Municipal Drinking Water Safety

The link between groundwater, pathogens, and public health

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CLEAN, SAFE DRINKING WATER is a hallmark of Wisconsin's communities. Our abundant groundwater resource has allowed communities to develop water supplies without the costly treatment required to remove pathogens (bacteria and viruses) found in water drawn from lakes or streams. However, new research shows that even groundwater can become contaminated with pathogens that can cause illness.

Communities that do not currently disinfect their water supply should understand the causes and risks of illness linked to drinking contaminated groundwater. Relatively simple changes can help ensure a healthy, safe water supply.

Wisconsin's public drinking water: Where does it come from?

About 4 million, or 70 percent, of all Wisconsin residents get their drinking water from one of 612 municipal water systems.[1]

Several large municipal systems, including Milwaukee, Green Bay, and Appleton, use surface water. Such surface water systems, which serve about 1.8 million residents, are required by federal and state laws to disinfect the water to remove pathogens.

NEW RESEARCH shows that groundwater can become contaminated by viruses from untreated sewage.

Disinfection is not mandated for the municipal systems that supply groundwater to over 2 million residents. Nonetheless, all but 60 of the state's municipal groundwater systems disinfect their well water.

Groundwater geology: Where does well water come from?

As communities use water from wells, the pumping lowers the water table and groundwater flows into the well from the surrounding aquifer. The contributing area or "capture zone" of a well is the area of land surface where rainfall and snowmelt infiltrate to the water table and flow to the well (fig. 1).

Any contaminant within a capture zone is a potential contaminant at the well, because pollutants entering the

Wisconsin's private wells

Approximately 1.7 million, or 30 percent, of Wisconsin residents rely on private wells for their drinking water supply. Homeowners are not required to test their wells, but such wells should be tested annually for pathogens. Homeowners may choose to connect to community water supplies where available. Connection to community water systems is especially preferred to the use of private wells in subdivisions, where septic systems or sanitary sewer systems can leak outward and contaminate groundwater.

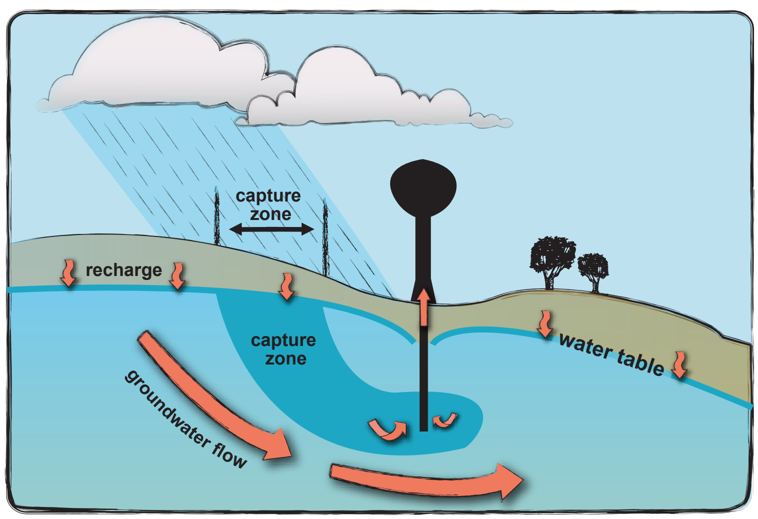


FIGURE 1. The capture zone of a well. Any contaminant within this zone is a potential contaminant at the well.
Source: Adapted from *Factors affecting areas contributing recharge to wells in shallow aquifers*, USGS Water-Supply Paper 2412.

water table are carried along with the flow of groundwater to a well.

The location and size of the capture zone depend on the direction of groundwater flow, the geology of the aquifer, and pumping and recharge rates (recharge is precipitation that reaches the groundwater system).

What contaminants have been found in groundwater?

Most groundwater pollution is related to structures and activities at or near the ground surface. Examples include landfills, land spreading of human or animal waste, underground storage tanks, septic and sewer systems, and industrial sites. These contaminant sources contribute bacteria and viruses; nitrate; and chemicals such as gasoline, pesticides, and industrial solvents to groundwater.

Many of these pollutants naturally degrade by biological or chemical processes, and many potential contaminants are diluted as they mix with uncontaminated groundwater. However, these processes do not fully protect groundwater quality.

Over the years, wells in cities and villages have become contaminated by a variety of compounds, and many wells in rural areas contain pesticides and fertilizers. Recent research shows that even municipal wells drilled hundreds of feet into bedrock aquifers are susceptible to contamination with pathogens.[2]

Related studies determined that municipal groundwater wells were contaminated by viruses from untreated sewage.[2,3,4,5] These viruses, known as human enteric viruses, are found in the human intestinal tract. Human waste is their only source in the environment. Such viruses detected in Wisconsin's water wells include noroviruses, adenoviruses, and enteroviruses.[2] The wells sampled in these studies were located in cities and villages, and evidence points to leaking sanitary sewers as the primary source of this contamination (fig. 2).

