

## GENERAL REVIEW ON REMOVAL OF ARSENIC FROM DIFFERENT WATER SOURCES

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*Abstract: Alarming information has emerged in recent decades about the widespread presence of arsenic in groundwater used to supply drinking water in many countries on all continents. Hundreds of millions of people, mostly in developing countries, daily use drinking water with arsenic concentrations several times higher than the World Health Organization (WHO) recommended limit of 10 µg/L. Human exposure to arsenic can take place through ingestion, inhalation or skin adsorption. Long-term consumption of arsenic rich water can lead to chronic health problems, such as fatigue, hyper pigmentation, keratosis, skin cancer, cardiovascular and nervous affections, and cancer of the skin and internal organs. Most environmental arsenic problems are the result of mobilisation under natural conditions, but man has had an important impact through mining activity, combustion of fossil fuels, the use of arsenical pesticides, herbicides and crop desiccants and the use of arsenic as an additive to livestock feed, particularly for poultry. Several treatment technologies have been adopted to remove arsenic from drinking water under both laboratory and field conditions. The major mode of removing arsenic from water is by physical-chemical treatment. The most commonly used metal salts for arsenic removal are aluminum salts such as alum, and ferric salts such as ferric chloride or ferric sulfate. Several sorptive media have been reported to remove arsenic from water. These are activated alumina, activated carbon, iron- and manganese-coated sand, kaolinite clay, hydrated ferric oxide, activated bauxite, titanium oxide, cerium oxide, silicium oxide, and many natural and synthetic media. Nano-filtration membranes are capable of removing significant portions of the dissolved arsenic compounds in natural waters. In recent years, a tremendous amount of research has been reported to identify novel technologies for arsenic removal, particularly low-cost, low-tech systems that can be applied in rural areas.*

*Keywords: Arsenic, Chronic health problems, Human exposure, Membranes, Metal salts, Treatment technologies.*

### I. INTRODUCTION

The acute toxicity of arsenic at high concentrations has been known about for centuries. It was only relatively recently that a strong adverse effect on health was discovered to be associated with long-term exposure to even very low arsenic concentrations. Drinking water is now recognized as the major source of human intake of arsenic in its most toxic (inorganic) forms.

The presence of arsenic, even at high concentrations, is not accompanied by any change in taste, odour or visible appearance of water. The presence of arsenic in drinking water is therefore difficult to detect without complex analytical techniques.

Alarming information has emerged in recent decades about the widespread presence of arsenic in groundwater used to supply drinking water in many countries on all continents. Hundreds of millions of people, mostly in developing countries, daily use drinking water with arsenic concentrations several times higher than the World Health Organization (WHO) recommended limit of 10 µg/L. The full extent of the problem and related consequences are at present unclear, given the longtime it takes for visible symptoms of arsenic related diseases to develop and the similarity of symptoms with those of other diseases. However, the effects of arsenicosis are serious and ultimately life-threatening, long term consumption of arsenic rich water can lead to chronic health problems, such as fatigue, hyper pigmentation, keratosis, skin cancer, cardiovascular and nervous affections, and cancer of the skin and internal organs.

The only ways to counteract the effects of arsenic contaminated water are to switch to unpolluted sources or to remove the arsenic before water is consumed. Sustainable production of arsenic free water from a raw water source that contains arsenic is very difficult due to the limited efficiency of conventional water treatment technologies, the high cost and complexity of advanced treatment and the generation of large volumes of waste streams that contain arsenic. The situation is most difficult in rural areas in developing countries where arsenic contaminated groundwater is the only drinking water source. In such areas, where centralised systems usually do not exist, arsenic removal technologies suitable for centralised water supply systems are not applicable. Efforts are being made to develop effective household treatment systems, but these too have proved problematic, both technically and operationally.

#### **HEALTH AND SOCIAL PROBLEMS WITH ARSENIC IN DRINKING WATER**

Human exposure to arsenic can take place through ingestion, inhalation or skin adsorption; however, ingestion is the predominant form of arsenic intake. High doses of arsenic can cause acute toxic effects including gastrointestinal symptoms (poor appetite, vomiting, diarrhoea, etc.), disturbance of cardiovascular and nervous systems functions (e.g. muscle cramps, heart complains) or death.

Arsenic toxicity strongly depends on the form in which arsenic is present. Inorganic arsenic forms, typical in drinking water, are much more toxic than organic ones that are present in sea food. Inorganic arsenic compounds in which arsenic is present in trivalent form are known to be the most toxic.

