Waterborne Pathogens: Emerging Issues in Monitoring, Treatment and Control

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This March issue of *On Tap* coincides with the Water Quality Association's Aquatech USA conference and exhibition where I will be speaking on the topic of emerging waterborne pathogens. The following provides background information related to the upcoming WQA presentation, which outlines some of the current challenges and future needs for providing a safe drinking water supply to consumers.

Microbial threats to water quality continue to emerge; however, technologies for monitoring, treating and controlling emerging waterborne pathogens are also evolving. Understanding the range of factors that lead to the contamination of water are important for developing appropriate tools to manage human health risks.

Characteristics of waterborne pathogens

Viruses. Understanding some of the inherent characteristics of waterborne microbes helps us to circumvent their adverse effects. For example, human viruses have a low infectious dose, meaning only a small number are able to cause disease when ingested. Therefore, it is important that our tools for water monitoring have the ability to detect very low levels of viruses in large volumes of water. Compared to bacteria, waterborne viruses are generally more resistant to conventional drinking water treatment processes. Thus the validity of using bacterial indicators to monitor water quality and treatment efficacy has been questioned.

Bacteria. Although bacteria tend to be more susceptible to drinking water disinfectants, they have the unique ability to persist in the environment in dormant stages or associated with biofilms that improve their chances of survival. Unlike viruses, bacteria are well adapted to grow outside of their host and may greatly increase in number given appropriate growth conditions. Regrowth of bacteria in hot water heaters (i.e., *Legionella*) and distribution systems (i.e., *Pseudomonas*) has led to adverse health outcomes and poor aesthetics.

Protozoa. Protozoan parasites, such as *Cryptosporidium*, are extremely resistant to chlorine and thus require additional treatment for their removal (i.e., via filtration) or inactivation (via ultraviolet light). *Cryptosporidium* is frequently isolated from surface water, both before and after standard treatment. They too have a low infectious dose but do not have the ability to grow outside of invaded hosts. Wild animals and calves are commonly infected and known to shed massive amounts of protozoa into the environment, contaminating food and water supplies.

Microbial contaminants in drinking water may cause either waterborne or water-based infections. Waterborne infections are caused by pathogens that originate in feces of infected animals or humans and are spread through the fecal/oral route of transmission. Only through the ingestion of feces can the pathogen spread to new hosts; thus person-to-person spread is also possible. Control of waterborne infections is focused on elimination of fecal contamination of source waters or removal of fecal contamination pre-consumption.

Water-based infections are caused by pathogens that have a different life cycle than waterborne pathogens, and in many ways are much harder to control. These organisms are naturally present in water, having either originated from the aquatic environment or spent part of their life cycle in aquatic animals. They spread to human hosts via direct skin contact between the host and the water or through inhalation. Person-to-person transmission does not occur with water-based infections. Because the causative agents of water-based infections are indigenous to the water environment, the source water cannot be protected from contamination. Controls are primarily focused on minimizing growth of water-based pathogens.

Waterborne outbreak surveillance

Surveillance data collected by the Centers for Disease Control and Prevention since 1971 shows less than an average of 700 cases of illness per year due to waterborne outbreaks in the United States.[1] Reported outbreaks are unpredictable, occurring in more than 41 states and from varied etiological agents, water sources and treatment operations. Overall, viruses, untreated groundwater and inadequately treated surface water are the primary causes of documented outbreaks. The most recent surveillance summary report, with data from 2005-2006, identifies deficiencies leading to 23 documented drinking water outbreaks. Twelve of the outbreaks (52 percent) were due to deficiencies that occurred outside the jurisdiction of the regulatory agency. Ten of the 12 outbreaks that occurred outside of the water utility's jurisdiction or at the point of use were due to *Legionella* (a water-based pathogen) contamination in the drinking water system. An additional 10 outbreaks (44 percent) were due to untreated groundwater use or treatment facility/distribution system failures.

Outbreak data represents only a small portion of the total burden of waterborne disease given that the CDC outbreak surveillance information is passively collected through voluntary reporting. Environmental monitoring data of treated municipal water supplies repeatedly shows the presence of viable protozoan, bacterial and viral pathogens likely to be consumed unless appropriate POU treatment technology is utilized. Specific studies have found that up to 60 percent of distribution systems tested positive for the ulcer-causing bacterium, *Helicobacter pylori*; 27 percent of treated municipal drinking water tested positive for the protozoan pathogen, *Cryptosporidium* and up to 32 percent of groundwater from 448 utility wells in 35 states tested positive for human viruses. These studies and others provide examples of source, treatment and distribution system vulnerabilities.

The relatively low level of reported waterborne outbreaks per year (~700) is inconsistent with clinical and epidemiological data, where tens of millions of people seek medical attention for stomach illnesses caused by known agents of food and waterborne disease transmission. Direct monitoring data, however, can be used to estimate the probability of infection based on exposure to microbial pathogens detected in drinking water. Assumptions can be applied relative to how much drinking water an individual consumes and the likelihood of a microbial pathogen being present. Researchers combine this data in mathematical risk-assessment models designed to predict the probability of infection from tap water consumption without POU treatment interventions. Using this approach, more than 19.5 million cases of waterborne disease are estimated to occur each year in the US.[2]

Roadblocks to resolution of waterborne disease

Globally, a child dies every 15 seconds of diarrheal disease. Up to 90 percent of the global gastrointestinal disease burden could be prevented with adequate sanitation and hygiene. Controlling the sources of water contamination, however, presents continued challenges. The greatest global polluters of our drinking water include humans, agriculture and climatic events.

Infected humans excrete massive amounts of pathogens into the environment. At any given time, an estimated 200 million people on earth have diarrhea. A single stool can contain a billion viruses.[3] Sick individuals may have 10 diarrheal stools or more a day. Because of the low infectious dose of enteric (i.e., gut) pathogens, as few as 10 viruses may cause disease when passed to another susceptible host. Likewise, infected livestock shed billions of human pathogens into the environment every day. Contaminants originating from agriculture, including fertilizers, pesticides and animal wastes account for up to 70 percent of the water pollution in the US.

Making matters worse is a good rainfall. Climatic events are closely linked to water quality where extreme precipitation events precede the majority of documented waterborne outbreaks. Pathogens from land and waste collection pools are washed into drinking water supplies following rainfall and may overtax otherwise reliable drinking water treatment schemes. Older communities with combined sewer overflows (where rainwater, industrial waste and domestic sewage are collected together and routed to the treatment plant or discharged back to the environment) may be at greater risk of exposure. Even properly designed sewer systems occasionally discharge untreated sewage back into the environment. These sanitary sewer overflows occur at a rate of up to 75,000 times per year in the US and are known to cause serious water quality problems.[4]

Next month, *On Tap* will continue this conversation, focusing on current technologies for improved detection and treatment mechanisms with the greatest promise for resolving the waterborne disease burden. Stay tuned!

References

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