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Review Article

Magnetic hetero-structures as prospective sorbents to aid arsenic elimination from life water streams

Anuradha Jabasingh S. [a,*], Ravi T. [b], Abubeker Yimam [a]

[a] *Process Engineering Division, School of Chemical and Bio Engineering, Addis Ababa Institute of Technology, Addis Ababa University, Ethiopia*
[b] *Department of Chemical Engineering, Sathyabama University, Chennai 600119, India*

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Abstract

Magnetic materials have been extensively used for the extraction of heavy metal ions from contaminated aqueous streams. This inherent characteristic of the magnetic particles has received considerable attention in recent years. The external magnetic field employed in the sorption process overcomes many hindrances established during the application of conventional sorbents for metal ion removal. Recent studies illustrate the severity of arsenic toxicity to be a major environmental health hazard in the contaminated ground water. Available literature has been reviewed to highlight the problem, including its malignancies. Magnetic sorbents with demonstrated high specific surface area and specific affinity for metal ions have been exceedingly beneficial for removing the toxic arsenic ions. In addition to this, these sorbents have demonstrated a promising performance in practical applications also. This review paper aims to summarize the magnetic structures and all recent progress in the research of novel magnetic materials for arsenic removal making it a promising technique in the frame of engineering chemistry is showcased herein and reviewed scrupulously.

Keywords: Adsorbents; Magnetic material; Arsenic removal; Sorption; Water treatment

Contents

* Corresponding author. Fax: +251 011 123 9480.
E-mail address: anu3480@gmail.com (A.J. S.).

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1. Introduction

The insufficiency of water has become a considerable threat to the well-being of human beings and animals. The drinking water quality has become a grave alarm with the swift boom in industrialization heading towards a developed society (Chen et al., 2009). The effluent generated from industries including textiles, chemicals, mining and metallurgy are accountable for contaminating the water streams (Dambies et al., 2000; Bourlinos et al., 2001). This contaminated water contains heavy metal ions including arsenic, zinc, copper, nickel, mercury, cadmium, lead and chromium which are a deleterious threat to human beings and harmful to the natural water resources. Of these, the most toxic is arsenic. Arsenic is found in abundance in the earth's crust. The long term geological changes and the anthropogenic sources contribute to its existence in profusion (Smedley and Kinniburgh, 2002; Li et al., 2012). It occurs in both organic and inorganic forms. In addition to its contribution by natural profusion methods into water streams, their intentional discharge from industries in the form of effluents also contributes to the toxicity existing in the water streams. In aquatic systems, though the organic form of arsenic undergoes bio-transformation, the inorganic arsenic exists in four oxidation states (−3, 0, +3, and +5). Arsenic has been known as deadly fatal since ancient time due to its several side effects (Goldschmit and Peters, 1934; Ferguson and Gavis, 1972). The order of lethality of arsenic species is dimethyl arsenic acid (DMA) < monomethyl arsenic acid (MMA) < arsenate < arsenite. Contamination of water streams with As(III) and As(V) pretense a severe and potential threat to the human and animal health (ATSDR, 2000). They cause damage to central nervous system, liver, and skin. Furthermore, arsenic causes liver, bladder, skin, and kidney cancers (IPCS, 2001; Feng et al., 2012). Stoppage of drinking the arsenic contaminated water is the mainstay in the management of arsenicosis, as specific chelation therapy has limited value. Therefore, the emergent techniques to remove As from contaminated water is an imperative task for a healthy society.

1.1. Health hazards caused by arsenic

Arsenic is an omnipresent element in the environment. It is produced by the reduction of arsenic trioxide with charcoal during the metal smelting operations. Power plants using high arsenic-containing coal, could be a major source of pollution in the environment through the source of arsenic contaminated wastewater discharged (Wang, 1997). Human epidemiological data, classify inorganic arsenics as Group I carcinogens (IARC, 1987). Hyperpigmentation, hypopigmentation, keratosis, hypertension, cardiovascular diseases, diabetes, and cancer, especially of skin, lung and bladder are the clinical demonstration of relentless arsenicosis in humans (ATSDR, 2000). Cancers involving other organs have also been implicated (IPCS, 2001). For example, sodium arsenate was found to cause tumors in mice (Ng et al., 1999). Long-term exposure to arsenic results in chronic arsenic poisoning known as arsenicosis, a serious condition reported to transpire in people who live in widespread areas with high arsenic concentrations in drinking water or in burning coal (Pi et al., 2000; Berg et al., 2001). Occupational exposure to arsenic can result in elevated un-metabolized inorganic arsenic in the urine due to the reduction of methylation capacity of the kidney (Ng et al., 1998). Skin lesions, which include melanosis and keratosis of the exposed regions of the hands and feet are comprehensive characteristics of chronic arsenic poisoning. These usually appear only after 5–15 years of arsenic exposure (Tseng, 1977). Chronic arsenic poisoning may also lead to the damage of internal organs, including the circulatory, neural, respiratory, renal and digestive systems. Black Foot Disease (BFD) has been the most severe manifestation of the exposure (Chen et al., 1999). Long-term exposure to inorganic arsenic in drinking water leads to peripheral neuropathy (Hindmarsh et al., 1977). Moreover, people occupationally exposed to arsenic through contaminated water are reported to have an increased risk of diabetes (Rahman and Axelson, 1995). Exposure to inorganic forms of arsenic has tremendously increased the risks of liver and kidney cancer among the human population (Tseng et al., 2002). It has been estimated that about 60–100 million people in Asia are at risk due to the ingestion and drinking arsenic-contaminated water (Ahmad, 2001). WHO recommended guideline value for arsenic in drinking water is 10 mg/L, however, many developing countries still have their standards set at 50 mg/L. Arsenic contamination in the groundwater has reached a very distressing level and requires abrupt consideration. Intrusion options may include, dug wells and deep tube wells in regions of low arsenic concentrations. Rainwater harvesting, pond sand filtration, low cost domestic filtration systems and most importantly, arsenic removal technologies such as iron hydroxide precipitation are the solution to the existing chaos related to arsenic contamination (Meng et al., 2002).

The arsenic removal technologies based on adsorption cum co-precipitation using iron or aluminum salts; adsorption on activated carbon, activated alumina, activated bauxite; reverse osmosis, ion exchange followed by the other alter-