PFAS removal from drinking water sources by activated carbon, ion exchange, and electrochemical oxidation

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NORTH CAROLINA PFAS Testing Network

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PFAS removal from drinking water sources

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PFAS removal by activated carbon

Investigate factors affecting PFAS adsorbabiltiy

- PFAS characteristics
- Granular activated carbon type
- Water matrix

Materials and Methods:
Rapid Small Scale Column Tests (RSSCTs)

Granular Activated Carbon types:
2 subbituminous coal-based (reagglomerated)
1 enhanced coconut

Water sources:
Coagulated surface water (TOC: 2.0-2.3 mg/L)
Coagulated surface water after biofiltration (TOC:1.2-1.5 mg/L)
Groundwater (TOC: <0.5 mg/L)

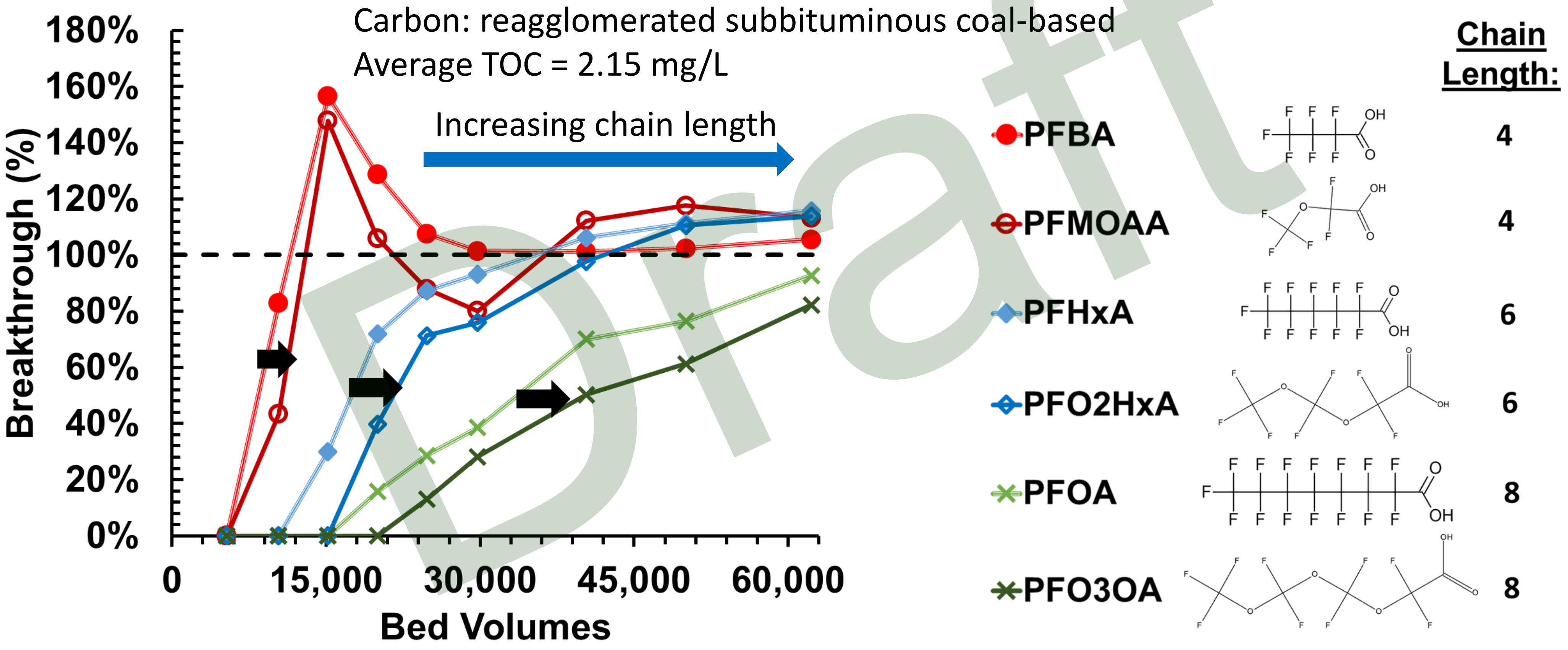
RSSCT Design:
Proportional Diffusivity (diffusivity is proportional to particle size)

