Water Quality Association

WATER QUALITY ASSOCIATION
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Arsenic Fact Sheet

	In Water As	Maximum Contaminant Level (MCL)
Arsenic (As)	When pH = 6-10, - As(III), arsenite as H_3AsO_3 and $H_2AsO_3^-$ - As(V) arsenate as $H_2AsO_4^-$ and $HAsO_4^{2-}$	**US EPA:** - MCL* = 0.010 mg/L (or ppm) - MCLG** = zero **WHO Guideline:** 0.010 mg/L
Sources of Contaminant	- Leaching from Natural Deposits - Wood Preservatives, Pesticides, Industrial Deposits - Petroleum Production - Semiconductor Manufacture - Coal Power Plants	
Potential Health Effects	- Serious Skin Problems, Endocrine Disruptor - Carcinogenic – skin, bladder, lung, kidney, liver, prostate - Harms Cardiovascular & Nervous Systems	
Treatment Methods Point-of-Entry Point-of-Use	- Iron oxide/ hydroxides - Activated alumina - Iron-Based Specialty Media Impregnated or Coated with Iron Oxide/Hydroxides - Distillation - Titanium Oxy/Hydroxide - Anion Exchange (Strong Base Anion Exchange Resins) - Manganese Greensand - Reverse Osmosis (RO)	

*Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

**Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

WHO- World Health Organization

The presence of arsenic (As) in nature is mainly found natural deposits of metalloids in the earth's crust and in ancient rock formations. Arsenic enters groundwater through erosion or from man-made sources such as wood preservatives, petroleum production, semi-conductor manufacturing, or due to misuse of animal feed additives and arsenic-containing pesticides (e.g.

Paris green). Since soluble arsenic is tasteless and colorless, a chemical water analysis is necessary to detect its presence and level.

Higher levels of arsenic are more commonly found in ground water sources than in surface water sources (lakes and rivers). Compared to the rest of the United States, the western states have more water systems with arsenic levels greater than 10 micrograms per liter (µg/L, ppb). Parts of the Midwest, New England, and Texas have systems whose current arsenic levels exceed 10 µg/L (or ppb).

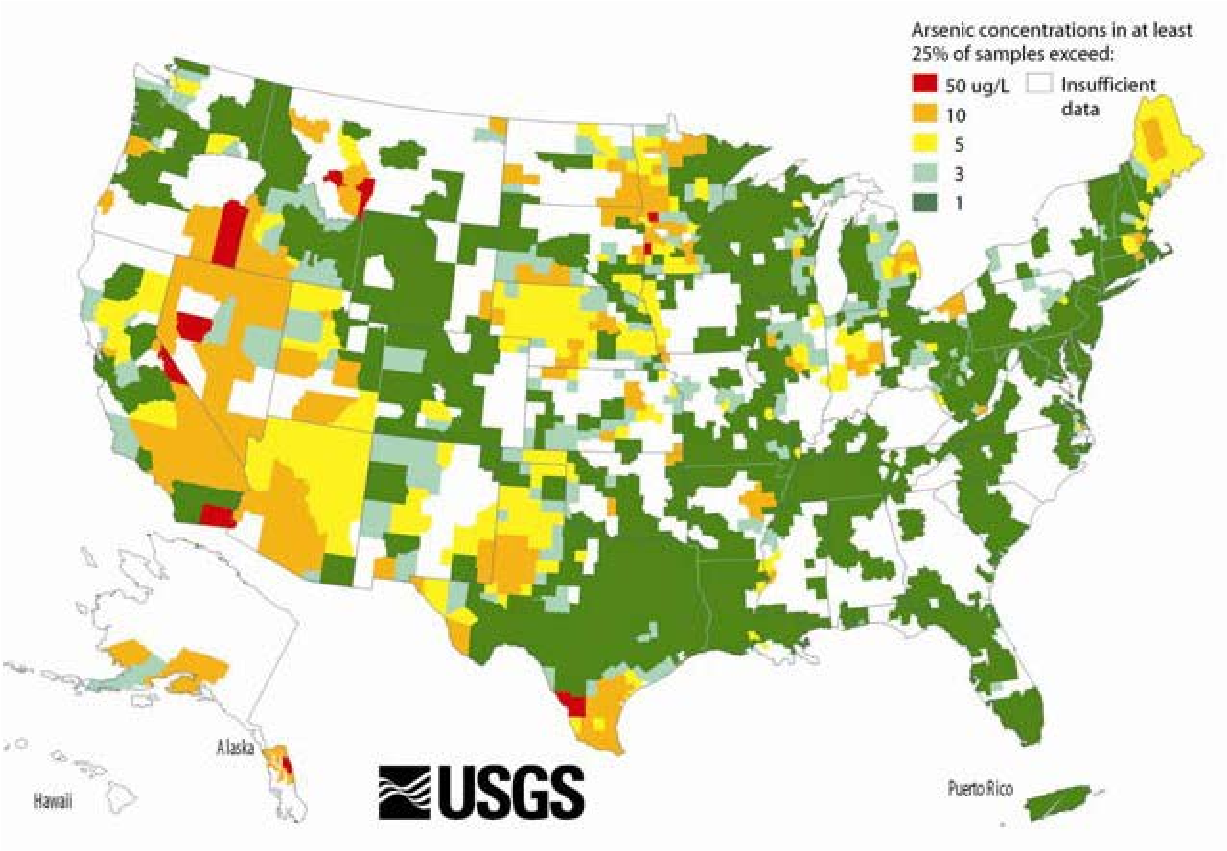

Figure 1 – US Geological Survey Map of Arsenic in Groundwater[1]

