

Arsenic in Drinking Water and Treatment Methods

What is Arsenic?

Arsenic (As) is a naturally occurring contaminant in drinking water originating from rock and soil deposits containing arsenic. The presence of arsenic can also result from human activities such as use of pesticides or glass and electronic production wastes. It is generally understood that most of the arsenic occurring in New England drinking water wells is associated with naturally occurring bedrock deposits.

A recent study by USGS released in 2011 highlights the prevalence of arsenic in private and public bedrock wells across the Northeast due to natural rock formations. Water testing indicated that approximately 13% of the studied wells (mix of public and private) were found to have arsenic in excess of the maximum contaminant level (MCL). Wells located along the eastern portion of New England have even higher levels of arsenic with about 23% of bedrock wells experiencing arsenic above the MCL. While public water supplies are required to routinely test for and treat for arsenic to levels below the MCLs, private wells are not regulated and are at risk if this water is not being tested and treated accordingly.

Link to USGS study *Quality of Water from Crystalline Rock Aquifers in New England, New Jersey, and New York, 1995-2007* <http://pubs.usgs.gov/sir/2011/5220/>

Arsenic is an odorless, tasteless, and colorless contaminant detectable only through analytical analysis. Arsenic is a human carcinogen or cancer causing agent with long term exposure potentially causing cancer, cardiovascular disease, immunological disorders, diabetes and other medical issues. In 2001, the US EPA reduced the maximum contaminant level (MCL) of arsenic in drinking water to 10 micrograms per liter (ug/L) or 10 parts per billion (ppb).

Arsenic is present as an inorganic contaminant in groundwater as arsenite, As(III) or arsenate, As(V). Arsenite is the reduced form of arsenic. Arsenate is the oxidized form of arsenic. Arsenite can exist in five forms in water or aqueous solution depending on the pH ($H_4AsO_3^+$, H_3AsO_3 , $H_2AsO_3^-$, $HAsO_3^{2-}$, AsO_3^{3-}) while arsenate can exist in four forms (H_3AsO_4 , $H_2AsO_4^-$, $HAsO_4^{2-}$, AsO_4^{3-}). The form that is present in a particular groundwater supply affects the treatment methods needed to successfully remove arsenic from drinking water.

Recent Research Suggesting the Need to Re-Evaluate the MCL

Recent research indicates that the current arsenic MCL may not be sufficient to protect pregnant women and babies. Consumption of low levels of arsenic through drinking water may decrease the amount of nutrients in the blood and breast milk of pregnant women, leading to growth and development deficits in

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babies. Research also indicates that low levels of arsenic in drinking water may compromise the body's immunity in these vulnerable groups.

Research on the carcinogenic affects of arsenic in drinking water at lower concentrations are ongoing.

Based on the recent research, a US EPA advisory panel will be re-evaluating the affects of arsenic in drinking water to determine if the current MCL is sufficient to protect public health. In addition to health impacts, the US EPA considers ability to accurately measure the contaminant and ability to reasonably treat the water, among other factors, when establishing an MCL.

Link to 2012 New Scientist Health article *New Concerns Over Safety of Arsenic in Drinking Water* <http://www.newscientist.com/article/dn21870-new-concerns-over-safety-of-arsenic-in-drinking-water.html>

Link to 2012 Science Codex article *'Safe' Levels of Arsenic in Drinking Water Found to Compromise Pregnant/Lactating Mothers, Offspring* http://www.sciencecodex.com/safe_levels_of_arsenic_in_drinking_water_found_to_compromise_pregnantlactating_mothers_offspring-92542

Link to the 2009 Environmental Health Perspectives research paper *Low-Dose Arsenic Compromises the Immune Response to Influenza A Infection in Vivo* <http://ehp03.niehs.nih.gov/article/info:doi/10.1289/ehp.0900911>

Available Analytical Methods

There are several approved methods for the accurate and reliable analysis of arsenic in drinking water. The approved practical quantitation limit (detection limit) is 3 ug/L at the $\pm 30\%$ acceptance limit., based upon current analytical methods.

The US EPA considers the lowest feasible limit for a potential MCL is 1.5 times the detection limit, to provide a wide enough operating range for compliance monitoring. This means if the current approved detection limit is 3 ug/L then an MCL could be as low as 4.5 ug/L. However, the US EPA will need to evaluate the cost impacts of imposing an MCL lower than 10 ug/L weighed against the potential benefits to public health.

