Tracking Pathogens to Their Source

What’s the issue?

Pathogens from human sewage and animal waste are among the oldest and most ubiquitous drinking water contaminants. The term “pathogen” is a general term used to describe all types of disease causing microorganisms including viruses, bacteria, prions, fungi, viroids or parasites.

In the late-1800s, the advent of modern epidemiology and germ theory led to the understanding that many diseases are caused by waterborne pathogens rather than harmful “miasmas” (vapors) in the air. By the early-1900s, many American municipalities had taken steps to keep drinking water sources separate from sewage sources and were adopting basic filtration and disinfection techniques. In 1919 Wisconsin municipalities were required under state law to follow basic sanitary engineering principles, review construction plans for proposed treatment plants and regularly analyze water samples at the State Laboratory of Hygiene. Actions like these improved the quality of drinking water so dramatically that it is still considered one of the greatest global advances in public health. Half of the decline in mortality from 1900 to 1940 – the largest recorded decline in mortality in United States history – is attributed to the introduction of these basic wastewater and drinking water practices (Cutler and Miller, 2005). Wisconsin’s last typhoid outbreak attributed to a public water system occurred in 1929.

Protecting groundwater from pathogen contamination remains a top public health priority since outbreaks of gastrointestinal illness related to well water still occur periodically. A notable example is the 2007 outbreak of norovirus caused by contaminated well water which sickened 229 diners and staff at a Door County restaurant (Borchardt et al., 2011). In cases like this, multiple treatment technologies are needed to insure safe drinking water.

The risk of waterborne disease outbreaks can be related to how quickly pathogens travel through the soil. If pathogens in groundwater move slowly or travel long distances, the risk of illness can be diminished. By the time groundwater has traveled from a fecal waste source (e.g., septic field, leaking sanitary sewer or manure at the land surface) to a drinking water well, it can be pathogen free due to natural processes that cause pathogens to cling to soil particles or die-off. In areas with thin soils, fractured bedrock or shallow water tables, the risk of waterborne illness is greater because pathogens can travel more quickly to wells. The size of different types of pathogens and their attraction to soil particles affect how they move through soil. This means that the presence or absence of one pathogen (e.g. a type of bacteria) does not always correlate with the presence or absence of others (e.g. viruses).
Because of the complicated nature of pathogen transport and the serious consequences of waterborne disease outbreaks, the Groundwater Coordinating Council (GCC) prioritizes research that evaluates how, when and where pathogens in groundwater may pose a threat to public health.

**GCC in Action: Viruses in Drinking Water**

It is difficult and expensive to comprehensively test for all harmful pathogens, so water samples are typically tested for “indicators” – organisms that are not necessarily harmful themselves, but are a warning sign that other, potentially harmful, pathogens may be present. Traditionally, the presence of coliform bacteria is assumed to be a reasonable indicator of the presence of most harmful microbial agents, including viruses. Since 2000, groundbreaking work by GCC agencies related to the occurrence of viruses in drinking water and the impact on human health have challenged these assumptions.

An early indication of the significance of the problem came in the early 2000s, when researchers at the Marshfield Clinic Research Foundation demonstrated that viruses in private wells do not exhibit strong seasonal trends and are not correlated with commonly used indicators such as total coliform and fecal enterococci (Borchardt et al., 2003a and 2003b). A subsequent study with the U. S. Geological Survey (USGS) looking at La Crosse municipal wells drew similar conclusions and further concluded that nearby surface waters were not the source for the viruses; rather, viruses in La Crosse wells were likely coming from leaking sanitary sewers (Borchardt et al., 2004; Hunt et al., 2005). This was not shocking in a city like La Crosse, where municipal wells are located in shallow sand and gravel aquifer, relatively close to underground pipe infrastructure. However, municipal wells completed at depth – below confining layers of shale that separate shallow from deep aquifers – were presumed to be well-protected. The geology in the Madison area meets this description, yet collaborators from the Marshfield clinic, the Wisconsin Geological and Natural History Survey (WGNHS) and the University of Waterloo discovered human enteric viruses in Madison municipal wells in 2007, indicating that all aquifers are potentially vulnerable to microbial contamination (Borchardt et al., 2007; Bradbury et al. 2013).

In recognition that disinfection with chlorine or ultraviolet light can dramatically reduce virus populations, a subsequent study compared drinking water quality and illnesses in Wisconsin communities that do not disinfect. This work concluded that 6% to 22% of gastrointestinal illness incidents were directly attributable to viruses in drinking water in these communities (Borchardt et al., 2012). Results were so compelling that the Department of Natural Resources (DNR) quickly developed a rule mandating disinfection of municipal drinking water, although this was repealed by the state legislature in 2011.
Ongoing research funded by the GCC will look at how enteric pathogens travel through the Silurian dolomite aquifer in NE Wisconsin, source tracking of viruses in the field and looking at the impacts of septic systems in SE Wisconsin.

This series of studies exemplifies how work by GCC researchers positions Wisconsin at the cutting edge of protecting the environment, economy and public health. Nationally, the Environmental Protection Agency (EPA) included virus types found in the Wisconsin studies on the list of 30 unregulated contaminants that were monitored from 2013 to 2015 - in 6,000 public water systems across the United States - in order to gather information to support future drinking water protection. Continued research along these lines follows in the footsteps of the great public health advances of 100 years ago to ensure that drinking water, a basic human need, is not jeopardizing public health.

Other Projects in Other Places

Tracking the source of bacteria

Definitively identifying the cause of bacterial contamination in drinking water wells was not always possible. Many projects funded by the Wisconsin Groundwater Research and Monitoring Program have developed new techniques for detecting, quantifying and monitoring microorganisms in groundwater and soils. Impressive results include a rapid molecular method to identify contamination from human waste without culturing organisms; a reliable method for detecting Helicobacter pylori in environmental samples; and an assay that distinguishes fecal pollution from grazing animals, like cows, from other sources like pigs or chickens. Improved laboratory methods enhance the ability of GCC agencies to quickly understand the root causes of bacterial contamination and identify appropriate solutions.

References


