Characterization of Oil and Gas Drill Cuttings for Critical Mineral Recovery and Reuse Potential as Soil Supplements

Maximilian Barczok, Ph.D.
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Authors and Contact Information

Maximilian Barczok[1,2]; Mengling Stuckman[1]; Wei Xiong[1,2]; Meghan Brandi[1,2]; Christina Lopano[1]

[1]National Energy Technology Laboratory, 626 Cochran Mill Road, Pittsburgh, PA 15236, USA

[2]NETL Support Contractor, 626 Cochran Mill Road, Pittsburgh, PA 15236, USA

Outline

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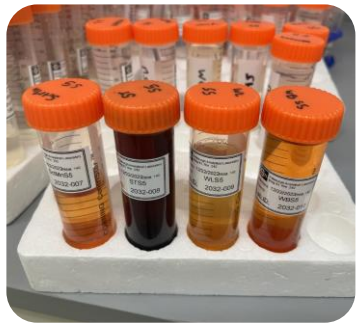


Introduction

- Research goals
- Importance of critical minerals
- Drill cuttings

Critical Mineral Recovery

- Treatment method
- Recovery of critical minerals
- Potential as domestic source

Reuse as Soil Supplement

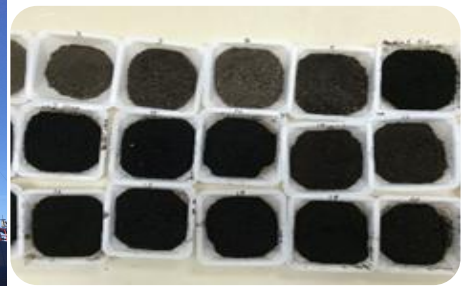
- Setup of experiment
- Biomass growth in each treatment
- Evaluation of soil quality

Future Projects

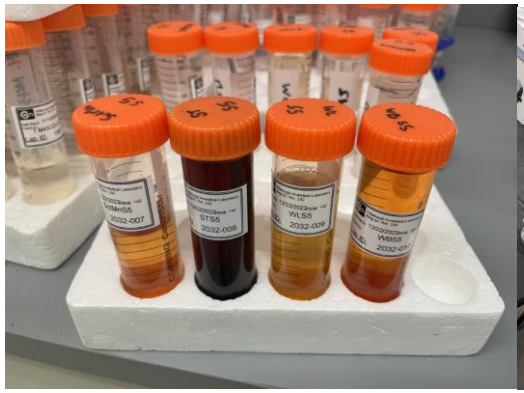
- Upscaling to green roof soil amendment potential
- Refinement of critical mineral recovery

Research Goals

1. **Critical Mineral Recovery:** Evaluate drill cuttings as potential domestic critical mineral source and extract elements of interest
2. **Reuse as Soil Supplement:** Reduction of waste by beneficial reuse of drill cuttings as soil amendments

Drill cuttings from hydraulic fracturing.

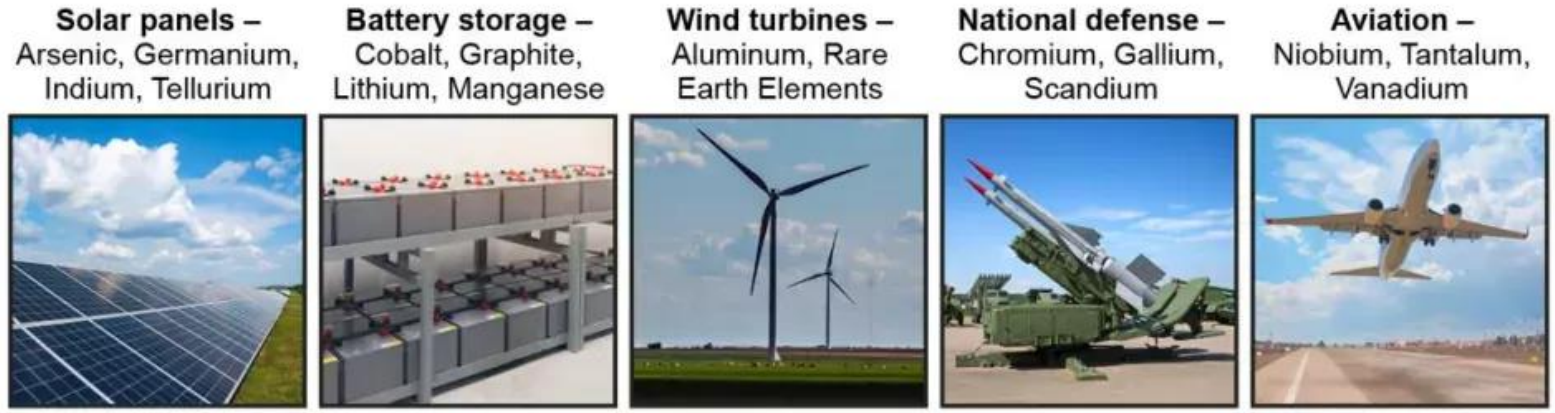



Treatment of cuttings.

