

Mitigating Rare Earth Element Contamination: A Geochemical Quantification of Sustainable Extraction Reagents

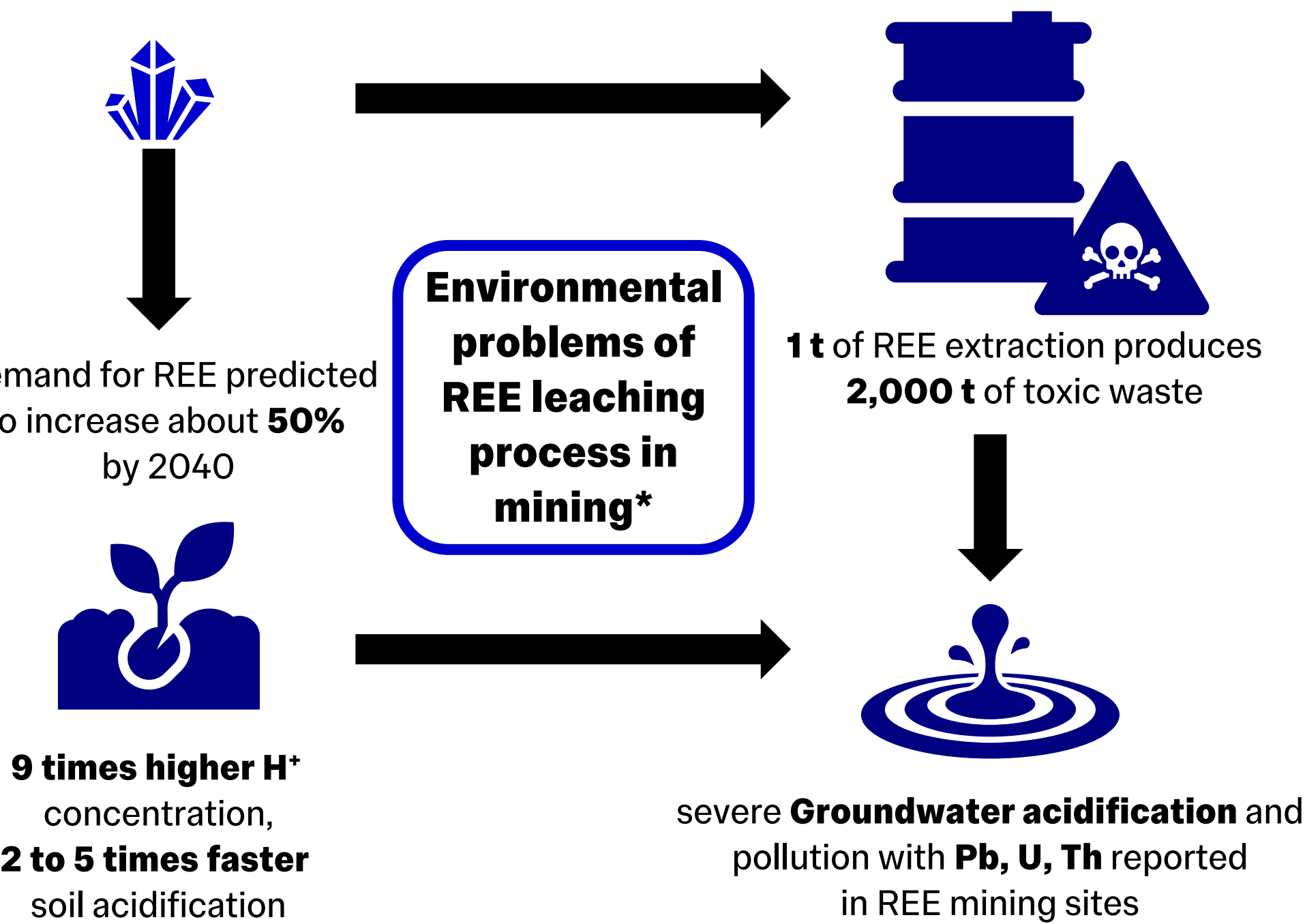
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Introduction

Rare Earth Elements (REEs) are critical for clean technologies, but conventional extraction methods create risks for water systems and ecosystems. More ‘sustainable’ approaches, with less release of toxic metals and less acidification, are needed.

