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Passive and enhanced CO_2 sequestration rates at diamond mines determined from field experiments: Results from Project CarbonVault

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Diamond mines produce kimberlite residues that consume carbon dioxide (CO_2) from the atmosphere [1]. As part of De Beers' Project CarbonVault^{TM}, field trials (1 m^3) were undertaken using 4.6 t of kimberlite residues from the Venetia Diamond Mine (South Africa) that were weathered for 1.5 yr. These experiments mimicked the conditions of the mine's residues deposits (control) and introduced new management practices to enhance weathering, including more frequent wet-dry cycles in fine residues (<1mm) and the use of organics in coarse residues (1–8 mm). Experiments used porewater samplers at various depths and sensors for monitoring moisture, conductivity, and pore gas CO_2 concentrations. Porewaters (n=193) were routinely analyzed to track changes through the experiment, and solids (n=373) were analyzed for total inorganic carbon (TIC) at the commencement and completion of the experiment. Solubility trapping increased from 130 to 210 g $CO_2/m^2/yr$ in the fine kimberlite residues by introducing enhancement strategies based on dissolved inorganic carbon (DIC). Feedstock reactivity and water retention were the two main factors affecting CO_2 removal rates. The addition of organics to coarse kimberlite residues increased DIC as mineral dissolution buffered the acidity generated by microbial respiration. Stimulating organic-mineral reactions increased solubility trapping from 210 to 795 g $CO_2/m^2/yr$ in kimberlite wastes. Secondary Ca-, Na- and Fe-carbonates were identified at the surface of the kimberlite residues despite the minor changes in TIC (final minus initial) in solids suggesting minimal mineral trapping of CO_2. The kimberlite heterogeneity, spatial variability, and the dissolution and re-precipitation of pre-existing calcite complicated carbon accounting with TIC. CO_2 sequestration rates via weathering of kimberlite residues are comparable to those estimated for basalt powders (80 to 400 g $CO_2/m^2/yr$) [2] yet were severely limited by the low water to rock ratio used in experiments that caused porewaters to be in near equilibrium with respect to kimberlite minerals and prevented ingress of CO_2. Greater CO_2 sequestration rates are achievable through dispersing residues while also harnessing organic-mineral interactions.

[1] Stubbs et al. (2022), Int. J. Greenh. Gas Control 113: 103554; [2] Kelland et al., (2020), Glob Change Biol.; 26: 3658–3676