Soil amendment for plant growth.

Critical Minerals & Rare Earth Elements (REE)

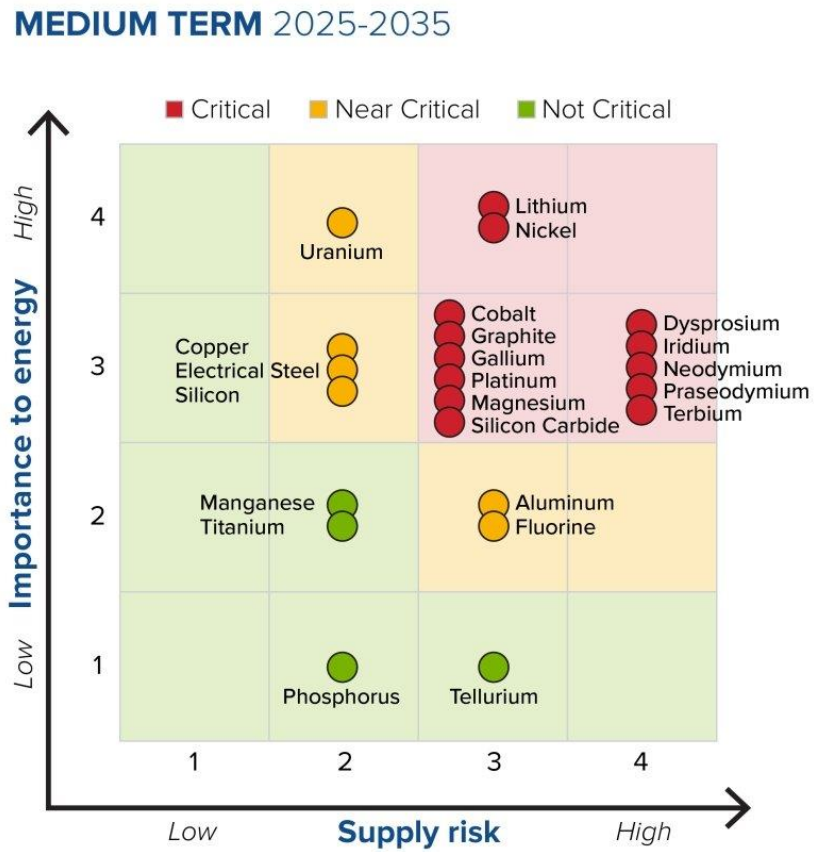
Examples of Critical Minerals Used in Advanced Technologies



Source: GAO analysis of agency documents; Photos: Stockadrik/tongpatong/Rawf8/swisshippo/muratart/stock.adobe.com. I GAO-22-104824

- High risk of supply chain disruption
- Essential to the economy or national security

Clean Energy Technology Drive Demand Expected to Increase Critical Mineral Demands by 5-50 Times



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

Source: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary
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Drill Cuttings From Unconventional Wells

Background

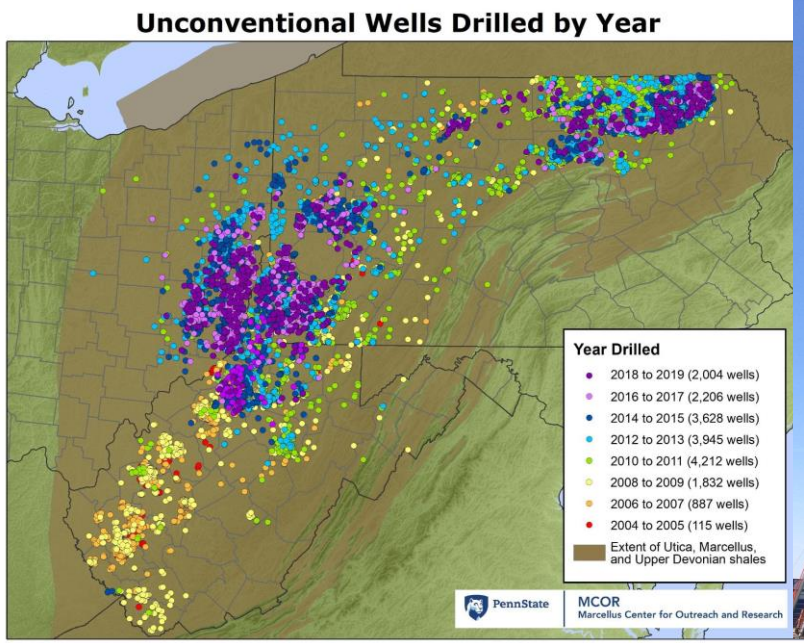

Photo: Drilling site in PA

- From 2004 to 2019: 18,829 unconventional wells were drilled in Pennsylvania, Ohio, and West Virginia alone.
- Around 2,000 tons of drill cuttings are produced from a typical well-drilling operation (per well). Drill cuttings contain both drilling fluids (water-/oil-/synthetic based) and shale rock cuttings.
- Around 800,000 tons of drill cuttings were sent to landfills from PA wells in 2023.