This project aims to:

- (1) compare REE recovery of five reagents
- (2) quantify acidification and toxic-metal release
- (3) test whether the scheme can also extract Fe-oxide-bound REEs in soil/regolith that are currently not utilizable



*Reference
1. Xu, Z., Yang, J., Zhao, Y., Hao, R. and Zhang, G. (2023) *Sci. Total Environ.*, 884, 163834.
2. Bicker, L. (2025) 'Poisoned water and scarred hills', *BBC News*, 8 July.
3. IEA (2025) *Global Critical Minerals Outlook 2025*. Paris: IEA.

Methodology

Samples	Deposit
LN-2-1-1, LN-2-8	Zudong
BK17-C6, BK17-C7	Bankeng
ZK12-64-23, ZK12-64-37	Puxiong

Reagents	Concentration	Leaching Mechanism
Hydroxylammonium chloride (HC)	0.125M	Reductive dissolution
Tetrasodium glutamate diacetate (GLDA)	0.25M	Chelation
Citric acid (Citric)	0.25M	Chelation
Sodium citrate (SC)	0.25M	Chelation
Ammonium oxalate + ascorbic acid (AA)	0.25M+0.125M (Half concentration)	Chelation + Reduction

- 0.5 g sample + 20 mL reagent, with reagent-only blanks
- End-over-end shaking (120 ± 10 rpm, 16 h), centrifuged (3000 rpm, 20 min)
- pH measured before and after extraction
- Acidified to 10 wt% HNO₃
- ICP-MS (Agilent 8900, Imperial): 1–1000 ppb calibration, 100 ppb indium internal standard

Results and Discussion

While conventional HC extracted REEs most efficiently, GLDA extracted

77%

of the REEs recovered by HC, while its toxic metal release rate (V, Zn, Pb, U and Th) all less than **10%** on average.

However, Ce(IV) oxides were mainly mobilized by reductants in Puxiong samples (HC and AA)

GLDA was the only alkaline reagent among all. SC was the most neutral reagent, but REE extraction rate was low compared to GLDA.

HC and AA released higher amount of toxic metals (Th, Pb, Zn, and V), compared to other reagents.

AA was run at half concentration, yet acidifying effect and toxic metal release rate suggests it is not the most sustainable replacement of conventional reagents.

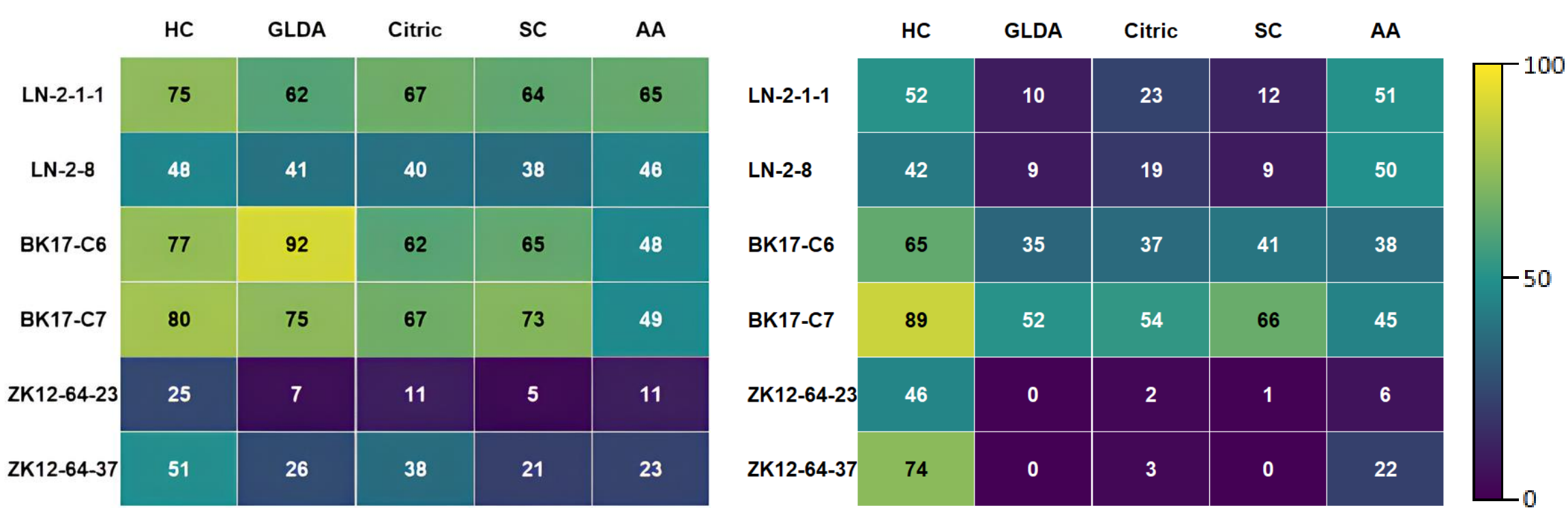


Figure 1. REE recovery (%) by sample and reagent: mean of REEs excluding Ce (left) and Ce (right) (%)

