UNIVERSITI TEKNOLOGI MARA

OXALIC ACID CROSSLINKED CHITOSAN AS AN ADSORBENT FOR THE REMOVAL OF Ce(III) ION FROM ACIDIC SOLUTIONS

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Thesis submitted in fulfilment
of the requirements for the degree of
Master of Science
(Chemistry)

Faculty of Applied Sciences

October 2025

ABSTRACT

Cerium (Ce), one of the most abundant and commonly used rare earth elements (REEs), poses increasing risks of water pollution due to rising demand. In this study, oxalic acid crosslinked chitosan (CHOA) was synthesized and characterized through quantitative and spectroscopic analysis to remove Ce(III) ions from aqueous solutions, while the adsorption efficiencies were investigated through batch adsorption studies. Spectroscopic and qualitative analyses confirmed successful crosslinking, improved surface area, and enhanced stability of the adsorbent material. ATR-FTIR, SEM-EDX, BET, and XRD analyses validated the structural and physicochemical changes in CHOA. Under the optimum conditions (pH of 4, CHOA amount of 0.01 g, 200 rpm stirring speed), CHOA exhibits a high adsorption capacity of 408.71 $mg.g^{-1}$ for a 30 min equilibrium time at 300 K. The kinetic data fit the pseudo-second-order (PSO) model, while the isotherm data follow the Freundlich model. The thermodynamic parameters, such as $\Delta G°$, $\Delta H°$, and $\Delta S°$, confirmed that the adsorption process was spontaneous, endothermic, and increased randomness at the solid-liquid interface, respectively. However, the desorption efficiency and regeneration of CHOA were low, with an approximate 40% desorption efficiency achieved after only two regeneration cycles using a strong acid. Therefore, ion exchange, chelation, and precipitation were identified as the primary mechanisms underlying the adsorption process. Due to its high adsorption capacity and rapid kinetics, CHOA exhibits strong potential for Ce(III) removal; however, further improvement is required for enhanced recovery and reusability.

ACKNOWLEDGEMENT

Alhamdulillah, all praise and gratitude be to Allah SWT for his endless blessings, strength, and guidance throughout this journey. I would also like to express my deepest gratitude to my supervisor, Prof. Ts. Dr. Megat Ahmad Kamal bin Megat Hanafiah, for his insightful advice, guidance, and continuous support throughout my MSc journey. His contributions have significantly enhanced the quality of my research and thesis. I am also sincerely thankful to my co-supervisor, Assoc. Prof. ChM. Dr. Yong Soon Kong and Dr. Agustono Wibowo for their constructive feedback, encouragement, and continuous support. I deeply appreciate their time and effort.

Special thanks to all the lab assistants in UiTM Pahang who provided technical support and assistance during my experimental work. To all my fellow colleagues, friends, and lab mates for their support, discussions, and insightful experiences that made this journey more meaningful.

I am forever indebted to my family for their endless love, patience, and prayers. Their belief in me has been my greatest motivation, and without their support, this journey would not have been possible.

Lastly, I would like to express my gratitude to everyone who has contributed, directly or indirectly, to the completion of my thesis. May Allah reward you all for your kindness.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

In recent years, rare earth elements (REEs) have been in significant demand across several industries, including the industrial sector as a photocatalyst (Alhaddad *et al.*, 2022), electrocatalyst (Majhi & Yadav, 2022), pollutant detector in the environment (Marcisz *et al.*, 2023), and the health sector as antibacterial activity, wound healing, and antifungal activity (Abdelhamid *et al.*, 2020). In 1993, REEs were produced as a by-product of the tin (Sn) mining process in Kinta Valley, Perak, Malaysia (Yaraghi *et al.*, 2020). Furthermore, the extraction of REEs is still widely conducted and is expected to continue. This is due to the numerous industrial sectors that utilize REEs as their primary materials. For example, Ce(III) is widely used in various industries because Ce(III) is the most found REE and has unique properties. Ce(III) can enhance the electrochemical characteristics, making it an efficient electrocatalyst (Shahroudi *et al.*, 2023). Cerium oxide is also used as a coating with long-lasting anti-corrosion capabilities (Xie *et al*., 2024). It is an important part of the catalytic process in methane decomposition (Makayeva *et al*., 2024). In the health field, Ce(III) has an important function as a diabetic wound healer (Kamalipooya *et al.*, 2024), and it is effective in addressing obesity-related metabolic disorders by curbing elevated insulin, triglycerides, and cholesterol resistance (El-seidy *et al.*, 2023).

On the other hand, recent studies show that long-term exposure to Ce(III) can harm the well-being of humans, animals, and plants. The potential risk of human health disruptions, such as lung inflammation, fibrosis, intestinal damage, and skin irritation, due to Ce(III) typically arises from exposure to environments contaminated with elevated Ce(III) concentrations. Furthermore, exposure to Ce(III) in animals indicates that an increase in Ce(III) doses in the animal's body leads to the accumulation of these elements, especially for the insoluble Ce(III) oxides. Consequently, the gradual expulsion of accumulated Ce(III) from the animal's body occurs at a slower rate, enhancing the toxic effects on the animal's body (Jomaa *et al*., 2024). The accumulation effects of Ce(III) on plants can disrupt the chloroplast formation process, while Ce(III) that plants cannot absorb may accumulate in the soil and eventually infiltrate both the