PROJECT SUMMARY

Title: Arsenic Contamination in Southeast Wisconsin: Sources of Arsenic and Mechanisms of Arsenic Release

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Background/Need: Groundwater in about 10 percent of wells open to Quaternary glacial and shallow bedrock aquifers in southeastern Wisconsin has arsenic concentrations greater than the U.S. Environmental Protection Agency's standard of 10 μg/l. Denser clusters of arsenic-impacted wells ($[As]_{aq} \geq 10$ μg/l) occur in localized areas. The lack of anthropogenic sources in these areas indicates that the arsenic is naturally occurring. Improved understanding of the controls on arsenic concentrations in groundwater is needed to inform efforts to prevent or reduce arsenic contamination in drinking water wells in southeastern Wisconsin.

Objectives: The objectives of this study were to characterize the source(s) of arsenic and the controls on arsenic concentrations in groundwater from the Quaternary and Silurian aquifers in southeastern Wisconsin.

Methods: We reviewed existing data to estimate the magnitude and spatial distribution of arsenic concentrations in groundwater from the Quaternary and Silurian aquifers in southeastern Wisconsin. Detailed field investigations were conducted near the city of Lake Geneva in Walworth County.

Using core samples from a borehole at Woods Elementary, geologic sources of arsenic were identified using X-ray diffraction and chemical extractions. We collected groundwater samples from private wells and a monitoring well installed in the borehole at Woods School. We also organized a private well sampling program in the Lake Geneva area. We examined water chemistry data for trends indicative of water-rock interactions that may mobilize arsenic. We conducted a pumping test at the Woods School monitoring well to evaluate the hydrogeology of the study area. Time series sampling during the pumping test provided information about the effect of pumping on arsenic concentrations.

Results and Discussion: The hydrostratigraphy in the Lake Geneva area includes a shallow aquifer consisting of glacially deposited sand and gravel. This aquifer is underlain by a confining unit of low-conductivity clayey till. A deeper discontinuous sand and gravel aquifer occurs beneath this confining unit on top of the Silurian dolomite. Pumping test results indicate that there is little hydraulic connection between the shallow Quaternary aquifer and the deeper Quaternary and shallow Silurian aquifers.

8 % of wells open to the Quaternary and/or Silurian aquifers in the study area have arsenic concentrations greater than 10 μg/l. Near the city of Lake Geneva, more than 20 % of Quaternary and Silurian wells have arsenic concentrations greater than the E.P.A. standard. The highest arsenic concentrations (85 μg/l) occur

in wells open to the Silurian dolomite. The maximum arsenic concentrations in wells open to Quaternary deposits are around 30 μg/l.

Low to moderate solid-phase concentrations of arsenic (2 mg/kg to 20 mg/kg) occur throughout the entire thickness of Quaternary sediments in the study area. From a mass balance perspective, such low to moderate solid-phase arsenic concentrations, under geochemical conditions that release arsenic to groundwater, are sufficient to lead to aqueous arsenic concentrations that exceed the 10 μg/l standard. Arsenic is released from aquifer sediments during laboratory experiments designed to dissolve (hydr)oxide minerals. These results, combined with groundwater chemistry data suggest that arsenic is released to the groundwater via reductive dissolution of (hydr)oxides. In the Lake Geneva area, hydrogeologic, and geochemical factors create reducing conditions that lead to arsenic mobilization in the deep Quaternary and upper Silurian aquifers. Groundwater in shallow Quaternary sediments is not as reducing as in the deeper system and is largely unaffected by arsenic.

Conclusions/Implications/Recommendations:

- Where geochemical conditions are sufficiently reducing, low solid-phase arsenic concentrations associated with (hydr)oxide minerals (on the order of a few parts per million) are sufficient to sustain groundwater arsenic concentrations greater than the 10 μg/l standard.
- All well owners in southeastern Wisconsin should test well water for arsenic because of the potential for even low levels of solid phase arsenic in glacial deposits to impact groundwater in glacial and shallow bedrock aquifers.
- New wells in the Lake Geneva area should not be completed in the deep Quaternary aquifer. The only viable alternative for existing arsenic-impacted wells is treatment to remove arsenic from drinking water.
- A single model of arsenic release is not adequate to account for the occurrence of arsenic in groundwater across the state. Oxidizing conditions cause arsenic release from sulfide minerals in the St. Peter aquifer in the Fox River Valley, but reducing conditions release arsenic to parts of the Quaternary and Silurian aquifers in southeastern Wisconsin. While the findings of this work are limited to the study area, similar geologic and geochemical conditions may be present in the Quaternary aquifer in other areas of Wisconsin.

Related Publications:

Root, T.L., expected spring 2005. Arsenic in Groundwater in Southeastern Wisconsin: Sources of Arsenic and Mechanisms of Arsenic Mobilization. Ph.D. thesis, University of Wisconsin –Madison, Department of Geology and Geophysics.

Root, T.L., Bahr, J.M., and Gotkowitz, M.B., 2005. Controls on Arsenic in Groundwater in Southeastern Wisconsin, *in* Vlassopoulos, D., Benning, L., Meng, X., and O'Day, P., Advances in Arsenic Research, American Chemical Society Symposium Series. (*In press)*

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Key Words: Arsenic, groundwater, Quaternary and Silurian aquifers, southeastern Wisconsin

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