

Removal of Arsenic from Water- Exploration of Different Approaches

**Tanmoy Das**

(Corresponding Author)
Assistant Professor,
Dept. of Chemistry,
The University of Burdwan,
Burdwan, W.B., India

**Biswajit Mandal**

Research Fellow,
Dept. of Chemistry,
The University of Burdwan,
Burdwan, W.B., India

Abstract

Approaches of removal of Arsenic from water –a review: Arsenic poisoning of ground /surface water adversely effects the huge population of several countries including in India, Bangladesh, Argentina, Mexico, Vietnam etc. Arsenic poisoning of ground water is a serious health hazard and it affects approximately 90 million people at global level. This review paper presents an overview of the available technologies used nowadays for the removal of arsenic species from water. There is a need for suitable filtering device for removal of arsenic from ground water. The applied techniques to remove arsenic species include oxidation, coagulation-flocculation, and membrane techniques. Arsenic exists in two prevalent oxidation states, with the trivalent arsenite [As (III)] exerting stronger toxicity effects on the aquatic biota than the pentavalent arsenate. We provide a synthetic outlook on the potential strategies of biological As (III) oxidation to As (V) by means of cell-detoxifying mechanisms or metabolic processes with the aim to enhance As removal efficiency.

Keywords: Arsenic, Pollution, Water Purification Technology, Arsenite oxidation, Water Treatment.

Introduction

Approaches for removal of Arsenic from water- a review: Arsenic poisoning of ground/surface water adversely effects the huge population of several countries including India, Bangladesh, Argentina, Mexico, Chile, Mongolia, Vietnam etc. Arsenic poisoning of ground/surface water is a serious health hazard and it affects approximately 90 million people at global level. The magnitude of the problem of Arsenic poisoning has reached such proportion in India, Bangladesh and Vietnam that it needs immediate attention. There is a need for suitable filtering device for removal of Arsenic from water which can be used at a household level and which is within the economic reach of ordinary households.

Review of Literature

Arsenic (As) is a toxic element widely distributed in aquatic environments, owing to geogenic processes occurring within aquifers rather than being derived from identifiable point sources of pollution. Being the 20th most abundant trace element in the earth's crust, arsenic (As) is a constituent in approximately 245 mineral species, which are predominantly ores containing sulfide, copper, nickel, lead, cobalt, or other metals [1,2]. Arsenic is widely used in various fields such as electronics, agriculture, wood preservation, metallurgy, and medicine [3]. These anthropogenic sources contribute to the release of arsenic to the environment in addition to its release from natural geological sources, for instance, by weathering of arsenic-containing rocks and volcanic activities. Arsenic is a naturally occurring metalloid that is very mobile in the environment. Its mobility largely depends on the parent mineral form, oxidation state, and mobilization mechanisms [4]. In terms of oxidation state, arsenic can exist in four forms, which are arsenite (As(III)), arsenate (As(V)), arsenic (As(0)), and arsine (As(-III)). Among these four arsenic species, the most prevalent forms, which are commonly found in water, are the inorganic arsenite and arsenate [5]. Because of slow redox transformations, arsenite and arsenate are present in both reduced and oxidized environments [4]. However, under anoxic reducing conditions (e.g., subsurface waters, reduced sediments), arsenic primarily exists as arsenite, whereas arsenate is prevalent in aerobic oxidizing environments, such as surface waters [6]. The pH also plays an important role in determining the state of arsenic [7]. This information is particularly useful in the determination of arsenic toxicity. Arsenic is known to be highly toxic to all life forms [8]. This element has been classified by the World Health Organization as a group 1 human

