

# Scalable and Regenerable Fibrous Amine-Functionalized Matrix (FAM) Sorbent for Efficient Enrichment of Critical Minerals from Coal Wastewaters

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## Abstract

Supply chain reliability for critical minerals and metals (CM) is a core focus of the U.S. Department of Energy, relevant not only to environmental change but to economic and national security. Critical minerals exist in low concentrations of high-volume coal/clay leachates, geothermal brines, and oil and gas produced waters. Both these considerations could make CMs recovery from these sources feasible yet challenging. Among the available methods to recover CMs, such as chemical precipitation, liquid-liquid extraction, membrane separation, ion exchange, etc., sorption is the most practical. This is due to the simplicity, low energy requirements, low negative environmental impact, and high efficiency when recovering CMs from even low-concentration sources. In this study, we present a novel Fibrous Amine-functionalized Matrix (FAM) sorbent that combines exceptional metal uptake performance with a particle-free design, which effectively eliminates the risk of particles leaching during operation. This sorbent demonstrates an impressive capacity for mineral uptake, coupled with fast metal uptake and release kinetics, allowing for rapid and efficient cycling. Furthermore, the material exhibited high selectivity toward target minerals, ensuring the enrichment of critical resources with minimal interference from off specification species. The regenerable nature of the sorbent also offers significant advantages for repeated use, contributing to its scalability and cost-effectiveness in industrial applications. By improving the efficiency and reliability of CM recovery, innovative sorption-based processes centered around the FAM can be developed. This new technology will play a key role in bolstering national security, improving the U.S.'s position within the global economy, and advancing versatile CM recovery technologies.

## Critical Mineral Supply Risk

MEDIUM TERM 2025-2035



- Supply chain bottlenecks
- Geopolitical dependence
- Resource scarcity
- Environmental and social concerns
- Regulatory and policy barriers
- Technological dependencies
- Limited recycling infrastructure
- Lack of diversification

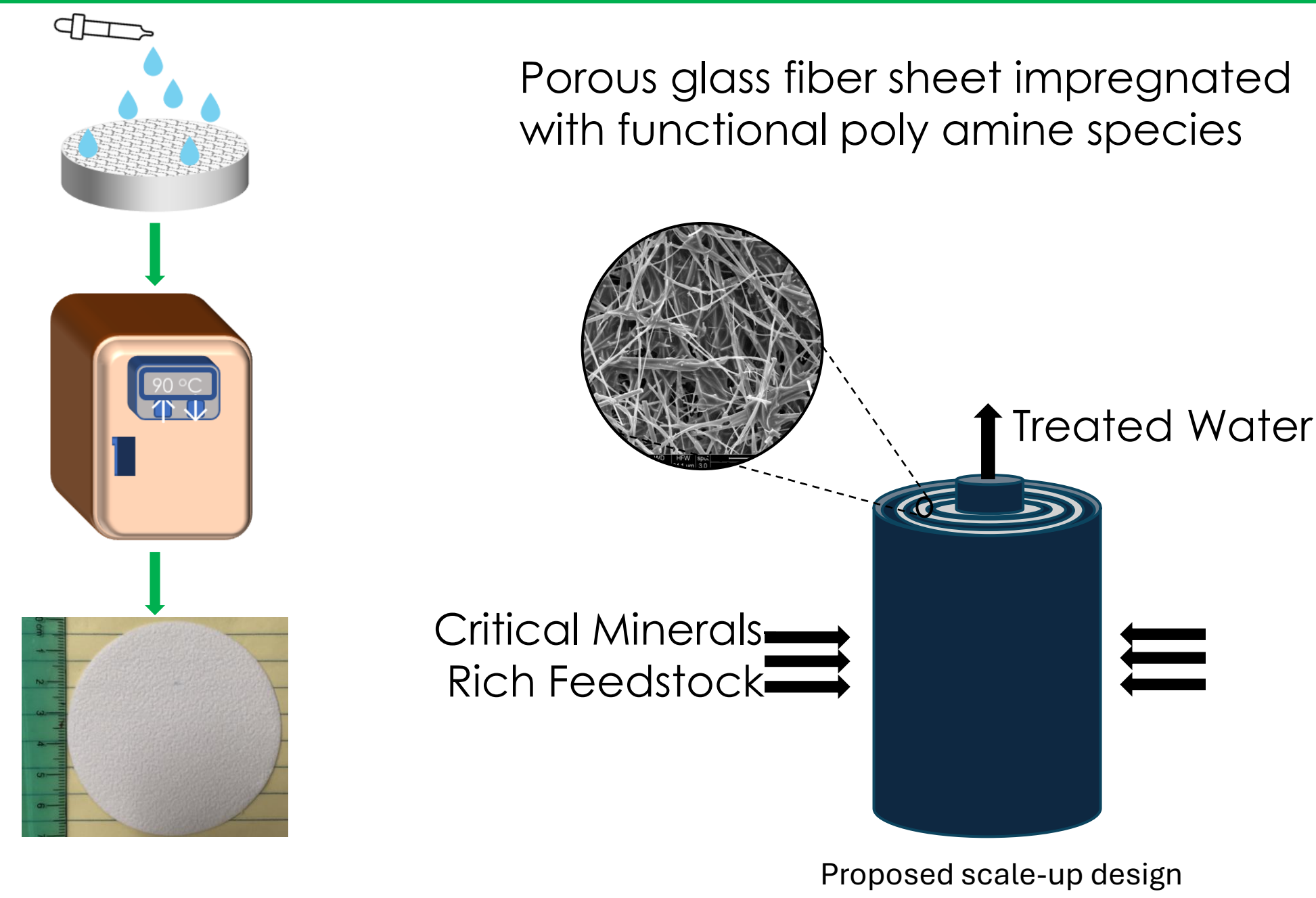
<https://www.energy.gov/cmm/what-are-critical-materials-and-critical-minerals>

