


Development of solid phase extraction based ion exchange process for selective separation of scandium and iron from low grade secondary sources

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INTRODUCTION

Applications



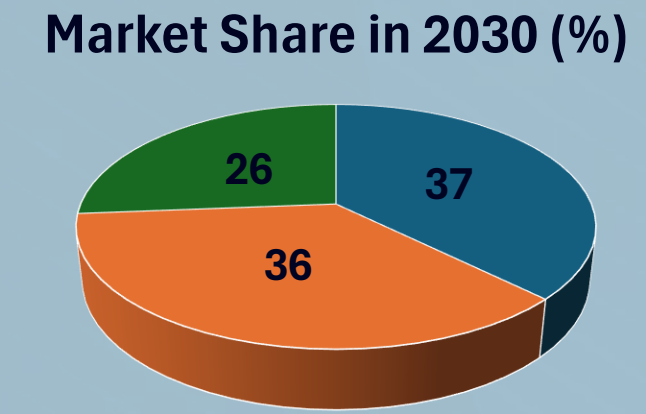
Why Scandium is a Critical Element?

- No current domestic mining and no production facilities in operation, completely dependent on imports for the past few years, which could present a potential supply chain risk
- Listed as a critical mineral by the USDOJ.

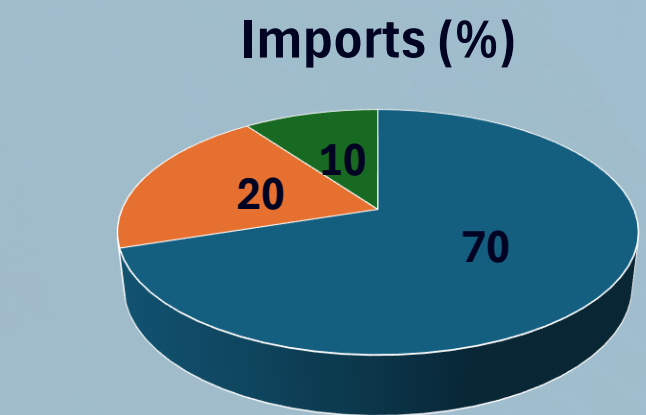
Scandium sourcing issues

- The shortage of primary resources is a main challenge for Sc.
- The US holds only 1% of primary sources including Sc
- Rising demand for scandium necessitates the development of efficient recovery methods from secondary resources like red mud and acid mine drainage (AMD).

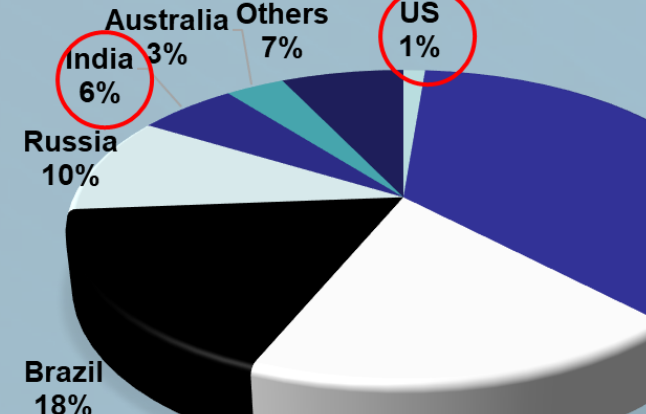
Market Share in 2030 (%)



Imports (%)



Secondary Resources



PROBLEM STATEMENT

- Secondary resources contain high levels of impurities, particularly iron, which complicates the selective separation of scandium.
- Existing purification methods (e.g., solvent extraction, precipitation) are often inefficient and environmentally harmful.
- Key issue:** Iron and scandium share similar chemical properties (oxidation state, ionic radii), leading to co-extraction or co-precipitation during purification.

