should ensure that lead screening tests are performed in infants and that children are assessed for symptoms of lead toxicity. If elevated blood lead levels are found, lead in the family's drinking water must be considered as a possible cause. Testing for lead in drinking water in homes, day care centers, and schools should be conducted by state-certified laboratories.

To prevent exposure to lead through drinking water, counsel families to use only cold water for drinking, cooking, and the preparation of infant formula because hot water can cause leaching. Foods that require or absorb water during preparation (such as soup, rice, and pasta) will absorb lead and other contaminants present in the water as well.[27] If cold water hasn't been accessed in several hours, instruct the family to let the tap run for at least 30 seconds or longer, in order to flush standing water from the system that may contain leached lead.[27]

Nitrates. The most common inorganic nitrates found in drinking water are potassium nitrate and ammonium nitrate, both widely used as fertilizers. Sources of organic nitrate contamination include livestock manure (especially from large-scale operations such as feedlots), leakage from substandard private septic systems, and discharge from municipal wastewater treatment plants.[30]

Nitrates convert to nitrites inside the body; this process interferes with the oxygen-carrying capacity of the blood. Even short-term exposure in infants younger than six months can lead to methemoglobinemia, an acute condition in which health deteriorates rapidly; if untreated, anoxia may be followed by brain damage and death. It's most common in infants who are already sick, eat foods high in nitrates (such as broccoli), and drink formula prepared with nitrate-contaminated water.[27] Symptoms include shortness of breath, bluish mucous membranes and skin tone, and at high levels of exposure, altered mental status and delirium. Symptoms of excessive nitrate levels in older children include irritability, tachypnea, altered mental status, and headache.

If elevated blood lead levels are found, lead in the family's drinking water must be considered as a possible cause.

NATURAL GROUND DEPOSITS

The erosion of natural ground deposits may cause the release of radionuclides, isotopes that emit some form of radiation, such as alpha and beta particles, ultraviolet light, and X-rays. Radionuclides are the result of naturally occurring decay of radioactive elements such as uranium and radium. Although there are hundreds of different radionuclides, only a few are common enough to be of concern. Exposure is associated with an increased risk of cancer.

Radon is a colorless, odorless gas produced by the natural decay of uranium. Its radionuclides (the most common is radon-222) emit alpha particle radiation. A carcinogen, radon causes approximately 20,000 lung cancer deaths annually.[31]

Radon is found in soil, rock, air, and water nationwide, although some geographic areas have higher levels than others. Data from public water suppliers indicate that elevated concentrations of radon in water occur primarily in the New England states, the Appalachian states, the Rocky Mountain states, and small areas of the Southwest and Great Plains.[32] Radon quickly leaves water that is agitated or exposed to air. Thus concentrations are low in municipal water supplies that use surface water

reservoirs; the highest concentrations are found in groundwater and private water supplies such as household wells. Maximum allowable contaminant levels for many radionuclides have been established in the National Primary Drinking Water Regulations; however, there is still no standard with regard to radon in drinking water.[6]

In the home setting, people are exposed to radon in several ways. Radon is distributed primarily through air. When water is agitated, as during showering and dishwashing, radon is released into the household air, boosting airborne radon levels and resulting in increased inhalation exposure. Radon in drinking water is believed responsible for about 180 deaths annually, causing stomach cancer when it's ingested in drinking water and lung cancer when it's released to air from drinking water.[32] Radon can also be present in natural gas supplies.

