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Recent development of arsenic removal from drinking water: A brief review

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Abstract

Arsenic is a macro element present in large amount in the earth crust, natural and underground water. Based on the property written on the chemistry periodic table it is an odourless and tasteless semi-metal element. Arsenic is typically found as arsenide [As(III)] and arsenate [As(V)] in the environment, with +3 and +5 oxidation states respectively. In 2006, maximum contaminant level, or MCL in drinking water for arsenic was decided as 10 micro grams/L. If the concentration level of arsenic in drinking water is above the MCL value then continuous use and drinking of such water can cause skin damage, circulatory problems, and an increased risk of cancer.

Keywords: Arsenic separation, physical, chemical, biological methods, emerging techniques

1. Introduction

Various scientific methods have been developed to remove arsenic from water. All the method can be categorized into three category chemical, physical and biological type1,2. Biological process is still in the initial stage considering large scale application purpose so in this review we shall mainly focus on the methods which are combination of chemical and physical type and conclude the review by mentioning the recent development in the biological removal method and few other emerging methods.

2. Methodology

As I have already mentioned in the introduction part that this review will be written in two parts focusing on chemical/physical method and biological process of separation, so I have divided the methodology into two separate subsections focusing on the field concerned.

2.1 Chemical/Phisical Treatment Technology

All chemical and physical treatment methods to remove the excess arsenic level in drinking water are consisting of the following steps. Each effective method usually involves more than one step in its flow chart. The list of the well-established steps are as follows-

a) Oxidation
b) Lime precipitation
c) Coagulation/filtration
d) Adsorptive media
e) Ion exchange
f) Reverse osmosis

Brief description and importance of each steps is as follows.

a) Oxidation is a chemical process which is used to convert As3+ [As(III) or arsenite] into As5- [As(V) or arsenate] form. This is necessary because As3+ is more soluble in water and higher solubility of the arsenite compound make the coagulation/ precipitation process less effective. But if we oxidized the whole arsenic content into As5- state using oxidizing agent like hydrogen peroxide, potassium permanganate or ozone then majority of the arsenic can be removed by simple and low cost precipitation or coagulation method.

b) Lime precipitation is commonly used for drinking water with very high level of arsenic contamination. This method reduces arsenic concentrations from high levels (e.g., hundreds of mg/L) to moderate levels (e.g., 1 to 5 mg/L) with a very low cost chemical substance lime. Precipitation formed is removed from water by using simple filtration method adopted for solids removal. And after that an additional process is applied to reduce the arsenic concentrations down to drinking water standards.

c) Another low cost and effective approach for arsenic removal is coagulation filtration method (CF method). In this method, firstly a effective coagulant material is added to the arsenic contaminated water which coagulate the soluble arsenic by charge neutralization technique which result the precipitation As5- (chemical processes) then the precipitation formed is removed by an effective and suitable filtration process (a physical process), based on the two steps involved in the overall process the technique is named as coagulation/filtration (CF) technique in the water treatment industry. Common coagulants used for arsenic removal are iron salts and potassium aluminum sulfate (common alum). Alum coagulation is less effective than iron coagulation, so in modern day technique, so use of alum is limited for drinking water with low arsenic concentrations. Typical iron salts used are ferric chloride and ferric

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sulfate. Following coagulation, a electronically develop process of multimedia filtration is used to remove precipitated arsenic.

d) Water coming out from effective CF treatment is good for drinking but some time a new layer of protection is incorporated in the process. This includes the application of Adsorptive media (AM) which are effective in removal of trace amount of soluble arsenic in water by selective adsorption of arsenic. As effective adsorption media we usually use iron based adsorptive media, titanium dioxide, zirconium, and other ion exchange resins. This process is favored by keeping the pH range of water in the range 5 to 7.

e) The ion exchange (IX) technique is somewhat different from the adsorptive media (AM) process. The basic difference is the type of chemical interaction involve between the arsenic removal agent and soluble arsenic. In ion exchange process the interaction is so strong that the media can't be regenerated by simple desorption technique. To reuse the costly media, we have to treat the media with sodium hydroxide and sodium chloride. But one disadvantage of this process is that it creates a liquid waste containing a high concentration of arsenic. Disposal of this waste may create another environmental problem for this reason IX is not very popular technique for arsenic removal.

2.2 Biologycal Treatment Technolgy

In these technique bacteria is used to remove the soluble arsenic from water. The process usually involves biological sulfate reduction to precipitate water soluble arsenic. As the process is bacteria dependent so we have to use organic nutrient in the drinking water. Major drawback of Biological systems for arsenic removal is that it require a relatively long residence time, such as 4 to 8 hours. Maintenance cost of this system is very low but we have to spend a lot to supply the nutrient to the bacteria.

Recently a new Scorodite method has been developed by PAQUES, a Dutch company, for removing arsenic from water through biological formation of bioscorodite (FeAsO4 . 2 H2O).In this method bacteria oxidize iron to ferric iron and arsenic to arsenate. Technology developers have claimed that this process has the following advantages-

- Air is used as an oxidant.
- High temperature is not required.
- The iron dose and solid waste volume are less than in ferric arsenate processes.
- Bioscorodite is more stable than scorodite produced from conventional processes.

2.3 Emerging Treatment Technologies

Electrochemical Arsenic Remediation (ECAR) uses a setup where low electrical current is used to create rust from iron plates in arsenic contaminated water and this artificially generated rust binds to arsenic and after that those arsenic absorbed iron plates are removed and finally the water is filtered by a simple filtration process. This method is claimed to be suitable for communities or countries that do not have the resources for standard coagulation/filtration plants. The ECAR process is reportedly much less expensive than conventional technologies.

Several nanomaterials have recently been developed for arsenic removal. In one technology developed by the National Institute for Materials Science, the inner walls of nanoporous substances are densely packed with a functional group that is sensitive to and selective for adsorbing arsenic (Water Online, 2012). This method is applicable towards low arsenic level. A distinctive and advantageous feature of the technology is that the color of the nanomaterial changes as arsenic is adsorbed. This nanomaterial is reportedly lightweight with rapid kinetics but also low-cost.

Another low-cost technology designed to address arsenic removal in developing countries is subterranean arsenic removal (SAR). This technology uses controlled oxidation with air and filtration to reduce arsenic to low levels. In a modified in situ process, water is oxidized above-ground and injected back into the aquifer, where ferric arsenate particles are then filtered. No chemicals are used and the sludge produced is immobilized underground.

3. Conclusion

Arsenic removal process is continuously developing with time. Good laboratory method don't guarantee the applicability in real situation because in practical purpose they have to satisfy the criteria of sustainability, low cost, effective removal and environment friendly. Considering these feature the old methods of adsorption, precipitation and filtration based techniques are good but the author of this review think that the future methods will be based on bio based removal technique or plant which will be applicable in so large scale that a single plat will be sufficient to supply sufficient water for a town.

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