RESEARCH GOAL

A major research gap exists in creating a process that achieves selective separation of Fe and Sc while also being environmentally conscious

“Solid-liquid extraction (SLE) is gaining attention for its proven ability to selectively separate target elements from low-concentration solutions, offering the advantages of easy regeneration and reusability”

Hypothesis: "In presence of excess chlorides, Fe forms anionic species while Sc forms neutral or cationic complexes. Anion exchange resins selectively adsorb Fe, leaving Sc in solution

RESEARCH OBJECTIVES

To develop an efficient process for the selective separation of Fe and Sc by

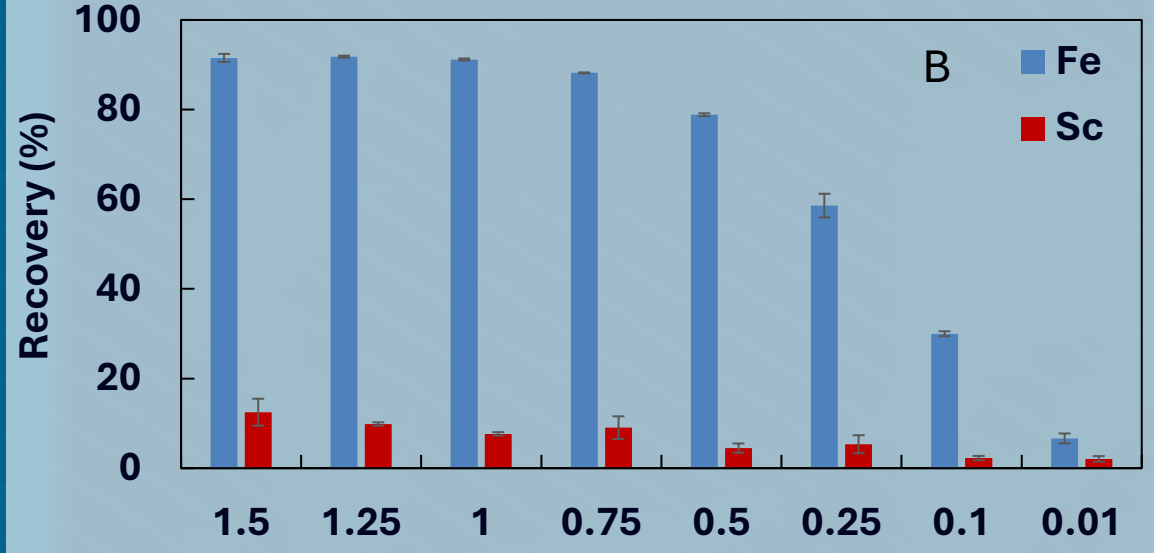
- Understanding the speciation in the presence of chloride ligands and adsorption mechanism
- Studying the effect of resin dosage, temperature, kinetics, adsorption isotherm

EXPERIMENTAL INVESTIGATION

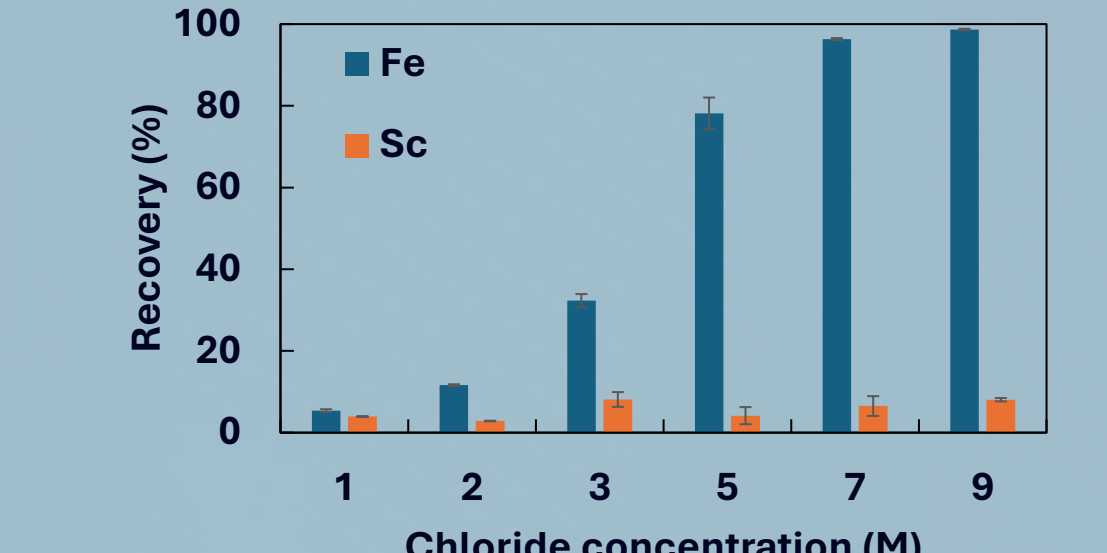
- Batch adsorption experiments
 - Resin dosage
 - Chloride concentration
- Desorption experiments

