Antimony Fate During Schwertmannite Transformation: Implications for Passive Remediation in Acid Mine Drainage–Impacted Environments

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Antimony (Sb) contamination frequently arises from the oxidative weathering of Sb-bearing sulfide minerals during mining and ore processing. In acid mine drainage (AMD) environments, schwertmannite is a commonly occurring metastable Fe(III) oxyhydroxysulfate mineral. Over time, it transforms into more stable phases such as goethite and jarosite. Schwertmannite plays a key role in regulating Sb mobility; however, its potential use—and that of its transformation products—as part of passive remediation strategies remains poorly characterized. This study investigated the geochemical behaviour of Sb(V)-bearing schwertmannite and its transformation under AMD conditions. X-ray diffraction (XRD) and Fe K-edge EXAFS spectroscopy showed that schwertmannite transformed to goethite at a higher pH (≈ 3) and to jarosite at a lower pH (< 2.5) over time. Antimony K-edge EXAFS spectroscopy revealed that Sb(V) was sequestered within the schwertmannite structure through partial substitution for Fe(III). During transformation, Sb(V) mobility initially increased, but it subsequently remained structurally incorporated in the transformation products via the same substitution mechanism. Dissolution experiments indicated that Sb(V) incorporation significantly reduced schwertmannite solubility, thereby decreasing Sb mobility. Furthermore, the retention of Sb within the newly formed, more stable mineral phases suggests that schwertmannite transformation creates a long-term sink for Sb in AMD environments. These findings offer new insights into the capacity of schwertmannite and its transformation products to immobilize Sb through natural geochemical processes. This work contributes to evaluating the effectiveness of in-situ iron mineral passive remediation approaches and informs strategies for managing secondary metal contaminants across the mining value chain.