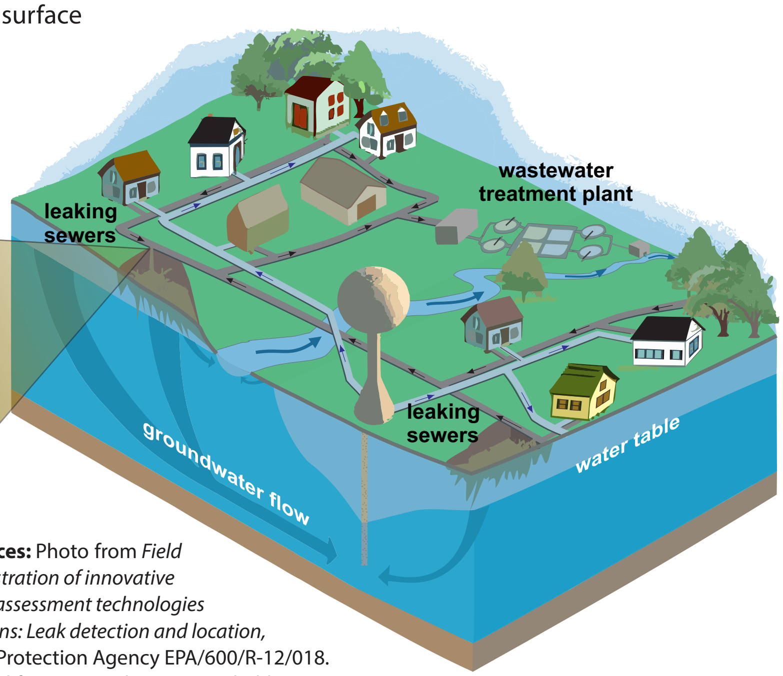
In addition to pathogens, sanitary sewage contains household chemicals, pharmaceuticals, flame retardants, and detergents[3]. These are often referred to as "emerging contaminants" because their discovery in surface water and groundwater is relatively recent. Most drinking water is not routinely tested for these compounds; although these chemicals can be detected at very small concentrations, there is no basis to determine their impact on the safety of drinking water and human health. The presence of these compounds in sewage is a compelling reason for communities to invest in routine maintenance and repair of sewer pipes.

Testing water for pathogens

Pathogens, such as bacteria and viruses, are disease-causing micro-organisms. Testing water for viruses is expensive and difficult, and this is not required of municipal water systems. As an alternative, drinking water wells are routinely tested for total coliform bacteria. Coliform bacteria live in soil, surface water, plants, and insects, but typically do not cause disease in healthy people.

A positive test result for total coliform bacteria indicates that a well is susceptible to surface water, and disease-causing pathogens may be present in the well water.

FIGURE 2. Leaking sewage pipes are a common source of groundwater pollution.



Sources: Photo from *Field demonstration of innovative condition assessment technologies for water mains: Leak detection and location,* Environmental Protection Agency EPA/600/R-12/018. Illustration adapted from *Groundwater—our hidden asset,* UK Groundwater Forum.

Wells that test negative for total coliform bacteria are considered bacteriologically "safe." These wells are not, however, safe from viruses. Viruses are much smaller than bacteria. Due to their small size, viruses can reach wells more quickly and easily than the larger bacteria. Wells that repeatedly test free of coliform bacteria have tested positive for human enteric viruses.[4] This finding demonstrates the need for disinfecting all groundwater supplies.

WELLS that repeatedly test free of total coliform bacteria have tested positive for human enteric viruses.

The link between drinking water and illness

A source of pollution unique to groundwater beneath cities and villages is the network of pipes within the sanitary sewer system. Unfortunately, many of these sewers date back to the early 1900s, and they are cracked and leaky. Inward leakage to these pipes often causes overflows at sewage treatment plants during large rainstorms. However, these pipes also leak raw sewage outward and are common sources of groundwater pollution in urban areas, towns, and villages.[6]

In a recent study, investigators documented the health effects of virus contamination on communities that do not disinfect their water supplies.[5] They looked at 14 Wisconsin communities with populations above 1,000 that did not disinfect their municipal groundwater supplies. These water systems were tested for the presence of viruses at residential taps. At the same time, over 600 households were surveyed weekly to determine if any family members were suffering from illness that could be caused by virus-contaminated drinking water.

