

UV Disinfection of Groundwater

Groundwater-borne pathogen study sheds light on UV disinfection of municipal water systems.

The first study to explore the possible linkage between pathogenic viruses in groundwater-sourced municipal water systems and illnesses in communities was completed recently in Wisconsin. The intervention trial produced enlightening results likely to help shape EPA disinfection rules for one-third of the nation's communities that have historically relied on raw groundwater for their potable water supply. A number of earlier studies estimated that perhaps one-fourth to one-third of municipal wells could be contaminated with human viruses.

Mark Borchardt, Ph. D., a research scientist with the Marshfield Clinic Research Foundation, led the two-year, \$2.3-million study funded by the EPA. The study used ultraviolet (UV) disinfection reactors installed on municipal wellheads to inactivate any viruses present in the groundwater. All design plans

for the UV installations were approved beforehand by the state Department of Natural Resources.

Dr. Borchardt's team monitored the health of more than 1,700 study participants living in 621 households located in 14 Wisconsin communities served by 36 wells. Communities were selected on the basis of using non-disinfected groundwater for drinking water and hydrogeologic setting, primarily sand and sandstone aquifers. Households were eligible to participate if they had at least one child less than 12 years old who did not leave the community for more than 20 hours per week. Tests of water samples are completed; statistical analysis of the health data will be completed in 2009.

The scientist presented some of the study findings last December (2008) in Washington, DC, at an EPA Symposium on Groundwater-Borne Infectious Disease, Etiologic Agents and

Indicators. His study validated the earlier EPA conclusion, using an indirect, risk assessment approach, that there are, in fact, some groundwater-borne virus illnesses. Dr. Borchardt's work concluded that virus contamination of well water was common.

"Of 36 wells

in the 14 study communities, 34 had at least one sample that was virus positive by PCR [i.e., detection of virus DNA or RNA]," he noted. "Of the 392 well water samples tested during the study, 139 samples were positive for one or more viruses by PCR."

He adds that of the 191 samples collected immediately downstream from exposure to UV disinfection at the wellhead and before distribution resulted in one that tested positive for Hepatitis A, four contained enteroviruses, and 17 others were positive for adenoviruses, the virus most resistant to UV disinfection technology. The enterovirus and adenovirus positive samples were tested further for virus infectivity by cell culture methods. None of the enterovirus-positive samples were infectious and only three adenovirus-positive samples retained infectivity after UV disinfection.

"Our target UV dose of 50 mJ/cm² was very effective in eliminating viruses in a real-world setting," Dr. Borchardt said.

He has high confidence in the resulting benefits of the study and commends the participating communities and individual households for their commitment to the groundbreaking study. "We were particularly pleased that none of the communities dropped out during the duration of the study," Dr. Borchardt noted. "The EPA has had a growing recognition that groundwater is not as pristine as believed in the past. For the most part, it is pure but can be more contaminated than we realized. That doesn't mean groundwater is unsafe but it deserves a heightened awareness and more proactive manage-



During the study, Staab Construction, a Marshfield, WI-based contractor, temporarily installed the UV systems on wood cribbing at the wellheads like that shown here.

ment.”

He launched the study after an effective public information campaign and included modest monetary incentives to recruit the study participants. Raw data was compiled in more than 65,000 weekly diaries that summarized the health status of adults and children in the households during designated periods during the study. The team also collected saliva samples periodically for laboratory testing.

The domestic water supply was tested for both at the wellheads and in the homes for one-year before and after the application of UV. The water drawn from the study wells was subjected to disinfection by Wedeco UV reactors supplied by ITT Water & Wastewater (www.ittwww.com). The 17 Wedeco UV units were acquired at significant discount and installed by Staab Construction, also based in Marshfield. Greg Harrington, Ph. D., an associate professor of Civil & Environmental Engineering at the University of Wisconsin-Madison, led the design team.

Comparison of Sources

Unlike more extensively studied surface water sourced from rivers, lakes, or reservoirs that is subjected to intervening chemical disinfection, groundwater wells have been considered naturally purified during downward percolation through strata before reaching an aquifer. Amendments to the U. S. Safe Water Act called for studies of waterborne illnesses present in both sources, but groundwater-based systems until now have not been studied. Wisconsin, in fact, had not required any disinfection of municipal groundwater wells, but state—and federal—rules are likely to change as a result of the study, Dr. Borchardt foresees.

While the presumption of natural filtration remains generally true for bacteria, most viruses are significantly smaller—some even smaller than wavelengths of visible light—and can migrate downward to infiltrate an aquifer. Although the environment routinely bombards us with strains of bacteria and viruses, groundwater contaminated with the more harmful types can induce a num-

ber of illnesses, most commonly gastrointestinal. Children, the elderly, organ transplant patients, and other immunocompromised individuals are considered the most vulnerable to waterborne disease.

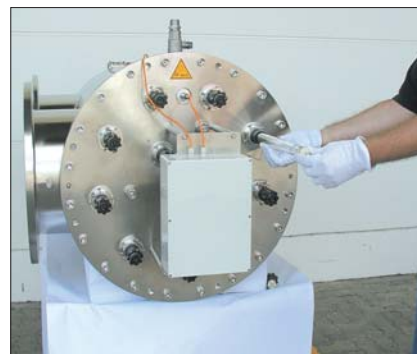
Advanced technologies offer more environmentally friendly alternatives to traditional chemical disinfection.

Among these, UV light disinfection has steadily earned application by both water and wastewater utilities. UV clearly eliminated viral pathogens at the Wisconsin wellheads before introduction into distribution lines, but the study also revealed pathogens still reached some household water taps despite UV disinfection. Borchardt suggests that subsequent contamination found at the tap occurred in the distribution systems, from intrusion of human wastewater, probably from leaking sanitary sewer lines.

The Village of Prairie du Sac was so impressed with the effectiveness of the UV systems during the study that they negotiated to purchase the technology for continued use. The community's



Wedeco UV Reactor—supplied by ITT Water & Wastewater—undergoes inspection.



The heart of UV technologies are these tubular glass bulbs that are withdrawn, cleaned and reinserted periodically for maximum disinfection efficiency. UV finds applications both in potable water and wastewater plants.

water utility has 1,800 connections served by 75-ft and 550-ft deep wells that tested virus positive at the outset of the study. During the course of the study, the findings show that with proper operation the Wedeco UV system can reliably eliminate bacteria and most viruses without resorting to chlorine disinfection commonly used across the nation.

The recently retrofitted deeper well, which draws 1,500 gpm during the day from 300 ft, is served by a Wedeco BX 1800, a system employing 18 UV lamps. The shallower, 500-gpm well is pumped once during the night and is served by a six-lamp Wedeco UV system, said Patrick Done, the director of public works. The water is pumped to a 400,000-gal water tower before distribution to the community. The added UV disinfection has not appreciably increased maintenance. The lamps are cleaned on a two- to three-week cycle to combat the high iron content in the water. Replacement lamps ran about \$500 last year.

UV disinfection has a higher up-front cost compared to traditional groundwater chlorination methods. However, if a community is required to construct a costly reservoir adjacent to a well in order to achieve a mandated CT value (chlorine concentration x time), UV disinfection is an attractive and cost-effective disinfection technology. 