

PATHWAYS TO ACCELERATED CARBON MINERALIZATION IN MINE TAILINGS

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Alkaline waste generated from mining of magnesium silicate rocks reacts spontaneously with atmospheric carbon dioxide (CO₂) to precipitate carbon in solid mineral form. The total capacity of these mine tailings to sequester carbon is about ten times greater than greenhouse gas emissions of associated mining and mineral processing. Waste from mining activity globally has capacity to sequester 100-200 Mt of CO₂ per year. However passive, or unintentional, CO₂ mineralization at individual mine sites is modest (1-50 kt/yr), and typically limited by CO₂ supply. Acceleration of these reactions represents an opportunity to generate considerable greenhouse gas offsets for the industry, and to develop expertise in carbon mineralization that is relevant to accelerated weathering at Earth's surface and mineral trapping in low temperature aquifers and reservoirs.

Experimental acceleration of carbon mineralization is readily achieved through enhanced delivery of CO₂, wherein reaction rates are limited by rates of cation (e.g., Mg²⁺) supply from mineral dissolution. Further acceleration requires optimization of mineral dissolution processes. Continuous-flow dissolution experiments on minerals and mine tailings exhibit rapid, transient cation release rates that decay to slower rates indicative of conventional steady-state bulk mineral dissolution processes (Fig. 1A). The transient initial phase of the experiments can release a significant amount (5-10%) of the total cation content of the material. It reflects the dissolution of highly soluble trace minerals, and surface processes in sheet silicate minerals which together we take to represent the labile cation capacity of the material. Longer-term steady-state cation release is much slower and represents recalcitrant cation capacity indicative of bulk mineral dissolution. The labile cation content represents the carbon mineralization capacity of alkaline mine wastes accessible with existing low-cost technologies while recalcitrant cation content is unlikely to be tapped at existing carbon prices (Fig. 1B). Measured labile cation content of mine tailings varies substantially between and within deposits, with implications for how carbon mineralization capacity should be characterized and how carbonation intervention would be incorporated into mine operations. Specific mines and specific alteration types with high labile cation content, which for some mines is sufficient to offset total mine greenhouse gas emissions, should be the focus of pilot scale carbon mineralization projects.

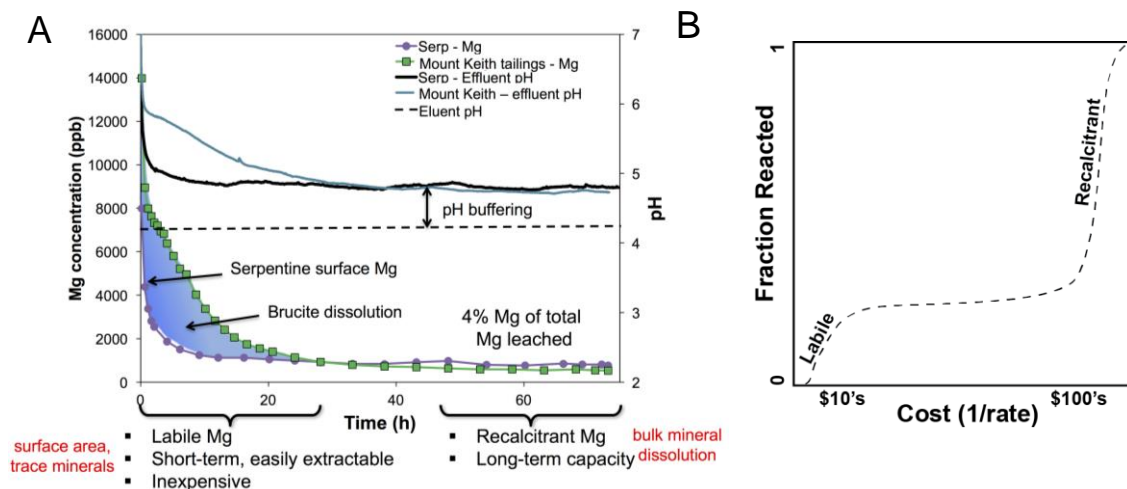


Figure 1: A. Cation release rates (Mg²⁺) from mineral and tailings dissolution experiments in flow through reactors. Labile cation release rates are defined by transient period of fast release and followed by slow release of recalcitrant cations. B. Labile cation content represents the carbon sequestration capacity of mine tailings easily accessible with existing low-cost technology while recalcitrant cations represent high cost or future sequestration capacity.