In groundwater, arsenic can combine with other elements to form both inorganic and organic compounds. The inorganic derivatives are considered more toxic than the organic forms, and usually exist in potable water in two chemical valence states: Arsenite (As III) or Arsenate (As V). The arsenite species exists in anaerobic/anoxic (reduced or low oxygen) waters as H_3AsO_3 or $H_2AsO_3^-$. The specific form depends on the pH of the water. At pH 9.2, Arsenite exists as a 50-50 mixture of H_3AsO_3 (can be written as $HAsO_2$) and $H_2AsO_3^-$. At less than 8.5 pH, Arsenite exists primarily as the neutral (non-ionized) species, H_3AsO_3 . The As V species exists in aerobic (oxidized) waters up to 9 pH as a mixture of $H_2AsO_4^-$ and $HAsO_4^{2-}$, and as a 50-50 mixture at 7.0 pH.

> You can get information on the presence of arsenic in your drinking water from your local Utility or state EPA. You can also call USEPA's drinking water hotline (1-800-426-4791) for more information. Alternatively, the Environmental Working Group (ewg.org) publishes studies looking at arsenic levels in drinking water, and they maintain a searchable "Tap Water Database".

As mentioned above, two conditions that dominate the behavior of arsenic in water are its state of oxidation (valence) and the pH of the water. Generally, aerated surface waters contain arsenate (As V) while the reductive well waters contain arsenite (As III). Municipally treated waters containing free available chlorine (FAC) will generally oxidize arsenite (As III) to the arsenate (As V) form. **NOTE: Chloraminated water utilizing only monochloramine (NH_2Cl) will not completely oxidize As III to As V.**

Generally, negatively charged (ionized) As V (as $H_2AsO_4^-$ and $HAsO_4^{2-}$) is much easier to remove than uncharged As III (H_3AsO_3 or $HAsO_2$). Tests to determine the concentration of each form, also known as speciation, must be performed to choose the proper removal technique. Current technology suggests that several techniques may be used to remove the Arsenate, As III, and organic forms of arsenic from drinking water. Techniques include:

- Iron Oxide/Hydroxides and Activated Alumina Media Filtration
- Manganese Greensand Filtration
- Strong Base Anion Exchange Resins
- Distillation
- Reverse Osmosis

Some specialty media include:

- Iron Oxide/Hydroxide-Impregnated Or Coated Activated Alumina
- Anion Exchange Resins
- Titanium Oxy/Hydroxide

Health Effects

Toxicity of arsenic to humans is well known and researched, and ingestion of as little as 100 milligrams (mg) can result in severe poisoning. Arsenic levels in water are normally much lower, but low concentrations still can lead to chronic symptoms. The effect of arsenic, when ingested in small amounts, appears very slowly. In fact, it may take several years for the poisoning to become apparent. Chronic arsenosis can in its most extreme form, cause death. Inorganic arsenic is absorbed readily from the gastrointestinal track and becomes distributed throughout the body tissues and fluids. Ingestion of inorganic arsenic leads to a number of health effects as follows:

Effects	Effected Biological Systems
Cancerous	- Skin - Urinary - Respiratory - Liver - Digestive
Non-Cancerous	- Cardiovascular - Pulmonary - Immune - Nervous/Neurological - Endocrine - Visual

The US EPA's final arsenic rule was issued in 2001. It revises the Maximum Contaminant Level (MCL) from 50 µg/L to 10µg/L and sets the Maximum Contaminant Level Goal (MCLG) to zero in the drinking water. Both community water systems (CWS) and non-transient, non-community water systems (NTNCWS) are required under this rule to reduce the arsenic concentration in their drinking water to 10 µg/L or lower.

For details of toxicological and epidemiological effects of arsenic in drinking water, please refer to the National Research Council report published by National Academic Press given in the references below.

Treatment Methods

Residential Point-of-Entry	- Iron Oxide/Hydroxides - Activated Alumina - Anion Exchange in A Fixed Bed (Requires Regeneration) - Manganese Greensand (Requires Regeneration) - Titanium Oxy/Hydroxide - Iron-Doped, Anion Resin and Activated Alumina
Residential Point-of-Use	- Iron Oxide/Hydroxides - Activated Alumina with Or Without Iron Oxide Coating Anion Exchange - Distillation - Titanium Oxy/Hydroxide - Reverse Osmosis (RO)
Municipal	- Iron Oxide/Hydroxides - Activated Alumina - Anion Exchange in A Fixed Bed (Requires Regeneration)

	- Coagulation With Iron Hydroxide (Initially Added as Fecl$_3$) o Followed By Filtration Through a Bed Of Adsorptive Granular Media (i.e. Carbon)
Visit WQA.org or NSF.org to search for products certified to WQAS-200, NSF 53, 58, 62 for arsenic reduction.	