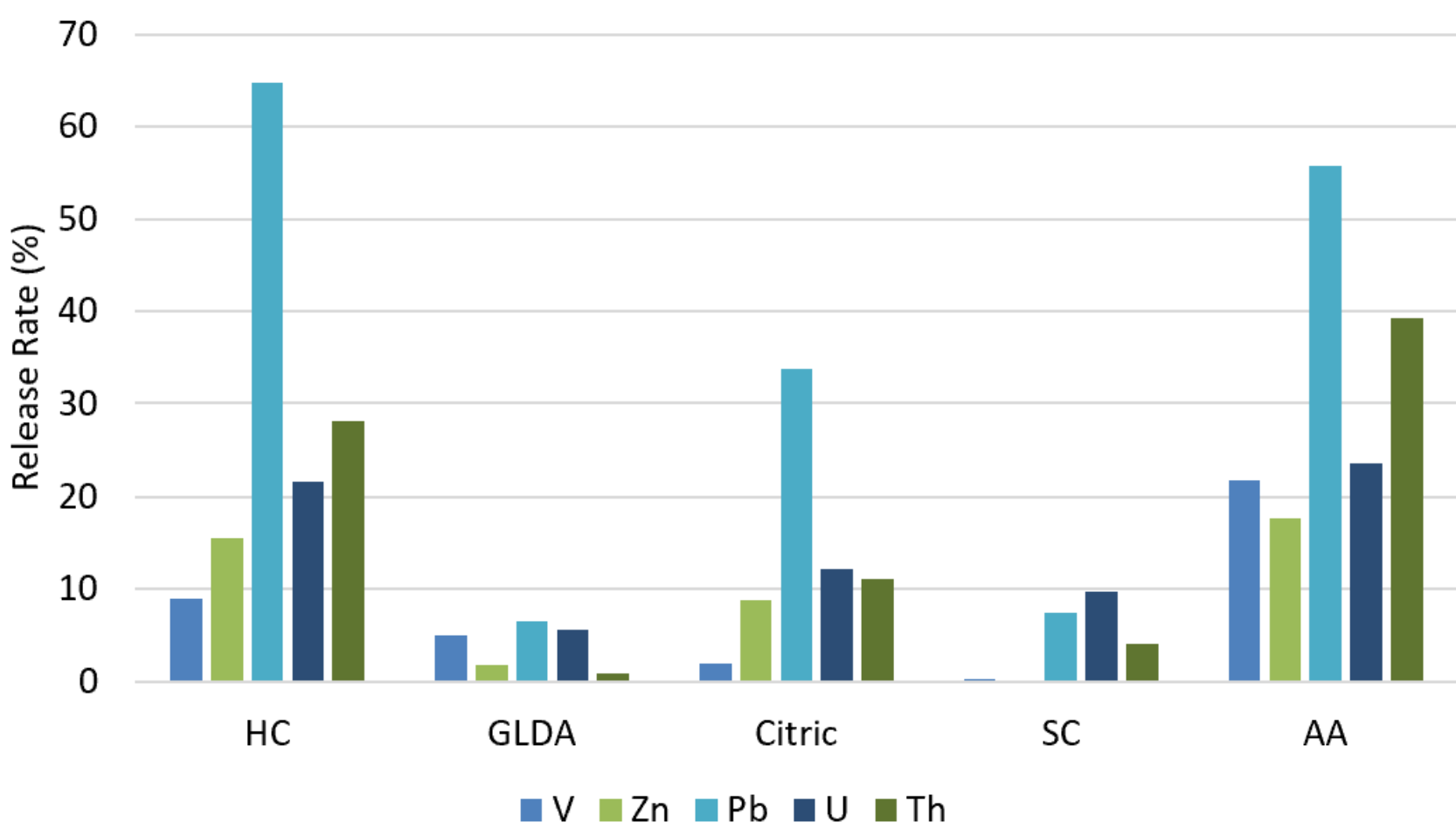


Figure 2. Toxic metal release rates of each reagent of Puxiong and Bankeng Samples (%)