https://marcellus.psu.edu/files/2022/03/tristate-wells-2019.jpg
Ball et al., Waste Management Research, (2012)
Fact Sheet - Onsite Burial (Pits, Landfills), http://web.ead.anl.gov/dwm/techdesc/burial/
Pennsylvania Department of Environmental Protection, 2023 - https://www.dep.pa.gov/DataandTools/Reports/Oil%20and%20Gas%20Reports/Pages/default.aspx

Drill Cuttings from Unconventional Wells

Background

Potential recovery of critical minerals and reuse as soil supplement to support plant growth

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Critical Mineral Contents in U.S. Shales

NATIONAL ENERGY TECHNOLOGY LABORATORY

Sample	Ba (ppm)	V (ppm)	Cr (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	Ti (ppm)	Li (ppm)	REE (ppm)	TOC (%)	Notes
MS-5HA	30167	150	84	70	36	79	3711	24	168	2	High clay
MS-5HB	51723	917	80	363	229	1691	2390	4	204	10	High pyrite
MS-5HC	48515	250	44	97	66	99	1972	BDL	160	3	High calcite
MS-5HD	47938	824	85	228	139	561	3177	BDL	159	7	Medium pyrite
MS-476	1302	382	104	216	177	357	5045	18	235	4.2	High clay
MS-505	1010	465	74	249	180	116	3667	BDL	**239**	7.8	High clay
MS-548	790	1165	104	517	282	1671	2175	8	232	13	High Pyrite
MS-967	488	1112	97	518	**294**	62	2351	6	153	12	High Pyrite
BAK-229	188	**1575**	131	**654**	125	284	2950	**72**	169	**19**	High TOC
BAK-254	207	65	73	BDL	BDL	BDL	2950	23	146	4	High calcite
BAK-300	110	392	56	249	65	**2567**	1644	5	87	8	High quartz
WC-310	2385	132	201	103	41	452	**8268**	BDL	184	5.6	High quartz
WC-400	947	148	188	99	34	222	2849	BDL	130	4	High quartz
WC-460a	9561	123	185	101	41	197	3551	BDL	183	5.5	
WC-460b	2836	113	178	102	38	285	5138	BDL	179	5.4	
WC-480	1592	138	**206**	105	46	189	4006	BDL	217	4.9	
Utica	**76271**	53	45	33	67	106	1929	BDL	123	11.1	High Calcite

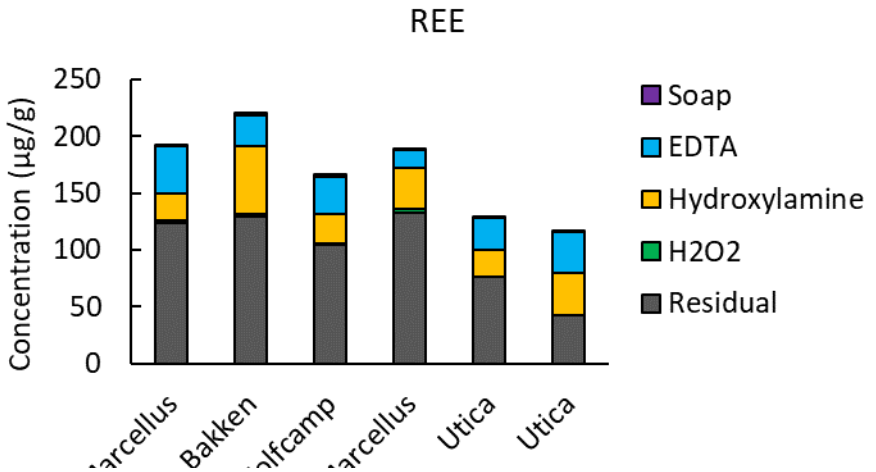
- High TOC correlates with high CM such as REE, V, and Ni
- Drill cuttings high in barite

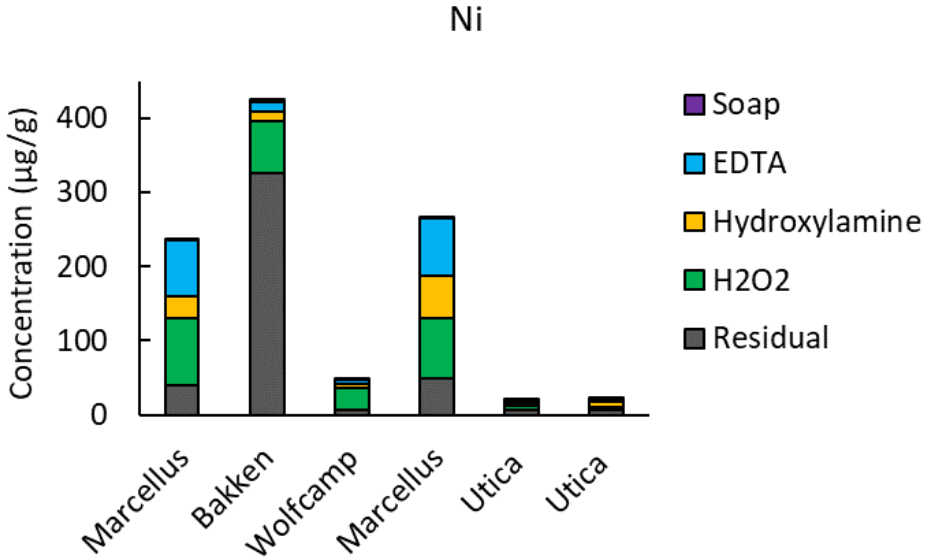
Treatment of Cuttings for Critical Mineral Recovery and Reuse as Soil Supplement

