Removal of Heavy Metals using Emulsion Liquid Membrane- A Mini Review

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Abstract

Water is one of the most important key for life. Due to rapid industrialization and urbanization, huge amount of wastewater is generated on daily basis. Several hazardous pollutants are present in wastewater therefore it is very necessary to treat the wastewater before its use and discharge and it also becomes very evident to treat wastewater in order to fulfil the basic needs of freshwater. Moreover, among several pollutants, heavy metal present in the wastewater have severe hazardous impact on human being as well as on environmental, therefore removal of heavy metals from wastewater must be done before its utilization. There are various treatment techniques for the removal of heavy metals from wastewater viz. adsorption, ion exchange, solvent extraction, precipitation etc. But due to have some limitations like low efficiency, less economical, more energy consumption, non-ecofriendly etc. these methods are not so much effective. Membrane process is one of the effective methods for wastewater treatment and it also overcomes these limitations. Now a day, liquid membrane emerges as an efficient technique among membrane separation process. The present review paper deals with the type of liquid membranes used to specifically remove the heavy metals such as cadmium and cobalt from wastewater.

Keywords: - *Wastewater, Heavy metals, Liquid Membrane, Emulsion, Cost effective*

INTRODUCTION

According to international water association, the wastewater generation would be 61000m3 /day by 2030 [1]. The world population is going to increase to 10 billion by 2050 [2, 3]. Also, the impact of toxic materials which are being produced by the industries such as mining, dye, paper and pulp is increasing tremendously on environment. In order to reduce this impact, it is obvious to remove the metals from wastewater, as they can be used for different purposes. In addition to that, the treatment of wastewater excluding heavy metals can be treated efficiently with the different available methods for their purification and utilization. The sources of toxic heavy metals are as follows [4]:

▪ Mining and extraction
▪ Smelting and reprocessing ▪ Waste disposal
▪ Volcanic eruptions
▪ Fossil fuel combustion
▪ Agriculture
▪ Metallurgical industries

The effluents from textile, mining, paper and metallurgical industries contains considerable amount of toxic metal ions. Also, it has huge impact on health and environment. Some of the most dangerous toxic ions are chromium, cadmium, mercury and lead. While some heavy metal such as zinc, arsenic and nickel have comparatively less amount of environmental and health impact [5]

REMOVAL OF HEAVY METALS USING LIQUID MEMBRANE

1. Removal of cadmium by using emulsion liquid membrane

Cadmium is the toxic heavy metal which is found from discharge of various manufacturing industries namely cadmium- nickel batteries, phosphate fertilizers and pigment industries and have environmental impact [6]. In addition to that, cadmium is also a minor constituent of base metal ore and coal deposits. There have been various processes to remove the cadmium metal from wastewater which includes precipitation of metal hydroxide and filtration [7], used where higher concentration is treated. In contradictory to simplicity, the adjustment of pH to alkaline is a challenging task because most of the sludge is acidic in nature [8].

Ion exchange by ionic resin [9] an alternative but it limitation of being exhausted and require more energy of its regeneration. However, addition of chemical reagent to regenerate causes pollution, which needs to be avoided [10]. Another method is adsorption of cadmium on the surface of carbon or alumina [11], but it also an expensive treatment when pure sorbents are used.

Bio-filtration can also be opted for removal of cadmium but due to lack of constant source of nutrients and strict control of condition it becomes less effective [12]. Liquid-liquid extraction is also used for separation of cadmium by using specific solvent. However, large amount of extracted phase causes costly stripping steps making it expensive as well as less efficient [13].

Removal of heavy metals from wastewater is also attempted by using reverse osmosis and ultra-filtration but due to membrane fouling this method becomes less effective [14]. Alternatively, emulsion liquid membrane can be used for separation as it combines two stages extraction and stripping, making it efficient. However, stability of emulsion is a major problem in commercial industrial application. Also, the emulsion made by commercial emulsifier shows weak performances.

To eradicate this problem, (Hamid mortaheb, 2009) [15], designed and synthesized polyamine type surfactant which was more stable and gave comparatively better performances. Hamid mortaheb, 2009 [15] synthesized a poly amine surfactant by thermal degradation of butyl rubber followed by addition of hydrocarbon solvent with reaction of maleic anhydride and polyethylene polyamine. The emulsion is prepared by adding synthesized surfactant and NaOH solution in homogenizer.

