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Removal of lead by an emulsion liquid membrane Part I

Rania Sabry[a], Azza Hafez[a]*, MaalyKhedr[a], Adel El-Hassanin[b]

[a]*Chemical Engineering and Pilot-Plant Department, National Research Center, Cairo, Egypt*
Tel. +20 (2) 3370933; Fax +20 (2) 3370931; email: hafeza@link.net
[b]*Natural Resources Department, Institute of African Research and Studies, Cairo University, Egypt*

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Abstract

An extensive study on removal of lead (II) from aqueous solution using an emulsion liquid membrane (ELM) technique is presented. The study has highlighted the importance of emulsion stability for maximizing the removal of lead (II). The ELM consists of di-(2-ethylhexyl) phosphoric acid as a carrier, commercial kerosene as organic solvent, span 80 as an emulsifying agent and sulphuric acid as stripping phase. The important factors studied which affect the ELM stability and removal of lead are emulsification time (5–30 min), emulsification speed (1000–3000 rpm); the concentrations of surfactant (2–12 % v/v), carrier (1–12 % v/v), internal phase (0.25–3 molar H_2SO_4) and the effect of volume ratio of the oil phase to the stripping aqueous phase (O/A) (0.3–3.5). The results showed that it is possible to remove 99–99.5% of lead after 5 min contact time by using ELM at the optimum operating conditions.

Keywords: Emulsion liquid membrane; Stability; Lead removal; Surfactant; Carrier; Internal phase

1. Introduction

Hazardous wastes may account for approximately 2–20% of all wastes in the world [1]. Some of the most important categories of wastes are liquid organic chemicals, solvents and heavy metals. The continuous use of heavy metals in industrial applications with the production of contaminated wastewaters is a serious environmental problem. As heavy metals are not biodegradable, they tend to accumulate in living organisms causing various diseases and disorders.

In particular, lead (II) is considered as highly toxic heavy metal, which is commonly used in a number of industrial applications such as storage battery manufacture, television tube, printing pigments, fuels, photographic material and explosives manufacturing. Lead bearing wastewater resulted from all these industries must be disposed off after treatment.

*Corresponding author.

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Several attempts have been made to treat such types of effluents for facilitating easy disposal, or to recover the chemicals and recycle the process water. Methods of purification are: chemical precipitation [2], adsorption [3], ionic exchange [4], and solvent extraction [5] which are still in use. However, industries are looking for competing alternative technologies which may overcome some of the inherent disadvantages of these methods.

One of the promising methods for the separation of such effluents is the emulsion liquid membrane (ELM) process, invented by Li et al. [6], about 30 years ago.

The main advantages of the ELM system are: (a) high interfacial area for mass transfer, especially at the inner oil–water interface, due to the small size of the aqueous phase droplets; (b) high diffusion rate of the metal ion through the membrane; (c) simultaneous performance of extraction (at the outer interface) and stripping (at the inner interface) in the same system, and (d) capability of treating a variety of elements and compounds in industrial setting at a greater speed and with and a high degree of effectiveness, with varying contaminant concentrations and volume requirements.

Many successful applications of ELMs for separation processes in general, and especially for removal of heavy metal ions from wastewaters, have been reported in the literature [7–9].

The main objective of this work is to investigate the influence of various parameters affected the emulsion liquid membrane formation and its stability and testing the performance of the prepared ELM on removal of lead by using synthetic solution with different concentrations.

2. Experimental and materials

2.1. Chemicals

The chemicals used are sorbitan monooleate (span 80) from Sigma Chemical Co., bis-(2-ethylhexyl) phosphoric acid [D2EHPA], Fluka, Mr 322.43, product of the United States, sulphuric acid [H_2SO_4] analar (BDH Laboratory Suppliers, BH15 Ltd., England), hexamine [hexamethylenetetramine], $(CH_2)_6N_4$ ADWIC, product of El Nasr Pharmaceutical Chemicals Co., MW 140.19, min. assay 99%, n-heptane $CH_3\,(CH_2)_5\,CH_3$, Lab-Scan, Analytical Science, Analytical Reagent AR, assay (GC) 95%, lead nitrate $Pb(NO_3)_2$ Laboratory Rasayan. Purified LR, MW 331.21, min. assay 99%, Prolabo, code: 26086.08 and xylenol orange tetra sodium salt indicator.

2.2. Procedure

The experimental scheme has been classified into two major parts. The first part is the formation of the ELM and the determination of its stability by using different operating parameters. The second part is concerned with the investigation of the performance of the ELM on the removal of lead from prepared synthetic solutions.

In 250 ml beaker, a 25 ml portion of di-(2-ethylhexyl) phosphoric acid (D2EHPA) [1–12% v/v] and sorbitan monooleat (span 80) [2–12% v/v] in organic solvent (kerosene) are emulsified at stirring speed [1000–3000 rpm] by means of a motor-driven emulsifier. 25 ml of H_2SO_4 [0.25–3 molar] is added drop wise to the stirred organic phase until 1:1 volume ratio of organic membrane solution to stripping solution. The solution is stirred continuously for different time (5–30 min) to obtain a white ELM.

In 250 ml beaker, 10 ml of the prepared ELM (organic phase and internal phase) is added to 100 ml of external aqueous solution (pure water in the case of measuring the emulsion stability or lead nitrate in the case of removal of lead). The contents are stirred by means of jar tester stirrers at variable speeds (100–400 rpm) for a different transfer time.

The double emulsion (W/O/W) is allowed to be spontaneously separated by gravity in separating funnel and the feed phase (external aqueous phase) is filtered through a whatman filter paper (No. 42) to be analyzed.