IEAGHG 8th Post Combustion Capture Conference

16th to 18th September 2025 Marseille, France

Sustainable CO_2 Capture Using Recovered Silica-PEI: Capacity, Efficiency, and Economic Viability

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Abstract

Silica-polyethyleneimine (silica-PEI) and, more recently, silica-alkoxylated polyethyleneimine (APEI) adsorbents are promising materials for CO_2 capture due to their high adsorption capacity and selectivity. Enhancing their cost-effectiveness and sustainability is essential for broader commercial applications in post-combustion carbon capture (PCC) and direct air capture (DAC). In this study, spent silica-PEI/APEI adsorbents were subjected to pyrolysis at 500°C for 1 hour to recover organic components from PEIs, followed a burn stage in air (500°C) for 1 hour, then by reloading the recovered silica with fresh PEI for reuse. The results show that the total porosity and mesopore volume of the recovered silica exhibited only a slight decrease compared to the initial silica, with the total pore volume reducing from 1.72 cm^3/g to 1.37 cm^3/g, and the mesopore volume reducing from 1.60 cm^3/g to 1.25 cm^3/g. The fresh silica achieved an optimal PEI (molecular weight is 800 g/mol) loading 47%, while the recovered silica maintained a slightly lower optimal loading of 45%. Correspondingly, the CO_2 adsorption capacity of the selected PEI decreased from 14.2 wt.% to 13.1 wt.% for the 47% PEI on the initial silica and the 45% PEI on the recovered silica, respectively. Despite this slight reduction, the overall CO_2 capture capacity and efficiency were minimally affected, demonstrating that recovered silica can be effectively reused for multiple capture cycles. This study highlights the potential of spent silica-PEI/APEI adsorbents to provide a sustainable and economically viable approach to CO_2 capture, reducing material costs while maintaining adsorption performance in both PCC and DAC applications.

Keywords: Silica-polyethyleneimine, recovered silica, carbon capture, sustainable

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