He concluded that:

- Removal efficiency increases with increase in surfactant concentration up to certain extent.

- The optimum concentration was found to be 0.04M • The ratio of organic phase to internal phase was found to be 2. And removal efficiency increases with increase in this ratio.
- H+ ion n external phase is responsible for the removal efficiency of cadmium.

2. Removal of cobalt(II) from wastewater

The toxic heavy metals such as cobalt, nickel cadmium, mercury, copper, etc. can potentially damage the health and environment. Out of which, cobalt has serious ill effect such as asthma, damages heart and causes genetic changes in living organisms [16]. But it also has wide range of application in paint and ceramic industries [17].

Thus, it is evident to recover the cobalt from wastewater as it has various applications and to protect the health of living organisms. There have been different processes by which separation of cobalt can be done such as adsorption, precipitation, ion exchange, nano-filtration, bisorption and solvent extraction.

However, as per their reports, these processes are neither economical nor effective, making researchers to find an alternative which is effective and economical as well. Liquid membrane found out to be a solution which is economical yet effective. Emulsion liquid membrane (ELM) is used to separate the cobalt from wastewater by using hydrodynamic cavitation and is more efficient than bulk liquid membrane (BLM) and supported liquid membrane (SLM) [18].

The reported literature suggests that droplet size of emulsion should be clearly defined. Moreover, the conventional liquid emulsion membrane has disadvantages of swelling of liquid droplets which leads to rupture in internal phase making it inefficient [19]. If the size of droplet is reduced, then rupture can be minimized and process becomes efficient. Also, these smaller droplets can be achieved by the use of cavitation process, which would lead to form more stable emulsion and enhanced removal efficiency.

Sohan et al., 2019 [20] performed experiment with hydrodynamic cavitation by using Aliquot 336 as carrier, Span 80 as emulsifier agent and NaOH for internal phase stripping. The hydrodynamic cavitation is achieved by using centrifugal pump (power=1.28 kW, 2800 rpm) and orifice plate, used as cavitation inducer, of diameter 1 mm and 5 mm. Sohan et al., 2019 concluded that:

- 100% extraction of cobalt (II) with 1:3 ratio of aqueous phase to membrane phase with minimum droplets breakage and for 6 min emulsification time.
- The required time for preparation of stable emulsification was observed to be lower for 1 mm orifice plate than 5mm plate.
- The feed phase to emulsion ratio has direct influence on efficiency of extraction.
- With increase in carrier concentration, viscosity of the emulsion increases which is good to form emulsion.

Table 1 shows different ELM system for removal of heavy metals such as chromium and arsenic. Figure 1 represents the schematic diagram of ELM.

Table 1: ELM system for heavy metals such as chromium and arsenic

Solute	*External Feed phase*	*Extractant*	*Surfactant*	*Diluent*	*Internal phase*	*Effciency recovery*	*Reference*
Arsenic	5.5 mg/L As(III) (as $As(OH)_3$) in 0.4 M H_2SO_4	10 vol% 2-ethylhexanol	2 vol% ECA 4360 polyamine	88 vol% n-heptane	2 M NaOH >95%	>95%	[21]
Chromium	HCl	Aliquat 336	3 wt% SPAN 80	Kerosene	0.1 M NaOH		[22]
Chromium	Cr_2O_2 7 in 0.5 N H_2SO_4	20% tri-n-butyl phosphate (TBP)	4%–5% SPAN 80	n-Hexane	0.1 N NaOH	>99%	[23]
Chromium	0.000962 N $K_2 Cr_2O_7$ pH 1.6	0.05 M alamine 336	-	89.8 wt% HYVIS 2, 10 wt% Shellsol 2046, 0.2 wt% polyisobutylene	0.25 M NaOH	80%	[24]
Chromium	75–100 mg=L $K_2Cr_2O_7$ pH 5.1–5.4	0.5 vol% Aliquat 336	1.5 vol% Paranox 106	5 vol% decanol, kerosene	0.005–0.01 M NaOH	-	[24]

