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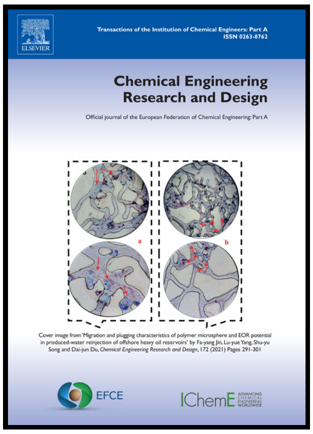

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Nurul Aniyyah Mohamad Sobri, Noorlisa Harun, Mohd Yusri Mohd Yunus

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A Review of the Ion Exchange Leaching Method for Extracting Rare Earth Elements from Ion Adsorption Clay

Nurul Aniyyah Mohamad Sobri [a,b], Noorlisa Harun [a*], Mohd Yusri Mohd Yunus [a,c]

[a]*Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300 Kuantan, Pahang, Malaysia.*

[b]*Department of Chemical, Faculty of Engineering Technology, Universiti Kolej TATI, Jalan Panchur, Teluk Kalong, 24000 Chukai Terengganu*

[c]*Centre for Sustainability of Ecosystem & Earth Resources (Earth Centre), Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300 Kuantan, Pahang, Malaysia*

*Email corresponding author: noorlisa@umpsa.edu.my

Abstract

As the demand for REEs rises, ion adsorption clay emerges as a promising alternative REE source. Ion exchange leaching is the most effective way for REE extraction since 90% of the total REEs exists in an ion exchangeable phase. Recent research focused on enhancing REE leaching efficiency through leaching experiments to identify optimal leaching solutions and conditions. This review aims to summarize the findings from various studies examining the factors that influence REE leaching efficiencies. These factors include the type and concentration of leaching solution, pH, temperature, leaching time, flow rate, liquid-to-solid ratio, and particle size of the clay. This study also provides an overview of mathematical modelling methods utilized to describe the leaching process, including Fick's law, the Kerr model, the Shrinking Core model, Darcy's law, and the Van Deemter equation. The paper highlights the process of determining the rate determining step among these models, deriving the rate constant based on three leaching parameters (solution concentration, temperature, and clay particle size), and presenting the final equation of the Shrinking Core model. These insights will offer valuable guidance on leaching conditions before conducting actual experiments, presenting a more efficient and cost-effective methodology.

Keywords: Rare earth elements (REEs); Ion adsorption clay; REE leaching efficiency; Mathematical Modelling; Shrinking Core model.

1. Introduction

Rare-earth elements (REEs) have become increasingly significant in modern technological devices due to their electrochemical, magnetic, alloy-strengthening, and luminescent properties. Typically, REEs are used in small quantities in various high-tech applications because they can significantly improve the performance, durability, and efficiency of products (Ganguli & Cook, 2018). REEs are widely utilised in the manufacturing of cell phones, computers, laptops, televisions, hybrid cars, wind turbines, solar cells, hard discs, chemical catalysts, military equipment, robotics equipment, aerospace materials, and a range of other high-tech REEs applications (Alshameri et al., 2019; Jowitt et al., 2018; Yan et al., 2020). Due to increased product demand from developing technologies including hybrid and electric cars, magnets, and optical instrument applications, the market for REE metals, which was valued at USD 13.2 billion in 2019, is forecast to rise at a CAGR of around 10.7% from 2020 to 2026 (Kiran & Sayan, 2019). Sufficient REE supply is necessary to meet the demands for REEs. According to the United State Geological Survey (USGS) Mineral Commodity Summaries 2022, global REE reserves were 120 million tonnes at the end of 2021, with China accounting for 36% of the reserve with 44 million tonnes, Vietnam with 22 million tonnes, Brazil and Russia each with 21 million tonnes, India with 6.9 million tonnes, Australia with 4 million tonnes, and other countries with 0.3 million tonnes (Cordier, 2022).

REE resources have been identified worldwide in various geological formations as by-products of other minerals. More than 200 REE-bearing minerals occur in nature including silicates, carbonates, phosphates, halides, and oxides (Balinski et al., 2019; Chakhmouradian & Wall, 2012; Charles et al., 2021).