Critical Materials Institute

Microbial Mediated Recovery of Recycled Rare Earth Elements

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REE are critical to energy and national security

- Lanthanides (include Sc & Y)
- Rare Earths are used in batteries, magnets, light phosphors, catalysts, abrasives, etc.
- Anticipated shortfall in HREE supply from China in next 10-15 years
- Demand for REE to increase
- New domestic sources are limited
- Waste streams are a major source of REE

**Increase and diversify supply, increase efficiency of processing, develop substitutes, reuse and recycle materials**

Sources: Dudley Kingsnorth/Industrial Minerals Co Australia; pubs.usgs.gov/
Challenges

- Recovery of metals from recyclable and waste materials involve intense temperature, pressure and harsh chemical multi-step processes

- Leaching of metals from urban wastes have high energy/capital costs, high CO₂ emissions, low efficiency of extraction, other environmental impacts and associated health hazards.

Our challenge is to develop clean, efficient, and low cost processes for REE extraction

Source: greenpeace.org
**Why Microbes?**

**Biological factories**

- Advantages of developing a microbial process:
  - Historical biomining (Cu, Au, Zn, Co, U)
  - Catalysis (dissolution kinetics)
  - Resilient and adaptable (pH/temperature tolerant, metal resistant)
  - Spatially specific (penetrate, biofilms)
  - Resourceful (efficient and specific)

A microbial mediated process can facilitate REE extraction from recyclable materials

Source: ameslab.gov, Heather Owen UWM bacmap.wishartlab.com, easycalculation.com
Microorganisms can be used for leaching and recovery of REE, removal of non-REEs, and selection of REE.
Bioleaching microbes

- Microbes adapted to low pH, high temperature
  - Acidic hot springs
  - YNP Norris Geyser Basin

- Microbes adapted to alter REE solubility
  - Bull Hill rare earth mine
  - Blackfoot Bridge phosphate mine
  - AERC phosphor powders

Collected microorganisms from environments where REE dissolution characteristics may be evident
Organisms for dissolution

Enriched for microorganisms
- Mineral acid production
  - Autotrophs (sulfur oxidizers)
- Organic acid production
  - Heterotrophs (glucose)

Enriched acid producing microorganisms with potential for solubilizing or concentrating REE materials from wastes
Phosphor solubilizers

Evaluated activity
- Acid production (pH, HPLC)
- Phosphate solubility (CaPO$_4$ clearing)

*Isolated acid producing, phosphate solubilizing microbes*
Primary organic acids produced were citric, gluconic, succinic
Isolated microorganisms capable of REE dissolution; similar to those with potential leaching/adsorption capabilities
Biological Process for REE Recovery

Strain isolation

Recycled materials

Strain discovery

Phosphor powders

Strain engineering

Biological Process

Leach

Immobilize

REE Recovery

Sources: RER Bull Hill; Allen 2010 Cur. Opin. Chem. Biol. 14:247; Veolia; Aliexpress
CMI and INL are advancing the DOE mission by developing biological capabilities for sustainable processing of valuable REE resources

- Reduce dependence on foreign REE sources
- Lower environmental hazards
- Reduce wastes
- Build a sustainable bio-based economy

Sources: copper.com.au; freegrab.net; dailytech.com; mining.com
Acknowledgments

- Critical Materials Institute (AMES)

- LLNL
  - Yongqin Jiao
  - Mimi Yung

- INL
  - Debby Bruhn
  - Dayna Daubaras
  - Vicki Thompson
  - Joni Barnes
  - Francisco Roberto (Newmont)
  - Jennalee Reiss (BYU-Idaho)