Removal of Arsenic Toxicity from Water by Various Methodologies

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Abstract:

Arsenic contamination of drinking water is one of the biggest environmental and health issue for developing countries. Removal of arsenic from water is done by various techniques. The contemporary techniques can be categorized under few classes. This article summarizes all those techniques and discuss the detail of the methodologies in use. A comparative study of arsenic removal techniques is explored as well to find out the state of the art regarding cost and effectiveness.

Introduction:

Arsenic comes under metalloid category in the periodic table and can be found in various natural organic and inorganic compounds[1]. Also, arsenic is considered as one of the trace elements which can be found in various minerals in earth's crust[2]. Different natural and human activities are responsible for the discharge of arsenic to the surroundings and water bodies. Arsenic appears as any one of the four possible state. These are elemental arsenic (oxidation number 0), arsenite (oxidation number 3), arsine (oxidation number 3) and arsenate (oxidation number 5). Arsenate and arsenite which are pentavalent and trivalent inorganic arsenic compounds, respectively, are very common in aqueous medium[3,4]. Arsenic prefers to stay in arsenate form in aerobic conditions such as at the surface level of the water-bodies, whereas arsenite is the prevalent form in anarobic conditions such as confined aquifers or lower level of the water-bodies[5]. Both of these arsenic species have extreme harmful effects on human bodies[6,7]. The extent of toxicity of arsenic can be traced to reported case of its use for human killing[8]. Arsenic has been assigned to group 1 of the carcinogenic agent according by WHO. Recurring consumption of arsenic contaminated water with arsenic concentration over 50 μg/litre causes arsenicosis, a form of cancer develop in kidney, bladder or skin[9].

State of the Art:

The cost of any of the removal technologies depends on various aspects. Arsenic concentration in the water under treatment i.e. the influent water strongly affects the removal cost. Cost of the chemicals and materials required, pH of the water, time required for regeneration, quality and quantity of the involved human resources, geographical area of the removal plant etc. are other different factors influencing the removal cost. Over twenty different technologies were compared on the basis of arsenic removal cost and the expense in USD for cleaning up one meter^3 of water were reported. The removal cost is range-bound between ~90USD/meter^3 to less than one USD/meter^3 [10].

The efficiency is the other important aspect along with the removal cost while ranking a removal technology. The removal efficiency of the technologies reported were within the range from 50% to ~100%. Though the mere comparison of the removal efficiency values can be somewhat misleading as these trends might change depending on the concentration of arsenic contamination as well. Methodologies that are more efficient for highly concentrated influent water may show less efficiency for water with low arsenic contamination. Also, the laboratory tested efficiency may or may not be sustainable when it is transferred to large-scale plant set-up.

Different Methodologies:

Various technologies comprising physical, chemical and biological methods have been used for arsenic removal. Though most of the contemporary techniques can be categorized under only six different methods. Those are A) Coagulation, precipitation followed by filtration, B) Oxidation, C) Adsorption methods, D) Biology based methods, E) Ion exchange based methods, and F) Membrane based methods[10]. Additionally, some of the contemporary techniques have been developed as mergers of these six different techniques[9,11].

Figure 1. Depiction of various categories of arsenic removal techniques. There are six prime classes of contemporary arsenic remedial methodologies.

A) Coagulation, precipitation followed by filtration: In this method trivalent arsenite is oxidised to pentavalent arsenate. This is followed by formation of insoluble arsenite complexes[12]. Various metal ions are used for this purpose such as sodium aluminate, aluminium sulfate etc. Some of the iron compounds are also used as common coagulants.

B) Oxidation: This process can be considered as one of the precursor step for most of the different arsenic removal methods. The process involves oxidation of arsenic(III) compounds to arsenic(V) compound. In most

of the case this oxidation is done chemically. Though other methods such as photochemical oxidation is used as well[13]. In general, the oxidation step is always followed by another coagulation step to form insoluble arsenate compound by means of any of the chemical or biological coagulants.

C) Adsorption methods: Adsorption based methods rely on various adsorbates which facilitate the coagulation of the toxic arsenic compound present in water. These adsorbates could either be synthetic or naturally occurring. The inorganic adsorbate based methods normally require an oxidation step before the adsorption step. Though there are adsorption based methods which do not require any oxidation step.

D) Biology based methods: Biology based techniques use various naturally occurring biological materials either as coagulants or as filtering materials[14]. Biomass obtained from specific trees is one of the example of such biological material.

E) Ion-exchange based methods: In these techniques, specific immobile resin phase is used to separate out the toxic arsenic compounds. The resin is chosen considering the chemical affinity of the arsenic compound towards it. In general, arsenite present in the water is oxidized to arsenate form. Afterward the sample water is run through the immobile resin phase. Due to the chemical affinity arsenate binds to the resin and the water that comes out is devoid of toxic arsenic compounds[15].

F) Membrane based methods: The membrane based methods rely on various membranes that are used to separate out the arsenic after the coagulation step[16]. Membranes are made of hundreds of millions of tiny pores which work as impediments for the larger coagulated arsenic compounds. Hence, the membranes work as the filter to remove toxic arsenic. Membrane based techniques can be varied on the basis of the pores size and the amount of pressure need to be applied. Both of these factors are affected by each other and needed to be carefully considered depending on the coagulated particle size.

Conclusion:

Arsenic is considered as one of the common toxic materials that can be found in our surroundings and specially in various water sources. In some of the developing countries, including India, this a major concern as chronic consumption of highly concentrated arsenic contaminated water leads to life threatening diseases like cancer. Trivalent arsenite and pentavalent arsenate are the two most common forms of water soluble arsenic. Most of the common remediation strategies involve oxidation of arsenite to arsenate by chemical or biological techniques. Afterward, coagulation or flocculation of the soluble arsenate is achieved to form aggregated insoluble particles using different kinds of coagulates. The last step generally contains separation of arsenic compounds from water by diverse approaches. Different types of membranes or ion-exchange resins can be used for such separation purpose. An efficient arsenic removal techniques can be a stepwise combination of some of these above mention methods.

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