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Waste mining: Challenges and opportunities for rare earth element recovery

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Rare earth elements (REEs) are essential for clean energy technologies, advanced manufacturing, and national security applications. U.S. dependence on imports has motivated efforts to diversify domestic supply and develop environmentally responsible extraction and processing methods. Industrial waste streams such as coal fly ash represent potential unconventional resources for REE recovery and offer opportunities for both resource recovery and waste reduction. The heterogeneous nature of waste-derived feedstocks presents significant scientific and technological challenges. REEs occur in complex multiphase assemblages, which constrain accessibility and limit extractability. Development of efficient recovery strategies therefore requires molecular-scale understanding of how element partitioning, phase associations, and interfacial processes control REE distribution and reactivity. This talk will discuss a systematic approach to characterizing REE speciation and spatial distribution using complementary techniques that span molecular to bulk scales. By integrating advanced spectroscopy and microscopy characterization with thermodynamic calculations, we identify the structural hosts and coordination environments of REEs and evaluate their relationship to leaching behavior and reaction pathways. Linking speciation with extractability provides a framework for improving selective recovery while reducing residual waste and potential environmental impacts.