Arsenic

What is it?

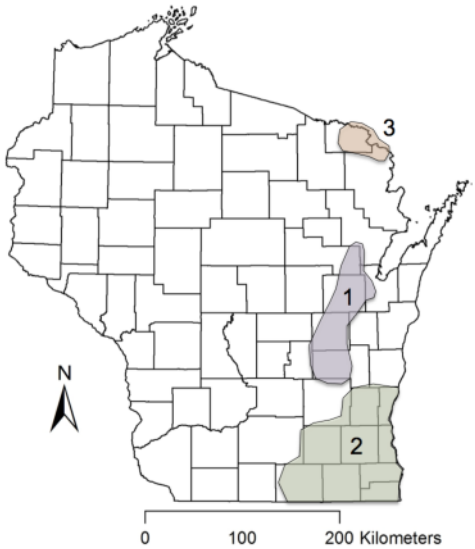
Arsenic is an odorless and tasteless, naturally occurring element present in soil and rock. Under certain environmental conditions, arsenic can dissolve and be transported in groundwater. It can also be released as a by-product from agricultural and industrial activities. Everyone is exposed to small amounts of arsenic since it is a natural part of the environment, but under some geologic conditions elevated amounts of arsenic can be released to groundwater.

Arsenic-rich minerals, such as arsenic-rich pyrite (pictured), are natural sources of arsenic in groundwater in Wisconsin. *Photo: JJ Harrison.*

The health-based enforcement standard (ES) for arsenic in groundwater and the maximum contaminant level (MCL) for arsenic in public drinking water are both 10 parts per billion (ppb) (WI NR 140.10, WI NR 809.11). Some people who drink water containing arsenic in excess of the MCL over many years could experience skin damage or problems with their circulatory system, and have an increased risk of getting cancer.

Occurrence in Wisconsin

In Wisconsin, most arsenic found in groundwater is naturally occurring, released from minerals in bedrock and glacial deposits. Arsenic has been detected above the ES in the groundwater in every county in Wisconsin. Arsenic contamination of groundwater is common in northeastern Wisconsin in areas around Winnebago and Outagamie County and moderately high levels of arsenic (10 ppb – 30 ppb) are also common in some parts of southeastern Wisconsin.



Arsenic is common in northeastern Wisconsin (regions 1 and 3) and southeastern Wisconsin. *Figure*: *Luczaj and Masarik, 2015*.

In *northeastern Wisconsin*, a geologic formation called the St. Peter Sandstone contains arsenic-rich minerals. When sulfide minerals common in this rock are exposed to oxygen in the air – either at the water table elevation or from drilling activity – chemical reactions solubilize these minerals and lead to very high levels of arsenic in water (exceeding 100 ppb, or 10 times the ES). In low-oxygen groundwater environments, arsenic can be released from the St. Peter Sandstone at lower concentrations which may still exceed the ES. This more moderate contamination may result from the same sulfide minerals or from arsenic that is bound to iron oxide minerals.

In *southeastern Wisconsin*, most wells draw from glacial sand and gravel deposits or Silurian dolomite formations. While oxidizing conditions tend to release arsenic from sulfide

minerals in northeastern Wisconsin, reducing conditions (where dissolved oxygen is low) tend to release arsenic from iron compounds in the glacial deposits and dolomite of southeastern Wisconsin.

GCC Agency Actions

Naturally-occurring arsenic was unexpectedly discovered in Wisconsin in 1987 during a feasibility study for a proposed landfill in Winnebago County. Follow up sampling by the Department of Natural Resources (DNR) and reports from nearby homeowners revealed a pressing need to determine the distribution and frequency of the problem. As a result, over the next several years the DNR, the Department of Health Services (DHS), and local health officials teamed with researchers funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP) to sample thousands of private wells in the Winnebago and Outagamie County area and analyze where and why arsenic levels were elevated (Burkel, 1993; Burkel and Stoll, 1995). As researchers identified first the geologic formation, then the chemical reactions responsible for the situation (Pelczar, 1996; Simo, 1995 and 1997; Gotkowitz et al., 2003), the DNR outlined a Special Well Casing Depth Area and developed well construction guidelines to protect drinking water wells in this area from contamination. Simultaneously, the DHS worked with local health officials to inform residents of health risks, provide low-cost testing of private wells, and gather information about people with long-term exposure to arsenic in one of the largest epidemiological studies ever conducted in Wisconsin (Knobeloch et al, 2002; Zierold et al., 2004).

