Practical PFAS Treatment with Sawdust

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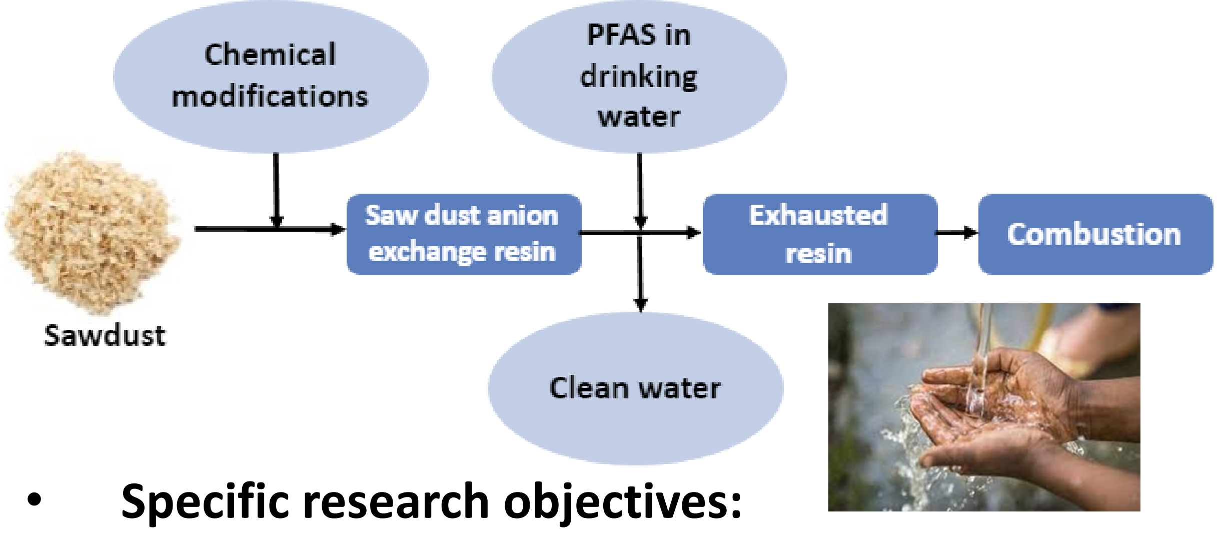
Project Goal

- **The goal of this project** is to develop a practical and cost-effective approach to treat PFAS in drinking water using functionalized sawdust biomass



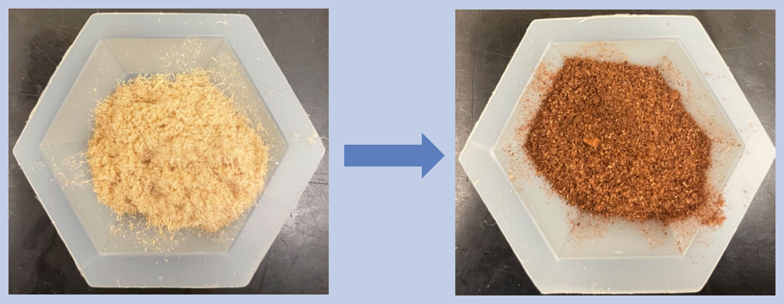
- **Specific research objectives:**
  - Functionalize sawdust into biomass-based anion exchange resin
  - Determine PFAS removal from drinking water using functionalized sawdust
  - Determine if PFAS composition has effect on removal efficiency

People, Planet, and Prosperity

- **Per- and Polyfluoroalkyl Substances (PFAS):** Man-made chemicals persistent in the environment
  - Considered emerging contaminants by US EPA
  - Protentional threat to human health and environment
- **Treatment** is needed in solid waste landfills, drinking water, wastewater
- **People – PFAS Potential Health Effects and Toxicity:**
  - Develop a solution to reduce PFAS in Cincinnati drinking water and meet EPA guidelines
- **Prosperity – Significant Economic Benefits:**
  - New jobs in forestry and environmental industry
  - Highly cost-effective (water utility companies)
  - Potential to develop waste-free processes
- **Planet – Reducing Environmental Risks**
  - Potential to protect the environment and improve water quality in Cincinnati.
- **Educational Support:**
  - Understand that natural biomass from the planet can be used for cleaning drinking water (human health)
  - Understand how much PFAS exists in tap water (polymer production industries)
  - Recognize the critical balance between prosperity of industry and protection of human health and the ecosystem
  - Identify the community issues in drinking water system

Results and Developments

Sawdust Functionalization



Raw Sawdust | Functionalized Sawdust

Fig. 1. Synthesis of functionalized sawdust

- Raw sawdust reacted with epichlorohydrin and dimethylamine in alkaline solution
- A biomass-based anion exchange resin (FS) created for PFAS removal