## Disclaimer

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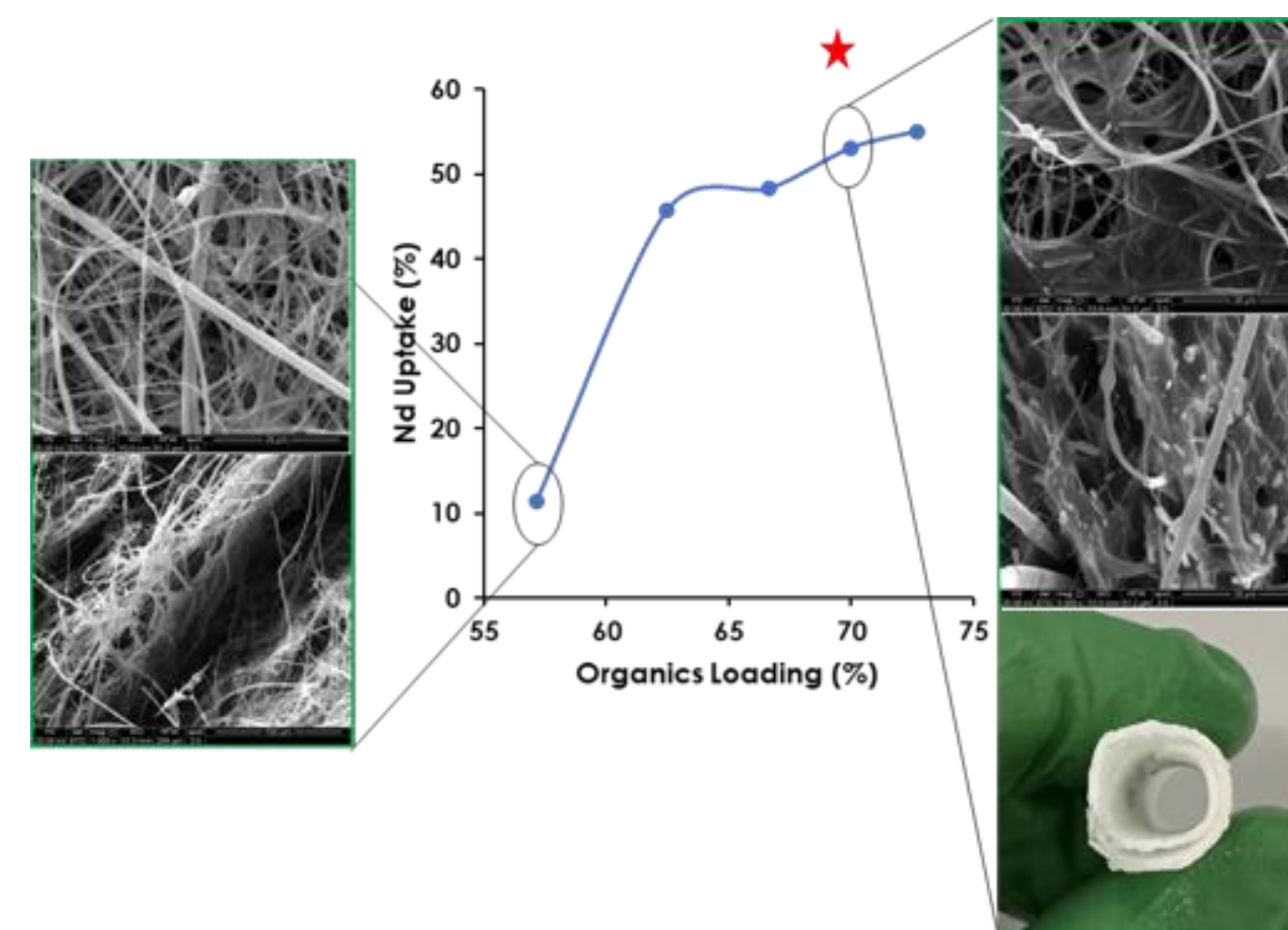
## NETL Patented FAM Sorbent