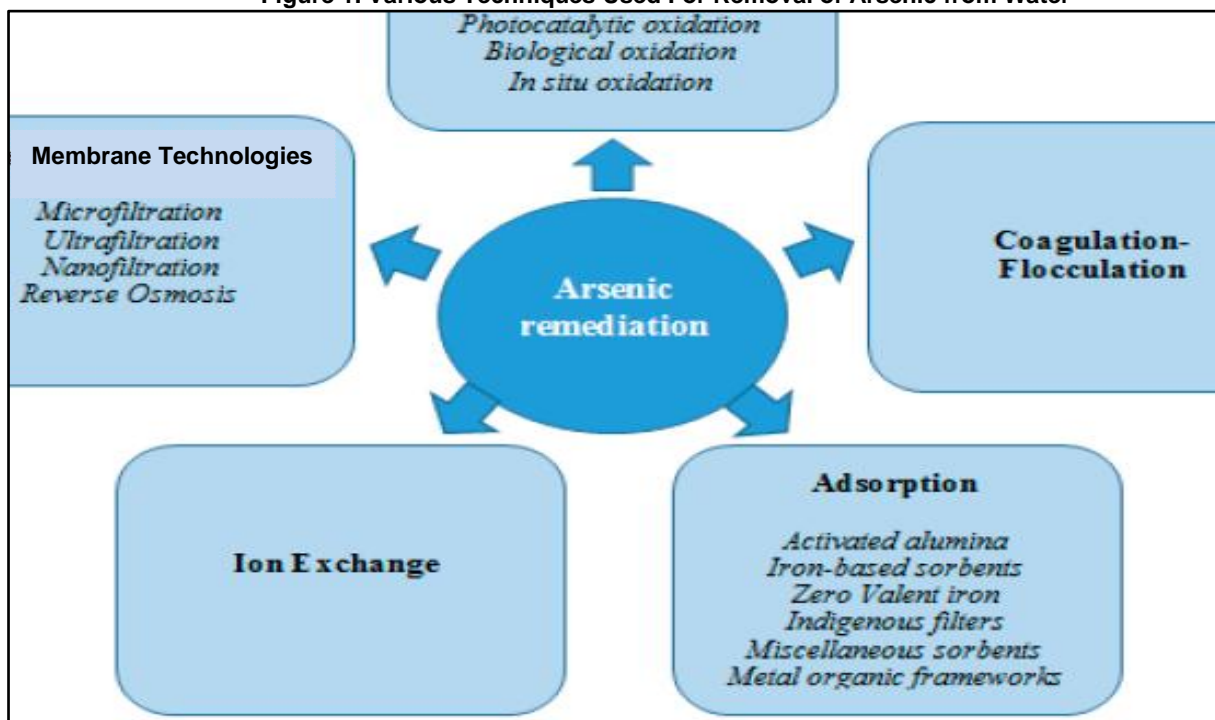
carcinogenic substance [9]. Recently, many studies have been conducted regarding the environmental fate and behavior of arsenic due to several arsenic pollution cases worldwide and the hazards associated with these. Upon chronic intake of inorganic arsenic being present in concentrations above 50µg/L in drinking water, different kinds of skin lesions (e.g., hyperpigmentation, hyperkeratosis) and cancers (e.g., skin, lung, kidney, bladder) can develop, which are collectively termed as arsenicosis [8]. Worldwide, groundwater arsenic contamination is worst in Asian countries, especially in Bangladesh and West Bengal, India [10, 11]. In both areas, the majority of the population depends on tube wells for water supply. Since the arsenic source is geogenic nature, it has been reported that 79.9 million and 42.7 million people in Bangladesh and India, respectively, are exposed to contaminated groundwater having concentration above 50 µ/L [12, 13]. In Bangladesh,

the arsenic concentration in some tube wells is as high as 4730 µg/L [10]. For the past three decades, several studies have been shown that drinking arsenic contaminated water should be one of the major concern for the health of mankind.[14,15].

Method of Removal Techniques

The chemistry and composition of arsenic-contaminated water are the major factors determining the removal of arsenic [8]. Most of the available removal technologies are more efficient for arsenate given that arsenite is predominantly non-charged at pH below 9.2 [16]. This makes the trivalent form of arsenic less available for precipitation, adsorption, or ion exchange. Accordingly, treatment technologies are believed to be more effective by using a two-step approach consisting of an initial oxidation from arsenite to arsenate followed by a technique for the removal of arsenate [5].