In the early 2000s, the US EPA lowered the MCL for arsenic from 50 ppb to 10 ppb (the current standard), which raised concerns for schools and residents in southeastern Wisconsin that had been observing arsenic levels in the 10-50 ppb range. Initial testing by the DNR and the Wisconsin Geological and Natural History Survey (WGNHS) revealed that the geochemical explanations for arsenic contamination in northeastern Wisconsin could not explain the problem in southeastern Wisconsin (Gotkowitz, 2002), so the WGRMP funded further research to analyze the new situation and develop more appropriate guidelines (Sonzogni et al., 2003; Bahr et al., 2004; West et al., 2012). One of the important outcomes of these studies was improved understanding of how chlorine disinfection, which is often used to treat microbial biofilms (slime) in wells, can affect the release of arsenic (Gotkowitz et al, 2008). Shock chlorination of private wells should be limited in much of northeastern Wisconsin because it has a strongly oxidizing effect that encourages release of arsenic from sulfide minerals. Well chlorination does not similarly affect arsenic bound to iron compounds in groundwater environments such as southeastern Wisconsin. In these settings, well disinfection may in fact reduce arsenic levels by controlling microbes that contribute to iron dissolution.

The extensive research completed in Wisconsin over the past 20 years illustrates the highly variable nature of Wisconsin's geologic sources of arsenic to groundwater. A well with no detectable arsenic can be right across the street from a well that tests well above the MCL. Arsenic concentrations can vary over time, too. This makes regular testing – with efficient, accurate, and affordable methods – critical. WGRMP-funded researchers have been important partners in this and have designed portable field sampling kits, improved upon existing laboratory methods, and are currently working on sensors that can immediately detect arsenic levels in groundwater.

Future Work

Sampling and testing private wells remain important priorities for understanding and managing arsenic contamination in Wisconsin. To encourage private well sampling, local health departments continue to offer fee-exempt testing to low income families. The DNR and some county governments are also working to both promote well sampling programs and explore impediments to private well sampling.

In the areas of the state that are known to be vulnerable to arsenic contamination, there is a focus on reducing exposure. Several communities have expanded the service area for public water systems and moving homes from private wells to public supplies has been effective in reducing exposure in towns like Algoma in Winnebago County.

Areas outside the original region of concern in northeast Wisconsin and the more recent area of concern in southeast Wisconsin have not been as well described. Recent revisions to NR 812 now require wells to be tested for arsenic, in addition to bacteria and nitrate, during pump installation or when testing is requested during property transfers involving existing private wells, which may help to fill this data gap. In addition, researchers from the WGNHS funded by the WGRMP are currently working to understand the mineralogy of the Tunnel City rock formation in western Wisconsin, which may help define the risk of arsenic contamination in that region.

Further Reading

DNR overview of arsenic in drinking water wells [link]

DNR special well casing depth areas for arsenic [link]

DHS overview of arsenic health effects [link]

WGNHS report on arsenic release due to well disinfection [link]

WGNHS report on preliminary investigation near Lake Geneva, Wisconsin [link]

DHS report on arsenic in Wind Lake Private Wells, Town of Norway, Racine County [link]

Wisconsin Natural Resource magazine article on arsenic in private wells [link]

Luczaj, J.A., M.J. McIntire, and M.J. Olson Hunt. 2016. Geochemical characterization of trace MVT mineralization in Paleozoic sedimentary rocks of northeastern Wisconsin, USA. Geosciences, 6(2):29. Available at http://www.mdpi.com/2076-3263/6/2/29

