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Technologies for removal of Arsenic from wastewater

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Abstract
Availability of clean water has become a major concern worldwide. Arsenic, one of the most toxic element exists in organic as well as inorganic forms with varying valence states, As(III), As(V) and As(0). Chronic arsenic exposure has devastating health effects like cardiovascular diseases, cancer and eventual death. Water pollution due to Arsenic has focussed attention on its decontamination. This paper presents a review of the available technologies used for the removal of arsenic species from water. Conventionally applied techniques to remove arsenic species include oxidation, coagulation-flocculation, membrane techniques and nanoparticles for the remediation of contaminated water.

Keywords: Arsenic, coagulation-flocculation, oxidation, adsorption, membrane technologies, nanoparticles

1. Introduction
Naturally occurring elemental arsenic is ubiquitous and is present in both organic and inorganic forms. Natural water is mostly contaminated with the more toxic inorganic form rather than organic one. Over 200 different mineral forms of arsenic occur, of which Arsenates are about 60%, sulfides and sulfosalts make 20%, and arsenides, arsenites, oxides, silicates, and elemental arsenic make the remaining 20% .Anthropogenic sources exceed the natural sources of arsenic by 3: 1.The major man-made sources of arsenic contamination are arsenial pesticides, fertilizers, dust of burning fossil fuel, animal, and industrial waste disposal. In natural water, arsenic exists as inorganic arsenate (As(V)) and arsenite (As(III)). Ground water mainly contains As(III) due to the prevailing reducing conditions, while As(V) is mainly found in the more oxidized surface waters [1].

Arsenic is one of the most toxic elements that can be found. Humans may be exposed to arsenic through food, water and air. Exposure may also occur through skin contact with soil or water that contains arsenic. Levels of arsenic in food are fairly low, as it is not added due to its toxicity. But levels of arsenic in fish and seafood may be high, because fish absorb arsenic from the water they live in. Luckily this is mainly the fairly harmless organic form of arsenic, but fish that contain significant amounts of inorganic arsenic may be a danger to human health. Exposure to inorganic arsenic can cause various health effects, such as irritation of the stomach and intestines, decreased production of red and white blood cells, skin changes and lung irritation. It is suggested that the uptake of significant amounts of inorganic arsenic can intensify the chances of cancer development, especially the chances of development of skin cancer, lung cancer, liver cancer and lymphatic cancer. A very high exposure to inorganic arsenic can cause infertility and miscarriages with women, and it can cause skin disturbances, declined resistance to infections, heart disruptions and brain damage with both men and women [2]. Based on World Health Organization (WHO) guidelines, arsenic concentrations in drinking water should be strictly limited to 10 µg/L [3] In this paper, a overview is presented of the conventional techniques used for the removal of As species from water.

Coagulation-Flocculation
Coagulation and flocculation are among the most employed and documented techniques for arsenic removal from water [4]. In coagulation, positively charged coagulants (e.g., aluminum sulphate ($Al_2(SO4)_3$), ferric chloride ($FeCl_3$)) reduce the negative charge of colloids, thereby making the particles collide and get larger. Flocculation, on the other hand, involves the addition of an anionic flocculant that causes bridging or charge neutralization between the formed larger particles leading to the formation of flocs.

During these processes, dissolved arsenic is transformed by the chemicals into an insoluble solid, which undergoes precipitation later [5]. Alternatively, soluble arsenic species can be incorporated into a metal hydroxide phase and be co-precipitated. Either way, solids can be removed afterwards through sedimentation and/or filtration

Oxidation

Oxidation involves the conversion of soluble arsenite to arsenate. This alone does not remove arsenic from the solution, thus, a removal technique, such as adsorption, coagulation, or ion exchange, must follow. Besides atmospheric oxygen, many chemicals like chlorine, chlorine dioxide, hypochlorite, hydrogen peroxide, potassium permanganate as well as bacteria, have already been used to directly oxidize arsenite in water [6].

Adsorption

Adsorption is a process that uses solids as medium for the removal of substances from gaseous or liquid solutions [7]. Basically, substances are separated from one phase followed by their accumulation at the surface of another. This process is driven mainly by van der Waals forces and electrostatic forces between the adsorbate molecules and the adsorbent surface atoms. This makes it important to characterize first the adsorbent surface properties (e.g., surface area, polarity) before being used for adsorption [8]. Adsorbents used include activated carbon, coal, red mud, fly ash, kaolinite, montmorillonite, goethite, zeolites, activated alumina, titanium dioxide etc. Adsorption of arsenic strongly depends on the system's concentration and pH. At low pH, arsenate adsorption is favored, whereas for arsenite, maximum adsorption can be obtained between pH 4 and 9 [9].

Membrane Technologies

In view of drinking water production, membrane filtration is a technique that can be used for the removal of arsenic and other contaminants from water. Typically, membranes are synthetic materials with billions of pores acting as selective barriers, which do not allow some constituents of the water to pass through [10]. A driving force, such as pressure difference between the feed and the permeate sides, is needed to transport the water through the membrane [11]. Generally, there are two categories of pressure-driven membrane filtrations: (i) low-pressure membrane processes, such as microfiltration (MF) and ultrafiltration (UF); and (ii) high-pressure membrane processes, such as reverse osmosis (RO) and nanofiltration (NF) [12].

Nanoparticles

Advances in nanoscience and nanotechnology have paved the way to the development of various nanomaterials for the remediation of contaminated water. Due to their high specific surface area, high reactivity, and high specificity, nanoparticles have been given considerable environmental attention as novel adsorbents of contaminants, such as heavy metals and arsenic, from aqueous solutions [13]. Carbon nanotubes and nanocomposites, titanium-based nanoparticles, iron-based nanoparticles, and other metal-based nanoparticles are among the most widely used and investigated nanoparticles for the treatment of arsenic-contaminated water [14, 15].

Conclusion

This study assessed the various techniques available for the remediation of Arsenic from wastewater. The criteria for best technology should include high removal efficiency, affordability, geographic applicability, and compatibility with other water treatment processes, process transferability and process reliability. The technologies, successful in the lab could be applied to mass scale removal.

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