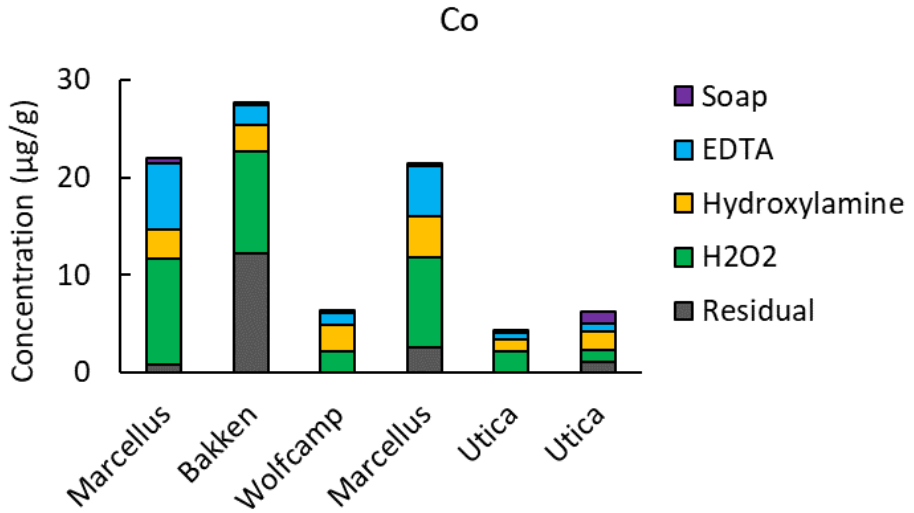
Step #	Targeted Fraction	Reagents	L:S ratio	L (mL)	S (g)	Temp (°C)	Duration (h)	pH
1	Diesel Removal	5% soap solution + sonication	5:1	35	7	25	0.15	
2	Carbonate + Barite	0.5 M EDTA (ethylenediaminetetraacetic acid) + sonication	10:1	35	3.5	25	0.15	8
3	Bond to Amorph FeO	0.25 M NH_2OH•HCl in 0.05 M HCl	20:1	30	1.5	60	2x1.5	
4	Bond to Organics and Sulfides	1) acidified 30%H_2O_2	10:1	10	1.0	25/85	1 + 1	2-3
		2) acidified 30%H_2O_2	10:1	10	1.0	85	1	2-3
		3) 1 M ammonium acetate wash	50:1	50	1.0	25	16	2.0
5	Residual	$LiBO_2$ Digestion	-	-	0.1	-	-	-

Good Recovery of Essential Critical Minerals

- Soap + sonication removes up to 90% of diesel
- EDTA and Hydroxylamine are effective at recovering REE (up to 46%) – (Dy: up to 85%; Nd: up to 74%) – P shows high correlation to REE recovery (r^2 = 0.81)
- Other critical minerals have up to 90% recovery such as Co, Ni, and Cu