RESULTS

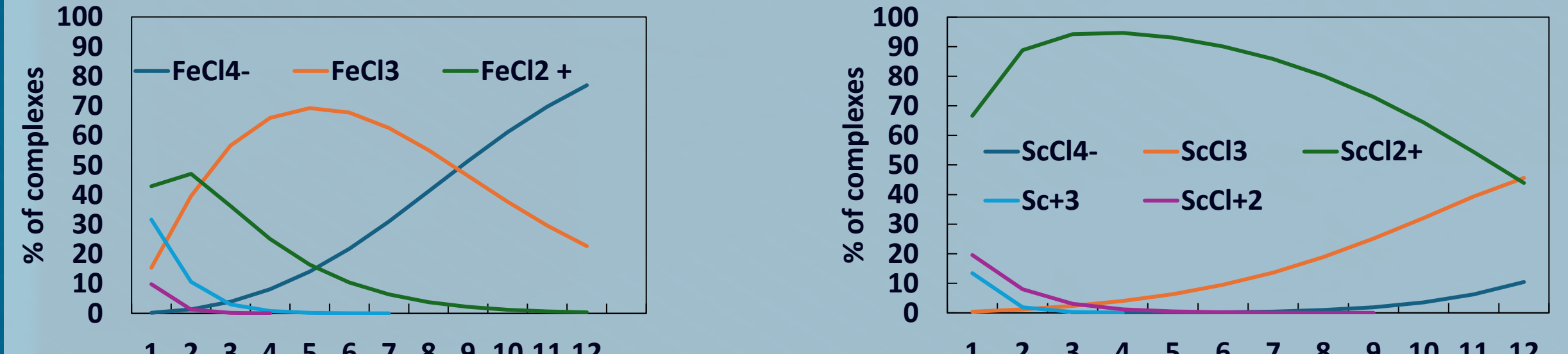
Effect of resin dosage: “1 g of resin captured most of the Fe”



Effect of chloride concentration: “Chloride concentration influence the speciation”



Speciation of Fe and Sc with varying chloride concentration

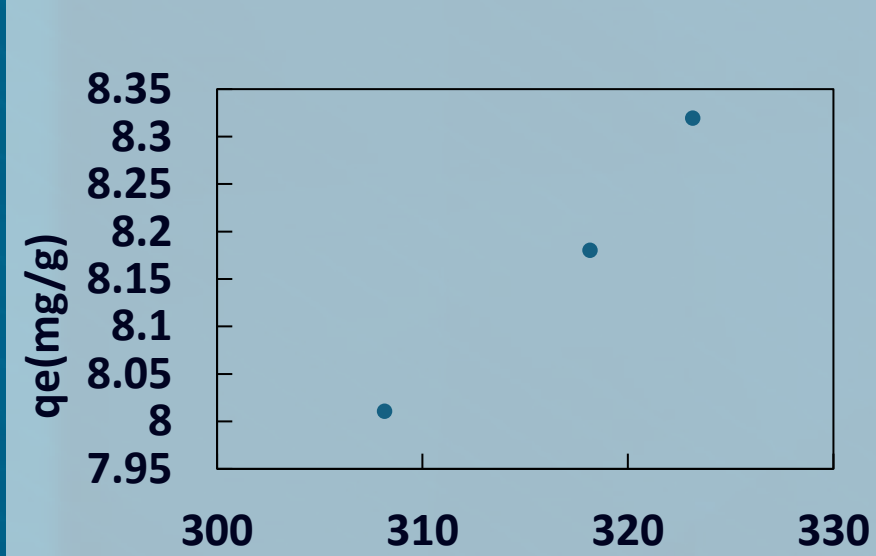


Adsorption mechanism:

