CHAPTER I
INTRODUCTION

1.1 Introduction

The combustion of fossil fuels generates substantial CO_2 emissions, making it the largest source of anthropogenic greenhouse gases. Therefore, post-combustion CO_2 capture, along with its proper utilization or disposal, is essential in power plants to enhance the sustainability of energy production from fossil fuels, such as coal (de Aquino et al., 2020; Muriithi et al., 2020).

There are several techniques for CO_2 removal. The development of CO_2 capture through adsorption on solid sorbents has gained significant interest due to its low energy requirements, simplicity, and cost-effectiveness (Kaithwas et al., 2012; Keawkumay et al., 2024).

Zeolites are commonly used in a range of applications, including ion exchange for water purification, catalysis, detergent formulation, building materials, and gas adsorption, especially CO_2. Zeolites are especially recognized as adsorbents. Their high adsorption capacity is attributed to their excellent thermal stability, stable crystalline structure, low density, uniformly sized channels, large surface area, and substantial pore volume (de Carvalho Izidoro et al., 2024). Zeolites are crystalline microporous aluminosilicates consisting of tetrahedral TO_4 units (T = Si or Al) interconnected through shared oxygen atoms (Wittayakun et al., 2008). The silicon-to-aluminum ratio (Si/Al) significantly affects the zeolite structure and adsorption capacity.

One of the challenges in zeolite synthesis is the high energy consumption and the use of silica sources which are non-environmentally friendly, for example, fumed silica and silicon alkoxides (Sharma et al., 2015). Recently, there has been increasing interest in synthesizing zeolites from low-cost materials, including rice husk, fly ash, rice husk ash, and kaolin. Additionally, silica derived from waste materials, such as silica gel waste, has proven to be a promising raw material for the synthesis of zeolites due to its high silica content (Khaosomboon et al., 2018).

Silica gel is commonly used as a desiccant, adsorbent, or in chromatography, but improper disposal can lead to environmental challenges. The continuous increase in silica gel waste has made its disposal a growing concern. Converting this waste into value-added products offers a sustainable solution. Due to its high silica (silicon dioxide) content, silica gel waste can serve as a valuable precursor for zeolite synthesis.

This research aims to synthesize zeolites NaA, NaX, and NaY using a silica source from silica gel waste and to compare their CO_2 adsorption capacity to commercial zeolites. The study also examines the effect of the Si/Al ratio on adsorption performance. Additionally, the physicochemical properties, morphology, basicity and N_2 adsorption–desorption isotherms of the synthesized zeolites derived from silica gel waste are analyzed and discussed.

In addition to the main thesis body, an unsuccessful study of the adsorption of wintergreen and eucalyptus essential oils onto synthesized zeolites from fumed silica is reported in the Appendix. The issue was attributed to the zeolite's low adsorption capacity for fragrance molecules, which hindered the precise determination of the adsorbate amount. The research details, including methodology and data, can be found in the Appendix.

1.2 Objectives

This study aims to achieve three key objectives. First, it emphasizes the synthesis of phase-pure zeolites NaA, NaX, and NaY from silica gel waste as a silica source using the hydrothermal method. Second, it aims to evaluate the CO_2 adsorption capacity of the synthesized zeolites (NaA, NaX, and NaY) in comparison with their commercial counterparts to assess their performance. Lastly, the study aims to examine the effect of the zeolite Si/Al ratio and framework structure on adsorption capacity, providing insights into how these factors affect CO_2 capture efficiency.