

Comparative study of arsenic(V) removal from aqueous solution using Aliquat-336 and 2-ethyl hexanol through emulsion liquid membrane



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ABSTRACT

One of the concerns of the world today is the contamination of water bodies by arsenic. Emulsion liquid membranes (ELM) resemble a promising alternative to the current separation processes, demonstrating various points of interest in terms of effectiveness, selectivity, and operational expenses. For the design of emulsion liquid membrane, the most significant step toward productivity is the selection of the surfactant and its concentration. In this work, emulsion liquid membrane was used to remove As(V) from aqueous solution. The emulsion was prepared with the help of Aliquat-336 or 2-ethyl hexanol as extractant, kerosene as a diluent and Span-80 as an emulsifying agent. Sodium hydroxide (NaOH) was used as an internal phase. It was found that extraction performance of Aliquat-336 is 78.45% whereas 2-ethyl hexanol is 87.5%. This indicates that 2-ethyl hexanol is better extractant in comparison to Aliquat-336. The surface tension value of membrane phase has also been studied to analyze the effect of extraction rate.

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1. Introduction

Arsenic(As) is a very toxic element, which can be harmful to human health. World Health Organization (WHO) has set the permissible limit of 10 ppb [1]. Arsenic is typically found as +3 and +5 oxidation state in the environment. Variable oxidation state is the cause of its harmful effect. The two predominant species arsenite and arsenate, in which the oxidation states are As(III) and As(V), respectively have become problematic in many areas in the world because of their high toxicity for humans and the environment. Air, food, and water are the sources through which humans are exposed to Arsenic. Millions of people are suffering from the toxic effects of arsenic all over the world especially in the Asian countries such as India and Bangladesh due to natural groundwater contamination, industrial effluent and drainage problem [2]. Arsenic can cause circulatory problems, skin damage and an increased risk of cancer. Due to arsenic contaminated drinking water, many people in South East Asian countries are suffering serious health issues, such as, cancer, skin lesions, metabolic and cardiac disorders [3]. Various methods such as adsorption, phytofiltration, ion exchange, chemical precipitation and membrane processes have been adopted for

separation of arsenic from contaminated water sources [4]. Separation of arsenic by solvent extraction using suitable organic solvents from copper electrolyte or acid solutions has been reported by many researchers [5–7]. But after extraction due to requirement of secondary stripping stage in solvent extraction, it is not preferred. Solvent carryover, solvent losses, etc. are the other disadvantages of this process. Processes like coagulation, adsorption, chemical precipitation and ion exchange have several disadvantages such as low mass transfer rates, low diffusion rates, less efficiency, large inventory cost along with costly equipment.

In the process of coagulation, arsenic is removed from solution through the mechanisms such as precipitation, co-precipitation, and adsorption [8]. Precipitation is the formation of insoluble compounds. The incorporation of soluble arsenic species into a growing metal hydroxides phases (e.g. co-precipitation with Fe(III)) is known as co-precipitation. The adsorption is the electrostatic binding of soluble arsenic to external surfaces of the insoluble metal hydroxide [9–11].

Currently coagulation technology can be efficiently used to reduce arsenic from concentration levels of 400 µg/L to as low as 10 µg/L at a rate of 500 L/sec, if parameters like pH, oxidizing and coagulation agents are properly controlled [12].

In ion exchange process cross linked synthetic resin called matrix consisting of charged functional groups was used. The charged functional groups are attached to the matrix through cova-

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lent bonding [13]. The ion exchange process is less dependent on pH of water. Pre-oxidation of As(III) to As(V) is required for removal of arsenite by ion exchange as the arsenite is uncharged. Excessive oxidant has to be removed to avoid damage of sensitive ions. Regeneration of resin is done using NaCl solution as the resin gets exhausted.

Another separation technique is use of liquid membranes. Liquid membrane (LM) is a relatively new and prospective separation system consisting of a liquid film through which selective mass transfers of gases, ions, or molecules occur via permeation and transport processes. LM has several advantages over the solid membranes and solvent extraction [14] such as (a) high interfacial area for mass transfer (b) high diffusion rate of the metal ion through the membrane (c) simultaneous extraction and stripping in the same system, and (d) capable for separation of wide range of elements and compounds in industrial settling with greater efficiency.

Liquid membranes work very efficiently in the extraction of harmful and valuable metals present in very low concentrations in groundwater. Usefulness of liquid membranes has been studied by various authors [15,16]. Ahmed et al. [17] studied on droplet size of the emulsion membrane at different rotational speeds. They have also studied on the effect of various parameters such as surfactant, internal phase and diluent on emulsion stability. Different types of liquid membranes used for separation of metal ions are (i) emulsion liquid membranes (ELM), (ii) bulk liquid membrane (BLM), and (iii) supported liquid membrane (SLM) [18–20]. Out of these, ELM has been the scope of study in our research. Emulsion liquid membrane is a separation technique, which requires organic solvent, extractant and surfactant for its formulation. All the components play important roles. Surfactant adds stability to the emulsion and also acts as an emulsifying agent whereas organic solvent acts as diluents. Extractant is used for the transportation of metal ion from feed phase to the stripping phase. ELM offers some intensity features such as larger interfacial area, high efficiency and simple operation methods.