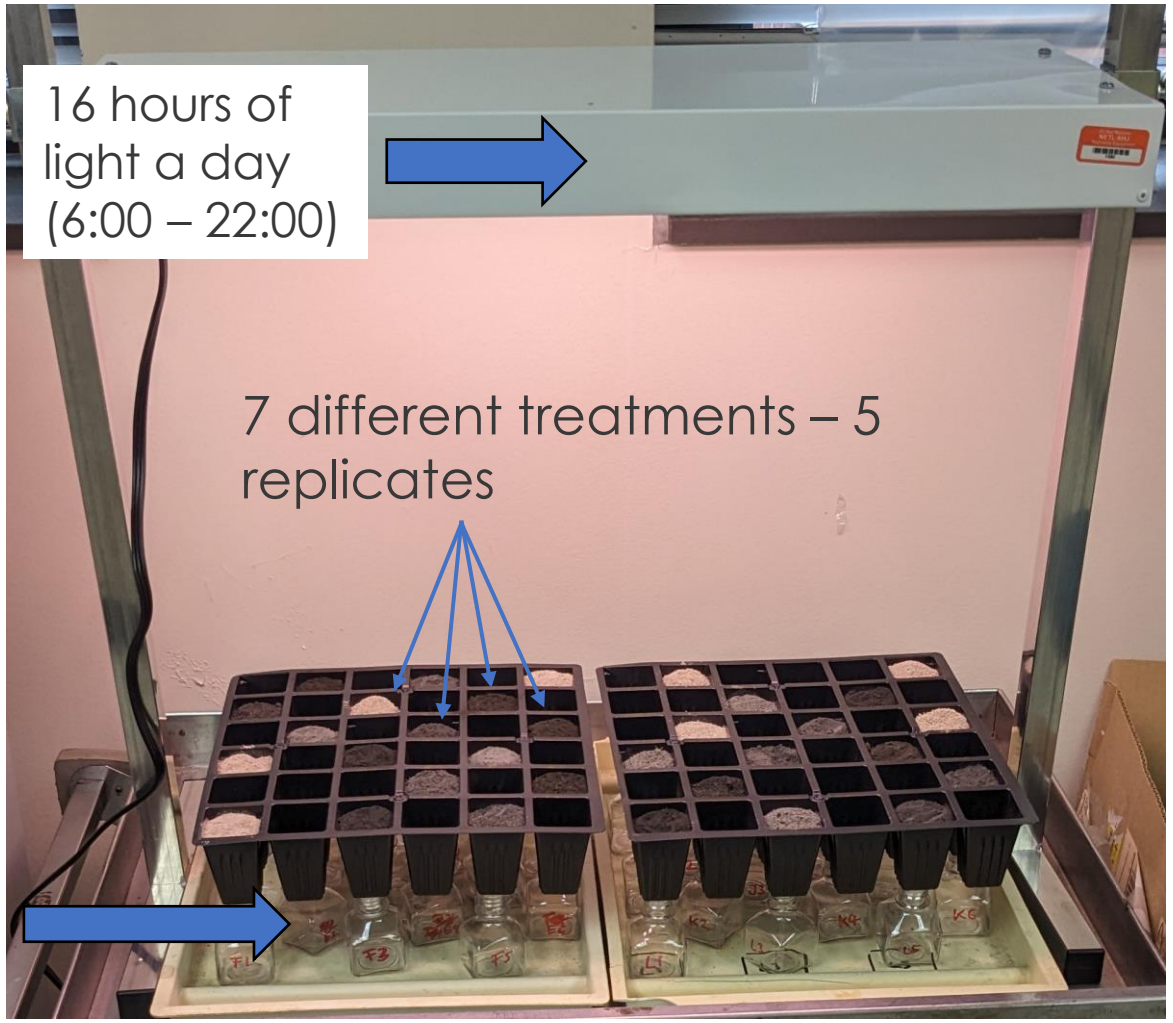






Treated Cuttings as Soil Amendments

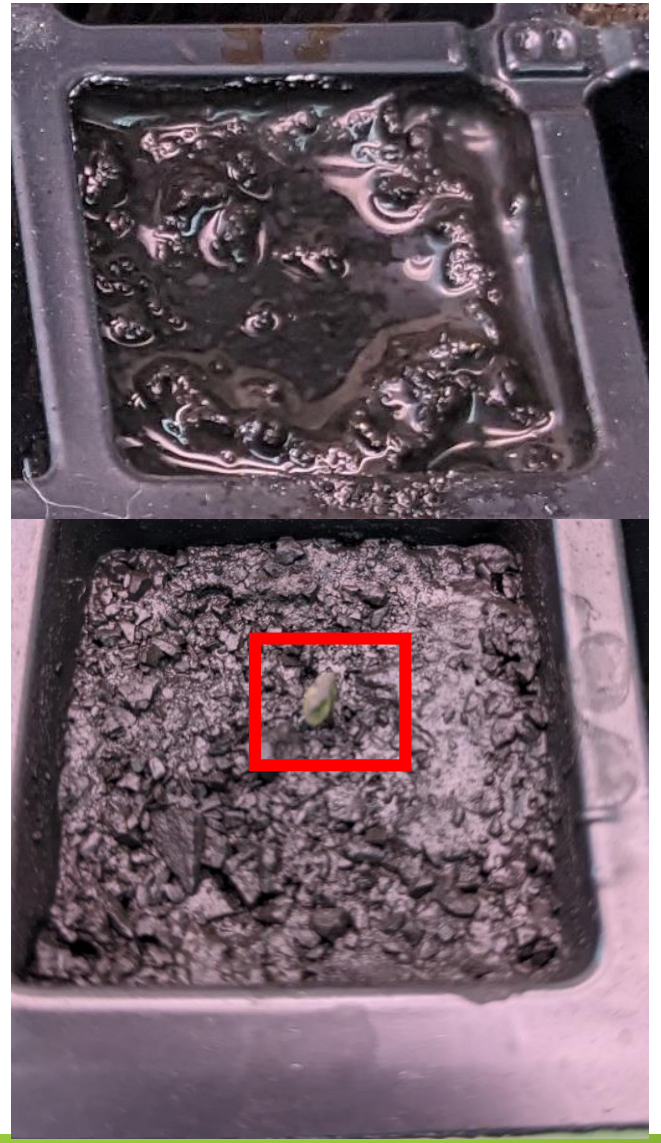
- Based on Early Seedling Growth Protocol for Soil Toxicity Screening (Norton, 1996)
- 7 different treatments
  - Artificial soil control
  - Artificial soil with seeds (0% cuttings)
  - Raw drill cuttings
  - Treated drill cuttings
  - 25% treated cuttings/75% artificial soil
  - 50% treated cuttings/50% artificial soil
  - 75% treated cuttings/25% artificial soil
- Watered daily (except weekend)
- Lettuce seeds



