Title: **Assessment of Virus Presence and Potential Virus Pathways in Deep Municipal Wells**

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Background/Need: Among the many waterborne pathogens of humans, enteric viruses have the greatest potential to move deeply through the subsurface environment, penetrate aquitards, and reach confined aquifers. Previous research revealed the presence of viruses in water from two of three deep bedrock wells sampled in Madison, WI. Virus presence in these wells was particularly surprising because the wells were cased through a regional aquitard thought to provide protection for the wells. This present study is a follow-up to the previous work, and is intended to determine the potential sources of the viruses and their pathways to the wells.

Objectives: The objectives of this project are (1) to obtain a time series of virus, isotopic, and geochemical data from several municipal wells completed in a deep bedrock aquifer, (2) to use these data sets to evaluate virus presence and, if present, the potential sources of the viruses and pathways to the wells, and (3) to evaluate the possibility that virus transport occurs through the well casing, grout or annular space. This one-year project was entirely conducted in Madison WI, using wells owned and operated by the Madison Water Utility.

Methods: During 2007 and 2008 investigators sampled six deep municipal wells for viruses on an approximately monthly basis. Three of these wells had shallow casings, and three were cased through a regional aquitard. Investigators also collected virus samples from local lakes and from untreated sewage and sampled groundwater and lake water for major inorganic ions and isotopes of hydrogen and oxygen.

Results and Discussion: Viruses were detected at least twice in every one of the six wells, but no well was virus-positive in every sampling round. Overall, 43 percent of the samples were virus-positive, and virus concentrations ranged from 0.00 to 6.15 genomic copies per liter (gc/l), with a mean of 0.47 gc/l. Lake samples were positive 78 percent of the time, and ranged from 0.00 to 27.6 gc/l, with a mean of 5.8 gc/l. Not surprisingly, Madison sewage was extremely high in viruses, with all samples positive, and concentrations ranging from about 50,000 to over two million gc/l, with a mean of 581,000 gc/l. Virus results varied significantly with time, and there is apparent correlation between virus levels in sewage, lakes, and groundwater.

Several different species (serotypes) of viruses were identified in wells, wastewater, and lake water during this study, and in many cases wells and wastewater contained identical virus serotypes. Detected viruses include Enteroviruses echovirus 3, echovirus

6, echovirus 11, Coxsackie A16 and B4, adenoviruses 2, 6, 7, 41, as well as G1 norovirus and rotovirus.

Conclusions/ Implications/ Recommendations: The apparent correlation between viral serotypes found in wastewater, lakes, and groundwater suggests very rapid transport from the surface to groundwater. Viral serotypes vary seasonally and annually, and so correlation between surface and subsurface serotypes would be unexpected if transport times from the surface to groundwater exceed many months. The Madison Lakes are probably not the main source of the viruses found in the wells. The most likely source of the viruses in the wells is the leakage of untreated sewage from the Madison sewer system.

To protect human health, communities in Wisconsin and elsewhere that use groundwater for a drinking water source should consider using chlorination or other water treatment techniques to deactivate viruses, and work to ensure that these systems are operating correctly. Consuming untreated groundwater should be discouraged. Sampling for viruses requires a time series approach because virus concentrations, and virus species, vary with time in individual wells. Untreated sewage contains very high concentrations of viruses and should be considered a source of groundwater contamination.

Human enteric viruses might be excellent tracers of recently recharged groundwater in urban settings. They have the desirable tracer characteristics of detectability over several orders of magnitude, high mobility, and are time-specific due to constantly changing serotypes.

Related Publications: This report is also available as open-file report WOFR 2008-08 from the Wisconsin Geological and Natural History Survey. See http://www.uwex.edu/wgnhs/wofrs.htm

Key Words: viruses, groundwater, isotopes, contamination, municipal wells

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Final Report: A final report containing more detailed information on this project is available for loan from Wisconsin's Water Library, University of Wisconsin - Madison, 1975 Willow Drive, Madison, Wisconsin 53706 (608) 262-3069.