Figure 1. Various Techniques Used For Removal of Arsenic from Water



Most technologies for Arsenic removal are plagued by the basic difficulty of removing arsenate (As^{3+})¹. The more successful techniques are ones that have been used on large municipal supplies but they are not practical for residential applications because of space requirements, the use of dangerous chemicals, frequent monitoring and expenses. The two most common techniques for residential water correction have been reverse osmosis (RO) and activated alumina. Activated alumina requires the use of caustic chemicals and a very large volume for the high flow rates available with this invention, RO is no longer certified as an arsenic removal technique because of its inability to reduce arsenate (As^{3+}) significantly.

In an approach arsenic contaminated water was allowed to pass through successive layers of sand and wood charcoal at a controlled flow rate.

Weight of the layers of charcoal was varied (606 g, 754 g, 457 g) while weight of the layer of sand was 4480 g. It was found that removal of arsenic was higher with lower rates through the layer of charcoal. This method may be adopted as cheap and simple technologies for removal of arsenic from drinking water.

In one precipitation method of arsenic removal with aluminum or iron hydroxides is the best known and most frequently applied technique. The treatment process consists of coagulation followed by flocculation, sedimentation, and filtration.

Here oxidation of arsenite to arsenate by sunlight is a very slow process. An investigation of precipitation methods indicates that the removal of arsenic by coagulation is a function of oxidation states of arsenic, pH of the water and the initial arsenic concentration. Iron salt is more preferable than alum

because of its greater stability. 92% removal was achieved using 20 mg/l of alum in 0.1 mg/l of arsenic on water at pH 6.6 and 96% removal was achieved using 10 mg/l ferric sulphate in 0.1 of arsenic in water at neutral pH range with 6 hours retention time.

In on recent reported method naturally occurring laterite soil was selected as an absorbent and was devised into an earthen Kalsi for a household filter.²

In essence then techniques for removal of arsenic from water are based primarily on a few basic processes:

1. Oxidation of As³⁺ to As⁵⁺ by addition of a suitable oxidizing agent: The oxidation reactions do not remove arsenic from solution but are often used to optimize other processes such as coagulation and absorption or ion-exchange.
2. Precipitation processes including coagulation and filtration: Dissolved arsenic forms a slow solubility (solid) mineral (such as calcium arsenate). This solid can then be removed through sedimentation and filtration.
3. Adsorption process: Various solid materials including iron and aluminum hydroxide flocs, have a strong affinity for dissolved arsenic. Arsenic is strongly attracted to absorption sites on the surfaces of these solids and is efficiently removed from solution by adsorption.
4. Ion exchange: Ion exchange is sometimes considered as a special form of absorption. Ion exchange is a physical/ chemical process by which an ion on the solid phase medium (the resin 'filter') is exchanged for an ion in the feed water. This solid phase is typically a synthetic resin, which has been preferentially chosen to absorb the arsenic.
5. Membrane filtration including reverse osmosis: Membrane filtration concentrates ions (including arsenic ions) on one side of the membrane, leaving pure water on the other side.
6. Bio-control: In this technique some sort of microbes which are inherently resistant to Arsenic – the Arsenic being accommodated into their reproductive multiplication (mitosis). The process is under investigation.

In the developing country context, the removal of arsenic from water is generally accomplished by either adsorption or oxidation, together with precipitation. Sand filters are often used to remove precipitate. This contaminated sand material tends to provide the greatest challenge for disposal.

Conclusion

Arsenic is recognized as a persistent contaminant in groundwater with severe impact on human health when exposed through, amongst other sources, drinking water. Arsenic emissions from natural sources, including not in the least certain Asian countries, and anthropogenic emissions urge for on-site remediation to reduce the toxicity risks. Conventional techniques generally focus on arsenate removal after an initial oxidation of arsenite by atmospheric oxygen, bacterial activity, or chemical reagents. Increasing the particle size of soluble

species is possible by a coagulation/flocculation process and allows removal by precipitation or membrane filtration in a consecutive step. Ion-exchange resins alternatively are capable of directly immobilizing As ions, but this process is subjected to pH influences and competition from co-occurring ions such as phosphate or silicate. Nevertheless, practical use of these conventional and non-conventional techniques are still limited due to the fact that their adsorption capacities are still too low and there is a lack of potential to regenerate and reuse the adsorbents. As far as arsenic removal is concerned, the membrane filtration is the most preferred one.