During the course of this study to obtain optimized outputs, the volume of diluent, extractant and surfactant were kept constant. In our study for removal of arsenic from water through ELM, Aliquat-336 and 2-ethyl hexanol were used as carrier, Span-80 as a surfactant, sodium hydroxide as a stripping agent, and kerosene as a diluent. Effect of various parameters such as volume and stripping phase, volume of feed phase, pH and comparative study of efficiencies of Aliquat-336 and 2-Ethyl hexanol have been carried out in this paper. Also characterization of membrane was done by examination of its surface tension with respect to increasing concentration of internal phase in order to get optimum extraction conditions. In this aspect, the present study aims to investigate in detail, the influence of all parameters affecting batch extraction of As(V) from synthetic aqueous solutions.

2. Materials and methods

2.1. Reagents

All chemicals used were of AR grade. Sodium arsenate (Na_3AsO_4) – was purchased from Sigma Aldrich. Aliquat-336 ($\text{C}_{25}\text{H}_{54}\text{ClN}$) and 2-Ethyl Hexanol ($\text{C}_8\text{H}_{18}\text{O}$) were used as carrier. These compounds are chosen on the basis of previous studies done in this field by several authors [21,22]. High percentage of Arsenic ions recovery has been reported by Marino and Fogli [22] using Aliquat-336 due to its reaction with the dissociated (H_2AsO_4^- and HAsO_4^-) and undissociated (H_3AsO_3) metal species. Span-80 ($\text{C}_{24}\text{H}_{44}\text{O}_6$) – the non-ionic surfactant used for stabilizing the emulsion was obtained from SDS fine chemicals. Span 80 (sorbitan mono-oleate) with molecular weight of 4128.68 g/mol was used as lipophilic emulsifier for

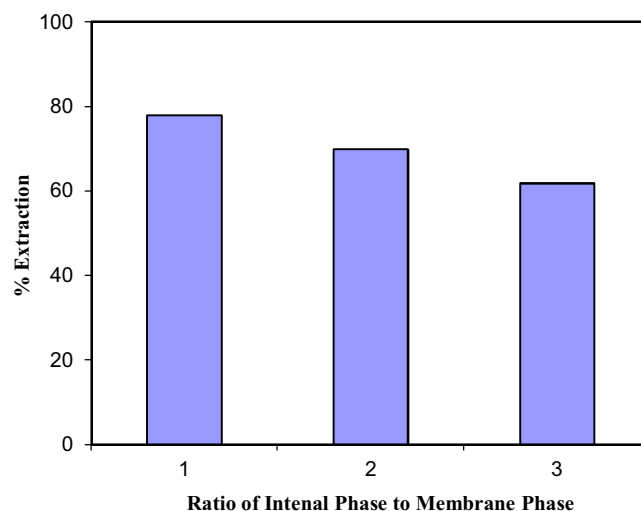


Fig 1. Effect of ratio of internal to membrane phase on percentage Extraction.

the extraction of arsenic(V) from water by this technique [16,22] Kerosene was purchased from local market. Binnal et al. suggested that sodium hydroxide (NaOH) and sodium carbonate (Na_2CO_3) can be used as stripping agent to check the extraction efficiency of As(V) from aqueous solution [21]. As(V) feed solutions in the concentration range of 100–500 ppm were prepared by dissolving sodium arsenate in bidistilled water.

2.2. Experimental procedure and setup

2.2.1. Feed phase preparation

As(V) feed solutions in the concentration of 100 ppm were prepared by dissolving sodium arsenate in de-ionized water. 2 M HCl was added to adjust the pH of the feed solution.

2.2.2. Emulsion phase preparation

50 ml of membrane phase was prepared by mixing the chemicals in the desired proportion, Aliquat 336–3%, Span 80–3%, Commercial kerosene – 94% (volume percent). The above mixture was agitated for 10 min at 3500 rpm to form a homogeneous membrane phase. In this homogeneous emulsion phase, internal phase of known molarity of NaOH was added slowly in different ratios to the prepared membrane phase. The two phases were agitated for 15 min at 3500 rpm using a motor driven agitator in a 1 L glass beaker to get a stable emulsion phase.

2.2.3. Extraction

Extraction was conducted in a 1 L beaker. To the feed solution, known quantity of above prepared emulsion was added in the pre-determined volume ratio of emulsion phase to feed phase. The phases were agitated for 5 min at 600 rpm. After extraction, the mixture was transferred to a separating funnel from the beaker. After the two phases were separated, the bottom aqueous phase was examined for concentration of As(V) by using atomic absorption spectrophotometer (AAS). The wavelength used for analysis was 193.7 nm.

3. Results and discussion

3.1. Effect of volume fraction of stripping phase

To see the effect of ratio of internal phase to membrane phase in extraction of As, three different volume ratio of 1, 2 and 3 were tried. From Fig. 1, it can be observed that on increasing the volume

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