Maximizing Value from Municipal Solid Waste Incineration Ash — Electrochemical and Chemical Methods for Material Recovery

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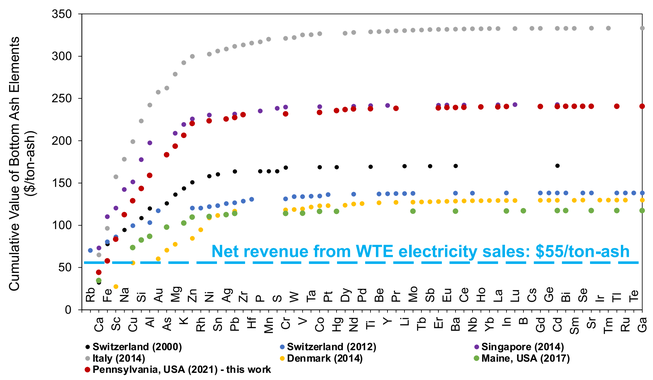
Introduction & Motivation

- 12% of the 292 million tons of municipal solid waste (MSW) generated annually in the US is burned for renewable energy at waste-to-energy (WTE) facilities[1]
- Due to the dropping prices of electricity, WTE is becoming less cost efficient than landfills
- Landfills are the third largest emitters of domestic methane and present no way to recycle materials

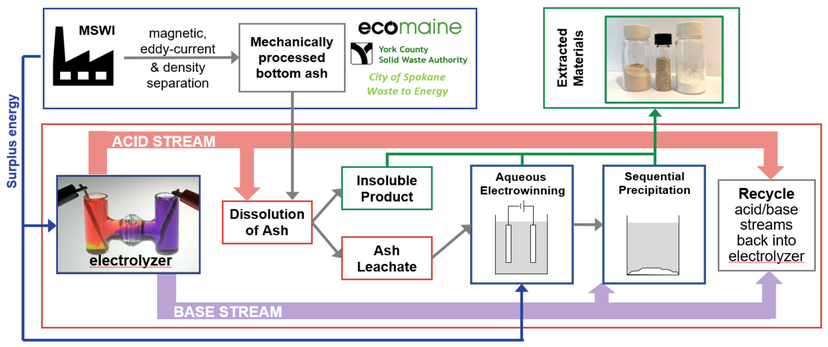
What kind of materials are in our trash?



Can we make WTE more economically beneficial by using it as a pipeline for materials recovery?

Green Chemistry & Our Technology

We propose using the cheap WTE renewable electricity to power an electrochemical mining operation to recover valuable materials out of MSW incinerator (MSWI) ash

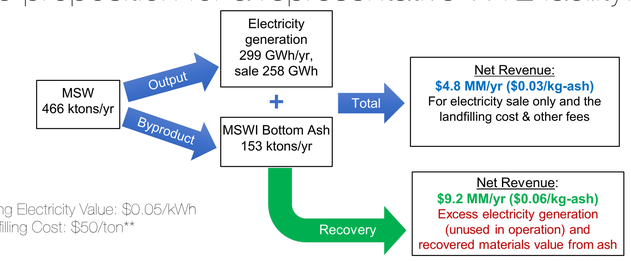


Electrochemistry allows for:

1. Selective recovery of different critical elements
2. Utilization of WTE renewable electricity
3. Zero-waste sequential process for high purity products
4. Environmentally friendly process requiring only salt, water, and electricity

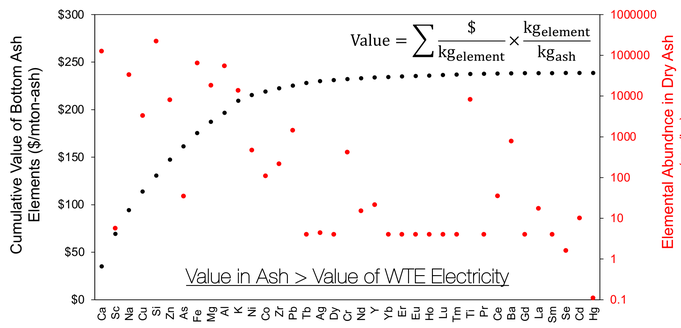
Technoeconomic Analysis

Value proposition for a representative WTE facility:



Assuming Electricity Value: $0.05/kWh and Landfilling Cost: $50/ton

We can estimate the value contained in the MSWI ash based on the value of its elemental components



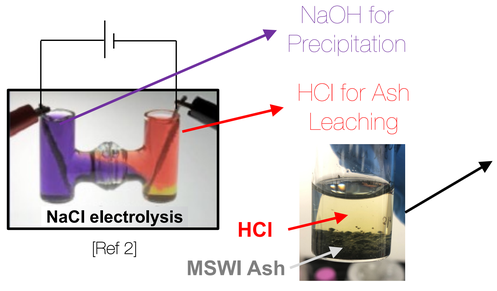
Total Estimated Ash Value: ~$0.25/kg-ash, Value of Mined Products: ~$0.14/kg-ash (Al, Cu, Fe, Mg, Ni, Pb, Zn)

Overall process feasibility will depend on factors including which elements are recovered, product purities/value, electricity prices, landfilling costs, and energy consumption.