Treated Drill Cuttings as Soil Amendment

- Untreated Cuttings
  - Often contaminated with diesel
  - Unfavorable pH for plant growth
  - High salinity (>5,000 ppm Na and >1 wt.% Ba)
  - Above background As levels (>40 ppm)

- Treated Cuttings
  - Removal of diesel
  - Unfavorable pH for plant growth
  - Reduced salinity (>1 wt.% Ba)
  - Reduced heavy metal contamination (79% and 73% reduction in As and Pb)



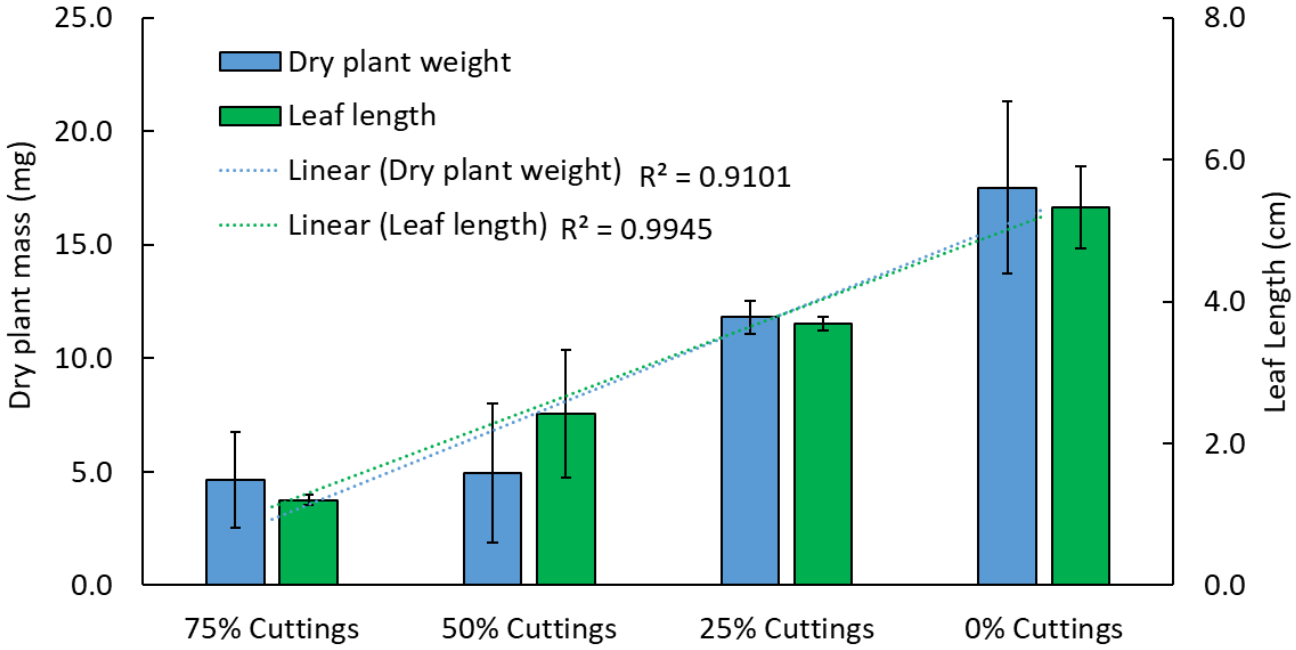
Treated Cuttings as Soil Amendment Support Plant Growth

0% cuttings

25% cuttings/
75% artificial
soil

Treated Cuttings Can Be Used as Soil Amendments

- Plants grown for 45 days
  - Fertilized after 2 weeks
- All mixtures of treated cuttings and soil had seedling growth (60 -100% germination)
- Correlation between plant growth and cutting content in soil
- 100% treated cuttings - died within a week
- Raw cuttings - no growth
- High salinity in the cuttings hinders plant growth



