Characterization of South African Coal Waste for Critical Materials Recovery

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# ABSTRACT

The escalating demand for Rare Earth Elements (REEs) amidst global supply constraints and geopolitical concerns has intensified the exploration of alternative, sustainable sources beyond conventional mining. South Africa's coal industry, characterized by extensive reserves and a substantial volume of coal waste, presents a promising, yet underexploited, potential for REE recovery. This study aims to characterize the coal waste from several key coal mines in South Africa, evaluating its potential as a secondary source of REEs and other critical raw materials (CRMs). Utilizing a combination of analytical techniques, including X-ray fluorescence (XRF), inductively coupled plasma mass spectrometry (ICP-MS), and X-ray diffraction (XRD), we assessed the concentration, distribution, and mineralogical associations of critical materials, including REEs, in coal discards and tailings. Results showed total concentrations of REY+Sc elements varying from 108 ppm to 273 ppm. MgO was found in concentrations varying from 0.04 wt% to 1.08 wt%, while SiO2 present in SA coal wastes showed concentrations varying from 7.0 wt% to 48.0 wt%. These findings were compared against the critical materials lists published by the European Union and Australia, highlighting the strategic importance of the identified elements in global supply chains and their relevance to current and future technological advancements. The study also explored potential recovery methodologies, assessing the environmental implications and evaluating the feasibility of employing sustainable extraction and processing technologies to recover these valuable resources from streams without economic value. By comparing SA local findings in South Africa with the critical materials lists of the EU and Australia, this research not only demonstrates the untapped potential of South African coal waste as a significant secondary source of critical materials but also proposes a strategic approach to resource recovery and mine waste valorization that aligns with global efforts towards a circular economy. This comparative analysis underscores the importance of international cooperation and knowledge exchange in securing the supply of critical materials, offering a path towards sustainable resource management in the coal mining sector.