Hydrogeochemical Modelling of Indium in a Mine Waste Environment: Opportunities for Recovery from Aqueous Sources

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Indium (In) plays a crucial role in the energy transition, particularly in copper indium gallium selenide (CIGS) solar panels, where its demand is projected to increase by approximately 200% by 2050. This surge has driven intensive exploration into various resources, including mining waste. However, the extraction of indium from mine aqueous sources as an alternative to traditional hard rock ore mining remains poorly understood. To address this issue, we present a hydrogeochemical model of indium aimed at developing a reactive transport model to simulate advection, diffusion, and fluid-rock interactions within the mine waste material in a multi-component environment. In this study, we used surface water samples from the abandoned Baal Gammon mine in Queensland, Australia, and the surrounding Jamie creek. Due to insufficient thermodynamic indium data, we compiled and created a database from literature. Using the geochemical code PHREEQC, we calculated speciation, complexation, mineral saturation indices (SI), and reactions to derive the stability regimes and kinetics of indium within the mine waste system. The results show that indium is distributed mainly as In^{3+}, $InSO_4^{+}$, $In(SO_4)_2^{-}$, and $InOH^{2+}$ in acid mine drainage (AMD). This was confirmed by simulating Pourbaix diagrams with different compositions of solutions. SI indicate that jarosite and schwertmannite are expected to precipitate and may control indium transport. We then couple the geochemistry with advection and diffusion in a machine learning approach to investigate how much indium could potentially be released into the environment if no treatment is applied. This work sheds light on the environmental impacts and recovery opportunities of indium from aqueous sources as an alternative in supply chains. Further research is needed to address the technological challenge of developing processes for the selective extraction of targeted indium dissolved constituents from AMD. This entails elucidating sorption/desorption reaction mechanisms, specifically in waters containing competing constituents.