There are no signs and symptoms of radon exposure. The most common health effect caused by radon exposure in residential settings is lung cancer, and it's well documented that smokers are at especially high risk. For example, according to the Agency for Toxic Substances and Disease Registry, a smoker exposed to radon is 10 times more likely to develop lung cancer than is a lifelong nonsmoker exposed to radon.[33] And a recent analysis of data from 13 case–control studies yielded more disturbing results: the researchers determined that among people exposed to radon, the risk of lung cancer in smokers was 25 times greater than in people who have never smoked.[34]

Nurses can encourage patients in areas known to have high radon levels to test their homes and water for radon. Explain that activities such as dishwashing, showering, doing laundry, and even flushing the toilet can release radon into indoor air and result in increased exposure through inhalation. Water filtration systems that use granulated activated charcoal can trap radon and reduce levels in drinking water. However, individual tap filters should not be used, because radon released through agitation can still enter the air and actually *increase* inhalation exposure. Instead, filtration systems should be installed at the site where water enters the house.

Arsenic, a naturally occurring element that is found in rock and soil worldwide, enters surface and groundwaters primarily through erosion. Inorganic arsenic compounds are used as wood preservatives and in the manufacture of insecticides, herbicides, glass, metals, and electronics; industrial discharge and runoff from landfills therefore contribute to arsenic contamination of soil, air, and water.

Because clinical manifestations of arsenic exposure differ among individuals, population groups, and geographic regions, there is no standard definition for arsenic poisoning. In children, there is some evidence that polymorphisms in the *CYT19* gene may affect arsenic metabolism and thus influence the manifestations of arsenic exposure.[35] Early symptoms of acute toxicity include vomiting, abdominal pain, and bloody "rice water" diarrhea.

Chronic arsenic poisoning after long-term exposure to contaminated drinking water manifests quite differently. Adverse effects include skin, lung, bladder, and kidney cancer, as well as conditions such as altered pigmentation and hyperkeratosis. Cancer generally appears after more than 10 years of chronic exposure.[36]

Urine testing is the most reliable way to assess whether arsenic exposure has occurred within the past few days. Hair and fingernail testing are useful for measuring high-level exposure that occurred six to 12 months earlier. Arsenic can be removed from well water at the household point of entry, using adsorption, reverse osmosis, or distillation.[37]

PRIVATE WATER SUPPLIES AND FILTRATION

About 15% of Americans obtain their drinking water from private water supplies, in most cases from groundwater drawn through wells.[38] There are no federal regulations for routine contaminant testing of privately supplied drinking water, and the EPA doesn't have the authority to regulate these wells. Almost all states license or register well installers, who must comply with basic construction standards, but after construction is completed, it's usually the homeowner's responsibility to maintain the well and ensure the safety of the water supply.

Suburban "sprawl" is bringing more businesses and industries into rural areas that rely on household wells; new housing developments are being built at the edges of rural and agricultural areas not served by municipal sewer and water supply lines. Many of these new homes rely on household wells and septic systems. Some homeowners may not have experience with maintaining these systems and may believe that well water is always pure; unfortunately, groundwater contamination is present in all 50 states.[38]

WHAT YOU CAN DO

Through patient education and community advocacy, nurses can help reduce the risk of waterborne illness in vulnerable populations and improve the status of the local drinking water supply. Becoming more knowledgeable is the first step.

Counsel patients and families about protecting their household water supply. Provide them with information about potential sources of contamination and ways to prevent this, as well as ways to minimize the risk of infection. Handwashing remains one of the most effective measures one can take to prevent microbial infections; remind patients and

family members to wash their hands before, during, and after food preparation, as well as after using the toilet or changing a baby's diaper.

Families should also be counseled on how to safeguard their groundwater. Protective measures include[39]

- pumping and inspection of septic systems at intervals recommended by the local health department.
- never disposing of hazardous materials in septic systems.
- not mixing or using pesticides, fertilizers, herbicides, degreasers, fuels, and other pollutants near wells.
- never disposing of wastes in dry or abandoned wells.

Explain to patients and families the value of having the household drinking water tested. It's a common misconception that contaminants in water can be detected through changes in its taste, appearance, or odor; many contaminants, including bacteria, heavy metals, radon, and synthetic organic chemicals, are detectable only through laboratory testing.