Available Treatment Methods

Arsenic removal processes include oxidation/co-precipitation/filtration, adsorption and ion exchange. Selection of a particular process depends on the type of arsenic to be treated, concentrations, volume of

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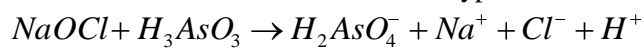


water to be treated, presence of other contaminants, capital and operation and maintenance costs, and the level of operational complexity.

Oxidation/Co-precipitation/Filtration

Oxidation involves the addition of a strong oxidant, typically sodium hypochlorite, to oxidize the arsenite to the arsenate form. For arsenic oxidation, the required oxidant amount is negligible when compared to that needed for iron and manganese oxidation, which is typically present in these groundwater sources in conjunction with arsenic. Typical practice is to use the theoretical stoichiometry plus 10% when estimating initial dosages of sodium hypochlorite. Other oxidants may also be used for arsenic oxidation. The following provides the stoichiometric reaction occurring with arsenic oxidation using sodium hypochlorite:

Arsenic/Sodium Hypochlorite Stoichiometry



Stoichiometry: 0.95 ug/L HOCl per 1 ug/L As

Co-precipitation involves the entrapment of arsenate within growing iron precipitates or adsorption of the arsenate to the ferric hydroxide particles. This process works since arsenate exists as negatively charged ions that are attracted to the ferric hydroxide particles. For co-precipitation to occur, iron must be present in sufficient amount, with an iron to arsenic ratio of 20:1 or greater with the pH less than 7.5. This means that for every 1 ug/L arsenic, at least 20 ug/L iron is needed for co-precipitation. Note that optimum removal of arsenic will occur when iron and arsenic are oxidized at the same time. If iron is not naturally present in sufficient quantities, provisions need to be made for the addition of a ferric salt, such as ferric chloride, which will create a ferric hydroxide floc for arsenic co-precipitation.



Typical Vertical Pressure Filter

A filtration system is needed to remove the oxidized and co-precipitated particles. The filtration system may be a pressure filter or open filter bed design. Often the water is being treated to remove other contaminants in addition to arsenic, such as iron and manganese. The entire water quality spectrum would need to be analyzed to determine the optimum treatment regime.

Adsorption

Adsorption involves the use of specially designed media to remove arsenic. As the arsenic laden water passes through the adsorptive media, negatively charged arsenic ions adsorb to the surface of positively charged media. This media is typically more capable of removing arsenate than arsenite. There are many

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types of media available including the most widely used activated alumina and iron based media. The media is commonly contained within a pressure vessel similar to that used for pressure filtration. The media may be backwashed to remove solids, but over time the media will become exhausted and the spent media needs to be regenerated or properly disposed of as either a solid or hazardous waste. This process requires limited operator attention and may be of particular interest to small systems.

Ion Exchange

Ion exchange is a treatment process that operates through exchange of ions in water with ions from an insoluble, permanent, solid resin bed. The resin media selected is dependent on the contaminant to be removed. Media beds are either positively or negatively charged to provide cation or anion exchange. Ion exchange media can remove both arsenite and arsenate but selection of the media will depend on the form present in the water supply. Over time as water flows through the resin bed, the media becomes exhausted and must be regenerated or properly disposed of as either a solid or hazardous waste. Ion exchange requires minimal operator attention and no backwashing. A smaller footprint may be possible as compared with conventional pressure filtration. Ion exchange has high resin replacement costs making it inefficient for larger facilities; however, this process may be economical for a very small facility due to the low labor costs. An evaluation would be needed to compare the capital, operation and maintenance costs, including labor and the cost to replace the resin.



Typical Ion Exchange Cylinder System

Summary

Selection of the exact process to meet your arsenic treatment needs should be done after careful consideration of the advantages and disadvantages of each method. Once you have decided treatment is needed, complete a treatment feasibility study. Compare processes through an evaluation of ability to treat, level of operator attention required, capital, operation and maintenance costs. Complete pilot testing of processes prior to committing to one process to make sure it is the best fit for your system. Our engineers have experience in working with water system suppliers on arsenic issues. CEI can work with you to determine which technology is the right fit for your system.

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