Diafiltration Cascades for the Efficient Recovery of Critical Minerals and Materials from Waste Streams

Team Nd^{3+} Irish: Merlin L. Bruening, Alexander W. Dowling, Maria Gibbs, William A. Phillip

Energy-efficient & environmentally responsible membrane-based process for recycling REE magnets.

Technology Summary

- *Develop a new paradigm in the* ***membrane-based separation of critical minerals*** that enables ***the recovery of neodymium and coproducts from end-of-life rare earth element permanent magnet scraps*** *without the use of environmentally taxing solvents.*
- ***Automated experiments*** will characterize and identify commercially-available nanofiltration membranes with targeted performance characteristics ***10× faster than current approaches***.
- ***Implementation and optimization of these innovative processes*** guided by a robust digital twin (mathematical model) that de-risks and accelerates technology development and adoption.

Value Proposition & Environmental Impact

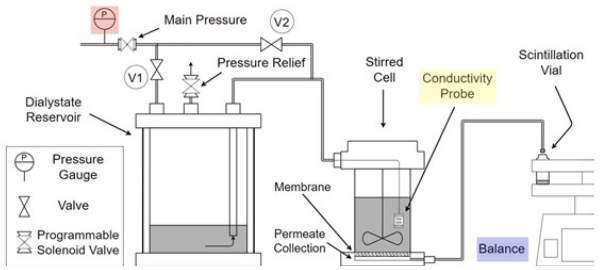
- Help to ***establish a resilient domestic recycling value chain*** *with* ***reduced transportation costs and emissions****.*
- *Rapid response time of membrane processes can* ***accommodate large spatial and temporal feed variations.***
- ***Reduced acid consumption*** *enabled by direct in process reuse.* ***No organic solvents needed***

Phase I Goals

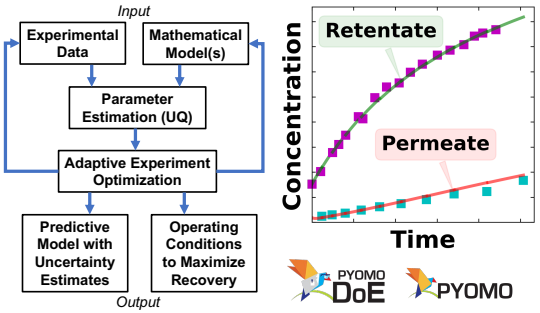
Milestone	Metric
Characterize Nd^{3+}, Fe^{2+}, and H^+ transport through 5 commercial membranes	Membrane with Nd:Fe selectivity ≥ 10
Identify 1-3 regional partners in the REE recycling chain	Identify at least 1 partner for Phase II
Perform proof-of-concept technoeconomic analysis	Quantify reduction in energy consumption, environmental impact

Automated, high-throughput membrane characterization informs membrane selection.

…, **A.W. Dowling**, **W.A. Phillip** (2022). DATA: Diafiltration Apparatus for high-Throughput Analysis, *J. Membrane Sci,* 641, 119743.



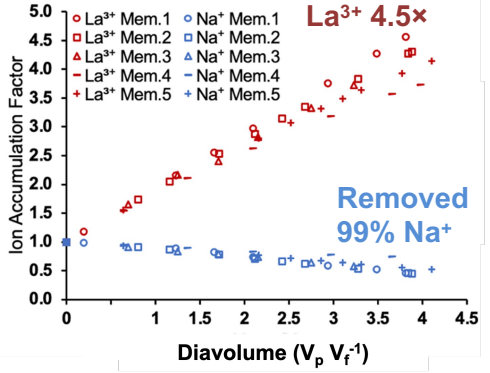
Digital twin guides experiments and optimizes process



…, **A.W. Dowling**, **W.A. Phillip** (2022). Optimal Diafiltration Membrane Cascades Enable Green Recycling of Spent Lithium-Ion Batteries. *ACS Sustainable Chemistry & Engineering*, 10(37), p. 12207–12225.

Staged diafiltration cascades for high purity Nd recovery and acid reuse.

…, **W.A. Phillip**, **M.L. Bruening** (2024). Combined nanofiltration and diafiltration for isolation of rare-earth ions, *J. Membrane Sci,* 711, 123173.