- **PCT/US23/85206**, Fibrous Amine-functionalized Matrix (FAM) for Contaminant Removal from Gaseous and Liquid Sources, Methods of Making and Use.

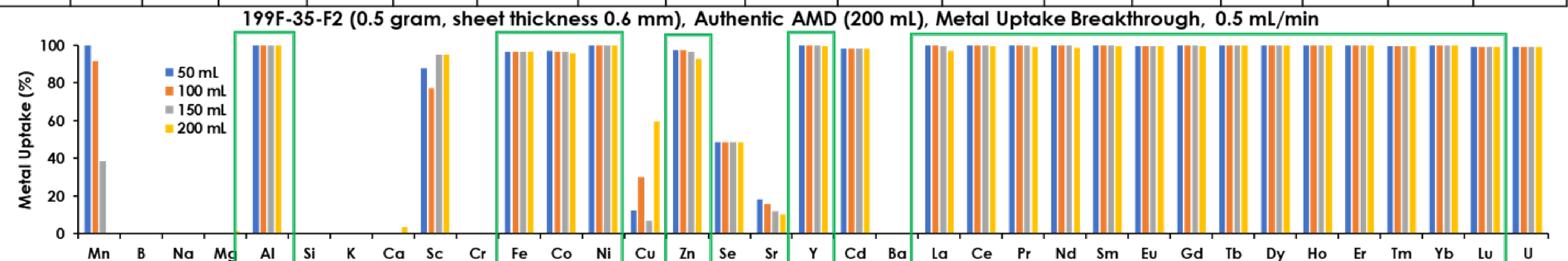
## Results

- FAM Morphology & Metal Uptake Performance



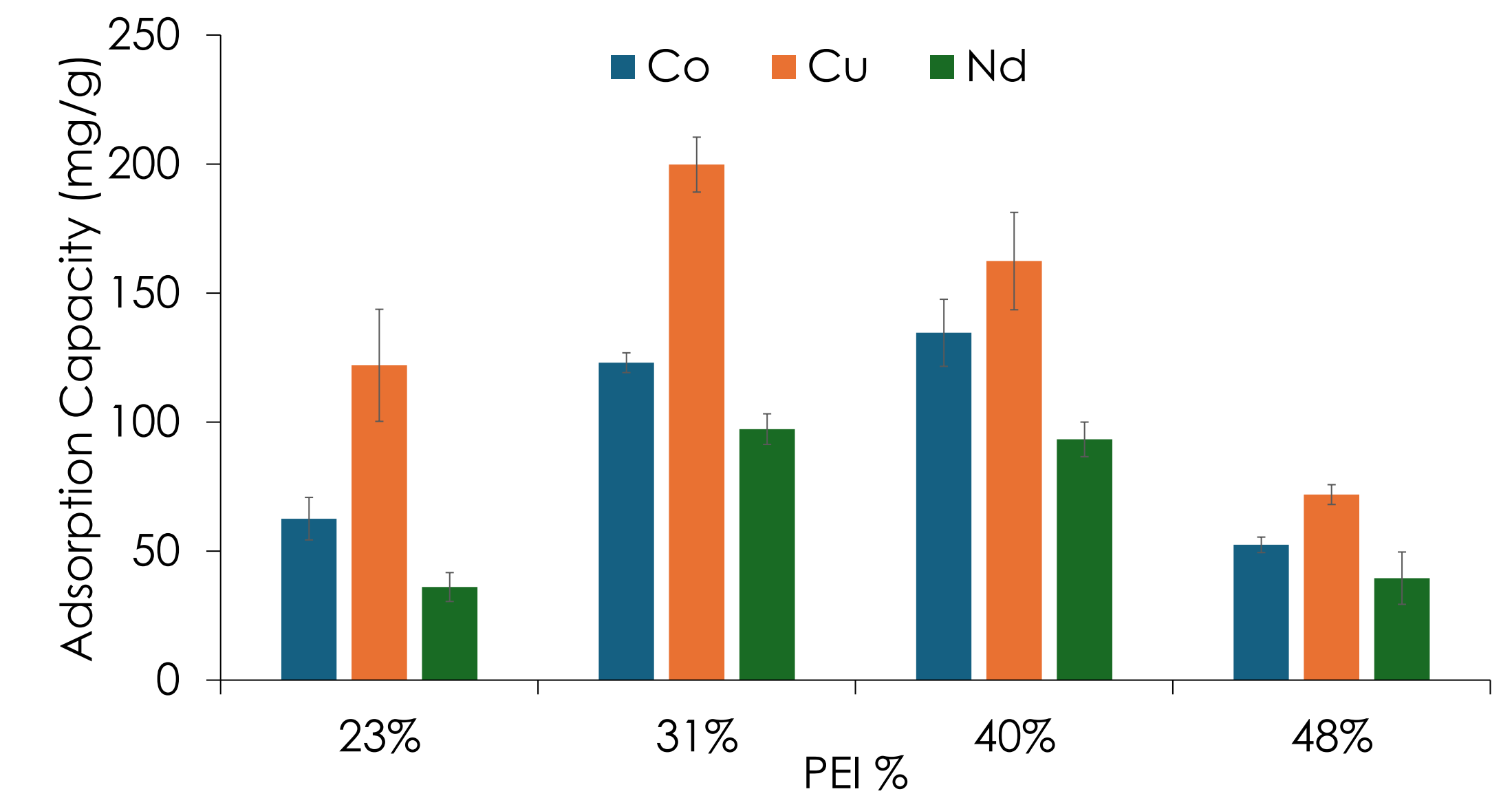
- Metal Uptake from Authentic AMD

Pittsburgh Botanical Garden Acid Mine Drainage (AMD) Metal Composition (ppb)																	
Mn	B	Na	Mg	Al	Si	K	Ca	Sc	Cr	Fe	Co	Ni	Cu	Zn	Se	Sr	Y
13588	16.5	1746	47044	7595	9333	3439	60158	0.53	0.08	182	270	315	3.04	569	2.38	134	41.5
Cd	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	U	
0.83	12.1	15.4	39.6	5.9	26.9	8.06	2.13	11.1	1.73	8.35	1.62	4.05	2.91	2.91	0.42	0.35	

