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Effects of mineral reactivity and seasonality on enhanced rock weathering of kimberlite mine residues

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Kimberlite residues at diamond mines have the ability to remove carbon dioxide (CO_2) from the atmosphere through weathering processes that can be accelerated by implementing new management practices that enhance mineral dissolution and CO_2 supply.[1,2] Field experiments (m^3-scale) were conducted (February 2020 onward) using fine (<1 mm) and coarse (1–8 mm) kimberlites residues from Venetia Diamond Mine (South Africa) as part of De Beers' Project CarbonVault™. These experiments aimed to monitor CO_2-aqueous-rock interactions and determine CO_2 removal rates under current mine conditions (control) and practices that further enhance rock weathering (ERW) including intensifying wet-dry cycles, tilling, and the use of organics. Volumetric water content, conductivity, temperature, and CO_2 concentrations in the residues were measured remotely using a network of sensors. Porewaters and solids were routinely collected to develop geochemical and pedogenetic models. CO_2 removal rates in the field were greatly influenced by kimberlite reactivity, climate seasonality, and ERW practices. Periods of higher rainfall and temperature were linked to greater CO_2 ingress, whereas in the dry and cooler season, a hardpan limited CO_2 ingress. In contrast, surface tilling and water content optimization resulted in greater CO_2 ingress in the ERW experiments. In the coarse residues amended with organics, CO_2 increased from approximately 0.04% to 2% due to microbial respiration. As a result, alkalinity increased from 4 to 20 mmol indicating greater solubility trapping of CO_2. Greater cation release was also observed in ERW experiments, predominantly when ERW practices were intensified. ERW also showed a positive impact in potassium leaching from kimberlite that can be beneficial for establishing vegetation on mine residues as part of mine restoration. With ERW, the average CO_2 mineralization rate increased from an initial 40 to 66 g $CO_2/m^2/yr$ and from 8 to 29 g $CO_2/m^2/yr$ in the fine and coarse residues, respectively. Our field experiments provide insights into kimberlite residue weathering, estimate ERW rates, and identify management practices that promote greater CO_2 removal. [1] Mervine et al. (2018), Mineral. Petrol. 112, 755–765 [2] Wilson et al. (2011), Environ. Sci. Technol. 45, 7727–7736.