Bacteriologically Driven REE Recovery from Mary Kathleen Uranium Mine Tailings: Potential Formation of Biogenic REE-Minerals.

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The global transition to renewable energy technologies and circular economic principles has fuelled an increasing demand for rare earth elements (REE) due to their unique physicochemical properties. Given their difficulties in processing, securing a stable and sustainable supply of REE for critical technologies to supporting the green energy transition is a significant challenge. Currently, global REE supply relies on a combination of recycling and primary production; however, these sources are unlikely to keep pace with projected future needs. Hence, geochemical waste streams, such as mine tailings, present a promising but underutilised source of REE.

Relinquished in 1986, tailings at the historic Mary Kathleen (MK) uranium mine site in North-Western Queensland have very high (~3 wt%) total REE concentrations, that have generated REE-containing leachates for nearly four decades. Initial geochemical analyses of the mine tailings indicated the presence of ~5 wt% water soluble REE. Based on BSE-SEM analysis of the tailing materials, the REE (Ce: 399 ppm, La: 273 ppm, Nd: 70 ppm, Pr: 31 ppm in solution) are likely leaching from highly concentrated, ultra-fine mineral particles. In a laboratory experiment, the REE-impregnated acidic water (pH=4.30) produced by water washing MK tailings was periodically fed into a cyanobacteria-sulfate reducing bacteria bioreactor (180 days) and samples (water and biofilm) were collected bi-monthly for ICP-OES, SEM-EDS, metagenomics, and proteomics analyses. Preliminary data obtained for ICP-OES analysis of the water collected from the bioreactors demonstrate 90.0-99.9% removal of REE from the solution, indicating bacteriologically mediated intracellular or extracellular organo-metal composites, or secondary REE-mineral precipitation, as REE-CO_3, REE-S, REE-O, and/or REE-PO_4.

Recovering REE from solution via traditional methods, i.e., crystallization ponds, is challenging due to their similar physicochemical properties. With selective biogeochemical processing, biologically mediated REE recovery may offer novel, REE processing pathways providing potential REE-fractionation, transforming a waste into a resource.