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Copper coprecipitation and adsorption with hydrous Mg carbonates via brucite carbonation: Application to remediation of ultramafic mine tailings

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Magnesium-bearing ultramafic mine tailings, which contain high concentrations of Ni and Cr as well as economically valuable metals such as Co, Cu, Zn, and Fe, are highly reactive and likely to transform rapidly into hydrated magnesium carbonates (HMC)[(1,2)]. This carbonation process not only contributes to atmospheric CO_2 sequestration but may also concentrates critical metals, whose demand is projected to reach 37 million tons per year by 2050 to meet our transition toward low-carbon energy[(3)]. This process has been the subject of several studies; however, the mechanisms by which metals of economic interest are incorporated into HMC and the effects of these metals on the stability and growth/transformation kinetics of these phases have not yet been studied quantitatively.

This study investigates Cu behavior during brucite carbonation over one month at 25, 40, and 60°C, with initial Cu concentrations ranging from 0.02 to 157 mmol.L^{-1}. Microscopic and spectroscopic analyses showed rapid and efficient Cu removal, with more than 95% of aqueous Cu removed through coprecipitation with forming hydrous Mg-carbonate phases such as nesquehonite ($MgCO_3 \cdot 3H_2O$), dypingite ($Mg_5(CO_3)_4(OH)_2 \cdot 5H_2O$) and hydromagnesite ($Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$). Temperature influenced HMC crystallization and Cu removal efficiency. Higher temperatures accelerated the co-precipitation process, likely by enhancing the rates of mineral formation and increasing the rate and overall yield of Cu incorporation into the solid phase. At higher Cu concentrations, distinct Cu-bearing phases formed, including hydrous carbonates such as malachite ($Cu_2(CO_3)(OH)_2$) and mcguinnessite ($Cu,Mg(CO_3)(OH)_2$), as well as Cu oxy-hydroxide and chloride phases. These phases have been identified in natural environments and old Cu mining sites, such as in the altered ophiolites of Monte Ramazzo (Italy). Additional adsorption experiments conducted on brucite and hydromagnesite showed that surface processes also contribute to Cu immobilization. Overall, these results highlight the potential role of hydrated Mg-carbonates as sinks for Cu in ultramafic environments. Future work should focus on evaluating the system under more realistic conditions, particularly in chemically complex matrices and on the methods for recovering copper as well as other economically valuable metals from these co-precipitated phases.

(1) Harrison *et al.* (2019), https://doi.org/10.1016/j.chemgeo.2018.11.003
(2) Stokreef *et al.* (2022), https://doi.org/10.1016/j.clet.2022.100491
(3) Elshkaki *et al.* (2016), https://doi.org/10.1016/j.gloenvcha.2016.06.006