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An overview of arsenic removal by pressure-driven membrane processes

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Abstract

Management of hazardous wastes, such as arsenic, is one of major public concern. Arsenic is a naturally occurring metalloid, which is widely distributed in nature. Recently, arsenic in drinking water attracted attention because some of the drinking water resources contain considerable concentrations of arsenic which cause acute and chronic symptoms in many countries, especially in Bangladesh, China, Mongolia, and Taiwan. In 2001, the USEPA promulgated a rule lowering the arsenic MCL from 5 μgL^{-1} to 10 μgL^{-1}. This paper offers an overview of geochemistry, distribution, sources, regulations, acute and chronic symptoms, and applications of membrane technologies in the water treatment research that have already been realized or that are suggested on the basis of bench or lab scale research. These membrane technologies include RO, NF, UF, and MF. Most of theses applications have proven to be reliable in removing arsenic from water. The possible influence of some source water parameters, membrane material, membrane types, membrane processes on arsenic removal efficiency by membrane technologies are also explored. This review paper also offers data relating to regulations of arsenic standard, acute and chronic symptoms that are caused by the exposure of arsenic to explain why water treatments need to use the membrane technology to meet the MCL standard.

Keywords: Arsenic; Characterization; Distribution; Toxicity; Arsenic regulations; Membrane technologies; RO; NF; UF; MF

1. Introduction

Arsenic is the twentieth most abundant element in the earth's crust, fourteenth in the seawater and the twelfth most abundant element in the human body [1]. Arsenic occurs naturally in air, water, and soil in many parts of the world as a metalloid and as chemical compounds both inorganic and organic [2]. Since its isolation in 1250 A.D. by Albertus Magnus, this class of compound was known as a therapeutic agent as well as a poison. Currently, arsenic compounds

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are used in agriculture, industrial applications, and feed additives. These natural and anthropogenic sources introduce a certain amount of arsenic into the environment and increase the arsenic concentration and distribution in the environment. Today, arsenic poisoning has become one of the major environmental worries in the world as millions of human beings have been exposed to excessive arsenic through contaminated drinking water. One of the most serious consequences of chronic arsenic toxicity is the arsenic carcinogenic influence on humans, as the element is classified as Group 1 carcinogenic substance to humans based on powerful epidemiological evidence [3]. Arsenic cannot be destroyed; it can only be transformed into different forms or combined with other elements to be converted into insoluble compounds. Therefore, there is a tremendous demand for developing expense efficient methods for arsenic removal from drinking water. Currently, a variety of methods have been developed for removing arsenic from drinking water [4]. The conventional physical-chemical processes used for arsenic removal can be classified on the basis of the principals involved: (a) precipitation; (b) adsorption; (c) ion exchange; (d) membrane technology. Precipitation is a process in which anions are combined with cations [5]. However, to effectively decrease arsenic to acceptable levels by this process requires a large amount of chemicals, this process also creates volumetric sludge, which is not easy to treat further or dispose of directly [6]. Arsenic III sulfide, calcium arsenate, or ferric arsenate were the most common precipitation methods of arsenic removal, but it has been shown that all of these materials are unstable under certain conditions and therefore not suitable for direct disposal to uncontained tailings as they will produce leachate containing arsenic [7]. The technology of adsorption is a process by using materials that have a strong affinity for dissolved arsenic. Arsenic is attracted to the sorption site on the adsorbent's surface, and is removed from water. This technology has shown to be an efficient way to remove arsenic from solution [8]. Activated carbon is by far the widely used adsorbent. However, the activated carbon still remains an expensive material. Ion exchange is the process by exchanging arsenic anions for chloride or other anions at active sites bound to a resin. Some ion exchange processes can do a very thorough job of arsenic removal from water, but this process has the disadvantage of releasing noxious chemical reagents used in the resin regeneration into the environment. Membrane technology removes arsenic by allowing water to pass through special filter media, which physically retain the impurities presenting in water. Experimental results showed that the membrane technologies remove more than just the arsenic, the membrane technologies also could effectively remove portions of all of the dissolved minerals and even prevent the microorganisms pass through the membrane to diminish the harmful diseases. Also, the membrane itself does not accumulate arsenic, so disposal of used membranes would be simple, maintenance and operation requirements are minimal, and no chemicals need be added. This review article will briefly summarizes membrane processes for the removal of arsenic in drinking water treatment.

2. Chemistry of arsenic

Arsenic, atomic number 33, is situated in Group 15 of the periodic table directly below phosphorus. The chemistry of arsenic is a very extensive subject. In the natural environment, arsenic is rarely encountered as the free element, which can occur in four oxidation states (–3, 0, +3, +5), but the two predominated oxidation states common in drinking water are oxyanions of trivalent arsenic and pentavalent arsenic [9]. Arsenic is also a redox-senstitive element, and its occurrence, distribution, mobility, and forms of arsenic rely on the interplay of several geochemical factors, such as pH conditions, reduction-oxidation reactions, distribution of other ionic species, aquatic chemistry