Nearly one-quarter of the water samples taken from residential taps contained enough viruses to cause illness. The 1,079 children and 580 adults surveyed reported 1,843 cases of acute gastrointestinal illness (AGI) during the study period. The investigators attributed 6% to 22% of those cases to contaminated drinking water. They also found that as much as 63% of AGI among children younger than five may be explained by periods of higher concentrations of norovirus in the drinking water. The source of these viruses was identified as leakage from municipal sanitary sewer systems.

Sewage may enter the drinking water system in two ways. Leakage from sewage pipes within the capture zone can reach the water table and flow with groundwater to the well. Leaked sewage can also enter the drinking water distribution system when water pipes are opened for maintenance or repair, or during short periods when pressure in the water pipes drops.

While disinfecting sections of the drinking water distribution system is good maintenance practice, preventing contamination at the wellhead (or during pressure drops in the distribution system) requires continuous disinfection of the water supply.[7]

Maintaining a sanitary drinking water supply

Routine disinfection of drinking water supplies protects citizens from waterborne illness. Disinfection has been a common practice in the United States since the early 1900s. The addition of small amounts of chlorine, exposure to ultraviolet light, or purging with ozone gas are the most common methods used to protect against pathogens. In the study of 14 Wisconsin communities, ultraviolet light was used to disinfect the water supply. This treatment reduced viruses to safe levels.[5]

The following discussion describes three technologies available for disinfecting water:

Sanitizing technology

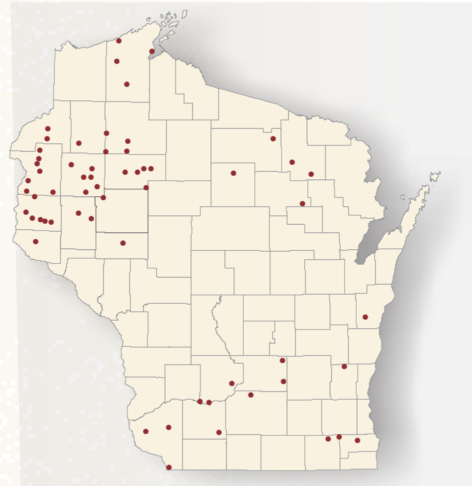
- **Chlorination** is the most frequently used method for disinfecting drinking water supplies. Chlorine gas, calcium hypochlorite, or sodium hypochlorite is added to the water supply at the wellhead. Chlorination is a persistent disinfectant that provides protection from the wellhead to the tap. Chlorination can impart a taste or odor to the water, and operators require training to properly maintain these systems.
- **Ozone gas** injected into the water supply effectively oxidizes pathogens and other chemicals, neutralizing their health impact. It imparts no flavor or odor, but unlike chlorine, it does not continue to provide sanitization throughout the distribution system. It can be expensive to install and operate.
- **Ultraviolet light** is used to break down organic molecules in the water supply, effectively eliminating most pathogens. It is safe to operate, and relatively inexpensive for small drinking water systems. Similar to ozone gas, ultraviolet light does not provide continual protection within the distribution system.

More information about drinking water sanitizing technologies can be found at http://www.nesc.wvu.edu/techbrief.cfm.

Status of Wisconsin communities treating drinking water

Most municipal water systems in Wisconsin disinfect their water supply. This process greatly reduces the risk of illness from water-borne pathogens. However, as of printing, 60 Wisconsin communities (listed here), with populations as high as 8,400, do not treat their water supply for bacteria and viruses.

Amani	Clear Lake	Exeland	Ladysmith	Roberts	Three Lakes
Baldwin	Colfax	Fall Creek	Lone Rock	Sheldon	Tomahawk
Balsam Lake	Crandon	Fall River	Luck	Shell Lake	Tony
Barron	Cumberland	Frederic	Maryville	Siren	Troy
Birchwood	Dallas	Friesland	Milltown	Somerset	Wabeno
Bloomington	Dane	Glen Flora	New Auburn	Spring Green	Washburn
Bluffview	Dresser	Hammond	North Cape	St. Nazianz	Webster
Bruce	Drummond	Hollandale	Port Wing	Star Prairie	Wheeler
Cameron	East Troy	Iron River	Radisson	Stitzer	White Lake
Chetek	Ellsworth	Kewaskum	Rice Lake	Stone Lake	Woodville



Source: Wisconsin Department of Natural Resources, January 2013, http://dnr.wi.gov/topic/drinkingwater/currentissues.html.

Learn more

For more details about state water regulations that apply to public drinking water systems, visit the Wisconsin Department of Natural Resources website at http://dnr.wi.gov/topic/DrinkingWater/currentIssues.html

To learn more about current research on viruses in groundwater, visit the Wisconsin Geological and Natural History Survey website at http://wisconsingeologicalsurvey.org.

Local engineering firms routinely assist in the design of site-specific disinfection systems for municipal water supplies.

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