Endnotes

1. Lowenbach, W.; Schlessinger, J. *Arsenic: A Preliminary Materials Balance; Lowenbach and Schlesinger Associates: Washington, DC, USA, 1979.*
2. Mandal, B.; Suzuki, K. *Arsenic round the world: A review. Talanta* 2002, 58, 201–235. [CrossRef]
3. Sharma, V.; Sohn, M. *Aquatic arsenic: Toxicity, speciation, transformations, and remediation. Env. Int.* 2009, 35, 743–759. [CrossRef] [PubMed]
4. Al-Abed, S.; Jegadeesan, G.; Purandare, J.; Allen, D. *Arsenic release from iron rich mineral processing waste: Influence of pH and redox potential. Chemosphere* 2007, 66, 775–782. [CrossRef] [PubMed]
5. Pous, N.; Casentini, B.; Rossetti, S.; Fazi, S.; Puig, S.; Aulenta, F. *Anaerobic arsenite oxidation with an electrode serving as the sole electron acceptor: A novel approach to the bioremediation of arsenic-polluted groundwater. J. Hazard. Mater.* 2015, 283, 617–622. [CrossRef] [PubMed]
6. WHO. *Arsenic in Drinking Water; Organisation, W.H., Ed.; WHO: Geneva, Switzerland, 2011.*
7. Henke, K.; Hutchison, A. *Arsenic Chemistry; John Wiley & Sons Ltd.: West Sussex, UK, 2009.*
8. Singh, R.; Singh, S.; Parihar, P.; Singh, V.; Prasad, S. *Arsenic contamination, consequences and remediation techniques: A review. Ecotoxicol. Environ. Saf.* 2015, 112, 247–270. [CrossRef] [PubMed]
9. Van Halem, D.; Bakker, S.; Amy, G.; van Dijk, J. *Arsenic in drinking water: A worldwide water quality concern for water supply companies. Drinking Water Eng. Sci.* 2009, 2, 29–34. [CrossRef]
10. Chakraborti, D.; Rahman, M.T.; Das, B.; Murrill, M.; Dey, S.; Mukherjee, S.; Quamruzzaman, Q. *Status of groundwater arsenic contamination in Bangladesh: A 14-year study report. Water Res.* 2010, 44, 5789–5802. [CrossRef] [PubMed]
11. Ahsan, H.; Chen, Y.; Zablotska, L.; Argos, M.; Hussain, I.; Graziano, J.H. *Arsenic exposure from drinking water and risk of premalignant skin lesions in Bangladesh: Baseline results from the health effects of arsenic longitudinal study. Am. J. Epidemiol.* 2006, 163, 1138–1148. [CrossRef] [PubMed]
12. Ratnaike, R. *Acute and chronic arsenic toxicity. Postgrad. Med. J.* 2003, 79, 391–396. [CrossRef] [PubMed]

13. Chen, Y.; Parvez, F.; Gamble, M.; Islam, T.; Ahmed, A.; Argos, M.; Ahsan, H. Arsenic exposure at low-to-moderate levels and skin lesions, arsenic metabolism, neurological functions, and biomarkers for respiratory and cardiovascular disease: Review of recent findings from health effects of arsenic longitudinal study in Bangladesh. *Toxicol. Appl. Pharmacol.* 2009, 239, 184–192. [CrossRef] [PubMed]
14. Maity, J.; Nath, B.; Kar, S.; Chen, C.; Banerjee, S.; Jean, J.; Santra, S. Arsenic-induced health crisis in peri-urban, moyna and Ardebok villages, west Bengal, India: An exposure assessment study. *Environ. Geochem. Health* 2012, 34, 563–574. [CrossRef] [PubMed]
15. Mazumder, G.; Dasgupta, U. Chronic arsenic toxicity: Studies in west bengal, India. *Kaohsiung J. Med. Sci.* 2011, 27, 360–370. [CrossRef] [PubMed]
16. Johnston, R.; Heijnen, H. Safe Water Technology for Arsenic Removal. Available online: <http://archive.unu.edu/env/Arsenic/Han.pdf> (accessed on 18 December 2015).