IEAGHG 8th Post Combustion Capture Conference

16th to 18th September 2025 Marseille, France

Magnesium Extraction from Tailings for CO_2 Mineralization: Insights from Roasting and Acid Leaching Tests

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Abstract

Increasing atmospheric concentrations of CO_2 have driven the need for innovative carbon capture and storage strategies. One promising approach is CO_2 mineralization, where magnesium-rich minerals react with CO_2 to form stable carbonate minerals. Mine tailings, a byproduct of mineral processing, can present a valuable feedstock for this purpose when they possess a high magnesium content. This study investigates magnesium extraction from a suitable mine tailings for potential CO_2 sequestration. Quantitative X-ray diffraction (QXRD) analysis confirmed the tailings to be primarily composed of 33% serpentine (lizardite) and 20% olivine (forsterite), along with lesser amounts of talc, chlorite (clinochlore), quartz and magnetite. Roasting these tailings with ammonium sulfate at 400°C followed by water leaching enabled 85% magnesium extraction, although this required particles to be <75 µm. In comparison, leaching with sulfuric acid resulted in 90% magnesium extraction. XRD of the acid-leached residue indicated near-complete decomposition of the serpentine and olivine phases, confirming the effectiveness of acid leaching in extracting magnesium. The leach residue (primarily quartz and talc) was separated via filtration using a 0.45 µm membrane. Subsequently, Fe, Ni, and Mn were selectively precipitated by gradually increasing the solution pH to 8, leaving a magnesium-rich solution. The extracted magnesium was precipitated as $Mg(OH)_2$ at pH > 8 then employed for carbonation using pure CO_2, obtained from an amine-based direct air capture (DAC) system. Carbonation of the $Mg(OH)_2$ was modelled using Aspen plus at both 400°C and ambient temperature, indicating that carbonation at 400°C will result in pure $MgCO_3$ while the carbonation under ambient conditions will favour the formation of hydrated magnesium carbonates. This work demonstrates a viable pathway for integrating the mineral carbonation of tailings with DAC-based CO_2, contributing to sustainable waste management and emissions reductions.

Keywords: Tailings, mineral carbonation, direct air capture, serpentine, olivine, CO_2 sequestration, acid leaching, roasting

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