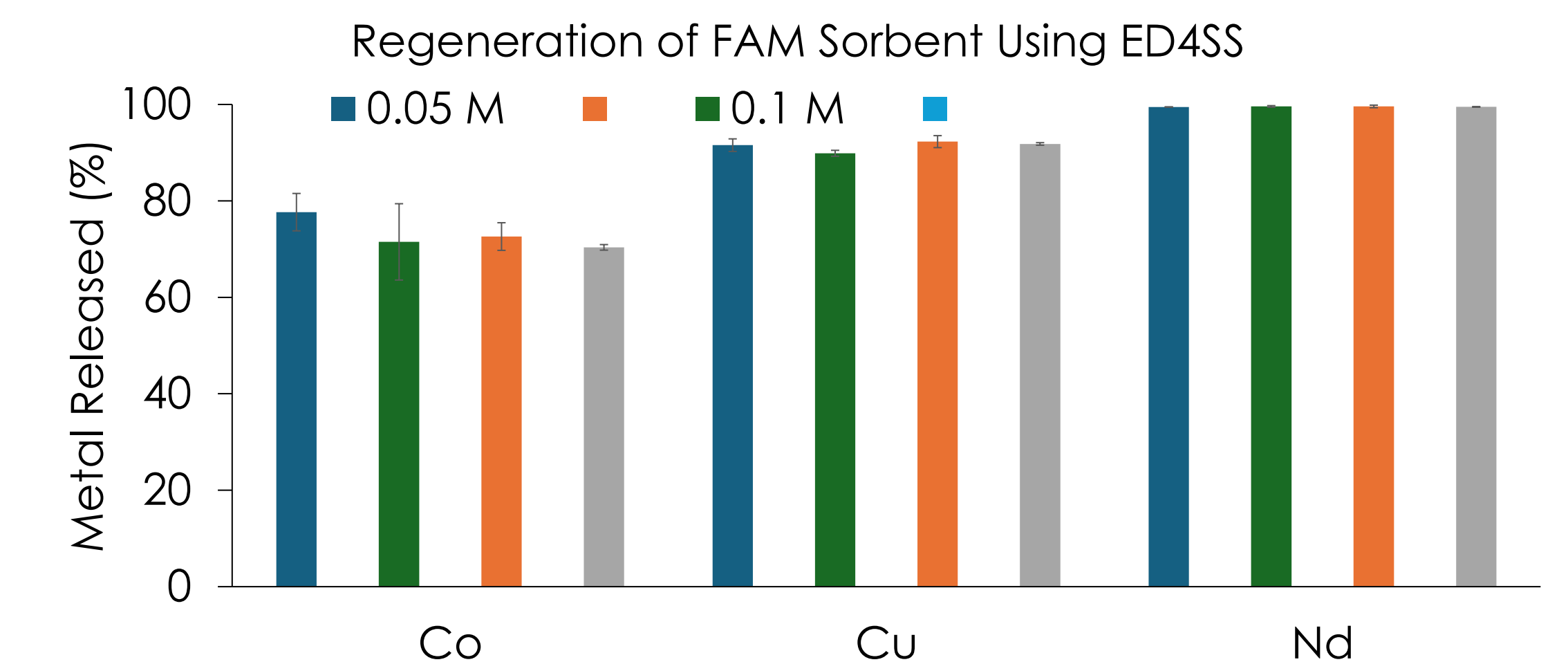


## Results-Continued

- Adsorption Capacities



- Sorbent Regeneration



## Conclusions

- FAM demonstrates scalability and robust mechanical strength, making it suitable for modular applications.
- Its capacity is competitive with those of reported sorbents in the literature.
- FAM exhibits effective regeneration performance for copper and neodymium.
- FAM showcases effective adsorption of critical minerals from AMD solution.