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Heat activation of brucite, serpentine, and hydrotalcites: Implications for CO_2 sequestration in ultramafic mine wastes

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Carbon dioxide sequestration using mine tailings has gained increasing attention as a strategy to reduce the carbon footprint of mining operations. The mineralogical composition of mine wastes strongly controls CO_2 sequestration capacities and rates. Heat activation, a pretreatment method, breaks down crystal structures, including calcination and dehydroxylation of carbonate-bearing (e.g., hydrotalcites) and hydroxyl-bearing (e.g., brucite and serpentine) minerals, enabling faster, more efficient carbonation. In this study, heat activation was applied to minerals with varying CO_2 sequestration reactivities: brucite [$Mg(OH)_2$; high reactivity], hydrotalcite group minerals [$Mg_6(Al,Cr,Fe)_2(OH)_{16}(CO_3)\cdot 4H_2O$; moderate reactivity], and serpentine group minerals [$Mg_3Si_2O_5(OH)_4$; low reactivity]. Pure brucite, hydrotalcite, and serpentine samples were heated to various temperatures (200–700°C) and times (0.25–10 h) to determine the optimal method of dehydroxylation and calcination for these minerals. Ore containing these minerals, sourced from the Decar Nickel District in British Columbia, Canada, were heated to 600°C for 1 h, the temperature and time which brucite transforms to periclase (MgO). Untreated and heat-activated samples were exposed to 10% CO_2 (1 atm) for 3 weeks to monitor CO_2 uptake by measuring total inorganic carbon. Untreated and heat-activated brucite samples completely carbonated, sequestering 601 kg CO_2/t. In contrast, the CO_2 uptake for the treated hydrotalcite minerals increased from 153 (untreated) to 304 kg CO_2/t, and the serpentine minerals increased from 11 (untreated) to 24 kg CO_2/t. Heat activation was also evaluated as a method to enhance nickel (Ni) extraction from ore, where untreated and heat-activated tailings were leached in a sulfuric acid solution, a process commonly employed in nickel mining processes. The results of these experiments demonstrate that heat activation can improve CO_2 sequestration efficiency in less reactive minerals, highlighting its potential as a viable strategy for enhancing carbon capture in mine tailings.