UNICEF reported 40,000 confirmed cases of arsenicosis in Bangladesh , other estimates indicate that at least 100,000 cases of skin lesions have been caused by arsenic, and that one in ten people who drink water with very high levels of arsenic (500 mg/l or more) over the long term may die from arsenic related cancers.

How quickly symptoms develop depends on water quality and especially on arsenic, iron and manganese concentrations, levels of water intake and on nutrition. Higher arsenic concentrations speed up the development of arsenicosis while the presence of iron and manganese in water can reduce exposure to arsenic through adsorption and precipitation into iron and manganese precipitates before the water is consumed. Lowering drinking water

intake and consuming food rich in proteins and vitamins can delay the development of symptoms.

**GUIDELINES AND STANDARDS**

Because of the proven and widespread negative health effects on humans, in 1993, the World Health Organization (WHO) lowered the health-based provisional guideline for a “safe” limit for arsenic concentration in drinking water from 50 µg/L to 10 µg/L (i.e. from 0.05 mg/l to 0.01 mg/l). WHO retained this provisional guideline level in the latest edition of its standards. The guideline value for arsenic is provisional because there is clear evidence of hazard but uncertainty about the actual risk from long-term exposure to very low arsenic concentrations. The value of 10 µg/ was set as realistic limit taking into account practical problems associated with arsenic removal to lower levels.

The WHO provisional guideline of 10 µg/L has been adopted as a national standard by most countries, including Japan, Jordan, Laos, Mongolia, Namibia, Syria and the USA, and by the European Union (EU). India has also adopted WHO guideline for arsenic.

**WORLD WIDE EXTENT OF ARSENIC PROBLEM**

Arsenic concentrations above accepted standards for drinking water have been demonstrated in many countries on all continents and this should therefore be regarded as a global issue. Arsenic has been reported in groundwater in the following countries, shown in table 1.

Table 1: Countries in which arsenic found in groundwater  
Source: Branislav Petrusovski et al. (2007)

Asia	Bangladesh, Cambodia, China (including provinces of Taiwan and Inner Mongolia), India, Iran, Japan, Myanmar, Nepal, Pakistan, Thailand, Vietnam.
Americas	Alaska, Argentina, Chile, Dominica, El Salvador, Honduras, Mexico, Nicaragua, Peru, United States of America.
Europe	Austria, Croatia, Finland, France, Germany, Greece, Hungary, Italy, Romania, Russia, Serbia, United Kingdom.
Africa	Ghana, South Africa, Zimbabwe.
Pacific	Australia, New Zealand.

**SOURCES OF ARSENIC IN WATER**

Arsenic is the twentieth most abundant element in the earth’s crust. Arsenic occurs in the environment in rocks, soil, water, air, and in biota. It is mobilised in the environment through a combination of natural processes such as weathering reactions, biological activity and volcanic emissions as well as through a range of anthropogenic activities. Most environmental arsenic problems are the result of mobilisation under natural conditions, but man has had an important impact through mining activity, combustion of fossil fuels, the use of arsenical pesticides, herbicides and crop desiccants and the use of arsenic as an additive to livestock feed, particularly for poultry. Although the use of arsenical products such as pesticides and herbicides has decreased significantly in the last few decades, their use for wood preservation is still common. The impact on the environment of the use of arsenical compounds, at least locally, will remain for some years.

Drinking water is derived from a variety of sources depending on local availability: surface water (rivers, lakes, reservoirs and ponds), groundwater (aquifers) and rain water. These sources are very variable in terms of arsenic risk. Alongside obvious point sources of arsenic contamination, high concentrations are mainly found in groundwaters. Arsenic occurs as a major constituent in more than 200 minerals, including elemental arsenic, arsenides, sulphides, oxides, arsenates and arsenites. Although arsenic exists in both organic and inorganic forms, the inorganic forms are more prevalent in water and are considered more toxic.

## ARSENIC REMOVAL TECHNOLOGIES

Several treatment technologies have been adopted to remove arsenic from drinking water under both laboratory and field conditions. The major mode of removing arsenic from water is by physical-chemical treatment. Technologies for removing arsenic from drinking water include:

- Precipitative processes, including coagulation/filtration (C/F), direct filtration, coagulation assisted microfiltration, enhanced coagulation, lime softening (LS), and enhanced lime softening;
- Adsorption processes, specifically activated alumina (AA);
- Ion exchange (IX) processes, specifically anion exchange;
- Membrane filtration, including reverse osmosis (RO), and electrodialysis reversal (EDR);
- Alternative treatment processes specifically greensand filtration; and
- Point-of-use (POU) devices.