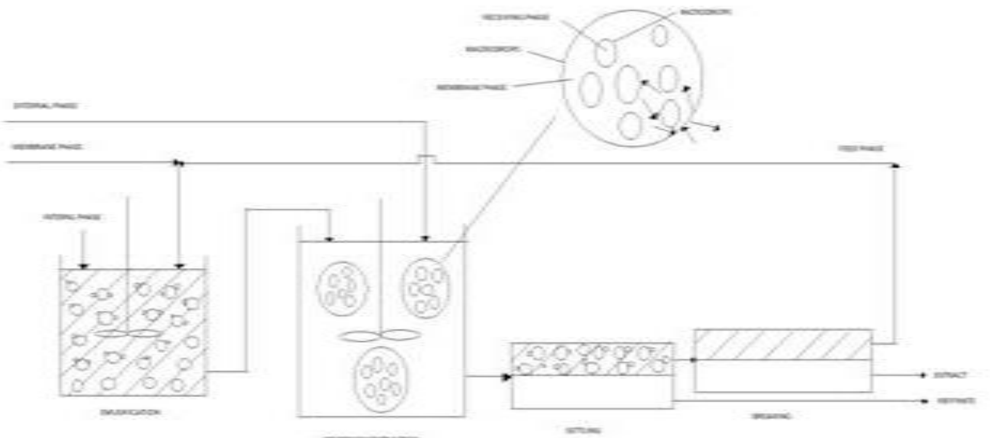

Figure 1: Schematic diagram of emulsion liquid membrane

DISCUSSIONS

It is obvious to treat the heavy metals from wastewater as it has health and environmental impact. Some of the heavy metals such as cobalt which has application in paint and ceramic industries must be recovered. Also, the toxicity of some metals such as cadmium restrict us its use in major industries. The removal of heavy metals can also enhance the treatment of wastewater. Moreover, the existing techniques to remove he heavy metal are insufficient or are uneconomical such as adsorption, ion exchange, bisorption. While liquid membrane, specifically, emulsion liquid membrane, are efficient and economical providing better alternatives. There is also a great scope for emulsion liquid membrane if stabilizing of emulsion droplet is found out with ease. The major concern while developing emulsion liquid membrane is stabilization of emulsion, choosing suitable carrier, and finding emulsifying agent which has higher stability. Also, the treatment ratio (aqueous phase to membrane phase) has to be chosen carefully and wisely to increase the removal efficiency. References [1] Corominas, Ll, et al. "Transforming data into knowledge for improved wastewater treatment operation: A critical review of techniques." Environmental modelling & software 106 (2018): 89-103. [2] AlMarzooqi, Faisal A., et al. "Application of capacitive deionisation in water desalination: a review." Desalination 342 (2014): 3-15. [3] Baysal, Asli, Nil Ozbek, and Suleyman Akman. "Determination of trace metals in waste water and their removal processes." Waste-Water Treatment Technologies and Recent Analytical Developments (ed. FSG Einschlag, L. Carlos) (2013): 145-171. [4] Singh, Umesh Kumar, and Balwant Kumar. "Pathways of heavy metals contamination and associated human health risk in Ajay River basin, India." Chemosphere 174 (2017): 183-199. [5] Janssen, L. J. J., and L. Koene. "The role of electrochemistry and electrochemical technology in environmental protection." Chemical Engineering Journal 85.2-3 (2002): 137-146. [6] Aziz, H. A., et al. "Removal of copper from water using limestone filtration technique: determination of mechanism of removal." Environment international 26.5-6 (2001): 395-399.

