

Electric arc furnace dust waste management: A process synthesis approach.

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Problem statement



In the form of oxides, silicates, and carbonates.

The residue from the solid collection system of steel mills is known as electric arc furnace dust (EAFD).

Component	% _{W-W}
Zn	34.7
Pb	2.4
Fe	20.4

Lead concentrations above 0.1%

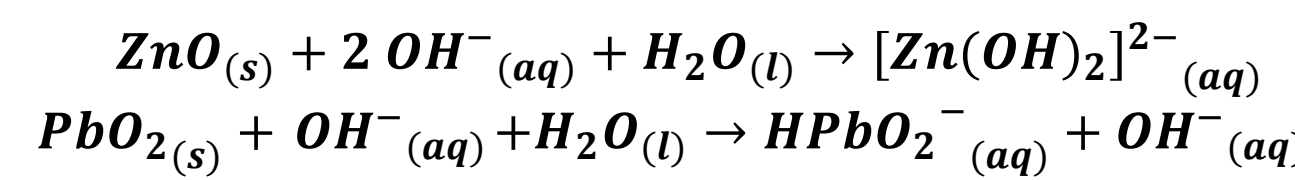
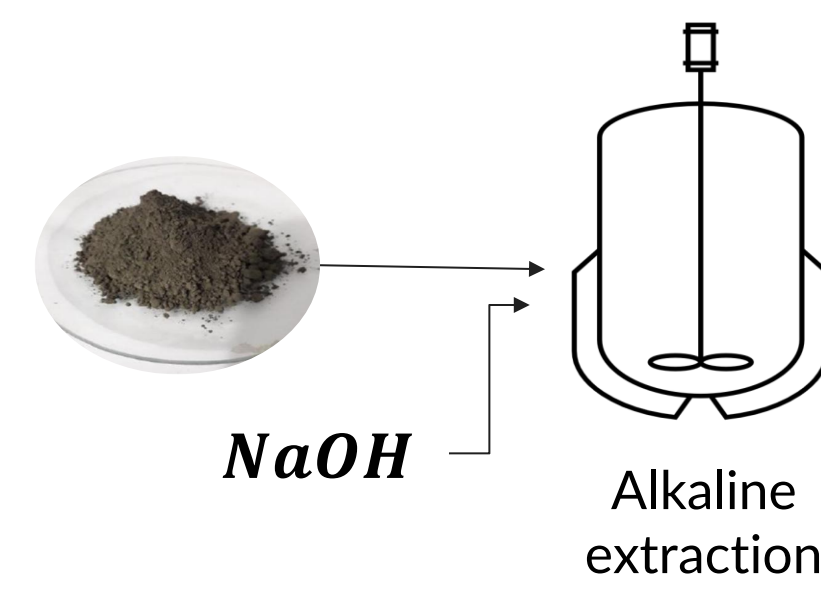
Prohibiting its disposal in sanitary landfills (SL)

