Electrochemical Recovery of Rare Earth Materials from Ashes

Jane Le

Advisor: Dr. Sibel Pamukcu, Civil and Environmental Engineering, Lehigh University

Background

- Rare earth elements (REEs) are critical to the world economy as they are essential for the existence of many everyday modern technologies such as mobile devices, computers, electric vehicles and military defense electronics.¹
- REEs divided by light REEs (LREEs) and heavy REEs (HREEs)

Results and Discussion

Electrodialysis

- More than 70% of REE extracted from coal ash
- About 50% of extracted mass found in catholyte
- HREE showed faster desorption and electromigration towards cathode compartment whereas mostly LREE found on CEM, suggesting influence of atomic number on extractability



Figure 1. Periodic Table of Elements highlighting REEs and color-coded based on light or heavy REE.

- The main method of extraction of REEs is mining which requires the heavy consumption of natural resources and is an unsustainable method of attaining REEs.
- Research has been conducted in the field of electrokinetics² for sustainable recovery of heavy metals which involves application of low-level electric current resulting in passage of positively charged ions from solid matrix to liquid matrix where they can



Figure 3. Percentage of REE in different matrices after ED experiment completion

be collected.

Purpose

- Extract rare earth elements from anthracite ash by electrodialysis (ED).
- Determine the optimal pH range that promotes the greatest probability of extraction by pH desorption utilizing ED.

Methods

• ED experiments conducted in 2-compartment cell. Best test conditions were determined to be 50 mA constant current application with pH adjustment for 3-day duration



pH Desorption

- pH that promoted the greatest probability of migration was <2.5
- About 68-100% of LREE and 17-88% of HREE were desorbed
- Gd, an HREE, desorption behavior was similar to that of LREE
- Extraction efficiency of LREE highest at pH of 1.21
- Extraction efficiency of HREE highest at pH of 0.86-1.21.



Figure 2. Schematic of 2-compartment ED cell. Ash-slurry in anolyte (left) compartment and catholyte solution in right compartment separated by cation exchange membrane (CEM)

 pH desorption tests determined optimal pH ranges for extraction of REEs by varying pH and agitating mixture in vertical rotating mixer at 21 rpm and room temperature

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 Image: Sector of the sector

Figure 4. Desorption rates per REE at various pH levels

References

[1] Massari, S. and Ruberti, M. (2013). "Rare earth elements as critical raw materials: Focus on international markets and future strategies".
[2] Pamukcu, S. and Wittle, J.K. (1992). "Electrokinetic Removal of Selected Heavy Metals from Soil," Environmental Progress, AIChE, 11(3), 241-250.