**Characterising the critical mineral value in**

**copper mine tailings for waste reduction**

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# ABSTRACT

Copper mining is responsible for generating approximately 46 % of the world’s tailings, amounting to nearly 3.7 billion tonnes annually. Many critical minerals, including cobalt (Co), tellurium (Te), selenium (Se), molybdenum (Mo), rhenium (Re), bismuth (Bi), indium (In), and arsenic (As), as well as strategic elements such as sulfur (S), lead (Pb), silver (Ag), and zinc (Zn), are commonly associated with copper (Cu) mineralisation and subsequently remain in Cu tailings. Recovering these elements as secondary resources for the green energy transition has the potential to generate side-stream revenue, enhance portfolio diversification, and financially support site rehabilitation efforts. However, a fundamental challenge for the industry is determining the most effective methodologies for identifying, characterising, and prioritising mine waste repositories, based on their critical mineral content and reprocessing potential.

To address this challenge, a comprehensive multi-scale characterisation approach is necessary, utilising a systematic top-down methodology to optimise resource allocation and expenditure. This study presents a structured roadmap for waste characterisation, demonstrated through a case study on Cu tailings within the North West Queensland Minerals Province. The approach integrates data collection across multiple scales—from repository-scale assessments down to mineral and elemental analysis—and evaluates findings in relation to reprocessing technologies. The workflow incorporates geophysics, geology, mineralogy, geochemistry, and geometallurgy, presented as a tailings characterisation toolbox. Specific techniques highlighted in this case study include a Loupe EM survey, geochemical analyses, facies classification, MLA mineralogical assessments, and geometallurgical test work. Key misconceptions about tailings composition and recoverable elements are addressed, highlighting overlooked value in mine waste. This research provides a structured methodology for assessing reprocessing potential and full-value mining opportunities, offering practical guidance for industry stakeholders aiming to maximise resource efficiency while supporting sustainable mining practices.