

# Arsenic toxicity and its impact research paper sample

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## **Research Report on Remediation Methods for Arsenic**

### Introduction

Arsenic contamination of groundwater used for potable water supply is one of the serious problems plaguing the world today. Worldwide, a large number of people are unknowingly exposed to drinking water that has arsenic content higher than the safety level. A study conducted in 2007 reveals that more than 137 million people in over 70 countries are potentially affected by arsenic contamination of drinking water resources (USA Today, 2007).

Though arsenic contamination is found in all the waters in the world, some of the places where the problem is a matter of concern is Bangladesh, Argentina, China, India, Chile, Mexico, the USA, and Thailand (WHO, 2014).

Arsenic is a tasteless and odorless semimetal that permeates the ground water sources either through natural deposits in the Earth or through industrial and agricultural practices. As per the guidelines set by the World Health Organization (WHO), the safe limit of arsenic in water supplies is 10 parts per billion (ppb) or 0.01 mg/L, but 137 million people worldwide consume drinking water with a higher level of arsenic while 57 million people consume drinking water with arsenic level higher than 50 parts per billion (USA Today, 2007). Arsenic contamination of groundwater has become a global concern because of a number of serious health hazards resulting out of continuous exposure to the toxicity of the arsenic contaminated drinking water. Apart from the use of alternative uncontaminated water sources, there are several techniques used for arsenic removal. Some of these arsenic removal processes are conventional like coagulation or filtration and ion exchange and some are emerging processes like iron oxide based

adsorbents, which are easy to operate requiring low investment (Driehaus, 2005). This paper will discuss the problem of arsenic at length, touching upon the impact of its toxicity and the conventional and advanced arsenic removal methods.

Arsenic occurs naturally in more than 200 different mineral forms out of which about 60% are arsenates, 20% sulphides and sulphosalts, and the remaining 20% are arsenite, arsenide, oxides, elemental arsenic and silicates (Duarte, Cardoso and Alçada, 2009). Initially, arsenic pollution of ground water was reported to be found in Bangladesh and in some Latin American countries, where the arsenic concentration level goes beyond 3.4 mg/L. In the USA, the Russian Federation, New Zealand, Spain, and Romania, arsenic concentration level hovers between 0.4 and 1.4 mg/L in carbonated water springs. In Portugal, the arsenic concentration of approximately 60 ppb for surface waters and 800 ppb for groundwater is found in regions like Alto Douro and Trás-os-Montes. Ribatejo, Beiras, Minho, and Alentejo are some regions in Portugal with arsenic level higher than 10 ppb (Duarte, Cardoso and Alçada, 2009).

Arsenic is a toxic element with no health benefits to humans. Though the presence of natural arsenic salts is found in all waters, the amount is very minimal. Most waters in the world have arsenic levels lower than 0.01 mg/L (WHO, 2014). Drinking arsenic rich water for a long period of time such as from 5 to 20 years results in arsenicosis or arsenic poisoning. Arsenicosis is caused by drinking arsenic rich water, ingestion of arsenic through food and inhalation of arsenic through the air. Absorption of arsenic through skin

being minimal, bathing, hand-washing and doing laundry with arsenic rich water do not pose serious health hazards (WHO, 2014).

The various health issues that emerge from drinking arsenic rich water include bladder cancer, lung cancer, kidney cancer, skin cancer, diabetes, reproductive disorders, high blood pressure, and various skin problems like thickening of skin, pigmentation change, and hard patches on the soles of feet and palms. In China, arsenic poisoning has caused severe disease of the blood vessels, leading to gangrene known as 'black foot disease' (WHO, 2014).

The National Academy of Sciences has made a risk estimation of lifetime risks of dying of cancer from the presence arsenic contaminants in tap water. The table below furnishes the results:

## **Arsenic Removal Techniques**

Arsenic removal techniques can be classified into three distinct groups; 1) small-scale filtration, 2) large-scale filtration, and 3) point of use filtration. Although the techniques used differ in each case, but the basic technologies used are more or less similar. The two major challenges to arsenic treatment are 1) minimization of arsenic in water without changing its physical/chemical properties and 2) production of arsenic free water at a low cost. These two differing criteria pose a challenge to the arsenic filtration of water. Below is discussed some of the conventional as well as advanced arsenic removal techniques.