Provide information about water testing protocols and interpretation of the test results. Wells should be tested annually for pH levels, coliform bacteria such as *E. coli,* nitrates, total dissolved solids, and any contaminants of concern locally.[38] For example, in areas of high radon activity (particularly, bedrock wells), radon testing of the water is indicated; in agricultural regions, testing water for herbicide and pesticide contamination is indicated. Testing should be performed more frequently if chemical or fuel spills are known to have occurred—regardless of when a spill happened—and whenever there is a change in water taste, odor, or clarity. Water testing should always be performed by the local health department or a state-certified laboratory, not by commercial vendors of water filtration systems.

Consider the possibility of waterborne illness when encountering acute gastroenteritis of unknown etiology. You can improve surveillance efforts for waterborne illnesses by assuming a higher index of suspicion in such cases. It's essential to obtain a drinking water history. Ask patients about sources of drinking water at home, school, and work; recreational water exposures (swimming and hot tub); and travel abroad. General questions about drinking water might include the following:

- What are your sources of drinking water at home (for example, municipal water from the tap, municipal water processed with a home filter, private well water, bottled water)?
- If you use a filtering system, has the filter been changed according to the manufacturer's directions?

If the patient has a well, ask:

- When was the last time your well water was tested for contaminants?
- What contaminants was it tested for?
- Do you use a state-certified laboratory for water testing?
- Do you use pesticides, fertilizers, or other chemicals on your lawn?

If there are children in the home, these questions might be helpful:

- Does your home have lead pipes?
- Have your children been tested for lead exposure?

The Consumer Confidence Report

In 1996 an amendment to the Safe Drinking Water Act required that all community water systems produce a "consumer confidence report" (CCR) annually, beginning in 1999, with the aim of giving consumers a "snapshot of their drinking water supply."[1] The Environmental Protection Agency (EPA) has estimated that this rule affects 55,000 water systems and serves to inform about 248 million Americans.[1] Larger water systems mail the CCR to paying customers and post it on the Internet; smaller systems (those serving fewer than 10,000 people) may disseminate information through newspapers. Nurses can help patients understand their CCR and use the information presented when making decisions about their drinking water.

States have the option of setting some alternative report requirements. However, all CCRs must adhere to certain baseline standards, including those listed above, to ensure that all consumers receive comparable reports containing the same type and amount of essential information[1]:

- the source of the drinking water
- a summary of the source's susceptibility to contamination
- levels of contaminants found in the drinking water and their likely health effects, as well as maximum allowable contaminant levels set by the EPA
- the likely source of identified contaminants
- an accounting of the system's actions to address the contamination
- educational information about selected contaminants

Some water systems, such as community systems serving fewer than 25 people, are exempt from having to publish a CCR.

The most significant limitation to a CCR's usefulness is that systems need only report levels of regulated contaminants—unregulated contaminants, such as pesticides and herbicides, need not be reported. Other limitations include the fact that a CCR provides data from the previous calendar year, rather than current data. And the language of the report can be technical or otherwise difficult for some to understand without assistance.

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Thinking Globally, One Water Jug at a Time

When one Googles the phrase "dirty water," the first hits include Web pages for the Boston Rock & Roll Museum (www.dirtywater.com) and the Dirty Water Club, a hip London hangout, apt tributes to the Standells' 1966 hit single "(I Love That) Dirty Water." Its chorus was a paean to Boston's Charles River: "Oh, I love that dirty water, oh Boston, you're my home." But to billions of people worldwide—the 2.6 billion who live without adequate sanitation and the 1.1 billion who lack access to safe drinking water[1]—dirty water means tragedy. According to the World Health Organization, diarrheal diseases kill 1.8 million people annually, most of them children in developing nations; 88% of these cases are attributed to contaminated drinking water, inadequate sanitation, and poor hygiene. And, as the *Washington Post* reported in March 2003, an analysis issued by the United Nations that year revealed that the planet's water supply is dwindling fast: by the year 2023, "the average supply of water per person worldwide will have dropped by one-third."[2]

Courtesy of Patrick Suleiman Bateganyais

Children at the orphan center in Moyo, Uganda, sing for the visiting nurses who provide PūR demonstrations and ongoing education about the importance of safe drinking water and good hygiene and sanitation practices.