Specialized waste management companies (WMCs) are needed

Impacting the overall process economy

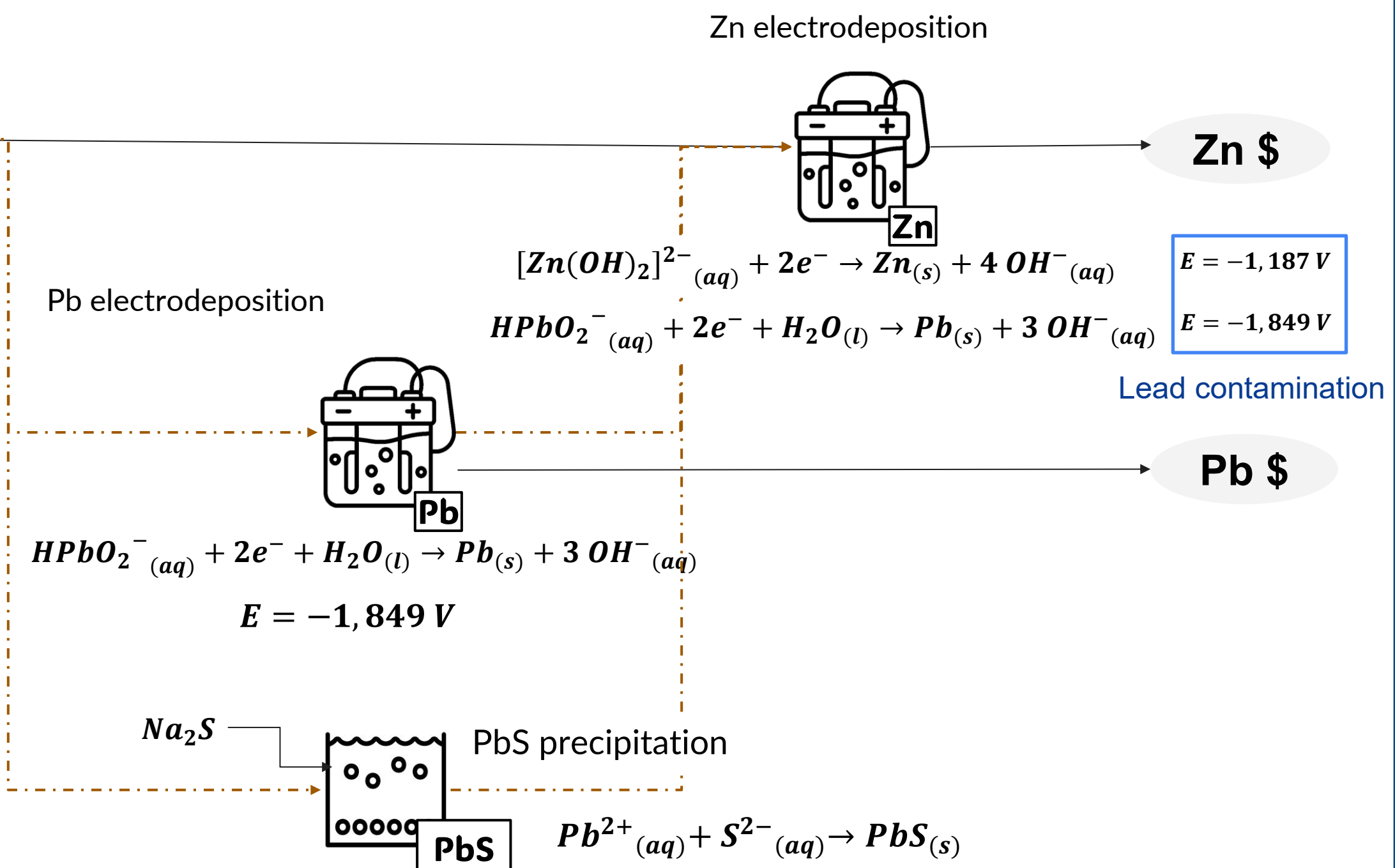
Management alternatives

Valuable metals recovery

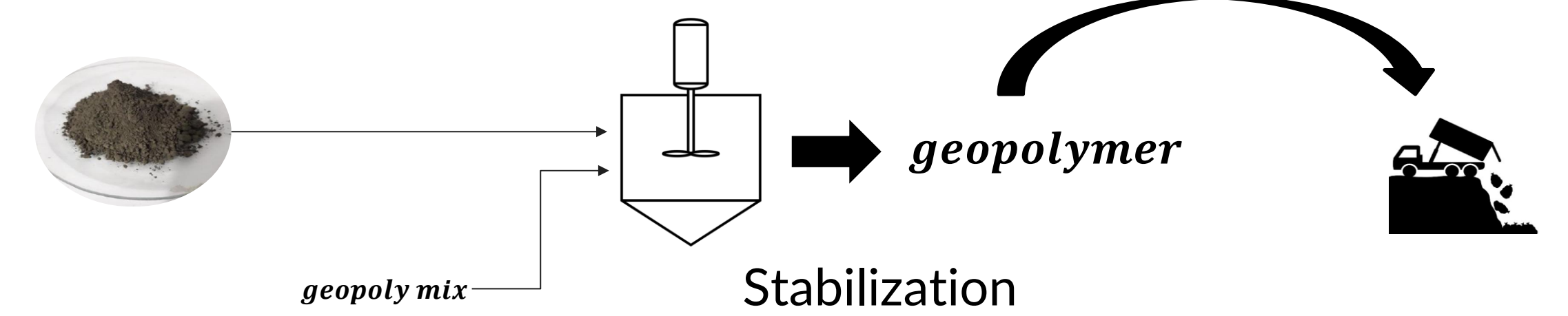


Objective

Develop a comprehensive management strategy for steel mill residue from a steelmaking company in Montevideo, Uruguay, by integrating experimental pilot-scale data, industrial data, and expert judgment.