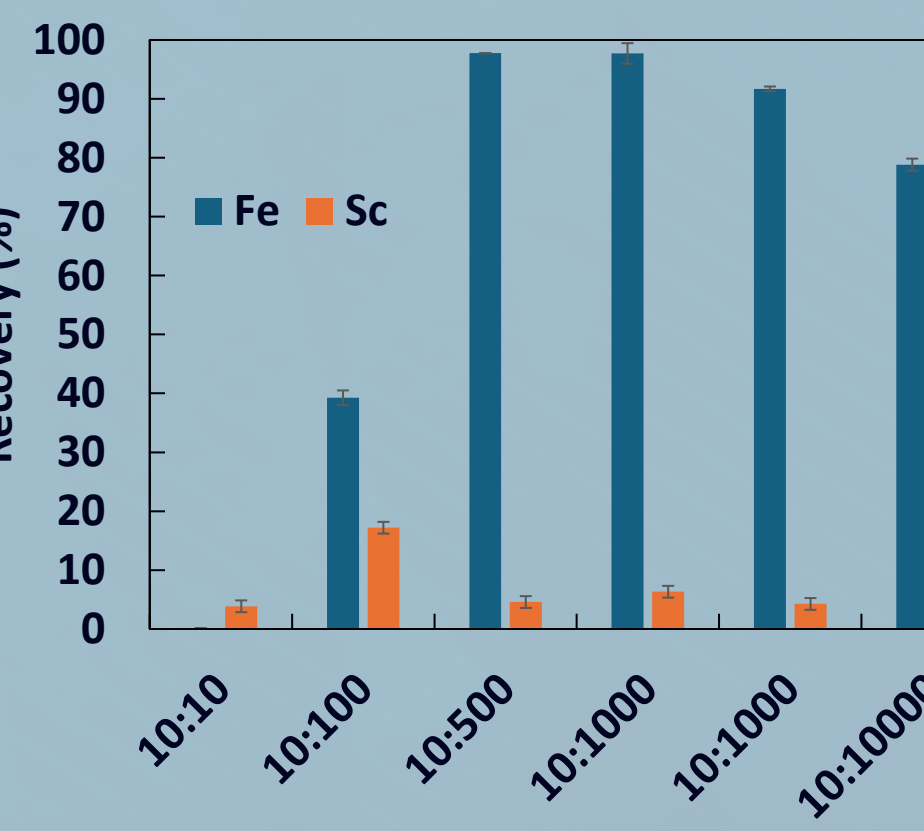
Anion exchange mechanism: Polymer support-N+(Cl-) + FeCl4- -> Polymer support-N+(FeCl4-) + Cl-

Ion association mechanism: Polymer support-N+(Cl-) + FeCl3 -> Polymer support-N+(Cl) . FeCl3

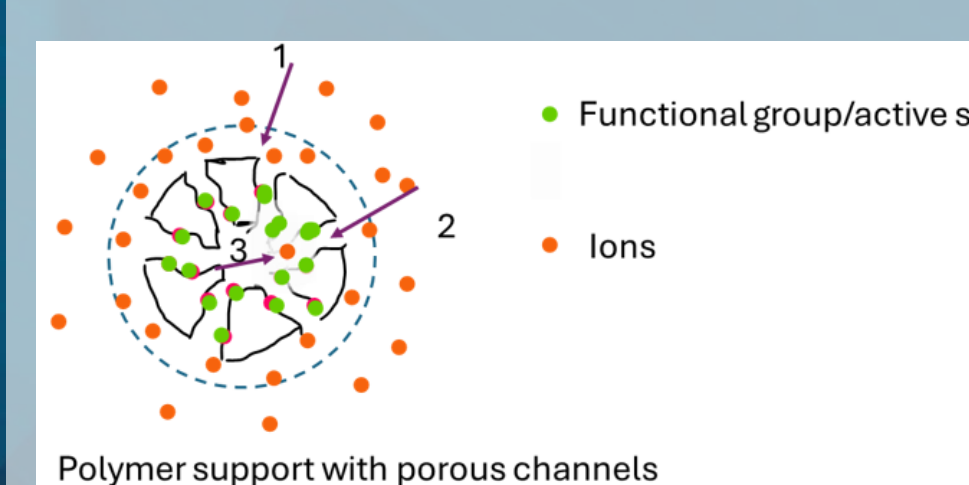
Effect of temperature: “Adsorption is spontaneous and slightly endothermic.”