Together with the International Council of Nurses (ICN) and the Centers for Disease Control and Prevention, the P&G Health Sciences Institute, a Procter & Gamble division based in Cincinnati, Ohio, has developed and tested a point-of-use water purifier (PūR Water Purifier). The product contains "the same ingredients used in municipal water systems"[3]—including a coagulant, an alkaline agent, a flocculent, and a chlorine-based disinfectant—packaged in single-use sachets.[4] The only equipment needed: two containers capable of holding 10 liters (2.5 gallons) of water each, and something to stir with.

Decontamination is a three-step process. The user[3]

- adds the contents of one sachet to a 10-liter (2.5-gallon) container of water and stirs for five minutes (allowing coagulation and precipitation of heavy metals, pesticides, and other chemical contaminants).
- filters the water through a clean cloth.
- lets the filtered water stand for 20 minutes (allowing disinfection).

In one recent study, researchers found that the purifier reduced 14 types of waterborne bacterial pathogens (including *Salmonella typhi, Vibrio cholerae, and Escherichia coli*) to undetectable levels and removed 99.8% of arsenic.[4] It also significantly reduced the levels of poliovirus, rotavirus, and *Cryptosporidium*. Its effectiveness was tested in U.S. Environmental Protection Agency "model" water samples and in field samples from Guatemala, Kenya, Pakistan, the Philippines, and South Africa. Similar results were seen in Bangladesh, where arsenic-contaminated water is common. Tests were conducted under both laboratory and "real-life" conditions, in which samples were stirred and allowed to stand after filtering for shorter-than-recommended times. Other studies have con-

Courtesy of Procter and Gamble

The PūR Water Purifier only requires two containers and something to stir with to complete decontamination.

- What kind of water do you use to prepare infant formula?

Patients identified as being at risk for drinking water–related illness should be provided with appropriate counseling. Offer patients information about water treatment systems and bottled water. All possible cases of waterborne illness should be reported to the hospital infection control department or directly to the local health department, as appropriate.

Take steps to safeguard the community water supply by becoming more knowledgeable about its drinking water, as well as existing and potential sources of contamination. By law all community

firmed the water purifier's effectiveness in removing arsenic and microbial contaminants.[5-7]

Earlier this year, the United Nations Children's Fund and P&G announced a joint campaign aimed at "providing home-based water purification" to families in developing countries; the company will supply PūR at cost (about 4 cents per packet).[8] Working with local nursing and health care organizations, the ICN continues to train nurses and other providers in the product's use and to coordinate outreach and distribution efforts. In Uganda the ICN and P&G, working in partnership with the Ugandan Association of Nurses and Midwives, are currently providing two centers for children orphaned by AIDS with PūR, as well as education in its use and the importance of improving drinking water safety and sanitation and hygiene practices. Within a 10-month period, diarrheal rates at the orphan centers have declined from between 12.5% and 14% weekly to almost zero. A similar project is scheduled to begin in Malawi later this year.—*Sylvia Foley, senior editor*

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water systems must produce an annual "consumer confidence report" on the status of the local drinking water supply; nurses need to become familiar with this document. (See *The Consumer Confidence Report*, page 49.) Ask your local water utility whether there has been a review of potential pollution sources; if not, urge the utility to perform one. Act as resource for patients, colleagues, and members of the community.

Other measures nurses can take include promoting policies and legislation that enforce and strengthen current drinking water regulations and support the modernization of old and deteriorating public water systems. Bottled water and water filtration devices can at best offer only short-term relief from the ills associated with contaminated water; the long-term solution lies in improving municipal and private water supplies. ▼

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