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Establishing ex-situ mineralization rates in mine waste using continuous CO_2 fluxes, electrical conductivity, and alkalinity measurements

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Ex-situ mineralization is a carbon removal technology based on mineral carbonation processes triggered by reactions between mine waste and the atmosphere. Depending on the mineralogy of the mine waste, weathering rates driven by CO_2 uptake can be slow and difficulty to measure. Therefore, developing monitoring systems that measure carbonation progress is essential for assessing carbon sequestration and process optimization.

Field experiments were conducted over one year to determine passive carbonation rates in mine waste feedstocks not typically targeted for ex-situ mineralization. These trials involved weathering one tonne of fine mine residues in a closed 1 m^2 cell with no seepage, but allowing infiltration, evaporation and gas exchange under ambient conditions. Water samples were periodically sampled from porewater samplers installed at various depths. Moisture, temperature, conductivity, and CO_2 sensors were used to continuously record these parameters in the upper 10 cm layer. Electrical conductivity and water quality data was used to determine seasonal fluxes of major elements and alkalinity fluxes dynamics in porewater.

The study results show that diffusivity of CO_2 in the fine residues was estimated up to 721 g $CO_2/m_2/yr$. Thermal gradients and water content in the tailings controlled the atmospheric CO_2 supply for mineral dissolution at the top 10 cm. DIC analysis indicated that solubility trapping rates varied between 130 to 210 g $CO_2/m^2/yr$, whereas mineral trapping by secondary carbonate was undetectable and carbon verification largely complicated by the geochemical heterogeneity of the tailings and impact of the cycles of dissolution and re-precipitation of pre-existing calcite within the tailings.

This study demonstrates that continuous monitoring of CO_2, DIC fluxes, and electrical conductivity provide a robust framework for determine baseline for CDR rates in mine tailings and also help determine operating limitations of ex-situ mineralization applications, such as impact of moisture content on carbon removal rates.