Effect of Concentration ratio (Sc:Fe): Anomalous behavior of Sc at higher Sc:Fe is due to electrostatic interaction between negative surface charge and Sc cationic species.



Kinetics:



- External diffusion from bulk solution to adsorbent surface (Described by Pseudo first order (PFO))
- Internal diffusion while travelling from adsorbent surface to the pore space (Weber and Morris model)
- Chemical interaction between active site and ion of interest (Described by Pseudo second order (PSO))

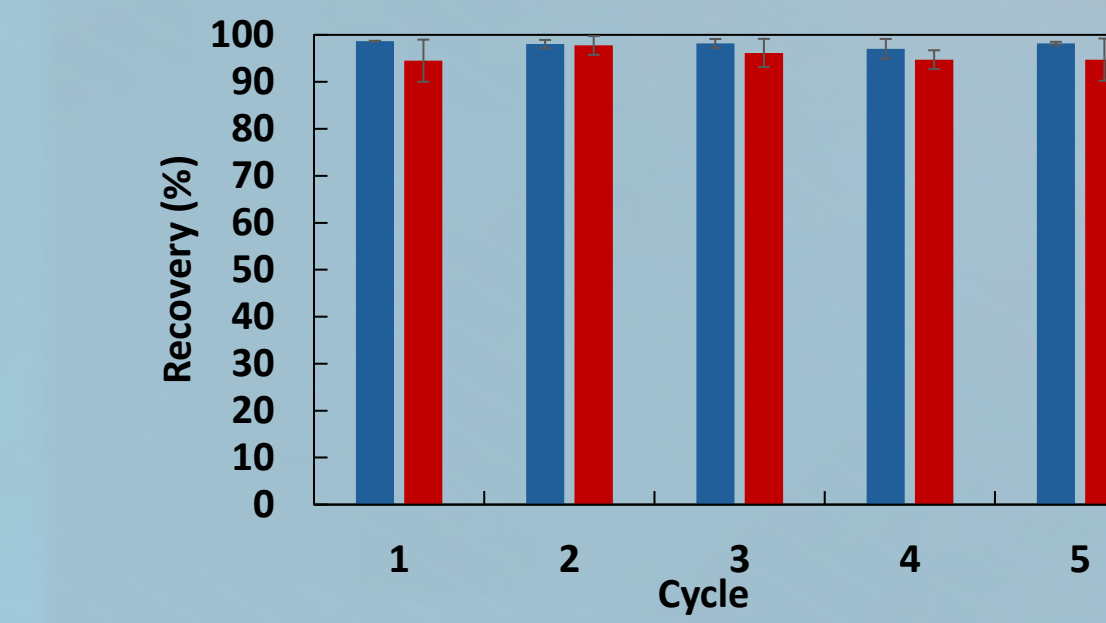
Rate of PFO $\frac{d(q_t)}{dt} = K_1 (q_e - q_t)$
 $q_t = q_e (1 - \exp(-K_1 t))$

Rate of PSO $\frac{d(q_t)}{dt} = K_2 (q_e - q_t)^2$
 $q_t = \frac{(q_e^2 K_2 t)}{(1 + q_e K_2 t)}$

Weber and Morris model, $q_t = K_{W\&M} \sqrt{t} + C$

“Adsorption is chemical reaction initially and later mixed controlled”

DESORPTION®ENERATION



“DI water was able to desorb >90% of adsorbed Fe. Resin did not lose any adsorption capacity across multiple cycles”

CONCLUSIONS

- Optimum conditions: 1g resin/10ml solution, 9 M chloride, 8-hour contact time.
- Fe recovery = 99%, Sc recovery <5%
- High selectivity for Fe (99%) due to speciation differences in chloride.
- Thermodynamic analysis shows spontaneous, slightly endothermic Fe adsorption.
- Resins demonstrated >90% desorption efficiency and reusability over 4 cycles.

SIGNIFICANCE&FUTURE WORK

- Expand selective separation to other REEs and enhance environmental remediation.
- Offers a sustainable solution for scandium recovery from waste sources
- Helps meet REE demand while reducing environmental harm from industrial waste.

REFERENCES

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