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A Kinetic Approach to carbon dioxide removal in mine waste: Modeling CO_2 Uptake in Reactive Tailings

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Carbon dioxide removal (CDR) refers to the intentional activities designed to capture CO_2 directly from the atmosphere and store it permanently (e.g. in excess of 20,000 years) away from the atmosphere. Among the portfolio of CDR pathways, geochemical pathways (in situ and ex situ enhanced mineralization) are increasingly gaining attention in the mining sector, particularly in Canada. These pathways accelerate the weathering of alkaline feedstocks in contact with CO_2, enabling sequestration from either concentrated CO_2 streams or ambient atmospheric CO2.

In mining environments, suitable mineral feedstocks include mafic and ultramafic rocks like basalt and serpentinite, as well as industrial by-products such as mine tailings, fly ash, steel slag, and other reactive alkaline materials including lime. This feedstock may already have been crushed, providing high surface area to further enhance its reaction with CO_2. Enhanced mineralization produces secondary carbonate minerals and aqueous alkalinity for durable storage. Several geochemical protocols have been developed to assess mine tailings suitability for CDR, including the distinction between passive (baseline) and active (enhanced) mineralization. For example, the Isometric OSEM provides a standardized protocol for establishing baseline CDR rates in tailings facilities. However, such assessments typically require extensive sampling, laboratory analysis, and pilot studies, making pre-feasibility assessments resource intensive.

This study builds on the publication of mineral dissolution kinetic databases for PHREEQC (Hermanska et al 2022, 2023) and Oelkers and Adassi (2025) to define a rapid mine-waste screening tool for potential carbon removal suitability. This kinetic modelling approach allows for the definition of high level estimates of solubility trapping and mineral trapping. Kinetic calculations provide an estimate of the mass of CO2 that can be stored and the timescale involved . This study present examples from a range of representative mine wastes that vary in sulphide content, alkalinity mineralogy, and reactivity to CO2 to demonstrate the applicability of the proposed methodology and its limitations.

This tool serves as a practical decision-support resource for mining companies by helping them prioritise suitable mine waste and make informed investments in detailed geochemical CDR assessments, pilot-scale projects, and scaling efforts.