References

Bahr, J.M., M.B. Gotkowitz, T.L. Root. 2004. Arsenic contamination in southeast Wisconsin: sources of arsenic and mechanisms of arsenic release. Wisconsin groundwater management practice monitoring project, DNR-174. Available at http://digital.library.wisc.edu/1711.dl/EcoNatRes.BahrArsenic

Burkel, R.S. 1993. Arsenic as a naturally elevated parameter in water wells in Winnebago and Outagamie Counties, Wisconsin. Wisconsin groundwater management practice monitoring project, DNR-087. Available at http://digital.library.wisc.edu/1711.dl/EcoNatRes.BurkelArsenic

Burkel, R.S. and R.C. Stoll. 1995. Naturally occurring arsenic in sandstone aquifer water supply wells of northeastern Wisconsin. Wisconsin groundwater management practice monitoring project, DNR-110. Available at http://digital.library.wisc.edu/1711.dl/EcoNatRes.BurkelNaturally

Gotkowitz, M.B. 2002. Report on the preliminary investigation of arsenic in groundwater near Lake Geneva, Wisconsin. Final report to the Wisconsin Department of Natural Resources, DNR-163. Available at http://wgnhs.uwex.edu/pubs/wofr200002/

Gotkowitz, M.B., J.A. Simo, M. Schreiber. 2003. Geologic and geochemical controls on arsenic in groundwater in northeastern Wisconsin. Final report to the Wisconsin Department of Natural Resources, DNR-152. Available at https://wgnhs.uwex.edu/pubs/000831/

Gotkowitz, M., K. Ellickson, A. Clary, G. Bowman, J. Standridge and W. Sonzogni, 2008. Effect of well disinfection on arsenic in ground water, Ground Water Monitoring and Remediation, 28: 60-67.

Knobeloch L. and H Anderson. 2002. Effect of arsenic-contaminated drinking water on skin cancer prevalence in Wisconsin's Fox River Valley. Proceedings of the 5th International Conference on Arsenic Exposure, San Diego CA.

Luczaj, J. and K. Masarik. 2015. Groundwater quantity and quality issues in a water-rich region: examples from Wisconsin, USA. Resources, 4(2):323-357. Available at http://www.mdpi.com/2079-9276/4/2/323

Pelczar, J.S. 1996. Groundwater chemistry of wells exhibiting natural arsenic contamination in east-central Wisconsin. MS thesis. University of Wisconsin-Madison. Available at http://digital.library.wisc.edu/1793/53154

Simo, J.A., P.G. Freiberg, K.S. Freiberg. 1996. Geologic constraints on arsenic in groundwater with applications to groundwater modeling. Wisconsin groundwater management practice monitoring project, WR95R004.

Simo, J.A., P.G. Freiberg, M.E. Schreiber. 1997. Stratigraphic and geochemical controls on the mobilization and transport of naturally occurring arsenic in groundwater: Implications for water supply protection in northeastern Wisconsin. Wisconsin groundwater management practice monitoring project, DNR-129.

Sonzogni, W.C., A. Clary, G. Bowman, J. Standridge, D. Johnson, M. Gotkowitz. 2003. Importance of disinfection on arsenic release in wells. Wisconsin groundwater management practice monitoring project, DNR-172. Available at http://digital.library.wisc.edu/1711.dl/EcoNatRes.SonzogniImport

West, N., M. Schreiber, M. Gotkowitz. 2012. Arsenic release from chlorine-promoted alteration of a sulfide cement horizon: Evidence from batch studies on the St. Peter Sandstone, Wisconsin, USA. Applied Geochemistry, 27(11):2215-2224.

Zierold K, Knobeloch L, and H Anderson. 2004. Prevalence of chronic disease in adults exposed to arsenic-contaminated drinking water. American Journal of Public Health, 94(11):1936-1937. Available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1448563/