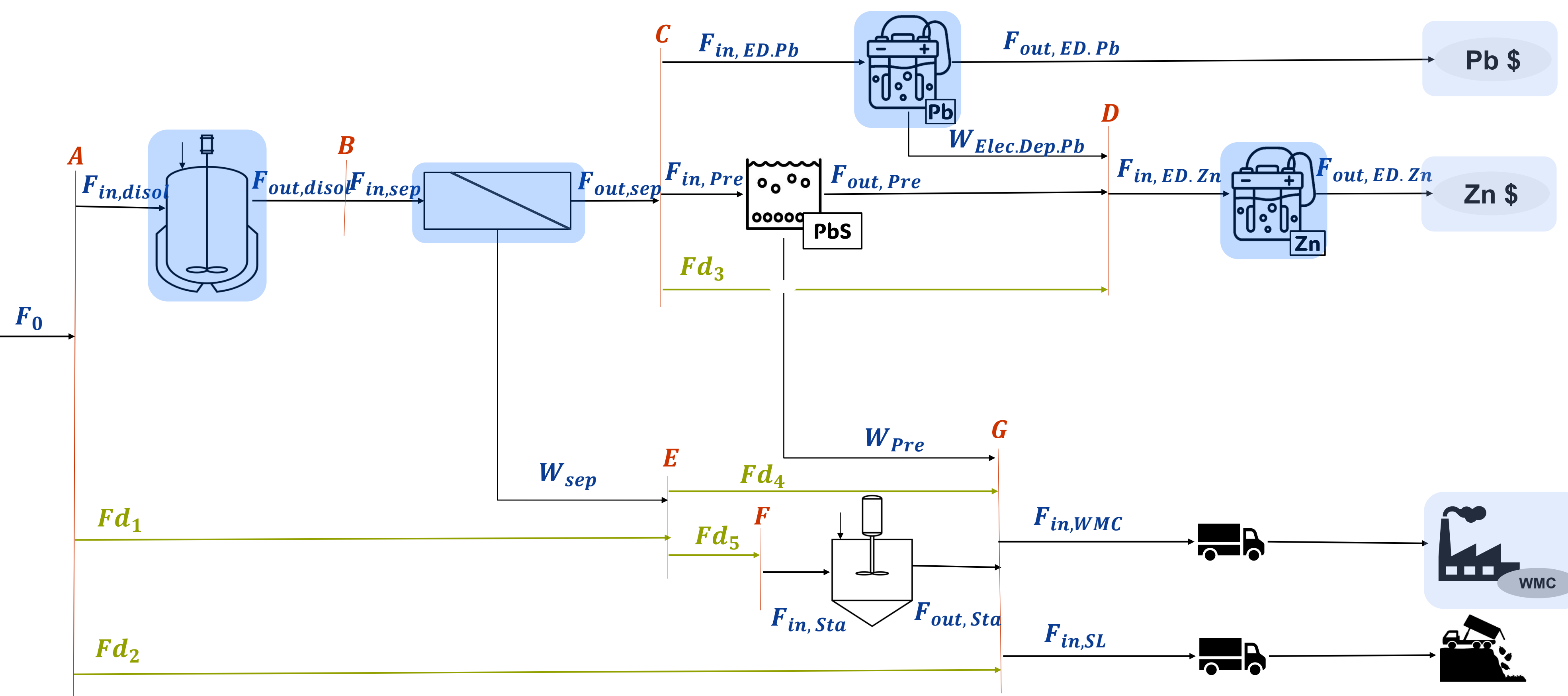
Geopolymer stabilization



Introduction

Methodology

Superstructure model



Mathematical model

Objective function

$$\max \text{Ben} - \sum_k y_k * \text{Cost}_k$$

Subject to

Mass balance of unit operations

$$F_{in,k,c} + R_{k,c} + G_{k,c} - F_{out,k,c} - W_{k,c} = 0$$

$$F_{out,k,c} - \varepsilon_{Ret,k,c} * (F_{in,k,c} + R_{k,c} + G_{k,c}) = 0$$

$$R_{k,c} - \sum_{cc} F_{in,k,cc} * \delta R_{k,cc} * \text{Conc}_{R,k,c} * Y_{R,k} = 0$$

$$G_{k,c} - \sum_{cc} F_{in,k,cc} * \delta G_{k,cc,k} * Y_{G,k,c} = 0$$

Regulatory constraints

$$\text{Conc}_{Zn} = \frac{F_{out,Zn,ED,Zn}}{\sum_c F_{out,c,ED,Zn}}$$

$$\frac{F_{in,Pb,IM}}{\sum F_{in,c,IM}} \leq \text{Lim}_{decreto}$$

Economic balance

$$\text{Ben} = F_{out,Pb,ED,Pb} * \$_{Pb} + F_{out,Zn,ED,Zn} * \$_{Zn} * (\text{Conc}_{Zn})$$

$$\text{Cost}_k - C_{FD,k} - C_{R,k} - C_{Trans,k} - C_{EE,k} = 0$$

$$C_{FD,k} - \sum_c F_{in,k,FD,c} * \$_{k,FD} = 0$$

$$C_{R,k} - \sum_c R_{k,c} * \$_{R,k} = 0$$

$$C_{Trans,k} - \frac{\$_{Trans}}{C_{AP,Trans}} * \sum_c F_{in,k,FD,c} = 0$$

$$C_{EE,k} - \frac{\$_{EE} * F * \Delta V_{k,Elec}}{\varepsilon_{k,Elec}} * \sum_{cs} \frac{G_{k,Elec,cs}}{PM_{cs}} = 0$$

