Authigenic iron oxyhydroxide rims attenuate deleterious element fluxes during sulphide oxidation in historical gold mine tailings

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Historical gold tailings pose significant environmental risks worldwide, primarily due to acid mine drainage and the release of toxic elements triggered by the oxidation of residual sulphides. The formation of metastable secondary iron oxyhydroxides during this process affects the mobility of these elements, yet the mass transfer between sulphide cores, oxyhydroxide rims, and the surrounding environment remains poorly understood. This study uses a gold tailings storage facility in South Africa's Klerksdorp goldfields as a natural laboratory to explore how these iron oxyhydroxide rims influence the mobility of Co, Ni, As, Pb, Zn, Au, and Cu following prolonged surface exposure. Employing a multi-analytical approach, LA ICP-MS, automated mineralogy, and wet chemistry, the study quantifies elemental release versus retention. Despite comprising less than 1% of the mineralogy, iron oxyhydroxide rims significantly retain As, Ni, Cu, and Zn (up to 15 %), while Co, Au, and Pb show minimal retention (<3%), indicating higher mobility. Results suggest that current natural immobilisation is inadequate for environmental compliance, underscoring the need for targeted remediation, including reprocessing and containment strategies to mitigate risk and recover valuable metals.