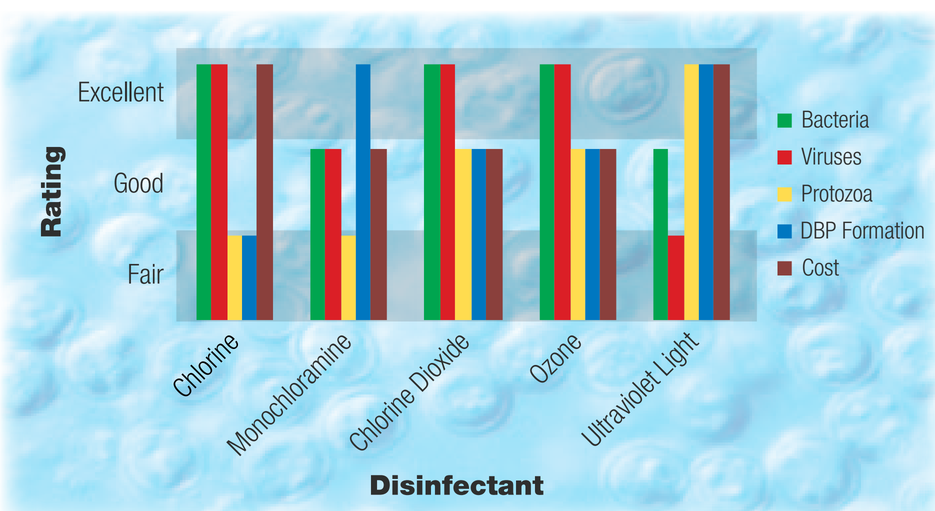
Controlling Pathogens in Potable Water

Joan Oppenheimer, M.S.P.H. – MWH

The water treatment industry developed from the desire to curtail waterborne disease epidemics prevalent during the 1800s and early 1900s. The threat of disease from pathogens in drinking water has been reduced through a combination of source control, application of appropriate physical and chemical treatment processes, and storage and distribution of treated water with a chlorine residual. While waterborne-disease outbreaks are much less frequent now, they still occur and are usually attributed to unusual watershed events, compromised treatment conditions, or compromised distribution systems.

The water industry continues to enhance treatment process requirements as new information is gleaned from outbreaks. A case in point was the 1993 Milwaukee outbreak that affected roughly 400,000 people. Unusual watershed conditions resulted in a large concentration of *Cryptosporidium parvum* in the water system even though the treatment facility met all existing regulations. This outbreak demonstrated that chlorine, the most commonly used chemical disinfectant, was completely ineffective in inactivating *Cryptosporidium parvum* at conventionally applied dosages. New monitoring and treatment requirements were instituted to address *Cryptosporidium* and are expected to become even more stringent in the coming decade.



Regulatory Requirements

The U.S. Environmental Protection Agency has promulgated a suite of regulations to limit pathogenic organisms in potable water supplies. However, most disinfectants form carcinogenic disinfection byproducts (DBPs) by reacting with the organic precursor material naturally present in source water. As a result, water utilities must provide a combination of source control, treatment, and residual disinfectant that can achieve the specified reductions of bacteria, viruses, and protozoan pathogens while meeting standards for control of DBPs.

Water utilities routinely monitor the distribution system for total coliforms, bacteria that have been used for decades as an indicator of fecal contamination. While the absence of total coliforms is an indication of water treatment effectiveness, it does not guarantee all pathogens have been removed or inactivated. The small size and simple structure of viruses make them more difficult to remove or inactivate than bacteria. Viruses and protozoan organisms are more difficult to monitor on a continual basis, therefore treatment processes must be validated and real-time process efficiency monitoring employed at treatment facilities. For surface water supplies, a combination of source control, treatment, and disinfectant application must achieve a 99.99 percent (4-log) reduction of viruses and a 99.9 percent (3-log) reduction of the protozoan pathogen *Giardia lamblia*. Through physical treatment (e.g., turbidity), water utilities must also achieve at least a 99 percent (2-log) reduction of the protozoan pathogen *Cryptosporidium parvum*. There are no treatment requirements for pathogen reduction in groundwater supplies, but disinfection requirements are being developed in response to groundwater survey findings that wells are more susceptible to pathogen contamination than previously believed.

Source Control

Protected watersheds and deeper groundwater supplies contain fewer pathogenic organisms than unprotected lowland surface waters or shallow groundwater under the influence of surface water. Watershed protection strategies consist of land acquisitions, best management practice controls, and even the use of genetic fingerprinting to identify and limit contamination sources within the watershed. In the future, state-approved watershed control programs will receive 0.5 log of credit toward the water supply's required log removal requirement for *Cryptosporidum parvum*.

