

The Removal of Arsenic from Potable Water

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Chemistry and toxicity

Because of its appearance, arsenic is considered a metalloid and is not a true metal. Arsenic exists in four valence (oxidation) states. Valence is defined as the combining power of an element with other elements or compounds. These four states are:

1. Arsenate (As^{+5})
2. Arsenite (As^{+3})
3. Elemental arsenic (As^{+1})
4. Arsine gas (As^{+3})

In water, if arsenic is present, it is predominantly in the As^{+5} (arsenate) form. Arsenite (As^{+3}), when present, is readily oxidized to arsenate in aerobic

waters at pH values above

7.0. Conversely, arsenate (As^{+5}) can be reduced to arsenite at low pH values.

Of the two predominant species, the trivalent form, arsenite (As^{+3}) is considerably more toxic than the pentavalent (As^{+5}) form, although it has been demonstrated that As^{+3} is better absorbed by the human body because it tends to react less with the membranes in the gastrointestinal tract.¹

Arsenic metabolism is a two-step process: arsenate (As^{+5}), entering a cell, is reduced to arsenite (As^{+3}), which is then methylated to arsenate. The methylation is a detoxification step, since neither MMA or DMA are as toxic to the system as is inorganic arsenic, although the chronic effects of MMA or DMA are not known.²

Arsenic removal processes

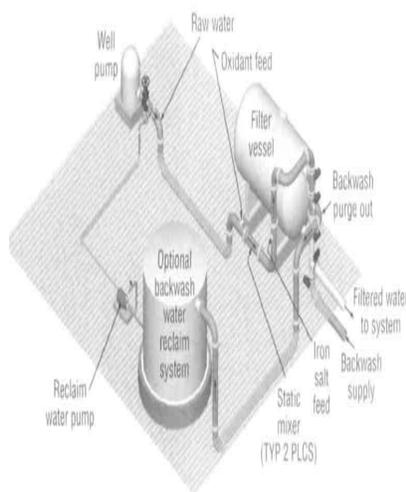
The U.S. EPA will identify a number of treatment options for the removal of arsenic as best available technology

(BAT). Discussed below, in no particular order of applicability, preference, efficiency or treatment cost, are some of the processes under consideration.

Reverse osmosis

This membrane process is primarily designed for the desalting of saline or brackish waters by the application of hydrostatic pressure.³ This overcomes osmotic pressure and drives the water to be treated through a semi-permeable membrane designed to allow passage of water, but not of dissolved contaminants.

Typical installation of coagulation/filtration process for arsenic removal



The process requires expensive and fragile membrane stacks, either cellulose-acetate or thin film composite. Cellulose-acetate membranes can be operated at up to 400 psi, but are subject to biological attack and hydrolysis. They also allow the salt passage to double after a service life of about three years. The more expensive

thin film composite membranes are capable of the same or

greater flux rate, but at half the applied pressure. These allow only a less than 30 percent increase in salt passage after three years. Both require considerable pre-treatment to prevent scaling, plugging and colloidal or biological fouling of the membranes.

Since the recovery of product water, as a percentage of feed water, is a function of applied hydrostatic pressure (up to 400 psi or more), the process tends to be quite energy intensive. Most reverse osmosis plants are designed for 75-80 percent recovery; i.e., up to 25 percent of the flow must be disposed of as a concentrated, possibly hazardous, waste.³ Reverse osmosis is quite capable of the removal of arsenic to very low levels. Process operation and maintenance costs, as well as labor intensity, will tend to rule out its application for all but small volume treatment systems.

Granular ferric hydroxide (GFH)

Granular ferric hydroxide (GFH) is an absorptive medium designed for the removal of arsenic, phosphates, chromium and other heavy metals. Raw water pH and contaminant concentration (e.g. iron, manganese, chromium, organics, silica, phosphates, etc.) determine the life of the media. Preoxidation of raw water is not required and both arsenic valence states are removed. Periodic backwashing of the media is required depending on raw water quality. GFH is presently classified as a non-regenerative media that must be removed from