CMI Accelerating Energy Innovations

Critical Materials Institute

Microbial Mediated Recovery of Recycled Rare Earth Elements

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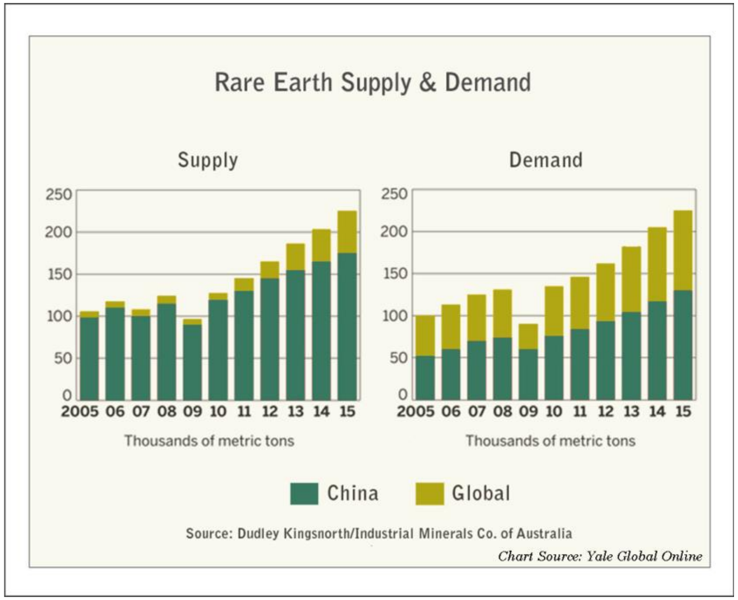
Importance

- 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

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 CO_2 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

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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)

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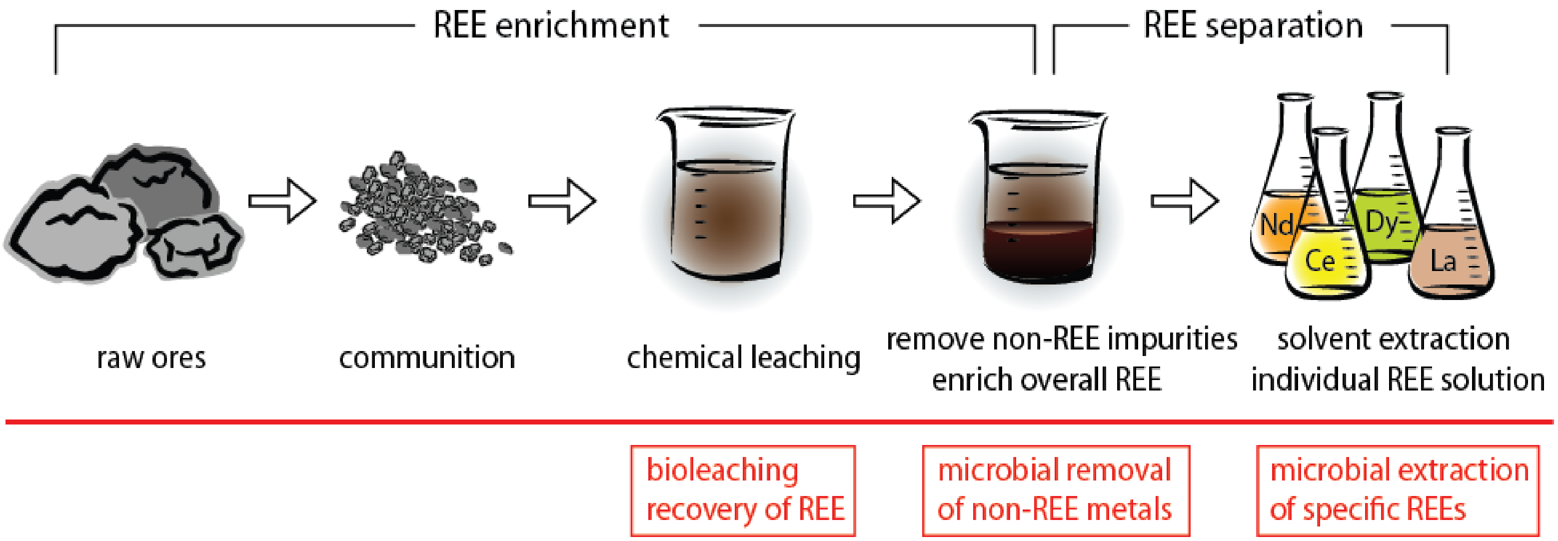
A microbial mediated process can facilitate REE extraction from recyclable materials