Treatment Technologies

The principal strategies for treatment rely upon either physical removal of the pathogenic organisms or inactivation by chemical or physical means. Inactivation results from a modification to the pathogenic organisms' cellular structure or metabolism, causing death or impairment of reproductive capacity.

Conventional removal methods include chemical coagulation and media filtration. Newer technology consists of membrane filtration processes. Properly designed and operated filtration systems can achieve the full reduction credits required for viruses, *Giardia*, and *Cryptosporidium*. Because continuous monitoring for viruses and protozoan cysts is difficult, proper filter operation is demonstrated by surrogate measurements such as turbidity for conventional systems and integrity monitoring for membrane systems. But even when full pathogen control can be accomplished through physical removal, an inactivation process is required to provide a second barrier.

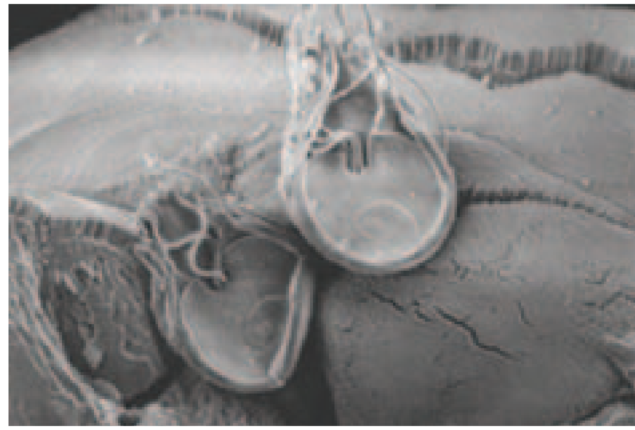
While the absence of total coliforms is some indication of water treatment effectiveness, it does not guarantee the removal or inactivation of all pathogens.

Chemical and physical disinfectants acceptable for use in potable water are chlorine, chloramines, chlorine dioxide, ozone, and ultraviolet light. Chlorine is the most widely used disinfectant in the United States. Utilities began to use other disinfectants during the 1980s and 1990s when *Giardia lamblia* and *Cryptosporidium parvum* were identified as causative agents of significant waterborne outbreaks. These protozoans, particularly *Cryptosporidium*, require significantly higher chlorine dosages than bacteria and viruses, resulting in unacceptable levels of DBP formation. Therefore, stronger oxidants, such as chlorine dioxide or ozone, or ultraviolet light, which is particularly effective for *Cryptosporidium*, are required whenever protozoan reduction levels cannot be achieved through physical reduction treatment methods and chlorine disinfection.

Disinfectants must be applied at a residual concentration level "C" for a sufficient contact time "t" that is deemed capable of achieving the required level of reduction for viruses and *Giardia*. After review of many disinfection studies, the EPA crafted disinfectant "Ct" tables that specify minimum Ct requirements needed to achieve specific log reduction levels for viruses and *Giardia*. Ct tables for *Cryptosporidium* are coming soon. As the list of disinfectants and microbial pathogens of concern expands, it has been discovered that the relative efficacy of a disinfectant is not uniform. For example, UV light radiation can achieve a 4-log reduction of most viruses at a dose of 40 mJ/cm^2, but for one kind, a 160 mJ/cm^2 dose is needed to achieve the same reduction. Some utilities are considering use of multiple disinfectants with the possibility of synergism, whereby the inactivation efficiency of two disinfectants combined might be greater than that of the same disinfectants individually.

Distribution Control

Protection from regrowth or system contamination following treatment is accomplished by maintaining a detectable disinfectant residual concentration throughout the distribution system and by maintaining the system under pressure. Demonstration of adequate control is achieved by monitoring total coliforms, which can be easily assayed, at specified locations within the distribution system. The absence of total coliforms minimizes the likelihood that fecal pathogens are present. Systems are required to monitor for total coliforms at a frequency proportional to the number of people served, and consumers must be notified of any positive sample results. A specified follow-up monitoring schedule must be completed whenever coliforms are detected.



Images: Cryptosporidium *oocysts (top) and* Giardia lamblia *cysts (bottom) courtesy of CH Diagnostic and Consulting Service, Inc., Loveland, Colorado.* Giardia *on rat intestine (center) courtesy of Randy Nessler, Central Microscopy Research Facilities, the University of Iowa.*

Looking Toward the Future

Infectious disease patterns have shifted throughout history due to human migration and urbanization, shifting trade and agricultural practices, genetic mutations, and climatic changes. New waterborne pathogens are likely to emerge in the future as genetic mutations enable a microbe to increase its virulence or adapt to a new host. The water industry must remain continually vigilant to ensure that current treatment practices are modified to protect against newly discovered waterborne pathogens.

Contact Joan Oppenheimer at joan.oppenheimer@mwhglobal.com.