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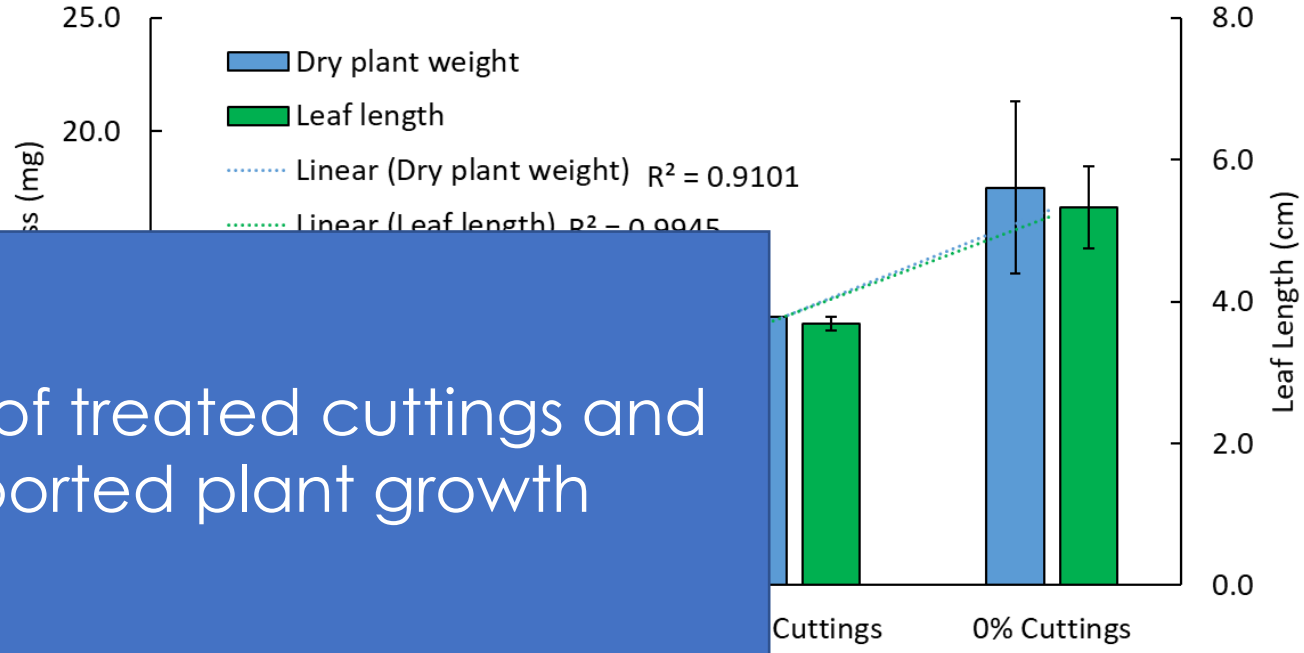
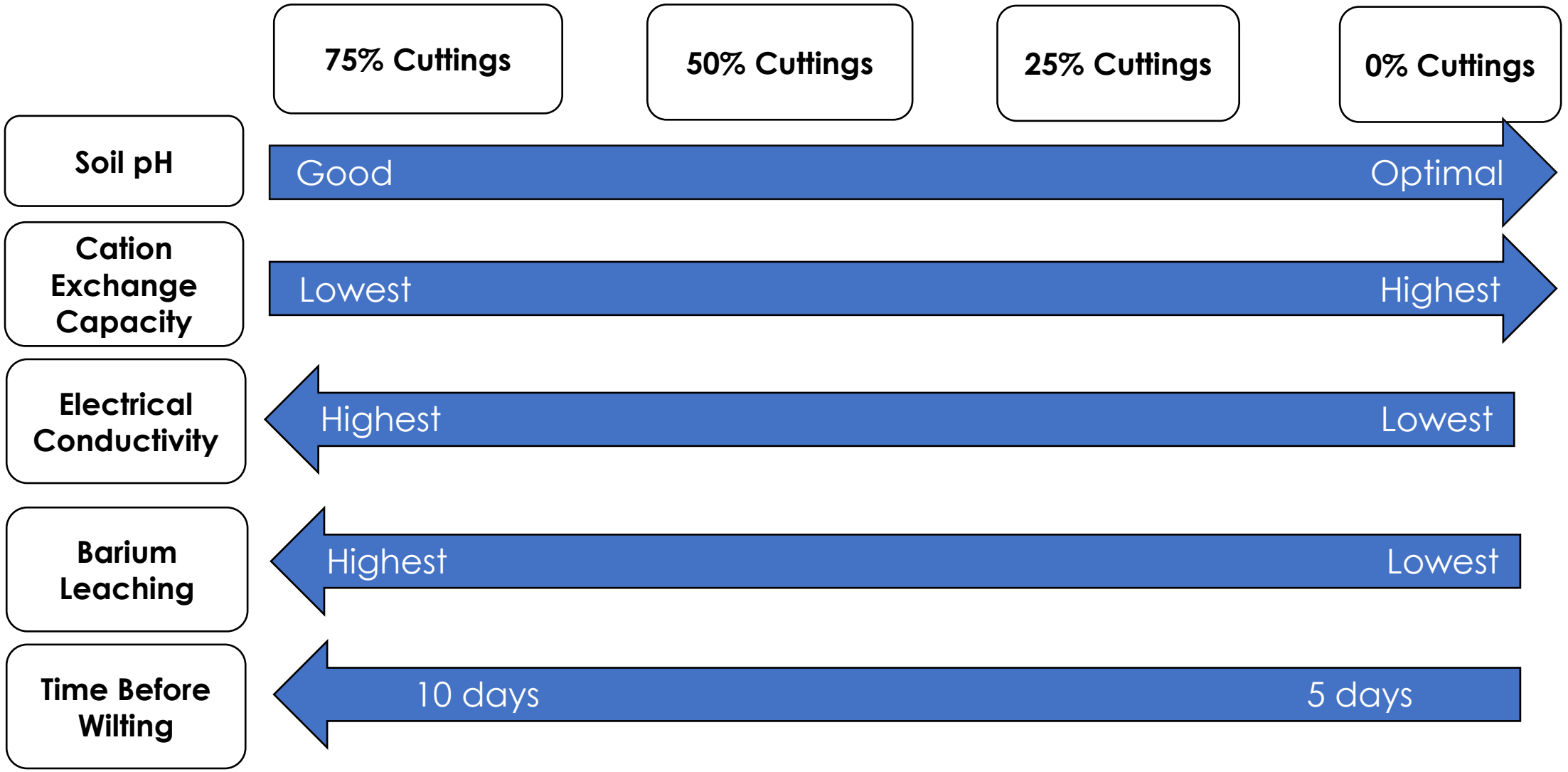