Many of these processes were evaluated to develop cost curves for the technologies. Discussions of the following technologies are for future consideration as viable processes for arsenic removal:

- Iron oxide coated sand;
- Nanofiltration;
- Iron filings and sulfur-modified iron; and
- Granular ferric hydroxide.

### *A. Coagulation/Filtration*

During coagulation and filtration, arsenic is removed through three main mechanisms :

- precipitation: the formation of the insoluble compounds  $Al(AsO_4)$  or  $Fe(AsO_4)$
- coprecipitation: the incorporation of soluble arsenic species into a growing metal hydroxide phase.
- adsorption: the electrostatic binding of soluble arsenic to the external surfaces of the insoluble metal hydroxide.

The most commonly used metal salts for arsenic removal are aluminum salts such as alum, and ferric salts such as ferric chloride or ferric sulfate. Ferrous sulfate has also been used, but is less effective. Excellent arsenic removal is possible with either ferric or aluminum salts, with laboratories reporting over 99% removal under optimal conditions, and residual arsenic concentrations of less than 1  $\mu\text{g/L}$ . Full-scale plants typically report a somewhat lower efficiency, from 50% to over 90% removal.

### *B. Adsorption and Filtration*

Several sorptive media have been reported to remove arsenic from water. These are activated alumina, activated carbon, iron- and manganese-coated sand, kaolinite clay, hydrated ferric oxide, activated bauxite, titanium oxide, cerium oxide, silicium oxide, and many natural and synthetic media. The efficiency of sorptive media depends on the use of an oxidizing agent as an aid to sorption of arsenic. Saturation of media by different contaminants and components of water takes place at different stages of the operation, depending on the specific sorption affinity of the medium to the given component. Saturation means that the sorptive sites of the medium have been exhausted and the medium is no longer able to remove the impurities. The most commonly used media for arsenic removal in small treatment plants include:

- Activated alumina
- Granulated ferric oxide and hydroxide
- Metallic iron
- Iron-coated sand or brick dust
- Cerium oxide
- Ion exchange media

Activated alumina is an effective treatment technique for arsenic removal. Factors such as pH, arsenic oxidation state, competing ions, empty bed contact time (EBCT), and regeneration have significant effects on the removals achieved with AA. Various strong-base anion exchange resins are commercially available which can effectively remove arsenate from solution, producing effluent with less than 1 µg/L arsenic. Granular ferric hydroxide is a highly effective adsorbent used for the adsorptive removal of arsenate, arsenite, and phosphate from natural water.

### *C. Separation Methods involving Membranes*

Membrane processes can remove arsenic through filtration, electric repulsion, and adsorption of arsenic-bearing compounds. The viability of microfiltration and ultrafiltration as a technique for arsenic removal is highly dependent on the size distribution of arsenic bearing particles in the source water. Nano-filtration membranes are capable of removing significant portions of the dissolved arsenic compounds in natural waters. Reverse Osmosis (RO) is a technology proven through several bench- and pilot-scale studies, and is very effective in removing dissolved constituents. Since arsenic in groundwater is typically 80- 90% dissolved, RO is a suitable technology for arsenic removal in groundwater. Membrane filtration is effective in removing both As(III) and As(V) species. However, efficiency in removing As(V) is higher than for As(III).

### *D. Emerging Technologies*

In recent years, a tremendous amount of research has been reported to identify novel technologies for arsenic removal, particularly low-cost, low-tech systems that can be applied in rural areas. Most of these technologies rely on oxidation of arsenite, followed by filtration through some sort of porous material, where arsenic is removed through adsorption and co-precipitation. Many of these systems make use of iron compounds, which have a very strong affinity for arsenic.

Conventional iron and manganese removal can result in significant arsenic removal, through co-precipitation and sorption onto ferric or manganese hydroxides. The mechanisms involved are the same as in coagulation and filtration. Most low-cost technologies for arsenic and manganese removal rely on aeration and filtration through porous media such as sand and gravel.

## CONCLUDING REMARKS

According to the brief study of the literature for various arsenic removal technologies, the following conclusion can be observed:

- Develop effective household treatment systems for rural areas which is technically and operationally less complex.
- Develop low cost point of use device which is affordable for rural people.
- To spread awareness in rural community related to arsenic problems in drinking water and its health effects.

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