

# Spatial Variability of Arsenic in Groundwater

Thomas R. Holm and Steven D. Wilson

Center for Groundwater Science  
Illinois State Water Survey

Arsenic (As), an element that occurs naturally in groundwater, causes several chronic health effects in elevated doses (Jain and Ali, 2000). In response to the link between As in drinking water and cancer (Smith et al., 1992), the U.S. Environmental Protection Agency lowered the maximum contaminant level (MCL) from 50 micrograms per liter ( $\mu\text{g/L}$ ) to 10  $\mu\text{g/L}$  (0.13 micromoles per liter or  $\mu\text{M}$ ), effective February 2006. Almost all Illinois water utilities satisfied the old MCL, but approximately 50 out of 1030 active groundwater systems were out of compliance when the MCL was lowered.

Most groundwater with As levels above the MCL also contains soluble iron (Fe) at a concentration high enough to require treatment to deal with aesthetic problems such as taste and laundry staining. Fe removal from groundwater requires the oxidation of soluble ferrous iron (Fe(II)) to insoluble hydrous ferric oxide (HFO) and filtration to remove the particulate HFO. Arsenic adsorbs to HFO (Dzombak and Morel, 1990), so Fe removal also removes some As, although As removal efficiency is highly variable (Holm et al., 2008; McNeill and Edwards, 1995).

Many Illinois groundwater treatment plants were designed for Fe removal, not As removal. Some of these facilities would need to be upgraded to satisfy the new As MCL (Holm, 2006; Peyton et al., 2006a, 2006b). Other Illinois plants do not remove Fe and, therefore, do not remove As (Wilson et al., 2004). Constructing new treatment systems for As removal is likely to be expensive (Frey et al., 1998, 2000) and most of these systems serve small communities for which the per-capita cost of installing a new water treatment system would probably be quite high (Frost et al., 2002). Another option for meeting the As MCL may be to drill a new well. The objective of this research was to characterize the spatial variability of As in Illinois groundwater to predict the likelihood of finding low-As groundwater in the vicinity of a high-As well.

Several studies of groundwater quality, including As occurrence and speciation, have been conducted in various parts of the Mahomet Aquifer. The Mahomet Aquifer is an unconsolidated sand and gravel aquifer that is contained in the buried Mahomet Bedrock Valley that extends across central Illinois from Indiana to the Illinois River. The aquifer is mostly overlain by thick layers of glacial till with interbedded sand layers that are used for water supply. Three major episodes of glaciation deposited sediments in the Mahomet Valley. The oldest and lowermost unit is the pre-Illinoian Banner Formation, which was generally deposited on the bedrock surface. The Mahomet Sand comprises this lower-most portion of the formation and fills the deepest parts of the valley with up to 150 feet of outwash sand (Kempton et al., 1991). The aquifer is a significant water supply in Central Illinois, used for private wells, community water supplies, and irrigation (Wilson et al., 1994, 1998). Panno et al. (1994) reviewed the

geochemistry of the aquifer and found that high As concentrations were more likely to be found in the western part of the aquifer than the eastern part.

Arsenic in Illinois groundwater can be highly variable over distances as short as tens of meters. The arsenic concentration at any point in these areas would be difficult to impossible to predict from a regional model, based on these results. Siting a new well would likely require that every nearby well of interest be sampled. Conversely, sampling existing private wells, when those wells exist, may be an economical way for a community to assess the possibility of siting a new well near their municipal well.

For all three study areas, TOC values were 2 mg/L or greater and most As concentrations were above the MCL. This is in agreement with earlier work in Tazewell County and is consistent with the hypothesis that HFO reduction is the source of As in these aquifers. For all three study areas, sulfate was generally undetectable for TOC values greater than 2 mg/L and detectable in most samples with lower TOC values. For all Hopedale and Tremont wells and six Wonder Lake wells, either As or sulfate was detectable, but not both. These data are consistent with complete sulfate reduction in areas with abundant organic matter and incomplete sulfate reduction in other areas. The data are also consistent with limitation of dissolved As by sorption to FeS in areas with active sulfate reduction.

As(III) was the main As species in all three study areas, in agreement with earlier results for Tazewell County. Values of pH and ORP were qualitatively consistent with As speciation for the Hopedale wells as indicated by an As Eh-pH diagram. For the other two areas, the ORP measurements were consistent with much lower proportions of As(III) (i.e., they were higher than expected).

Fifteen out of 17 wells showed no significant differences between filtered and unfiltered As concentrations. Clearly, particulate As concentrations were generally too low to be calculated by difference.

ORP measurements for the two softened Wonder Lake wells were much higher than for the eight untreated wells, as would be expected if the redox electrode responded largely to dissolved Fe. (Softening reduces the Fe<sup>2+</sup> concentration.) ORP measurements combined with general knowledge of the system may be useful in future field studies to indicate treated water when untreated water is expected.