CHAPTER 5

STABILITY OF EMULSION LIQUID MEMBRANE

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5.1 INTRODUCTION

Despite its proven effectiveness and successful implementation, the commercial utilisation of emulsion liquid membrane (ELM) for the removal of various heavy metals and solutes has encountered limitations due to emulsion instability. Emulsion instability encompasses concerns such as membrane leakage, coalescence, and emulsion swelling, all of which can substantially diminish the efficiency of solute extraction. Conversely, an excessively stable emulsion can introduce intricate challenges during the demulsification process. To tackle the critical issue of ELM stability, the primary focus should be on formulation design.

The instability of emulsion globules poses a significant challenge in the application of ELM, both in laboratory and industrial environments. Larger droplet diameters reduce stability and extraction efficiency due to a lower surface-to-volume ratio. Meanwhile, smaller droplet diameters result in more stable emulsions, increased mass transfer area, and higher extraction efficiency. However, if the droplets are exceptionally small, it becomes exceedingly difficult to destabilise the emulsion through mechanical means in the final processing step. Therefore, resolving ELM stability issues requires careful consideration of formulation and the parameters that affect it, including surfactant, carrier, and stripping agent concentration, homogenisation time, emulsifying speed, and more.

5.2 EMULSION LIQUID MEMBRANE STABILITY

In the ELM process, the stabilisation method and affecting parameters are very important to guarantee the process's efficiency in the treatment and recovery of a wide range of targeted solutes. The stability of the ELM process can be described based on swelling and breakage of the emulsion using Equation 5.1.

$$\text{Swelling/Breakage (\%)} = \frac{V_{\text{final}} - V_{\text{initial}}}{V_{\text{initial}}} \times 100 \tag{5.1}$$

where V_{final} is the volume of the emulsion phase after extraction, and V_{initial} is the volume of the emulsion phase before extraction. A decrease in the volume of the external phase after extraction indicates that water has been transported into the internal phase, a phenomenon known as the swelling effect indicated with a positive (+) symbol. Meanwhile, an increase in the volume of the external phase after extraction indicates internal phase leakage, which is known as the breakage effect indicated with a negative (–) symbol.

5.2.1 Stabilisation Method

In recent years, a mixture of surfactants or blended surfactants was introduced as one of the alternatives to improve ELM stability. This is because blended surfactants are capable of increasing the flexibility of the surfactant layer and improving the portioning of surfactant into the oil-water interface. Additionally, some studies have incorporated nanoparticles as stabilisers in the ELM process (Alitabar-Ferozjah & Rahbar-Kelishami, 2022; Shirasangi et al., 2023; Salman & Mohammed, 2019). This is mainly because the nanoparticles can provide additional stabilisation to the emulsion by forming a strong interfacial layer with the surfactant molecules, which can help to prevent the coalescence and flocculation of the droplets.

In blending surfactants, care must be taken with the ratio of hydrophilic-lipophilic balance and concentration of the surfactants. It has been observed that insufficient surfactant concentration would lead to scattering of the surfactant molecules across the interface of water and oil. The scattering of surfactants contorts the hydrophobic long-chain end of the surfactants, causing the formation of large emulsion droplets that reduce surface area for mass transfer and the occurrence of coalescence. Several researchers have found that the right pairing and appropriate portion of surfactants such as Span 80+Tween 80 and Span 80+Span 20 can produce synergistic effects, resulting in a more stabilised membrane (Suliman et al., 2022; Zaulkiflee et al., 2022). The use of blended surfactants in ELM offers exciting versatility and thus has seen significant advancements. Continued research in this area is expected to lead to further refinements and broader applications in the future.

Meanwhile, the addition of nanoparticles such as magnetic Fe_2O_3 (Suliman et al., 2022; Salman & Mohammed, 2019) or Fe_3O_4 nanoparticles (Mohammed & Jaber, 2022) or nanoparticles like Multi-Walled Carbon Nanotubes (MWCNT) (Alitabar-Ferozjah & Rahbar-Kelishami, 2022; Shirasangi et al., 2023) into ELM formulation to form a Pickering emulsion liquid membrane (PELM) has been shown to enhance the emulsion stability and extraction performance. The attractive benefits of using nanoparticles as stabilisers are two-fold, as the demulsification process has become simple (Hussein et al., 2019). This is especially true for magnetic nanoparticles, as the magnetic attributes ensure easy and immediate demulsification by simply applying an external magnetic field to attract the nanoparticles away from the interface of the emulsion droplets. Augmented stability and easier processing are crucial in maintaining the integrity and feasibility of ELM over extended periods of time, which is especially important in industrial applications.