CHAPTER 3

SYNERGISTIC FORMULATION IN EXTRACTION OF ORGANIC AND INORGANIC COMPOUNDS

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3.1 INTRODUCTION

In conventional extraction methods, efficiency and selectivity present significant challenges when attempting to separate target solutes from complex mixtures. Synergistic extraction is a game changer, harnessing the synergistic effect of different carriers. This approach leverages the complementary interactions between the carriers to improve the separation, extraction, and recovery of solutes. Typically, researchers tend to employ a single carrier in extraction systems when investigating the topic of ELM process. As such, various types of carriers have been explored for the extraction and separation of organic and inorganic compounds such as acidic, basic, and neutral carriers. However, the use of a single carrier is less efficient due to the limited loading capacity (Nguyen & Lee, 2018). To overcome this limitation, synergistic extraction can be integrated into the emulsion liquid membrane (ELM) process.

Synergistic extraction entails combining two or more carriers whose complementary mechanisms work together to create a more efficient and selective extraction process (Liu et al., 2018). Moreover, this synergism can be achieved by combining different types of carriers such as acid-acid, acid-basic, acid-neutral, etc. A synergistic extraction is indicated when the synergistic coefficient (SC) value exceeds one. Conversely, if SC is less than one, it suggests antagonistic extraction, whereas an SC of one signifies no synergistic extraction (Duan et al., 2017). Over the past five years, there has been a notable surge in research and development activities focused on extraction methods, particularly in the field of extraction processes utilising synergistic carriers as depicted in Figure 3.1 (retrieved from the Web of Science database, May 2023).

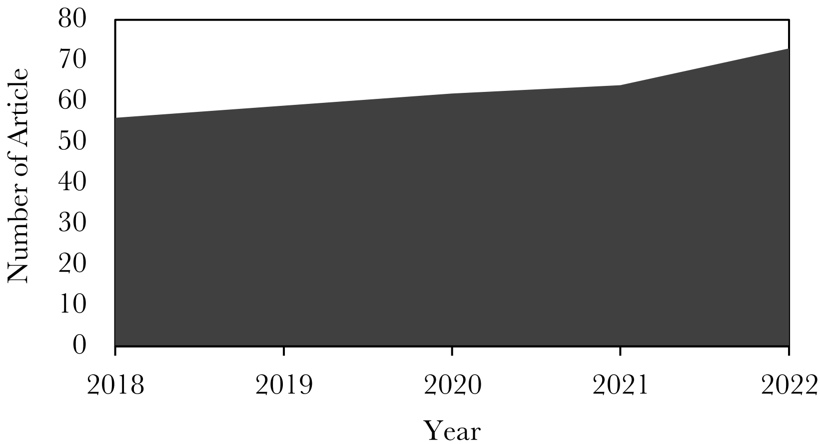

Figure 3.1 Recent trend on synergistic extraction (2018–2022)

In addition, the combination of specific carriers in a membrane with a predetermined concentration has been found to enhance the efficiency of solute ion transport, improve selectivity, and optimise the overall process. Besides, the utilisation of readily available carriers in combination offers greater benefits when compared to the laborious process of creating new carriers from scratch.

3.2 SYNERGISTIC EXTRACTION PROCESS

The synergistic formulation was developed using the liquid-liquid extraction method, and over many studies, a common method has been established and used to carry out synergistic formulations. An equal volume of the feed solution is mixed with an organic solution, consisting of a carrier dissolved in a diluent in an Erlenmeyer flask. The mixture is then subjected to agitation within an incubator shaker, operating at a speed of 300 rpm for 18 hours at a fixed temperature of 26 °C. Following the extraction procedure, the resulting mixture is transferred into a separating funnel and allowed to stand for a period ranging from 15 to 30 minutes to ensure thorough phase separation. The treated aqueous phase is then carefully separated to prevent any contamination from the organic phase. For organic compounds, ultraviolet-visible spectrophotometry or high-performance liquid chromatography is employed for analysis while inorganic compounds are analysed using an atomic absorption spectrometer. To assess the synergistic effects, an equal amount of the feed solution is combined with the organic solution which contains a mixture of carriers in a diluent, as shown in Figure 3.2. The organic and inorganic compounds extraction (*E*) performance distribution ratio (*D*) and SC can be calculated based on Equations 3.1, 3.2, and 3.3, respectively.

$$E\,(\%) = \frac{C_i - C_f}{C_i} \times 100 \tag{3.1}$$

$$D = \frac{C_{org}}{C_{aq}} \tag{3.2}$$

$$SC = \frac{D_{mixture}}{D_{carrier} + D_{synergist}} \tag{3.3}$$

where C_i and C_f represent the initial and final concentrations (in ppm) of organic and inorganic compounds in the feed phase for the extraction process. Meanwhile, C_{org} and C_{aq} denote the concentrations (in ppm) of organic and inorganic compounds in the organic (extracted) and aqueous (unextracted) phases after the extraction/stripping process, respectively. $D_{mixture}$ represents the distribution ratio of the synergistic extraction process, while $D_{carrier}$ and $D_{synergist}$ refer to the distribution ratio