Iron oxide, iron hydroxide and iron-coated activated alumina filtration media have shown effectiveness in removing both Arsenite (As III) and Arsenate (As V) from levels of over 50 parts per billion (ppb) or µg/L to effluent levels below 5 ppb (µg/L) for greater than 10,000 bed volumes before exhaustion. These removal systems operate best at <8 pH. Iron-based technologies can be susceptible to competitive adsorbates, such as silicates, vanadates (e.g., VO_4^{3-}) and phosphates. It has been demonstrated that each 0.5 mg/L increase in phosphate above 0.2 mg/L will reduce adsorption capacity by roughly 30% (US EPA, 2014). Therefore, a water analysis should be conducted prior to the selection of a removal technology.

For reductive water from wells, where As III is expected to predominate, an oxidation step such as chlorination or ozonation is necessary if a technique other than iron-based systems are used (e.g., RO and anion exchange). Potassium permanganate ($KMnO_4$) is also very effective in oxidizing As III to As V. Passing aqueous solutions of As III through a fixed-bed column of manganese dioxide (MnO_2) also has been shown to oxidize As III to As V and, at the same time, provide some removal capability.

Iron-based specialty media are also easy to operate and have a higher capacity than Activated Alumina (AA) media.

Some media can remove both As III and As V even though capacities may differ. The pH can be as high as 8.5 for many of these media, however the lower the pH, the more effective the As removal will be.

AA requires low maintenance and has potential for non-hazardous waste disposal after exhaustion. It is highly selective for As V, so As III must be oxidized to As V and the pH lowered, preferably to <6.5 or even lower if silica is present.

Distillation is useful when only small quantities of drinking water are involved. It has been shown to reduce arsenic to less than 2 ppb (µg/L).

Strong base anion (SBA) type I & type II resins in Cl^- form can effectively remove As V (as $H_2AsO_4^-$ or $HAsO_4^{2-}$). However, sulfate, selenium, fluoride and nitrate ions present in water will compete with As V ions ($H_2AsO_4^-$ or $HAsO_4^{2-}$) for exchange sites and may produce earlier exhaustion. Anion exchange is not effective to remove As III (as H_3AsO_3 or $HAsO_2$), since they are not charged (ionized), so it is necessary to oxidize it to As V by an acceptable technique (chlorination, permanganate or ozonation). Optimum pH for anion exchange removal is approximately >7. Regeneration can be done with brine (NaCl) solution.

Manganese greensand is best used for only As V reduction, so if As III is present, it should first be oxidized to As V.

> NOTE: Prior to installing and utilizing regenerative treatment technologies or bulk disposable adsorptive media, it is important to contact the local, regional or state regulatory authorities to determine proper disposal requirements.

Thin film composite (TFC) Reverse Osmosis membranes are best used for only As V reduction, so, again, As III should be oxidized by chlorination or ozonation, or other oxidation technique acceptable for the specific application that will not harm the membrane.

The treatment methods listed herein are generally recognized to be effective in reducing the listed contaminants sufficiently to meet or exceed the relevant USEPA MCL. However, this list does not reflect the fact that POU/POE devices and systems currently on the market may differ widely in their effectiveness in treating specific contaminants and performance may vary from application to application. Additionally, the effectiveness of many of these treatment technologies is reduced by interfering reductants and competitive adorbates. Always conduct a complete water analysis prior to any treatment application. Generally, it is recommended that devices and systems that are independently certified to appropriate NSF/ANSI standards should be preferably used. Whenever possible, assistance from a water professional or expert should be sought in the selection, installation and operation of a chosen technique.

Visit WQA.org to locate water professionals in your area. Note that Certified Water Specialists/Master Water Specialists have passed the water treatment education program with the Water Quality Association and continue their education with recertification every 3 years.

Regulations

In the United States the EPA, under the authority of the Safe Drinking Water Act (SDWA), has set the Maximum Contaminant Level Goal (MCLG) for arsenic at zero. This is the health-based goal at which no known or anticipated adverse effects on human health occur and for which an adequate margin of safety exists. The US EPA has set this level of protection based on the best available science to prevent potential health problems. Based on the MCLG, the US EPA has set an enforceable regulation for arsenic, the Maximum Contaminant Level (MCL), at 0.010 mg/L (10 ppb). MCLs are set as close to the MCLG as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In Canada, the regulated Maximum Acceptable Concentration (MAC) for arsenic in drinking water is also set at 0.010 mg/L.

References

Unless specifically noted, much of the information in this article is distilled from the collective wisdom of WQA Master Water Specialists; the men and women who make water better all over the world.

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