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Microfluidic analysis of seawater-based CO_2 capture in an amine solution with nickel nanoparticle catalysts

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ABSTRACT

Post-combustion CO_2 capture methods like amine scrubbing are currently being utilized to reduce CO_2 emissions from fossil fuel power plants. Aqueous monoethanolamine (MEA) solutions are typically used in these processes due to their high CO_2 absorption capacity and rapid reaction rate, but these solutions also produce environmentally harmful toxic wastewater and consume large amounts of freshwater. This research analyzes the effectiveness of seawater-based MEA solutions containing nickel nanoparticles (NiNPs) as catalysts, with the goal to minimize the amount of MEA required in the amine scrubbing process and eliminate the use of freshwater. This study is the first to use natural seawater solutions as an alternative to freshwater solutions for CO_2 capture. In a microfluidic environment, CO_2 microbubbles were generated and their change in size with respect to time was observed to determine the CO_2 absorption capacity and rate of the test solutions. Pure seawater demonstrated comparable CO_2 absorption to deionized (DI) water. Seawater-based amine solutions absorbed merely 1.79 % less CO_2 than DI water-based amine solutions. Seawater-based amine solutions demonstrated faster CO_2 absorption rates than their freshwater counterparts. Lastly, to further optimize CO_2 absorption, NiNPs were added to each test solution. Seawater with MEA and NiNPs absorbed only 1.15 % less than its DI water counterpart, confirming seawater's potential as amine-based solvent for industrial CO_2 capture applications.

1. Introduction

Excessive anthropogenic CO_2 emissions have driven global temperature rise, ocean acidification, and sea level rise over the last decades [1]. At present, significant quantities of CO_2 emissions are produced by fossil fuel combustion processes in power plants, accounting for 40 % of global CO_2 emissions [2]. Projected CO_2 emissions are expected to substantially exceed sustainable levels, resulting in dangerous long-term consequences for the environment and society [3]. A global temperature increase is associated with more intense precipitation events, including hurricanes, and mass extinction events in a variety of plant and animal species [4]. In addition, due to the continued rise of sea levels and resultant frequent flooding, over 300 million people are estimated to be displaced in the next decades; the economic and political strain caused by this extensive human displacement would be enormous [5]. As global energy demands continue to increase each year, innovative environmentally sustainable methods of power generation that actively address CO_2 emission reduction are essential to combat climate change and mitigate its detrimental effects [6].

Currently, post-combustion CO_2 capture is one of the most prominent technologies being utilized in commercial fossil fuel power plants to reduce their CO_2 emissions [7]. Post-combustion CO_2 capture is the process of removing CO_2 from the flue gas after the combustion process is complete. Typically, the captured CO_2 is then sequestered and stored utilizing complex chemical processes [8]. The modular nature of post-combustion CO_2 capture is a great advantage over other CO_2 capture methods such as pre-combustion carbon capture and oxy-fuel combustion. These methods are comparatively complex and costly to be retrofitted to current power plants [9,10]. Amine scrubbing is the dominant method for post-combustion carbon capture and has already been practically retrofitted to existing power plants [11]. In amine scrubbing, CO_2 rich flue gas and amine solution flow into an absorber unit where the amine solution absorbs CO_2 from the flue gas. After the reaction is complete, the CO_2 depleted flue gas is directed out of the

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