Big-M constraints

$$F_{p,k,c} \leq M_1 * y_k$$

$$R_{k,c} \leq M_1 * y_k$$

$$G_{k,c} \leq M_1 * y_k$$

$$W_{k,c} \leq M_1 * y_k$$

$$F_{d,c} < M_1 * b_d$$

$$\text{Cost}_k \leq M * y_k$$

Mass Balance Equations at Junctions

$$F_{0,c} = C_{0,c} * F_0$$

$$F_{0,c} = F_{in,c,disol} + F_{d1,c} + F_{d2,c}$$

$$F_{out,c,disol} = F_{in,c,sep}$$

$$F_{out,c,sep} = F_{in,c,ED,Pb} + F_{in,c,Pre} + F_{d3,c}$$

$$W_{ED,Pb,c} + F_{out,c,Pre} + F_{d3,c} = F_{in,c,ED,Zn}$$

$$W_{Pre,c} + W_{Sep,c} = F_{d4,c} + F_{d5,c}$$

$$F_{d1,c} + F_{d5,c} = F_{in,c,Est}$$

$$F_{out,c,Est} + F_{d2,c} + F_{d4,c} = F_{in,c,CIIU} + F_{in,c,IM}$$

Logical Constraints

$$y_{Disol} + b_1 + b_2 = 1$$

$$y_{ED,Pb} + y_{Pre} + b_3 = y_{Disol}$$

$$y_{Disol} = y_{Sep}$$

$$y_{Disol} = y_{ED,Zn}$$

$$y_{CIIU} + y_{IM} = 1$$

$$1 - y_{Sep} + b_4 + b_5 \geq 1$$

$$1 - b_5 + y_{Est} \geq 1$$

$$1 - b_1 + y_{Est} \geq 1$$

$$1 - y_{Est} - b_2 - b_4 + y_{CIIU} + y_{IM} \geq 1$$

Variable definition

$$F_{in,k,c} \in \mathbb{R}^n, R_{k,c} \in \mathbb{R}^n, G_{k,c} \in \mathbb{R}^n, F_{out,k,c} \in \mathbb{R}^n,$$

$$W_{k,c} \in \mathbb{R}^n, \text{Cost}_k \in \mathbb{R}, C_{FD,k} \in \mathbb{R}, C_{R,k} \in \mathbb{R},$$

$$C_{Trans,k} \in \mathbb{R}, C_{EE,k} \in \mathbb{R}, y_k \in \{1,0\}, b_d \in \{1,0\}$$

Results and discussion

The models are formulated in GAMS and solved using SCIP V9.1 on an Intel(R) Core(TM) i3-1005G1 CPU @ 1.20GHz 1.20 GHz processor with 2 cores and utilizing a maximum of 8 GB RAM. The EAFD waste management optimization model consists of 1354 equations, 718 continuous variables, and 13 discrete variables. The most economical alternative involves the **electrodeposition of pure Zn and pure Pb** with the residual dust dispose by the external waste management company.

Alt.	Management alternative	Profit (USD/ton)
1	Obtaining Zn and Pb separately by electrodeposition (residual dust to WMC)	-216
2	Direct to WMC (base case)	-239
3	Obtaining Zn (96 %) by electrodeposition (residual dust to WMC)	-259
4	Obtaining pure Zn and precipitate PbS (residual dust to WMC)	-601
5	Obtaining Zn and Pb separately by electrodeposition (residual dust stabilized to WMC)	-614

Conclusion

A model was developed using the process synthesis approach to support decision-making in the management of electric arc furnace dust. The results indicate a cost reduction compared to the actual management alternative can be achieved by recovering pure Zn and Pb through hydrometallurgical dissolution and electrodeposition.

Implementation

GAMS V47,5,0

Future work

- Perform a **parametric sensitivity analysis** to further explore the model's robustness and identify key influential parameters.
- Study the **impact of EAFD variability** on management profit, utilizing the **uncertainty** determined at the experimental level.

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