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Fe-S-Oxidising Microbial Consortia for the Reprocessing of Polymetallic Mine Waste: A Case Study from Northern Queensland, Australia

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Sustainable reprocessing of mine waste requires efficient, low-impact metal extraction technologies. This study evaluated bioleaching potential of waste rock from two northern Queensland sites: Rishton (RSA) and Baal Gammon (BGA) through integrating detailed mineralogical and geochemical characterisation with 16S rRNA gene sequencing.

RSA was dominated by 75% aluminosilicates with 25% amorphous content, 1% carbonate, and 3% pyrite. Chalcopyrite (1,015 ppm Cu) is encapsulated within iron sulfides and silicate gangue. Acid-base accounting classified RSA as non-acid forming (NAF), with net acid generation (NAG) pH 7.4–7.7 despite 3.10% S, necessitating acid pre-treatment (3.92 g H_2SO_4 / kg over 21 days to achieve pH 2.0) of its high acid-neutralising capacity.

BGA contained 19% Al_2O_3 and 14% SiO_2 with 7% pyrrhotite, chalcopyrite (5,753 ppm Cu), and 0.08% sphalerite. BGA is potentially acid-forming (PAF) with NAG pH 2.1–2.2 and 5.22% S, suitable for direct bioleaching to mitigate acid and metalliferous drainage (AMD).

Batch bioleaching experiments (0.5–1 mm particles, 50 days at 25 °C) compared the efficacy of inoculation with an indigenous BGA consortium and a non-indigenous consortium, isolated from Mt Morgan (MM) Gold-Copper mine site (Australia). 16S rRNA analysis revealed the indigenous BGA consortium was dominated by *Acidithiobacillaceae* (40–62%) and *Leptospirillaceae* (15–30%), largely absent in abiotic controls. These chemolithotrophs proliferated more successfully in the BGA than in the acid-neutralising RSA.

The indigenous BGA culture achieved superior zinc recovery from BGA sample (50%, 5.54 $mg.kg^{-1}.day^{-1}$) compared with the MM culture (35%, 2.77 $mg.kg^{-1}.day^{-1}$). Copper recovery was comparable across inoculated and uninoculated BGA treatments (~35%, ~40.3 $mg.kg^{-1}.day^{-1}$). Bioleaching of RSA with the MM culture achieved 5% Cu and 15% Zn extraction. The bioleached residue indicated increased amorphous content due to secondary mineral precipitation and incomplete sulfide liberation as constraints on extraction efficiency.

This study demonstrates that coupling site-specific mineral characterisation with indigenous microbial consortia has potential to enhance selective metal recovery from sulfidic PAF wastes. Sulfidic NAF material like RSA resisted acidophilic bioleaching, with tailored alkaline bioleaching recommended for investigation. Pre-treatment to enhance mineral liberation may also enhance recovery. Economic viability requires balancing improved recovery with additional processing costs.