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A Characterization of Critical Minerals in Coal Tailings with a Focus on Rare Earth Elements: Sydney-Gunnedah Basin, Australia

Authors : Jason Palozzi, Judy Bailey, Quang Anh Tran, Rohan Stanger

Abstract : In recent years, the topic of establishing an alternative source of critical minerals in by-products of coal mining, preparation, and utilization has gained significant momentum. Despite this, limited work has been done to characterize critical minerals in such materials produced in Australia. This study has investigated the concentration, modes of occurrence, and extractability of critical minerals in coal tailings that represent commercially important coalfields of the Sydney-Gunnedah Basin (SGB) in New South Wales (NSW), Australia. Tailings samples were collected from 10 coal handling and preparation plants (CHPP) that receive coal sourced from various coalfields of the SGB. Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) was used to determine the concentration of various elements listed as critical by the Australian Government. These included the rare earth elements (REEs), Co, Cr, Ga, Ge, Hf, In, Li, Mg, Nb, Ta, Ti, V, and Zr. To characterize modes of trace element occurrence in samples of high economic potential, the following imaging techniques were adopted: Scanning Electron Microscopy with Energy Dispersive X-rays (SEM-EDS), TESCAN Integrated Mineral Analysis (TIMA), and Synchrotron Radiation Induced Micro X-ray Fluorescence (SR-μXRF). By employing SR-μXRF, elemental maps were generated at a high spatial resolution (1μm), allowing for critical mineral distributions and element co-localizations to be detected down to a parts per million (ppm) level. A combination of nitric acid (HNO3) and hydrochloric acid (HCl) was utilized to determine the extractability of the REEs from tailings samples. It was found that the concentration of critical minerals in coal tailings was dependent on the source coalfield, with several samples containing elevated concentrations. Ga and V concentrations exceeded levels of the upper continental crust (UCC) by up to 2 times in certain samples, the concentration of Li and Co measured up to 3 times higher, and the concentration of REEs was up to almost 4 times higher than that of the UCC. Generally, coal tailings that contained lower ash contents exhibited lower concentrations of critical minerals due to fixed carbon acting as a diluent to ash-bound mineral phases. Monazite [(Ce, La, Th)PO4] was identified as the primary mode of light REEs, whereas xenotime [YPO4] and zircon [ZrSiO4] hosted a high relative abundance of heavier lanthanides and Y. During acid extraction experiments, the lighter REEs (La through to Gd) exhibited relatively high rates of recovery (70 to 80%) with solubility gradually decreasing with atomic mass down to approximately 30% for Lu. This trend reflects the observed variation in modes of mineralogical occurrence between light and heavy REEs. An increased demand for certain critical minerals may lead to the incorporation of alternative source materials that would have previously been considered uneconomical. This investigation has demonstrated that discarded tailings from the preparation of coal sourced from the SGB may represent an attractive solution to the impending critical minerals supply shortage.

Keywords : coal tailings, critical minerals, rare earth elements, waste to wealth
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