CHAPTER 2

EVOLUTION IN EMULSION LIQUID MEMBRANE

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2.1 INTRODUCTION

An emulsion liquid membrane (ELM) is a specialised system consisting of two immiscible liquids, typically water and oil, where one liquid is dispersed as tiny droplets within the other liquid. These droplets can be stabilised by surfactants or emulsifiers. ELM is used for various liquid-liquid separation processes, where the target components selectively transfer from one liquid phase, through the emulsion phase, and into the other liquid phase. It is a versatile technology widely applied in industries such as pharmaceuticals, environmental remediation, and chemical processing for its ability to efficiently separate and recover desired compounds from complex mixtures.

Ever since its inception in the 1960s, ELM has undergone remarkable evolution from a simple extraction technique to the competitive, widespread technology it is today. The full impact of ELM evolution cannot be fully appreciated unless one dives into its humble beginnings and realises how far ELM technology has come.

The patented use of ELM by Li et al. for the separation of hydrocarbons and industrial-scale desalination in 1968 marks the beginning of this technology for liquid-liquid separation processes (Raval et al., 2022). The most critical issues with ELM, namely its stability, especially in long-term operations and complications in emulsification as well as demulsification, were quickly recognised as the main hurdles to the large-scale application of ELM technology.

Considering these setbacks, early ELM studies focused on understanding the fundamental principles of mass transfer within emulsion systems. Moving forward from the pivotal point for ELMs in the 1970s, when novel carriers were extensively developed to enhance ELM efficiency, this past decade has seen this technology evolve into more creative and environmentally friendly solutions such as employing biodegradable green diluents like vegetable oils in the formation of organic phases. From the development of this technology over the years, a deeper understanding of how ELM technology has progressed and will continue to grow can be visualised.

2.2 CURRENT PROGRESS

The success of the ELM process mainly depends on the whole formulation of the membrane phase which includes the selection of the organic phase compositions, emulsifier/surfactant compositions, internal phase compositions, diluents compositions, and carrier compositions. In this process, a selected carrier is very important to extract targeted solutes in both internal and external phases. Meanwhile, the type of stripping agent as well as surfactant must be wisely chosen to reduce the co-transport of water during the solute extraction process.

Aside from that, the ELM application tends to be very specific because the carrier and stripping agent are formulated based on the targeted solute. Even a minute change in ELM formulation can significantly affect the extraction performance. An example of this is the employment of different carriers for zinc extraction performance, which is apparent from studies that used ELM for zinc extraction. Tahmasebizadeh et al. (2021) used D2EHPA as a carrier, resulting in 71.0% extraction, while Suliman et al. (2023) used synergist carriers of D2EHPA-Cyanex, resulting in a higher 93.1% extraction. Another example that highlights the importance of ELM formulation is copper extraction, demonstrated from the attempt by Zhu et al. (2022) using M5640 carrier, achieving an efficiency of 99.9% copper extraction, compared to only 94.0% with D2EHPA attempted by Zereshki et al. (2021). It also depends on the diluent used in the formulation. Most studies use petroleum-based solvents as diluents, such as kerosene (Asadian & Ahmadi, 2020; Ghorbanpour & Jahanshahi, 2023), toluene (Fathi et al., 2012) and hexane (Chaouchi & Hamdaoui, 2015). Typically, the substitution of the petroleum-based to a green-based diluent, while beneficial for the environment, can significantly influence the ELM system performance. However, this does not mean the ELM system using green-based diluents cannot perform as well as those using petroleum-based diluents.

In fact, some studies have proven that green-based diluents in ELM actually improved the extraction performance. Jusoh et al. (2022) successfully extracted silver with an efficiency of 97% from the simulated solution using palm oil as a green-based diluent with the stable ELM at optimal conditions. This supports the claim that the utilisation of synergistic carriers and green diluent would assist in enhancing extraction performance. Some of the ELM formulations for various solute extraction as reported in a previous study are summarised in Table 2.1.

It can be concluded that ELM is a tailor-made formulation which is a different formulation that can be applied for a different solute according to certain criteria such as the formation of the carrier-solute complexes and recovery product in the internal phase. The data in Table 2.1 shows the ELM provides high potential in solute extraction and is selectively separate from the feed solution.

2.3 FUTURE TREND

In recent years, the evolution of ELM technology has been marked by significant strides toward greater efficiency and environmental responsibility. The current progress in ELM encompasses three key areas as described in the following sections.