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Indigenous microorganisms and the bioavailability of organic matter drive the mobilization of potentially toxic elements and rare-earth elements in alkaline mine wastes

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The ever-increasing demand for technological and precious metals have resulted in intense mining activities producing large stockpiles of tailings. Alkaline mine tailings are considered non-acid forming. However, they contain divalent metals (e.g., Zn and Mn) and alkali metals (e.g., Ca, Mg) which may be harmful to the environment in high concentrations [1]. Often, natural toxic metal leaching is driven by indigenous microorganisms and catalyzed by the bioavailability of organic matter [2]. However, these factors have been overlooked in alkaline mine wastes. This study employed hydrogeochemical, molecular biological (targeted and shotgun metagenomics), and long-term leaching techniques to gain insights into the role of indigenous microorganisms, influence of organic matter in the mobilization of potentially toxic elements (PTE) and rare-earth elements (REE) and generation of alkaline mine drainage in Phalaborwa Mining Complex (PMC). The results confirmed the bioavailability of heavy metals such as Cu (4.4%) > Mn (5.4%) > Ba (4.3%), and REE such as Nd (31%) > La (23%) > Ce (20%), as the tailing contains a high volume of carbonate and phosphate minerals. Moderate concentrations of Total Organic Carbon (TOC) (0.73%) were also detected, which might enable the proliferation of bacteria (*Sphingomonas*>*Novosphingobium*>*Solirubrobacter*) and fungi (*Alternaria*>*Sarocladium*>*Aspergillus*). Functionality analysis of these indigenous microorganisms implied their ability to mobilize REE and PTE by producing siderophore (e.g., *pvdP* and *desC*) and organic acid-related pathways (e.g., gluconeogenesis, anaplerosis and fermentation to succinate). Long-term leaching tests (including biostimulation experiments) revealed the mobilization of high concentrations of PTE and REE through the presence of these compounds and how the bioavailability of carbon sources catalyzes the generation of neutral mine drainage. Overall, these results suggest the inclusion of TOC and long-term bioleaching tests in solid waste regulations and a sustainable alternative to recover REE from PMC alkaline tailings.

References

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