# From Waste to Resource: Mechanisms Dictating REEs Recovery from Fly Ash

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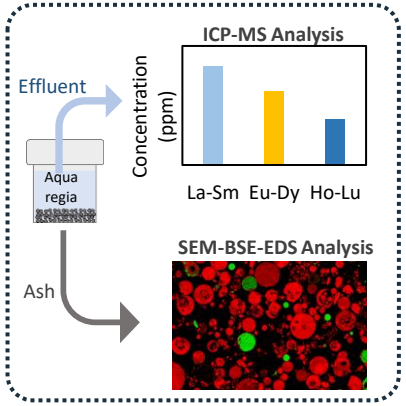
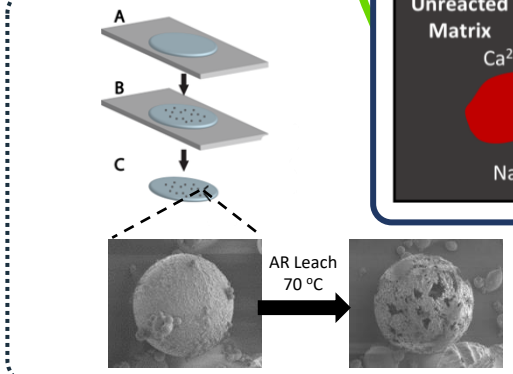
**Introduction:** Rare earth elements (REEs) are critical materials for clean energy applications, (ex.: wind turbines, solar panels, and electric transportation), and their demand is expected to increase in the upcoming years. Identifying nontraditional sources of REEs, therefore, is key for a low-carbon future. This work focuses on coal fly ash (a waste material) as an alternative source of REEs, and the mechanisms dictating recovery.


**Methods:** Initial properties were obtained via electron microscopy and spectroscopy methods. Bulk leaching experiments were carried out, and the resulting effluent and ash were analyzed for efficiency calculations and properties characterization. Direct microvisualization of surface-level changes was enabled by attaching the particles to a polymer.

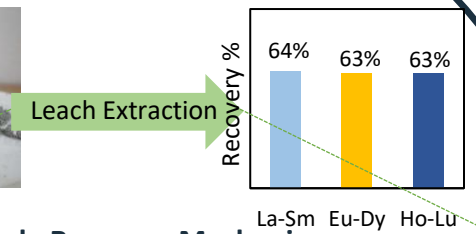
## Bulk Experiments



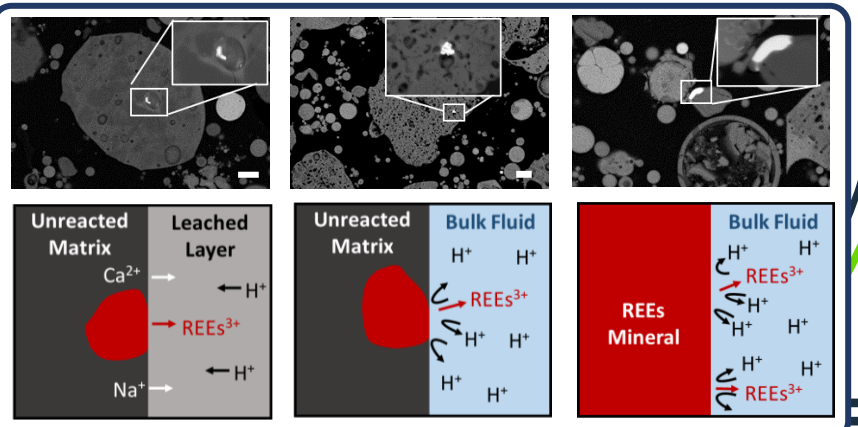

## Microscale Experiments



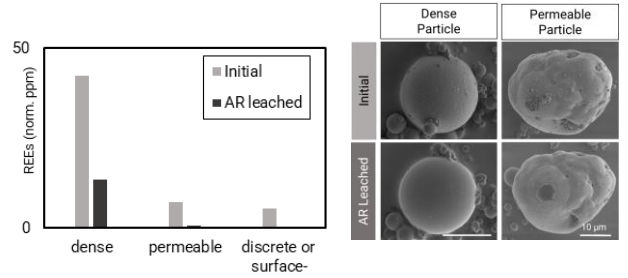

## Research Highlights



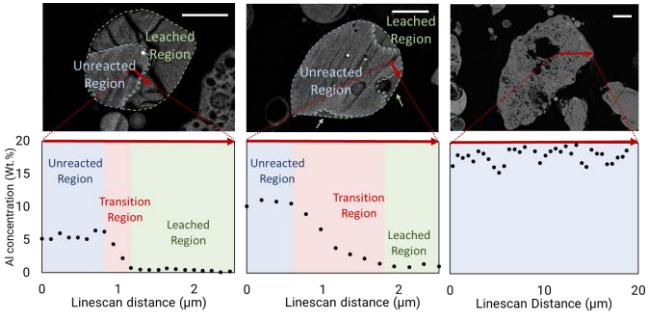

### Microscale Recovery Mechanisms




**Results:** REEs in fly ash are found (i) in dense particles, in (ii) permeable particles, or (iii) as discrete/surface-bound REE-bearing minerals. Chemical leaching recovered >60% of REEs in dense particles, >92% of REEs in permeable particles, and ~100% of discrete / surface-bound REEs.




Chemical and morphological data indicate that (i) REEs in dense matrix are recovered via cation exchange; (ii)REEs in permeable particles are recovered via pore-level dissolution; Discrete/ surface bound REEs dissolve directly in the solution.




**Key Takeaways:** Three types of REEs-hosting particles were identified in coal fly ash, each with a distinct recovery mechanism. This work highlights key microscopic phenomena controlling REEs release, and the data presented here will enable the development of more efficient and targeted recovery methods.

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