## Conventional Removal Methods

Coagulation/Filtration with metallic salt and lime followed by the actual filtration is probably the most well-documented method of arsenic removal. This method has three mechanisms to remove arsenic from water. Firstly, the metallic salt and lime, also known as coagulants, are added to water that forms precipitation and takes out a large percentage of soluble arsenic from the water. This is followed by a co-precipitation technique mostly using ferrous hydroxide that causes the co-precipitation percentage of soluble arsenic (Duarte, Cardoso and Alçada, 2009). Finally, this water is passed through a series of filters where adsorption and ion exchange happen. Iron and aluminium hydroxide have a strong affinity for dissolved arsenic. This absorbs the remaining dissolved arsenic from water. Coagulation/Filtration and softening with lime addition technique is economical, but has a lower efficiency (Feenstra, Erkel and Vasak, 2007).

Sorptive Filtration or Absorption Filtration uses media like activated alumina, activated carbon, manganese and iron coated sand, kaolinite clay, hydrated ferric oxide, and many other natural and synthetic media (Shrestha, 2012). The efficiency of these techniques is higher than normal coagulation/filtration process. Activated alumina has a good absorptive surface. The large surface area of activated alumina increases the absorption of arsenic from the water. The efficiency of this technique in removing arsenic is more than 95% (Feenstra, Erkel and Vasak, 2007). However, periodically, the activated alumina gets saturated and needs to be regenerated using caustic soda. While regenerating the system, highly arsenic contaminated caustic wastewater is produced, posing environmental

threats. Still, this is the most widely used technique for arsenic removal because of its simplicity and low cost.

Ion exchange is similar to the process of arsenic filtration using activated alumina. However, here, instead of using alumina coated sand as the medium, synthetic resins are used for filtration. Synthetic resin is generally based on cross-linked polymer. Unlike the alumina activated filtration, which has maximum efficiency only in weakly acidic condition, synthetic resins are available for all kinds of water condition from strongly acidic to strongly basic. Arsenite is a non-charged molecule, and therefore, it cannot be extracted from water using only ion exchange (AwwaRF, 2005). Hence, oxidation is a necessary first step in the ion exchange filtration process. The regeneration of synthetic resins is very easy. However, the initial installation cost of synthetic resins is higher than that of coagulation/filtration or sorptive filtration process.

Membrane technique, which, in many cases, is known as reverse osmosis process, is sometimes used to eliminate different types of contaminants including arsenic from water (AwwaRF, 2005). This membrane technique can be used to improve the overall chemical property of the water by removing unnecessary metallic ions, pathogens, and salts. Usually, two types of membrane filtration are used; low pressure membranes also known as micro-filtration, and high pressure membranes known as nano filtration (Shrestha, 2012). This membrane filtration is not affected by the pH level of water, but the presence of too many colloidal matters causes the membranes to choke quickly. Membrane technique is used in places where the water quality is not too bad and contains fewer amounts of impurities and is suitable for large-

scale operations (AwwaRF, 2005). It cannot be used in places like Bangladesh, India, and Pakistan, where the ground water contains a lot of impurities.

## **Advanced Removal Methods**

There are several areas in which current research is going on to find out other more efficient techniques for arsenic removal. However, all the recent efforts are concentrated on finding techniques that are cost-effective for small-scale installation and environment-friendly.

**Physical/Chemical.** The conventional physical/chemical technique using activated alumina is very widely used. However, one problem with this technique is a periodic regeneration requirement. The regeneration causes hazardous, highly polluting arsenic contaminated water, which, if not disposed properly, can create severe environmental damages (Lim, Shukor, and Wash, 2014). Recent research studies are trying to find out novel adsorbent materials that can improve the efficiency of the arsenic removal process without creating many environmental side effects (Shrestha, 2012). One of the methods suggested by the recent studies is to use titanium oxide as an immobilizer on a PET surface followed by a co-precipitation using ferric hydroxide can be a more efficient way than the activated alumina process. The use of these materials not only reduces the overall costs, but also poses less threat to the environment.