Analysis Support Slide: Diafiltration Cascades for the Efficient Recovery of Critical Minerals and Materials from Waste Streams

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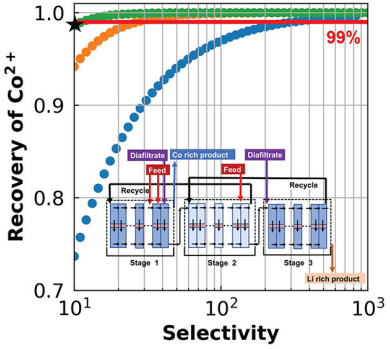
Concept: energy-efficient & environmentally responsible membrane-based process for recycling REE magnets.

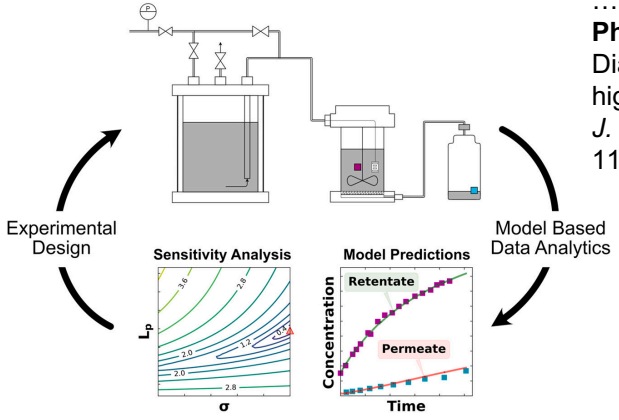
Prior Analysis

- ***Superstructure optimization of diafiltration cascades for battery recycling***. A different application but methods are transferable and result highlight that innovative process designs reduce need for ultrahigh membrane selectivity.

…, **W.A. Phillip**, **A.W. Dowling** (2022), Optimal Diafiltration Membrane Cascades Enable Green Recycling of Spent Lithium-Ion Batteries. *ACS Sustainable Chemistry & Engineering*, 10(37), p. 12207–12225.



- ***High-throughput characterization of membrane properties and uncertainty from dynamic testing data.*** Reduces the time needed to fully characterize membranes over representative feed stream compositions.

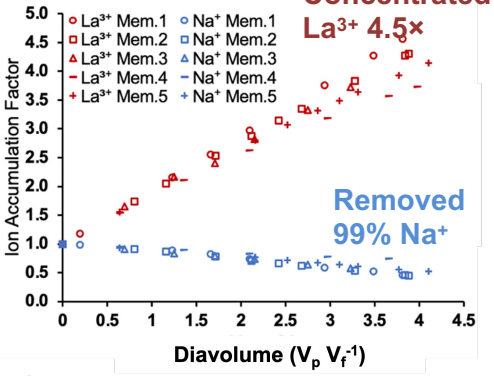


…, **A.W. Dowling**, **W.A. Phillip** (2022). DATA: Diafiltration Apparatus for high-Throughput Analysis, *J. Membrane Sci,* 641, 119743.

Prior Analysis (cont.)

- ***Diafiltration efficiently polishes La^{3+} from Na^{+} or H^{+} using commercially available membranes.*** A different REE system but diafiltration yields 99% pure La^{3+} from an equimolar La^{3+}:Na^{+} feed.

…, **W.A. Phillip**, **M.L. Bruening** (2024). Combined nanofiltration and diafiltration for isolation of rare-earth ions, *J. Membrane Sci,* 711, 123173.



Technical Support and Consultation Needs

- Provide data on quantity, quality, and variability of magnet recycling feed streams.
- Provide data on growth potential for Nd market.
- Critique and help refine proof-of-concept TEA.

Lab Partnership Preferences

NREL:
- Prior collaboration in DOE-sponsored DISPATCHES project
- UND PhD student recently interned and contributed to WaterTAP

ANL:
- Within a 2-hour drive of UND campus

LBL:
- Active collaboration in DOE-sponsored IDAES & PrOMMiS

ORNL:
- UND PhD student recently interned at ORNL