Source: ameslab.gov, Heather Owen UWM bacmap.wishartlab.com, easycalculation.com

Bioextraction Process

- A microbiological approach can be integrated into various stages of the REE extraction process



Microorganisms can be used for leaching and recovery of REE, removal of non-REEs, and selection of REE

Collection

➢ Bioleaching microbes

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

Collecting samples at Frying Pan Springs, YNP 84ºC pH 2.2

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

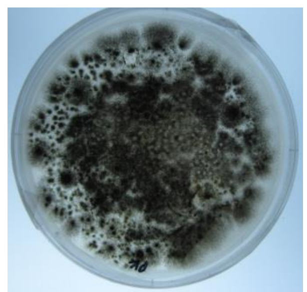
Blackfoot Bridge phosphate seam (dark)

Collected microorganisms from environments where REE dissolution characteristics may be evident

Enrichment

➢ Organisms for dissolution

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

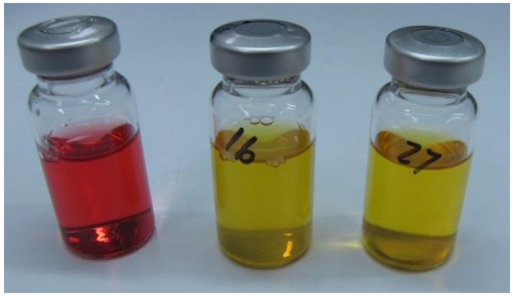


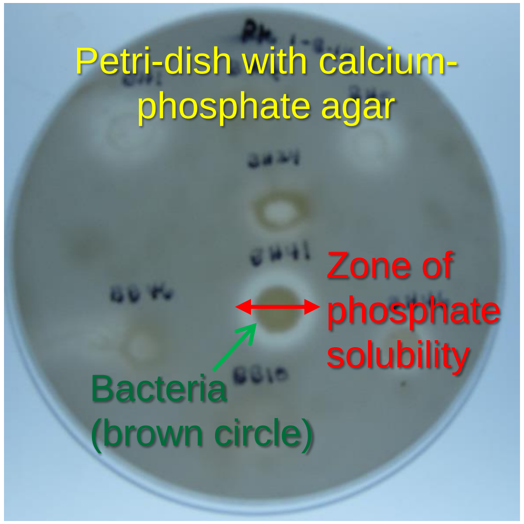
Enriched acid producing microorganisms with potential for solubilizing or concentrating REE materials from wastes

Microbial Isolation

➢ Phosphor solubilizers

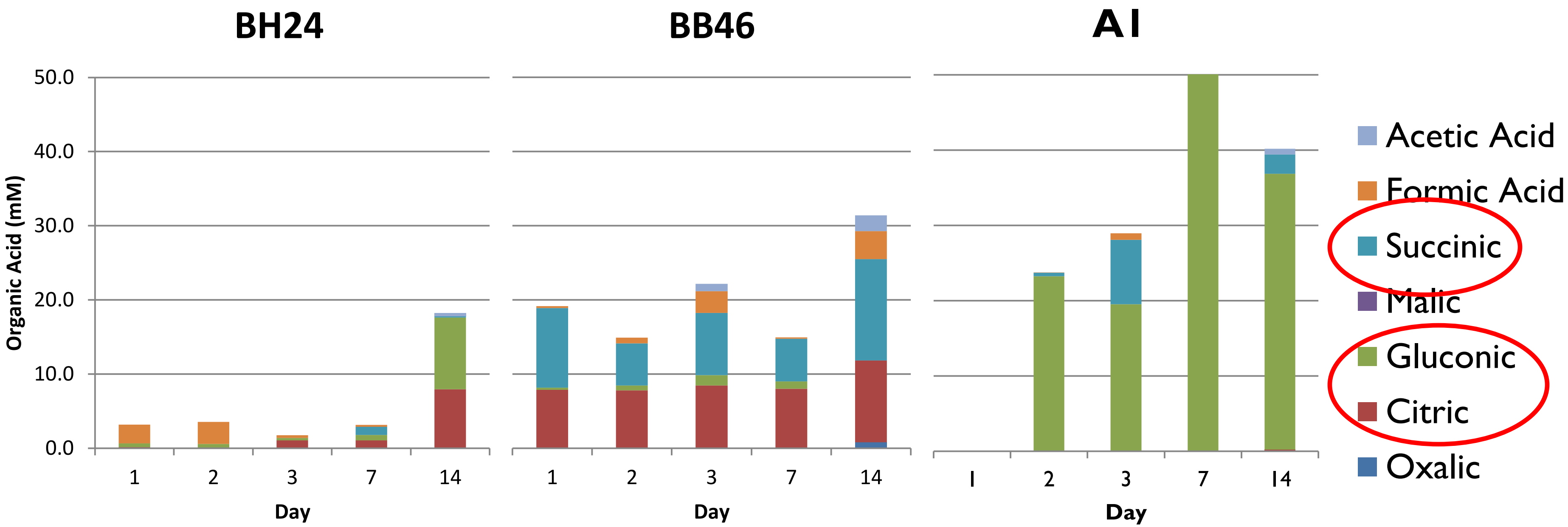
- ➢ Evaluated activity
  - Acid production (pH, HPLC)
  - Phosphate solubility ($CaPO_4$ clearing)





