Partitioning and Mobility of Deleterious Elements from Sulphide Oxidation in the Historical Gold Mine Tailings

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The Witwatersrand Goldfields, responsible for 27% of global gold production, face environmental challenges due to over a century of extraction, resulting in 6 billion tons of historical tailings. These tailings directly contribute to acid mine drainage and release deleterious elements from unrecovered sulphides. Iron oxyhydroxide alteration products, formed during sulphide oxidation, intricately regulate the mobility of deleterious elements through absorption and incorporation. Despite extensive research on the immobilization properties of iron oxyhydroxides, little attention has been given to understanding the mobility and distribution of deleterious elements during sulphide oxidation, especially regarding the sulphide core and secondary mineral alteration layers, and their impact on environmental contamination. This study extensively characterizes the 70-year-old Klerksdorp tailings dump within the Witwatersrand, focusing on deleterious element partitioning and mobility between sulphide grains and iron oxyhydroxide alteration rims. Using a multi-method approach, including laser ablation inductively coupled plasma mass spectrometry, automated mineralogy, and wet chemistry data integration, metal release and retention across phases were quantified. Results indicate that under net acid-producing conditions, iron oxyhydroxide alteration rims retain a significant proportion (3–15%) of As, Ni, Cu, and Zn (>250 ppm), whereas Co, Au, and Pb exhibit limited compatibility with iron oxyhydroxide alteration (<3% deportment). The majority of remaining deleterious elements reside in mobile, unstable phases, exceeding 88%. Projections highlight a significant partitioning of elements (As, Ni, Cu, Zn, and Pb) into the environment, exceeding 9000 tons, underscoring the urgency of addressing these challenges. Remedial measures for these historical Witwatersrand tailings dumps are imperative, potentially involving metallurgical reprocessing flowsheets targeting sulphides and effective mechanisms for capturing deleterious elements. Such comprehensive approaches are vital for mitigating risks to human health, aquatic systems, and local ecosystems. Additionally, capturing metals such as Cu, Co, and Ni could serve as secondary sources to support the green energy transition.