**Biological Technologies.** As most of the physical/chemical arsenic removal processes have shown some environmental side effects, in recent years, some biological removal techniques using indigenous bacteria have

emerged. In most of the arsenic contaminated water, arsenic compounds are soluble, making it bio-available for bacteria. However, these kinds of studies are only tested in laboratories, and still need to be tested under real scale conditions for their viability.

The biological technologies also go through the common physical/chemical processes like oxidation, precipitation, and absorption. It also then goes through other biological mechanisms like As (III) oxidation, As (V) reduction using bacteria, and methylation. It is extremely important to create a resistance mechanism for bacteria so that they can protect themselves from the toxic effects of arsenic (Duarte, Cardoso and Alçada, 2009).

There are two biological major techniques available to convert arsenate to arsenite. The first one is called the detoxification of cells. In this process, the arsenate ions enter the bacterial cells through phosphate transporters, and upon reaching the cytoplasm of the cells, the arsenate ions are converted into arsenite by the bacterial enzymes. Then this arsenite is excreted from the bacterial cells. These excreted arsenites are then filtrated out of the water using the normal physical/chemical techniques (Duarte, Cardoso and Alçada, 2009).

In the second biological mechanism, known as dissimilarity reduction, the bacteria belonging to phylogenetic groups gain metabolic energy by breathing arsenic. This process is also known as respiratory arsenate reduction. In this process, bacteria use arsenate as electron acceptor and then breathe out arsenite (Shrestha, 2012). However, the use of only this process can create a high level of contamination of arsenites in the water.

Phytoremediation Process. It has been observed that there are many plants



and roots in nature that can absorb concentrated and precipitated metals from water solution. Several plant species are known to accumulate metal. Water hyacinth, which is common among many waterways across the world, especially in the equatorial and tropical climates, is known to be one of the most efficient plants that can adsorb and precipitate metals. Hyacinth root can absorb both arsenate and arsenite from water effectively. In an experiment conducted by using the powder of hyacinth root, it was found that 93% of the arsenite and 95% of the arsenate were successfully removed from the water solution (Lim, Shukor, and Wash, 2014). It has also been found in some researches that the presence of some manganese producing bacteria and exopolymer producing bacteria can act as a catalyst in this process, further improving the efficiency.

**SONO 3 Arsenic Filters.** SONO 3 Arsenic Filters are based on the homemade filters used widely in Pakistan. These filters are getting attention from a lot of researchers to find out a cost-effective home-based solution against arsenic contamination. A SONO 3 filter uses three pitchers placed one above another. The first pitcher made of cast iron contains sand. The second pitcher made of either plastic or cast iron contains activated carbon and sand. The third pitcher made of either clay, plastic or cast iron contains brick chips. In this process, arsenic is removed by absorption while the water passes through the pitchers. The Massachusetts Institute of Technology (MIT) has further enhanced the design by putting simple cast iron nails on the top of the first pitcher (Lim, Shukor, and Wash, 2014). These iron nails rust easily forming iron oxide, which is an excellent adsorber of arsenic. This new addition has increased the efficiency of SONO 3 considerably.

## Conclusion

Arsenic contamination is a global concern because of a number of health hazards issuing from the drinking of arsenic contaminated water for a long period of time. The only solution available to arrest the condition is to find an effective solution for arsenic removal. There is a slew of arsenic removal techniques being used around the world. Some of these techniques are conventional, and some are emerging advanced techniques. A conventional method like coagulation/filtration, ion exchange using synthetic resins, and adsorption using activated alumina are some of the most widely used in the world. However, the recent focus of research has been towards designing and creating arsenic filters that are small-scale, cost-effective and environment-friendly. Changing some metallic components in the psychical/chemical process can increase the efficiency as well as decrease the environmental side effects. However, the most eco-friendly and cost-effective solutions of arsenic removal lie in the nature. Arsenic removal techniques using bacteria and some plant roots like water hyacinth are gaining popularity. Hopefully, in the coming future, more research in these areas will be conducted to find an effective, eco-friendly and large-scale solution for arsenic treatment.

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