Isolated acid producing, phosphate solubilizing microbes

Organic Acid Production



Primary organic acids produced were citric, gluconic, succinic

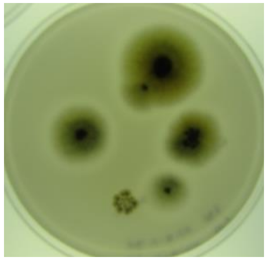
REE Dissolution

Phosphor, catalyst, oxides

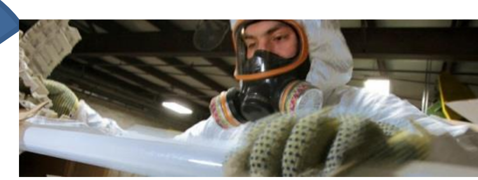
- *Preliminary screening results after 14 days:*
  - *Lamp phosphor reactivity*
    - *>10 mM Gluconic/citric acid, pH 3, 1% (Y, Eu)*
    - *BH24—Pseudomonas*
  - *Fluid cracking catalyst reactivity*
    - *>10 mM Citric acid, pH 3, 3% (La, Ce)*
    - *BB46—Pseudomonas*
  - *REE-oxide reactivity*
    - *>30 mM Gluconic acid, pH 6, >10% (Y, Eu)*
    - *A1—Penicillium*

Isolated microorganisms capable of REE dissolution; similar to those with potential leaching/adsorption capabilities

Biological Process for REE Recovery



Strain isolation

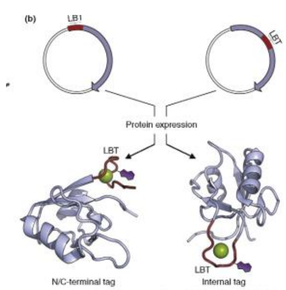


Recycled materials

Strain discovery

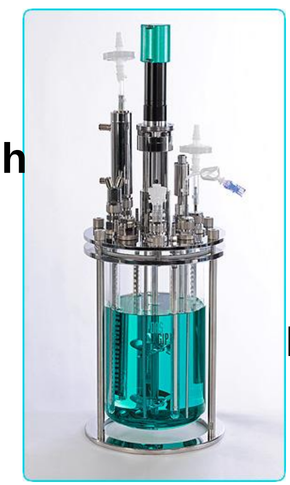
Biological Process

Phosphor powders



Strain engineering

Leach



Immobilize

REE Recovery

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Sources: RER Bull Hill; Allen 2010 Cur. Opin. Chem. Biol. 14:247; Veolia; Aliexpress

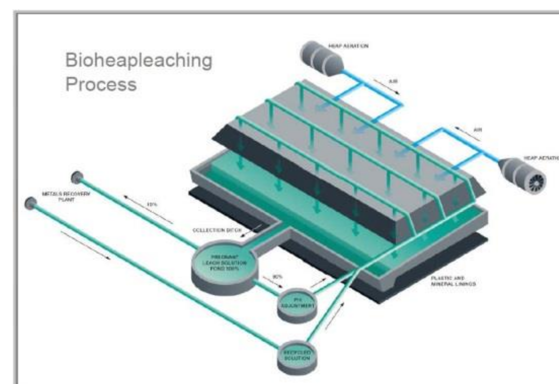
Significance

- **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

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