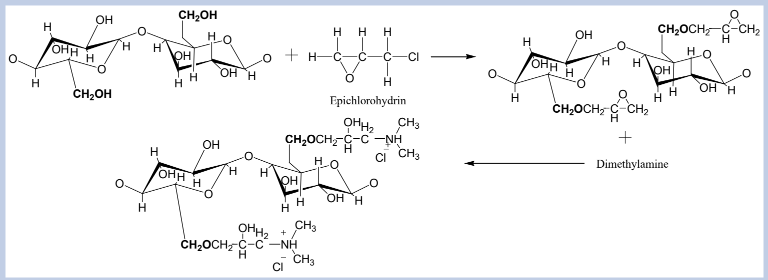
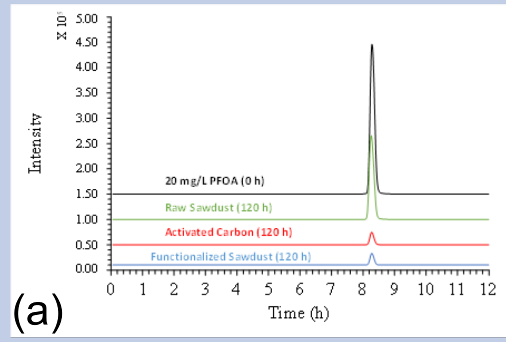


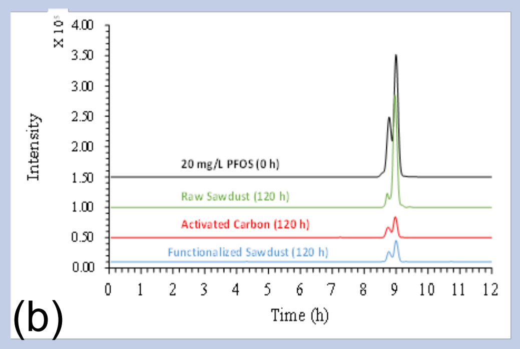
Fig. 2. Sawdust functionalization reaction

PFAS Adsorption

- Removal efficiency of GAC, FS, and raw sawdust have been assessed in PFOA and PFOS adsorption from water



(a) GAC, FS, and raw sawdust adsorbed 93.07%, **92.41%**, and 42.08% of PFOA

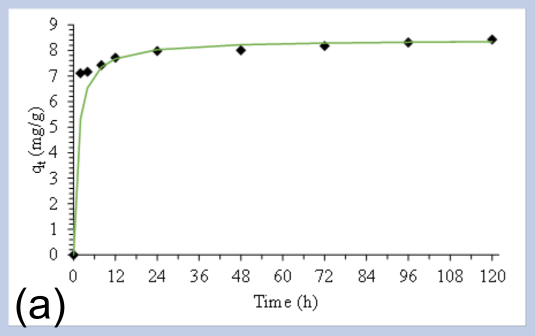


(b) GAC, FS, and raw sawdust adsorbed 84.24%, **83.85%**, and 36.61% of PFOS

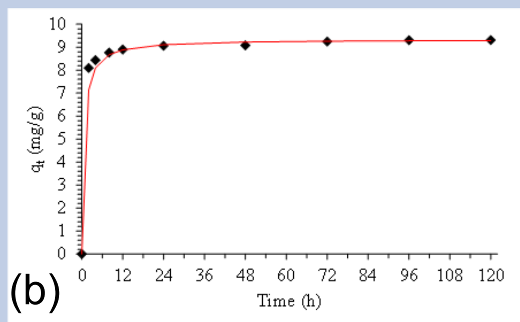
Fig. 3. Adsorption of PFOA (a) and PFOS (b) on GAC, FS, and raw sawdust

- FS will be an **excellent material** to remove PFAS in the test water

Adsorption Kinetics



(a) Adsorption rate constant of PFOA and PFOS is **0.17 and 0.10 g/mg/h**



(b) Initial adsorption rate of PFOA and PFOS is **15.12 and 7.25 mg/g/h**

Fig. 4. Adsorption kinetics of PFOA (a) and PFOS (b)

- The adsorption of PFOA and PFOS on FS was fast and the adsorption can be completed within 2 h

Adsorption Isotherm

- Adsorption isotherms are critical to evaluate the **adsorption capacity of FS** and to understand the **sorbate-sorbent interactions**

