Introduction

The excessive accumulation of the carbon dioxide (CO_2) in the earth's atmosphere and continuation of its ever-increasing emissions, majorly driven by industries is a leading cause of climate change and rise in global temperatures. This emphasizes the urgent need for innovative and scalable carbon capture and storage technologies to reduce the impact of climate change. Traditional CO2 capture methods, including chemical absorption, physisorption, cryogenic distillation, and membrane separation, face significant challenges in scalability, energy consumption, and environmental sustainability. The scale of capture and storage required for CCS is immense, potentially posing significant challenges to the global supply chain and affecting ongoing and future climate efforts. Both aspects necessitate the development and deployment of scalable and stable CCS technologies. Further, storing captured CO_2 presents significant challenges, including ensuring long-term containment, preventing leakage, and maintaining the stability of underground reservoirs. Furthermore, the complexities of geological heterogeneity, the risk of induced seismicity, and the extensive monitoring required to ensure storage integrity add to the difficulty.
In addition, the next-generation CO_2 capture technologies must not only be inexpensive but also fulfil net-zero criteria. In this work, authors have presented gas hydrate-based CO_2 capture and storage solutions which may further emerge as a promising alternative, offering energy efficiency, scalability and stability for large-scale CCS projects.

Method

In the present study, authors have investigated the comparative performances of various compositions of gas hydrate forming mixtures majorly having 1,3-dioxolane as an additive used to capture CO_2 from simulated CO_2 gas mixtures SCGM-A (85% N_2 + 15% CO_2) and SCGM-B (70% N_2 + 30% CO_2) by adapting improvised gas hydrate technology. Various experimental conditions were optimized for process intensification and scale-up by considering various gas compositions, temperatures, and pressures and their effect on the kinetics, efficiency, and stability of CO_2 hydrates. In order to conduct the experiments for the underground capture and storage of carbon dioxide, a ~10,000 cm^3 reservoir having provision of multi-layered structures (for gas hydrate growth and structural support) has been designed and fabricated.

Conclusions

It has been observed during the optimizations and scale-up studies that 1,3-dioxolane behaves as an effective CO2 gas hydrate former, with considerable formation kinetics, particularly for the highly CO2-concentrated mixture SCGM-B. With an experimental CO_2 capture of over 18.951 moles (833.3 g) per cycle, sustained for 120 hours without any signs of dissociation, the results affirm the robust stability of the stored CO2 under the given experimental storage conditions. This stability, coupled with the efficient performance of 1,3-dioxolane as a gas hydrate former, underscores its economic viability when benchmarked against other CCS alternatives for SCGM-A and SCGM-B gas mixtures, making it a promising candidate for scalable carbon capture and storage solutions.

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