DEPLOYMENT OF ION-EXCHANGE FLUORIDE CAPTURE AND RECOVERY TECHNOLOGY RESINS AND ADSORPTION IN HIGH-FLUORIDE REGIONS OF TANZANIA

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INTRODUCTION

Fluoride exposure in drinking water is a prime public health concern for many communities in Tanzania. Conventional defluoridation technologies are often ineffective in **selectively removing fluoride** and **generate sludge waste.** Hence, this project pioneers the use of **cheleating ion-exchange resins** as an advanced solution for fluoride remediation.

OBJECTIVE

- Evaluate the **effectiveness of metal-loaded chelating resins** in the removal of fluoride
- Assess **the performance** of these resins using **simulant groundwater** samples
- Determine **adsorption capacity** of selected metal-loaded chelating exchange resins under controlled laboratory conditions

METHODOLOGY

Adsorbent Selection & Rationale

Resins Selected: Three macroporous cation-exchange resins were functionalized for enhanced fluoride adsorption:

- Aminomethylphosphonic Acid (AMPA)
- Iminodiacetic Acid (IDA)
- Sulfonic Acid (SULF)

Selection Rationale:

- High Metal Affinity: Demonstrated strong chelating ability to bind the metal ions (Al^{3+}, Ce^{3+}, La^{3+}) crucial for fluoride removal.
- Mechanical Stability: The macroporous variants were specifically chosen to withstand the high osmotic pressure and physical stress of repeated column regeneration, ensuring long-term durability.

Figure 1: Experimental Workflow for Evaluating Fluoride Removal Resins

ACKNOWLEDGEMENT

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RESULTS

Batch Adsorption Study: Identifying the Best Performing Resin

- **IDA-Al** demonstrated the **highest fluoride adsorption capacity** at both low (0.128 mg/g) and high (4.48 mg/g) concentrations
- **Al-loaded resins** (AMPA-Al, IDA-Al, SULF-Al) consistently showed **superior performance** compared to other metals
- **IDA-Al was selected** for further testing in a continuous flow system due to its superior performance

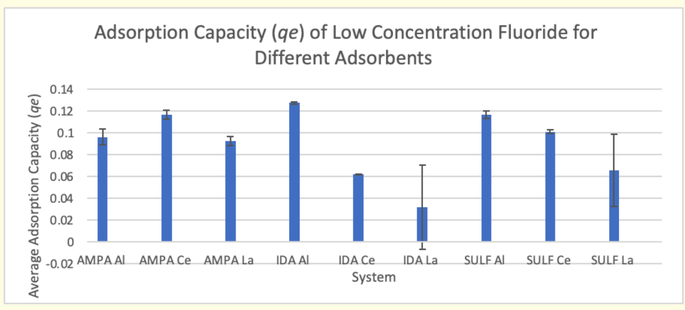

Figure 2.1: Bar graph of the adsorption capacity of low fluoride concentration across different adsorbents

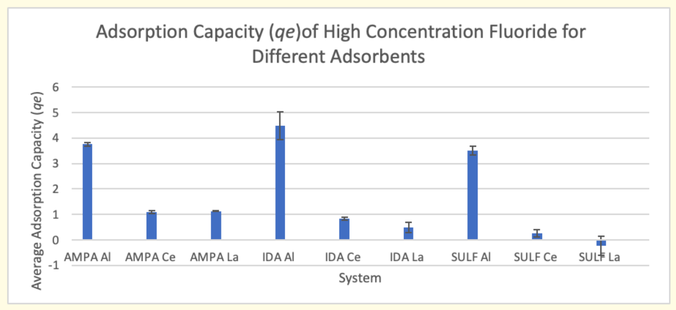

Figure 2.2: Bar graph of the adsorption capacity of high fluoride concentration across different adsorbents

Column Breakthrough: Assessing Practical performance

- The breakthrough profile showed a **characteristic sigmoidal curve**, confirming effective fluoride removal
- **Key Performance Indicators:**
  - ***High Initial Removal:*** The adsorbent was highly effective at removing fluoride in the early stages (up to ~91 mL eluted).
  - ***Extended Mass Transfer Zone:*** A gradual rise in effluent concentration (112 - 196 mL) suggests adsorption kinetics are controlled by intra-particle diffusion.
  - ***Saturation:*** The column reached full saturation and exhaustion after ~196 mL, indicated by the plateau in the curve.

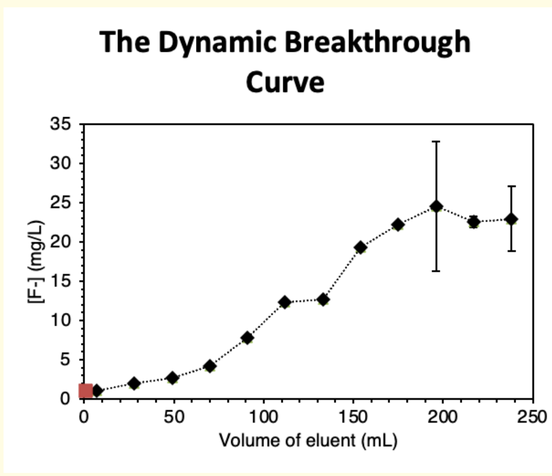

Figure 3: The Breakthrough Profile

DISCUSSION

- **Aluminum (Al^{3+})** was identified as the superior metal for fluoride adsorption, outperforming Cerium (Ce^{3+}) and Lanthanum (La^{3+}). This is consistent with **Pearson's Hard-Soft Acid-Base theory**, where the hard acid (Al^{3+}) has a strong, stable affinity for the hard base (F^-).
- The **IDA-Al combination** demonstrated the highest adsorption capacity. The IDA functional group **provides high selectivity** for metal ions, which, when loaded with Al^{3+}, **creates an optimal site** for fluoride binding.
- The column experiment confirmed that **IDA-Al is effective under continuous flow conditions**. The extended mass transfer zone in the breakthrough curve indicates **strong adsorption capacity**, with kinetics likely limited by intra-particle diffusion.
- **Study Limitations:** Key limitations include the lack of quantitative breakthrough modelling and an assessment of metal leaching and long-term resin stability.

CONCLUSION

IDA-Al resin is a highly effective adsorbent for fluoride removal, showing significant promise for Tanzanian water treatment. Its superior performance in batch and continuous flow tests confirms its potential. Future work will focus on optimizing sustainability and cost-effectiveness for real-world deployment.

REFERENCES