

Chapter 15

A Review of Techniques for Arsenic Removal From Water

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ABSTRACT

This chapter presents information on water, arsenic, arsenic in water, and its removal techniques from water and wastewaters. Survey of literature was conducted, and information was collected from published articles in databases (Google Scholar, PubMed, Elsevier, Scopus, Springer, and Magiran) using arsenic removal, wastewater treatment methods for arsenic removal, and pollution control as the keywords. A total of 142 articles were used for the study. The study revealed that techniques of arsenic removal can be divided into non-destructive and destructive methods. It was revealed that electrochemical oxidation, adsorption, and membrane techniques are the most common and effective processes. It was concluded that nanofiltration membranes prepared through single and bilayer polyelectrolyte deposition and electrocoagulation appeared to be the best method, being able to ensure the highest percentage removal (99.9%).

INTRODUCTION

The safe and adequate water is the wellspring and bedrock of life. It is the most important liquid in the world for maintaining both plant and animal life. It occupies lakes, streams, and vast oceans, and moves under the ground. The distribution of water available on Earth is 97.23% in the oceans, 2.14% in ice caps and glaciers, 0.61 percent as groundwater, 0.01 percent as fresh water in the lakes, and 0.01 percent

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in numerous other formations. The majority of the fresh water is available in frozen form at the North and South Poles and about one-third of the freshwater is available in the aquifers, rivers, ponds, lakes, streams, and springs. It has been reported that 99 percent of available water (oceans, seas, ice, most saline water, and atmospheric water) is not accessible for humans' consumption. The residual fraction of 1 percent is out of reach. On the basis of the volume of water available, it is estimated that surface water sources (ponds, lakes, streams and rivers) constitute only about 0.0067 percent of the water volume. Surface water sources are mainly used by people (Zahid and Peter, 2017). Water is a common solvent, that normally encompasses numerous impurities that are picked up from its environments.

Arsenic: Arsenic ions, radicals, and compounds are emitted into the natural environment by the natural weathering of rock and from anthropogenic sources (Karn and Pan, 2017). The presence of Arsenic in water can be in the form of As(V) (arsenate), As(III) (arsenite), 0 (elemental arsenic), and As(-III) (arsine) in surface environments. The toxicological effects of arsenic are related to its chemical forms and oxidation states. Organic compounds of Arsenic are less toxic than its inorganic compounds (Karn and Pan, 2017). It has been mentioned that As(III) is much more toxic than As(V) (Kan and Pan, 2017). With reference to the high toxicity of inorganic arsenic, the United States Environmental Protection Agency (USEPA) limits the maximum contaminant level of As in drinking water to 10 µg/L. Wen *et al.* (2013) reported that Arsenic concentration in groundwater of Xinjiang, China was 830 µg/L. Universally, arsenic (As) pollution of both groundwater and surface water with its adverse effects on human well-being has been reported in the literature since the late 1930s (Ghosh *et al.*, 2017). The fertile deltaic plains of rivers Ganges and Brahmaputra in India and Bangladesh are well-known Arsenic "hot spots," where high amounts of naturally occurring Arsenic have been associated with adverse health issues (Ghosh *et al.*, 2017). This has resulted in intense scrutiny of different biogeochemical processes associated with Arsenic cycling, its toxicity, mobilization, and distribution pattern in sedimentary aquifers. Over the years, several processes have been proposed by scientists to explain the mobilization of Arsenic from sediments. The processes are geothermal release, alkaline desorption, reductive dissolution of ferric Fe(III)-oxyhydroxides, reduction of arsenate (As(V)), and oxidation of As-bearing sulfides (Ghosh *et al.*, 2017). Amongst these processes, the most widely accepted mechanism for Arsenic mobilization in deltaic sediments is through the microbial reductive dissolution of Arsenic bearing iron-oxyhydroxides and/or dissimilatory As(V) reduction.

Chemistry of Arsenic in Water: Arsenic ion or radical occurs in water in several different forms depending upon the pH and oxidation potential of water. It can be found both in the trivalent (As (III)) and pentavalent forms (As(V)). The speciation of As in the ecosystem is mainly governed by the reduction-oxidation potential (E_h) and hydrogen concentration (pH conditions), (Smedley and Kinniburgh 2002, Mohan and Pittman 2007). In common, As(V) is the main variety under the aerobic conditions and occurs as the oxyanion forms ($H_2AsO_4^-$, $HAsO_4^{2-}$, and AsO_4^{3-} with $pK_{a1} = 3.60$, $pK_{a2} = 7.25$, and $pK_{a3} = 12.25$, individually) at the various pH values. However, under the reducing conditions (such as in groundwater), As(III) is the predominant form, present as the neutral species H_3AsO_3 at pH less than approximately 9.2 (Wang *et al.*, 2016). Figure 1 shows the forms that arsenic can take in water. In the reducing waters, arsenic is found primarily in the trivalent form (As(III)) as a form of arsenious acid which is ionized according to the equations (Ghosh *et al.*, 2017):



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