Evaluating Water Quality
Individual & Small Systems in Arizona

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Nearly 50 million people in the United States depend on individual wells for their drinking water. In most states, individual drinking water systems are not regulated by local health and environmental agencies, thus few studies have been conducted on the microbial quality of this water. Arizona has more non-disinfected water systems (including individual household wells, which are not currently regulated) than any other state. In addition, the state has many rapidly developing communities that are totally dependent on septic tanks, which can be a source of pathogens for groundwater contamination. Information is needed on the microbial and chemical safety of this water so that appropriate guidance can be developed to treat and protect groundwater.

Pathogens Are in the Water

A recent study by Borchart and others (2003) of individual household wells used to supply drinking water indicated that waterborne pathogenic human enteric (related to the intestinal tract) viruses such as hepatitis A, norovirus, and rotavirus were present. However, traditional microbial water quality indicators (total coliforms, *E. coli*, fecal enterococci, F-specific RNA coliphages, nitrate) could not statistically be associated with virus occurrence.

Almost 90 percent of the wells exceeded at least one primary or secondary standard.

Abbaszadegan and others (2003) tested groundwater from 448 sites in 35 states and found that about one-third of the groundwater drinking wells used by utilities contain human pathogenic enteric viruses, but again no significant relationship between enteric viruses and indicator bacteria was observed. The sources of pathogens may be septic tanks, leaking sewer lines, or other sources of land-disposed wastes.

The link between gastrointestinal illness and waterborne pathogens in drinking water has been studied widely. The Borchardt study correlated such illness to septic tank density in rural areas, where individual wells are the primary or sole water source. Other research of interest includes epidemiological studies showing a relationship between *Helicobacter pylori* infection and the use of non-disinfected drinking water (Embrey and others, 2002; Klein and others, 1991); and research that implicated *H. pylori* in groundwater used as drinking water with cases of stomach ulcers (Hegarty and others, 1999).

A New Study

A new investigation is underway to examine the occurrence of enteric viruses and water-based pathogens in small drinking water systems. A field study is assessing the occurrence of selected water-based bacterial and waterborne viral pathogens (see table below) in non-disinfected small drinking water systems and individual household wells in Arizona. In addition, concentrations of nineteen metals are being evaluated in the water samples by the City of Tempe's Water Quality Laboratory.

Designing the Test

The wells included in the study were selected in cooperation with the Arizona Department of Environmental Quality and county health departments. Selection criteria included representative samples from both shallow and deep groundwater, and different septic tank densities, substrates (such as alluvium or fractured rock), and climates (for example, arid warm or forested mountain). Permission of the well owner was also a significant factor in the selection of wells; to encourage their cooperation, owners were assured that

Water Quality Parameter	Rationale for Selection
pH	Affects the transport of viruses through soil
Turbidity	Potential indicator of surface contamination
Total Organic Carbon	Can affect the survival and growth of bacterial pathogens
Conductivity	Affects the transport of pathogens through the soil
Heterotrophic plate count bacteria	A general measure of the microbial quality of drinking water
Coliform and *E. coli* bacteria	Drinking water standards require the absence of these bacteria
Somatic and male specific coliphages (viruses that are parasitic in bacteria)	Are being considered by the EPA as indicators of the presence of enteric pathogens in groundwater
Aeromonas hydrophila (bacteria)	This opportunistic unregulated water-based pathogen is being monitored in select water supplies by the EPA
Helicobacter pylori (bacteria)	An opportunistic pathogen, capable of transmission by non-disinfected water supplies
Human enteric viruses	Viruses are more likely to contaminate groundwater supplies because of their small size and ability to survive for prolonged periods of time in groundwater

the location and results of their particular well would remain anonymous.

A total of 29 wells were sampled from five counties: 14 from Coconino and Yavapai counties in northern Arizona, and 15 from Cochise, Pima, and Santa Cruz counties in southern Arizona. Although a few small community wells were sampled, most were individual wells. Because seasonal changes in rainfall are known to have a significant effect on microbial groundwater quality, each well was to be sampled twice: during the wet winter season and the summer monsoon season. However, a dearth of precipitation in both seasons has meant that sampling has been underway for nearly two full years, with some locations still not complete. All samples are being analyzed for the parameters listed in the table and 19 metals.

Preliminary Findings

Sampling and analysis are not yet complete, but preliminary results demonstrate that individual non-disinfected groundwater systems in Arizona are susceptible to contamination and significant numbers of these wells do not comply with the U.S. Environmental Protection Agency's primary and secondary drinking water regulations. About 25 percent of water samples were positive for total coliform bacteria. Fecal coliforms were detected in a few samples, and *E. coli* was found in one. Nearly half of the samples were positive for *Aeromonas hydrophila*, which, although not regulated, has been associated with gastroenteritis in humans (Krovacek and others, 1995; Soriano and others, 2000). *Aeromonas* prefers to grow in warm water, which may account for its high prevalence in Arizona well waters. Because of these concerns with its presence in drinking water, EPA is requiring limited testing by large supply systems for *Aeromonas hydrophila* as an unregulated contaminant.

The temperature of water samples ranged from 8 to 31°C. The pH of groundwater averaged 7.46. Turbidity ranged from 0.06 to 4.33 NTU (standard turbidity units). Seventy-three percent of the wells exceeded the limit of 0.5 NTU established by the EPA. Nitrate concentration ranged from 0.19 to 44 milligrams per liter (mg/L), with an average of 11.24 mg/L, higher than EPA's drinking water standard of 10 mg/L.

More than half of the wells exceeded at least one primary contaminant standard such as arsenic, nitrate, or coliforms. Most of the wells exceeded at least one secondary standard (aluminum and total dissolved solids). Almost 90 percent of the wells exceeded at least one primary or secondary standard.

Additional tests for adenovirus, norovirus, and rotavirus using polymerase chain reaction will be completed in the coming months. Complete evaluation of *H. pylori* is pending as well. But already, the preliminary results indicate that pathogens do occur in individual and small water systems in Arizona, warranting greater protection for those who use them.

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References

Abbaszadegan, M., M. LeChevallier, and C.P. Gerba, 2003. Occurrence of viruses in U.S. groundwaters, J. Amer. Water Works Assoc., 95(9): 107-120.

Borchardt, M.A., P.-H. Chyou, E.O. DeVries, and E.A. Belongia, 2003. Septic system density and infectious diarrhea in a defined population of children, Environ. Hlth. Perspectives, 111: 742-748.

Embrey, M.A., J.M. Balbus, and R.T. Parkin, 2002. Handbook of CCL Microbes in Drinking Water. Washington, D.C., American Water Works Association.

Hegarty, J.P., M.T. Dowd, and K.H. Baker, 1999. Occurrence of Helicobacter pylori in surface water in the United States, J. Appl. Microbiol., 87: 697-701.

Klein, P.D., D.Y. Graham, A. Gaillour, A.R. Opekun, and E.O. Smith, 1991. Water source as risk factor for Helicobacter pylori infection in Peruvian children, The Lancet, 337: 1503-1506.

Krovacek, K., S. Dumontet, E. Eriksson, and S.B. Baloda. 1995. Isolation and virulence profiles of Aeromonas hydrophila implicated in an outbreak of food poisoning in Sweden, Microbio. Immunol., 39: 655-661.

Soriano, J.M., H. Rico, J.C. Mottó, and J. Mañes, 2000. Assessment of the microbiological quality and wash treatments of lettuce served in university restaurants, Int. Jour. Food Micrbiol., 58: 123-128.