Cuttings Affect on Soil Quality



Conclusions

Drill cuttings have high potential for critical mineral recovery:

- **Cu, Co, Ni, and REE** have a high recovery rate
- **V, Ba, and Li** have high concentrations and need recovery method refinement
- **Treated cuttings can be used as soil amendments** in concentration to grow plants

Important take aways:

- Drill cuttings have potential to serve as a **domestic source for some critical minerals**
- Mixtures of soil and treated drill cuttings **can support plant growth** leading to potential reduction of waste to landfill deposition
- Future work will include scaled up experiments and refinement of recovery

Acknowledgements

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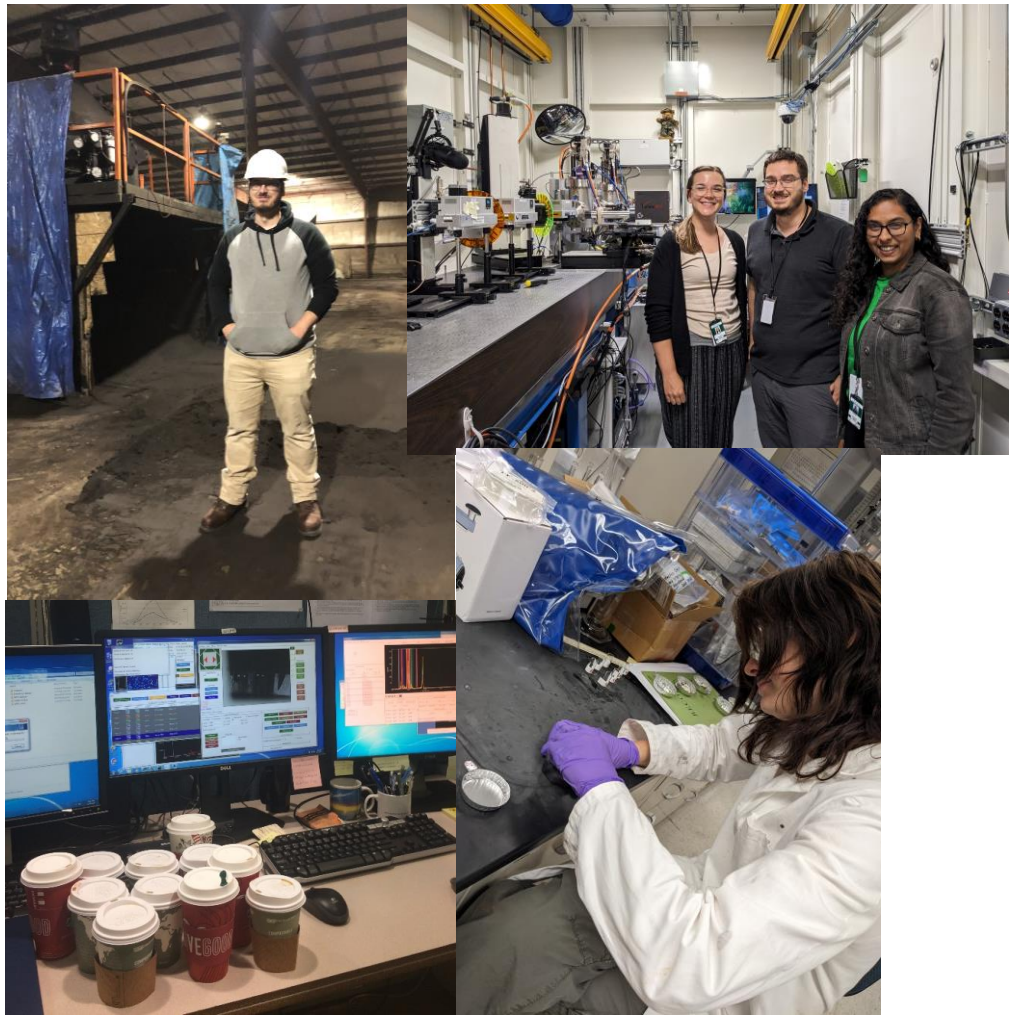

Acknowledgments

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CONTACT:
Maximilian Barczok
maximilian.barczok@netl.doe.gov