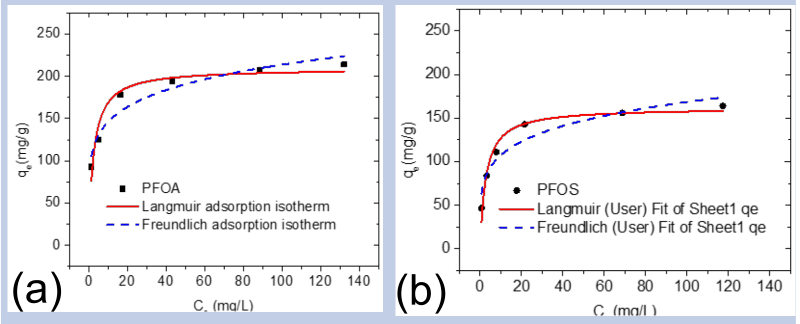


Fig. 5. Langmuir and Freundlich adsorption isotherms of PFOA (a) and PFOS (b) of FS

- The synthesized FS possesses high adsorption capacity for **PFOA (209.26 mg/g)** and for **PFOS (161.80 mg/g)**
- A good fit with the Langmuir model indicated monolayer adsorption of PFAS on the FS

Analytical Method Development & Column and Combustion Device Set-Up

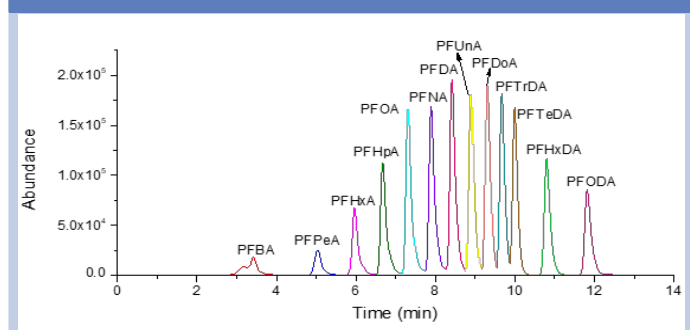


Fig. 6. Mass spectra by LC-QToF

- An analytical method was developed with LC-QToF to identify and quantify 13 PFAS compounds **(Fig. 6)**

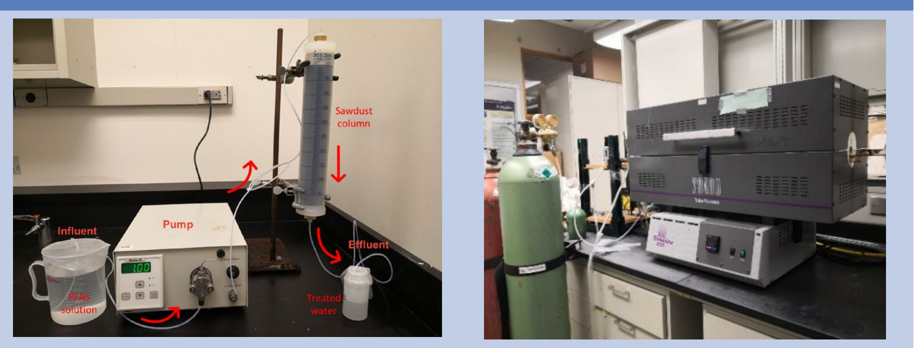


Fig. 7. Column test system (a) **Combustion system** (b)

- A column test device designed to assess PFOA/PFOS removal with FS (**Fig. 7a**)
- A thermal reactor system configured for the combustion of spent FS (**Fig. 7b**)

Anticipated Outcomes

- Functionalization of sawdust into biomass-based anion exchange resin
- Adsorption kinetics and isotherms to assess the efficiency of FS in removing PFAS in drinking water
  - Adsorption Isotherms: FS possesses high adsorption capacity for PFOA and PFOS removal
- Device Set-Up: Column test for PFAS removal and combustion of spent FS
- A practical analytical PFAS method with LC-QToF
- Student Training:
  - FS synthesis and FTIR characterization
  - Unique properties of PFAS
  - Adsorption kinetics and isotherm determination
  - PFAS analysis with LC-QtoF

Anticipated Conclusions

- Commercial sawdust has been functionalized into biomass-based anion exchange resin, which is highly efficient and cost-effective for PFAS removal
- Adsorption kinetics indicated that adsorption of PFOA and PFOS on FS was very fast (2h)
- Adsorption isotherms suggested that the synthesized FS showed high removal efficiency and high adsorption capacity for PFOA and PFOS removal
- FS will be an excellent material to remove PFAS in the tested water.
- More PFAS compounds should be tested, and a techno-economic analysis (TEA) is needed to assess the cost advantages of FS for PFAS removal

Acknowledgements

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