REFERENCES

1. Corominas, Ll, et al. "Transforming data into knowledge for improved wastewater treatment operation: A critical review of techniques." Environmental modelling & software 106 (2018): 89-103.
2. Al Marzooqi, Faisal A., et al. "Application of capacitive deionisation in water desalination: a review." Desalination 342 (2014): 3-15.
3. Baysal, Asli, Nil Ozbek, and Suleyman Akman. "Determination of trace metals in waste water and their removal processes." Waste-Water Treatment Technologies and Recent Analytical Developments (ed. FSG Einschlag, L. Carlos) (2013): 145-171.
4. Singh, Umesh Kumar, and Balwant Kumar. "Pathways of heavy metals contamination and associated human health risk in Ajay River basin, India." Chemosphere 174 (2017): 183-199.
5. Janssen, L. J. J., and L. Koene. "The role of electrochemistry and electrochemical technology in environmental protection." Chemical Engineering Journal 85.2-3 (2002): 137-146.
6. Aziz, H. A., et al. "Removal of copper from water using limestone filtration technique: determination of mechanism of removal." Environment international 26.5-6 (2001): 395-399.
7. Kim, Chulsung, et al. "Chromium (VI) reduction by hydrogen sulfide in aqueous media: stoichiometry and kinetics." Environmental science & technology 35.11 (2001): 2219-2225.
8. Yalçin, Sibel, et al. "Recovery of copper (II) and chromium (III, VI) from electroplating-industry wastewater by ion exchange." Separation Science and Technology 36.10 (2001): 2181-2196.
9. Reddy, Krishna R., and Supraja Chinthamreddy. "Sequentially enhanced electrokinetic remediation of heavy metals in low buffering clayey soils." Journal of Geotechnical and Geoenvironmental Engineering 129.3 (2003): 263-277.
10. Zamzow, M. J., and J. E. Murphy. "Removal of metal cations from water using zeolites."

Separation Science and Technology 27.14 (1992): 1969-1984.

11. Kadirvelu, K., C. Faur-Brasquet, and P. Le Cloirec. "Removal of Cu (II), Pb (II), and Ni (II) by adsorption onto activated carbon cloths." Langmuir 16.22 (2000): 8404- 8409.

12. Cervera, M. Luisa, M. Carmen Arnal, and Miguel de la Guardia. "Removal of heavy metals by using adsorption on alumina or chitosan." Analytical and bioanalytical chemistry 375.6 (2003): 820-825.

13. Chong, A. M. Y., Y. S. Wong, and N. F. Y. Tam. "Performance of different microalgal species in removing nickel and zinc from industrial wastewater." Chemosphere 41.1-2 (2000): 251-257.

14. Vainshtein, M., et al. "Model experiments on the microbial removal of chromium from contaminated groundwater." Water research 37.6 (2003): 1401-1405.

15. Mortaheb, Hamid R., et al. "Study on removal of cadmium by hybrid liquid membrane process." Journal of hazardous materials 177.1-3 (2010): 660-667.

16. Joint, F. A. O., WHO Expert Committee on Food Additives, and World Health Organization. Evaluation of certain food additives and contaminants: sixty-first report of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization, 2004.

17. Sandrin, Todd R., and Raina M. Maier. "Impact of metals on the biodegradation of organic pollutants." Environmental Health Perspectives 111.8 (2003): 1093-1101.

18. Olaniran, Ademola O., Adhika Balgobind, and Balakrishna Pillay. "Impacts of heavy metals on 1, 2- dichloroethane biodegradation in co-contaminated soil." Journal of Environmental Sciences 21.5 (2009): 661- 666.

19. Tvermoes, Brooke E., et al. "Review of cobalt toxicokinetics following oral dosing: Implications for health risk assessments and metal-on-metal hip implant patients." Critical reviews in toxicology 45.5 (2015): 367- 387.

20. Rengaraj, S., and Seung-Hyeon Moon. "Kinetics of adsorption of Co (II) removal from water and wastewater by ion exchange resins." Water research 36.7 (2002): 1783-1793.

21. Parbat, Sohan A., Bharat A. Bhanvase, and Shirish H. Sonawane. "Investigation on liquid emulsion membrane (LEM) prepared with hydrodynamic cavitation process for cobalt (II) extraction from wastewater." Separation and Purification Technology 237 (2020): 116385.

22. Goyal, Rahul Kumar, N. S. Jayakumar, and M. A. Hashim. "Chromium removal by emulsion liquid membrane using [BMIM]+[NTf2]− as stabilizer and TOMAC as extractant." Desalination 278.1-3 (2011): 50- 56.

23. Ho, WS Winston, and Norman N. Li. "Recent advances in emulsion liquid membranes." 1996. 208-221.

24. Vohra, D. K., S. Kaur, and A. Sharma. "Extraction of Cr (Vi) From Acidic (Sulfate) Aqueous-Medium Using Liquid Surfactant Membrane Emulsions." Indian Journal of Technology 27.12 (1989): 574-576.