TECHNICAL APPLICATION BULLETIN

Arsenic

Recognized Treatment Techniques For Meeting Drinking Water Regulations For The Reduction Of Arsenic From Drinking Water Supplies Using Point-of-Use/Point-of-Entry Devices And Systems

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Water Quality Association®

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Recognized treatment techniques for meeting drinking water regulations for the reduction of arsenic using point-of-use and point-of-entry (POU/POE) devices and systems.

Occurrence & Chemistry

The presence of arsenic (symbol: As) in nature is due mainly to natural deposits of the metalloid in the earth's crust, usually in ancient rock formations. Arsenic enters groundwater through erosion, or from man-made sources such as preservation of wood, petroleum production, semi-conductor manufacturing or due to its use as a feed additive and herbicide (e.g. Paris Green). Since arsenic is tasteless and colorless, a water analysis is necessary to detect its presence.

Higher levels of arsenic tend to be found more in ground water sources than in surface water sources (*i.e.*, lakes and rivers) of drinking water. Compared to the rest of the United States, the western states have more systems with arsenic levels greater than 10 micrograms per liter (µg/L). Parts of the Midwest and New England have some systems whose current arsenic levels are greater than 10 µg/L.

In groundwater, arsenic can combine with other elements to form inorganic as well as organic compounds; the inorganic derivates are considered more toxic than the organic forms. The inorganic forms exist in potable water in two chemical states, as As^{5+} (arsenate) or As^{3+} (arsenite).

Health Effect

The toxicity of arsenic to humans is well known, and the ingestion of as little as 100 milligrams (mg) can result in severe poisoning. The effects of the poison, when ingested in small amounts, appear 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 tract and becomes distributed throughout the body tissues and fluids. Studies link inorganic arsenic ingestion to a number of health effects. These health effects include:

> Cancerous Effects*:* skin, bladder, lung, kidney, nasal passages, liver and prostate cancer; and
> Non-cancerous effects*:* cardiovascular, pulmonary, immunological, neurological and endocrine (*e.g.*, diabetes) effects.

EPA's final rule issued in 2001 revises the Maximum Contaminant Level (MCL) from 50 µg/L to 10 µg/L and sets a Maximum Contaminant Level Goal (MCLG) of zero for arsenic in drinking water. Both community water systems (CWSs) and non-transient, non-community water systems (NTNCWSs) will be required to reduce the arsenic concentration in their drinking water to 10 µg/L or below.

Treatment Alternatives

The two conditions that dominate the behavior of arsenic are state of oxidation and pH. Generally, aerated surface waters contain arsenate (As^{5+}) and reductive well waters contain arsenite (As^{3+}). Tests to determine the concentration of each form must be performed in order to choose the proper removal technique. Current technology suggests that several techniques may be used for removing the arsenite, arsenate, and organic forms of arsenic from drinking water including iron based systems, activated alumina media filtration, manganese greensand filtration, anion exchange, distillation, and reverse osmosis.

Iron oxide, iron hydroxide, and iron coated filtration media have tested effective in removing both arsenite (arsenic III or As^{3+}) and arsenate (arsenic V or As^{5+}) species from levels of over 50 parts per billion (ppb) or ug/L to effluent levels below 5 ppb (ug/L) for greater than 10,000 bed volumes before exhaustion.

Arsenic in colloidal form can be removed by submicron filtration or solid block and precoat adsorption filters. An adsorption process such as filtration through activated carbon may remove organically bound arsenic. Deep back washable beds of granular activated carbon have produced reduction rates from 40 to 70 percent. But these are not traditional approaches in this area.

The treatment methods listed herein are generally recognized as techniques that can effectively reduce the listed contaminants sufficiently to meet or exceed the relevant MCL. However, this list does not reflect the fact that point-of-use/point-of-entry (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. Therefore, selection of a particular device or system for health contaminant reduction should be made only after careful investigation of its' performance capabilities based on results from competent equipment validation testing for the specific contaminant to be reduced.

As part of point-of-entry treatment system installation procedures, system performance characteristics should be verified by tests conducted under established test procedures and water analysis. Thereafter, the resulting water should be monitored periodically to verify continued performance. The application of the water treatment equipment must be controlled diligently to ensure that acceptable feed water conditions and equipment capacity are not exceeded.

Potential Treatment Method	Benefits / Concerns / Comments
Activated Alumina (AA)	Ease of maintenance, can be potentially disposed after exhaustion Highly selective for As^{5+}

	Arsenites must be oxidized to arsenates. pH needs to be low, preferably < 6.5
Iron based and other special Media	Higher capacity than AA media with same level of ease of operation. Some media can remove both arsenites and arsenates even though capacities may differ. pH can be as high as 8.5 for many of these medias
Distillation	Useful when only small quantities of drinking water are required. Shown to reduce arsenic to less than 2ppb.
Ion Exchange	Weak base anion (WBA) and strong base anion (SBA) type I & II resins (Cl^- form) can effectively remove As^{5+} (because As^{5+} exists in the form of singly and doubly charged $H_2AsO_4^-$ and $HAsO_4^{2-}$ anions in oxidizing waters) but sulfate, selenium, fluoride and nitrate can compete with arsenic for exchange sites and may limit run lengths. Anion exchange is not effective for As^{3+} (because As^{3+} exists as uncharged arsenious acid, H_2AsO_3, in water under reducing conditions) so water must be pretreated with an oxidizing agent in order to convert all of the arsenic present to As^{5+}. pH may best be adjusted to ~ 7. Regeneration can take place with brine solution (NaCl).
Manganese Greensand	Can remove arsenic along with iron and manganese present in the water by adding free chlorine or potassium permanganate to convert As^{3+} to As^{5+}. The arsenate (As^{5+}) ion forms a complex with the Fe or Mn and is removed with the iron and/or manganese by the filter media.
Reverse Osmosis (RO)	Thin Film Composite (TFC) RO membranes can remove As^{5+} but have trouble with As^{3+}; must pretreat the water with an oxidant in order to convert all arsenic to As^{5+} for effective removal of all species with reverse osmosis.

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. Therefore, selection of a particular product or system requires investigation of its performance capabilities based on results from competent equipment validation testing for the specific contaminant to be reduced.

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