Experimental Process and Results

Ash Processing

Necessary acids/bases for leaching of MSWI ash can be generated by electrolysis (e.g., chlor-alkali process)



[Ref 2]

Ash leaching separates elements from ash into a solution for us to recover from

Major Elements (ppm)		Minor Elements (ppm)	
Al	2346	Ag	0
Ca	7950	B	13
Cu	50	Ba	2
Fe	1851	Bi	3
K	222	Cd	1
Mg	853	Co	8
Na	1125	Cr	4
Pb	65	Ga	9
Zn	340	In	0
		Li	67
		Mn	52
		Ni	7
		Sr	18
		Tl	0

Composition of MSWI ash dissolved in 1M HCl for 24hrs

Materials Recovery Strategy

Materials can be recovered from the ash leachate through:

1) Electrowinning

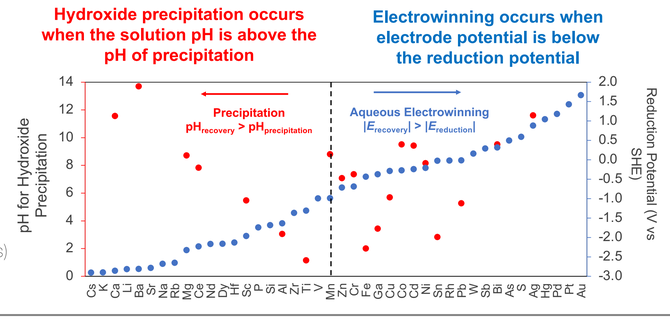
$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu^0_{(s)}$

+0.34 V (vs SHE)

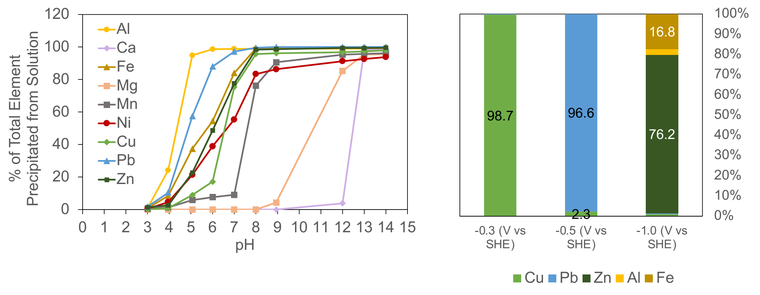
2) Chemical Precipitation

$Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)}$

pH = 12

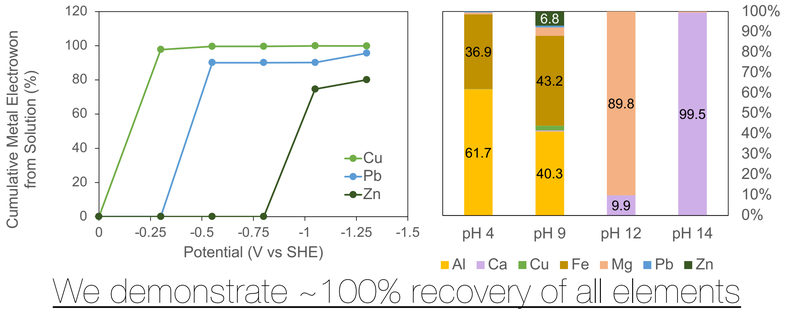


Electrowinning



We demonstrate ~100% recovery of Cu and Pb (with high purity >95%) and recovery of >80% of Zn

Precipitation



We demonstrate ~100% recovery of all elements including high purity >90% $Mg(OH)_2$ and $Ca(OH)_2$

Conclusions & Future Work

Conclusions:

- Electrochemical mining of MSWI ash can recover materials using cheap WTE renewable electricity
- Strategies for materials recovery using electrowinning and chemical precipitation show high degrees of recovery of high purity products
- TEA suggests ash mining to be a more cost-effective value proposition than just electricity generation

Future work will:

- Develop advanced technoeconomic models for optimizing process decisions
- Implement strategies for improving leaching/recovery efficiency, energy consumption, and product purity
- Investigate opportunities for further elemental recovery, various feedstocks, and product refinement

Acknowledgements

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References

1. Waste-to-energy (MSW) - U.S. Energy Information Administration (EIA)
2. Ellis, L.D., Badel, A.F., Chiang, M.L., Park, R.J.-Y., and Chiang, Y.-M. (2020). Proc. Natl. Acad. Sci. *117*, 12584–12591.
3. Zhang, D., Wang, M., Chiang, Y.-M., et al., *Cell Reports Sustainability* (2024)