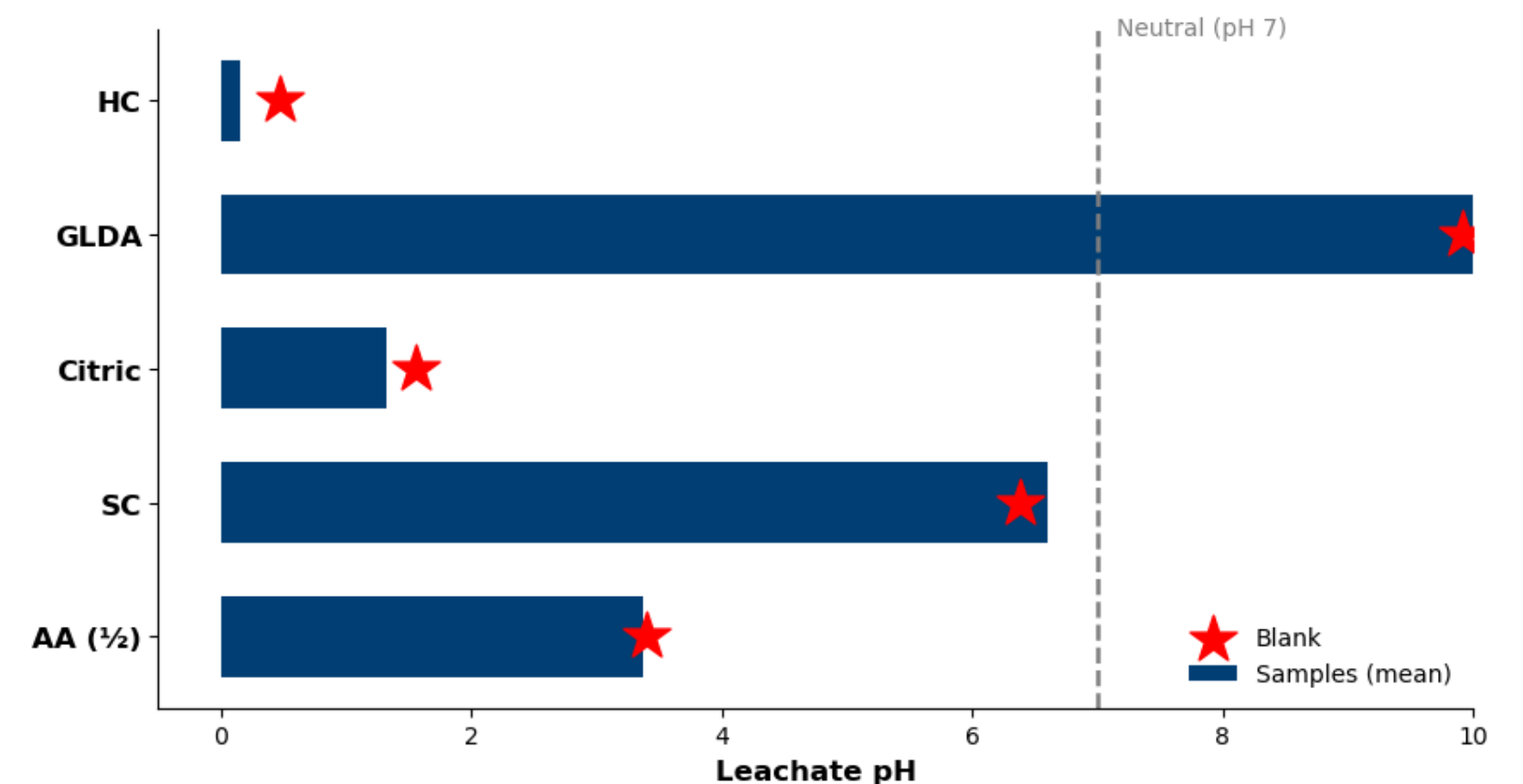


Figure 3. pH of each reagent during the extraction process

Conclusion

GLDA recovered ~77% of the REEs extracted by HC, with significantly less toxic metal co-extraction and no acidification, making it a promising sustainable leaching reagent. However, its alkaline impact requires further assessment. All reagents can dissolve Fe oxides, but Fe was not analyzed due to expected concentrations exceeding calibration limits. Future work should use ICP-OES or higher dilution factors to quantify Fe accurately.