EBCT: 10 min (Groundwater)
10, 15, and 20 min (Surface water)

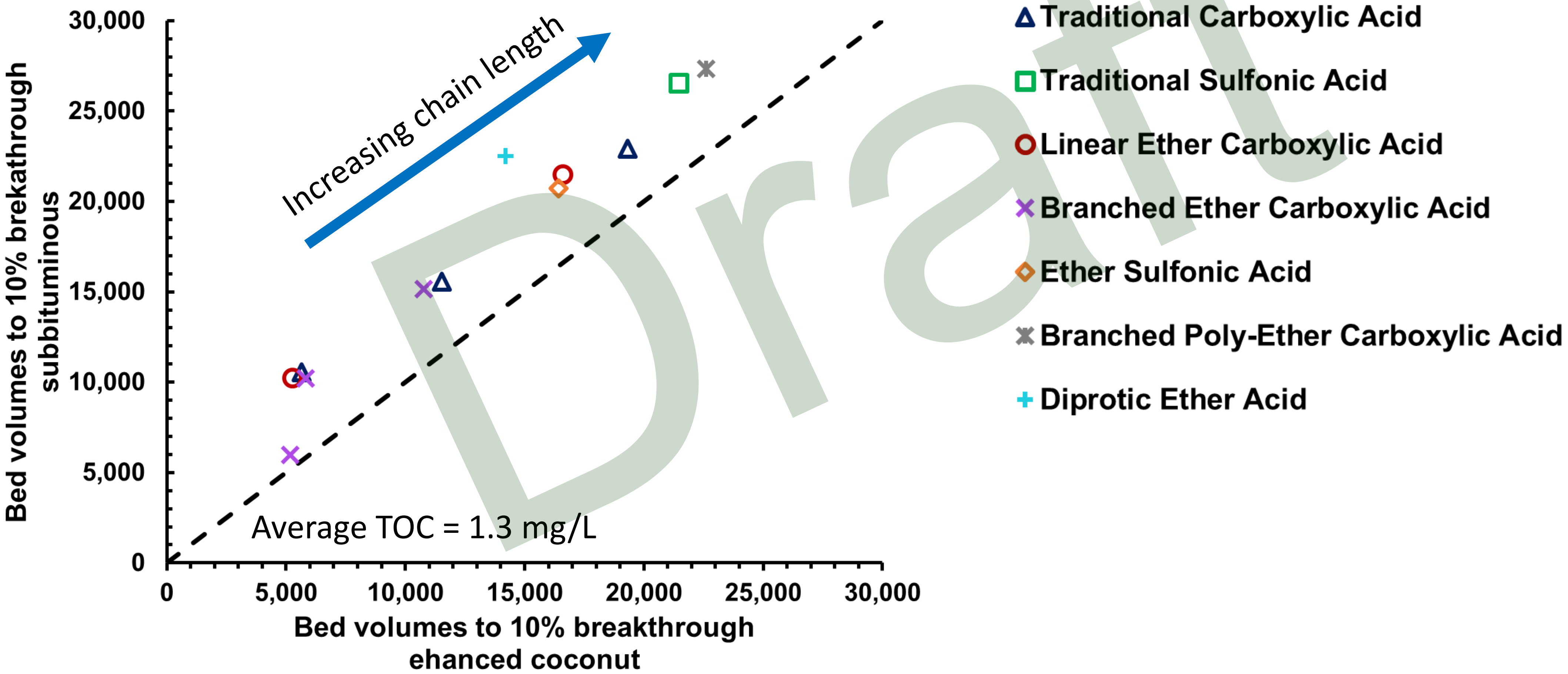
Adsorbates:
11 legacy PFASs and 12 PFEAs
GAC influent concentration: 100 ng/L

Analysis:
Large volume injection (200-900uL), LC-MS/MS, reporting limit: 10 ng/L

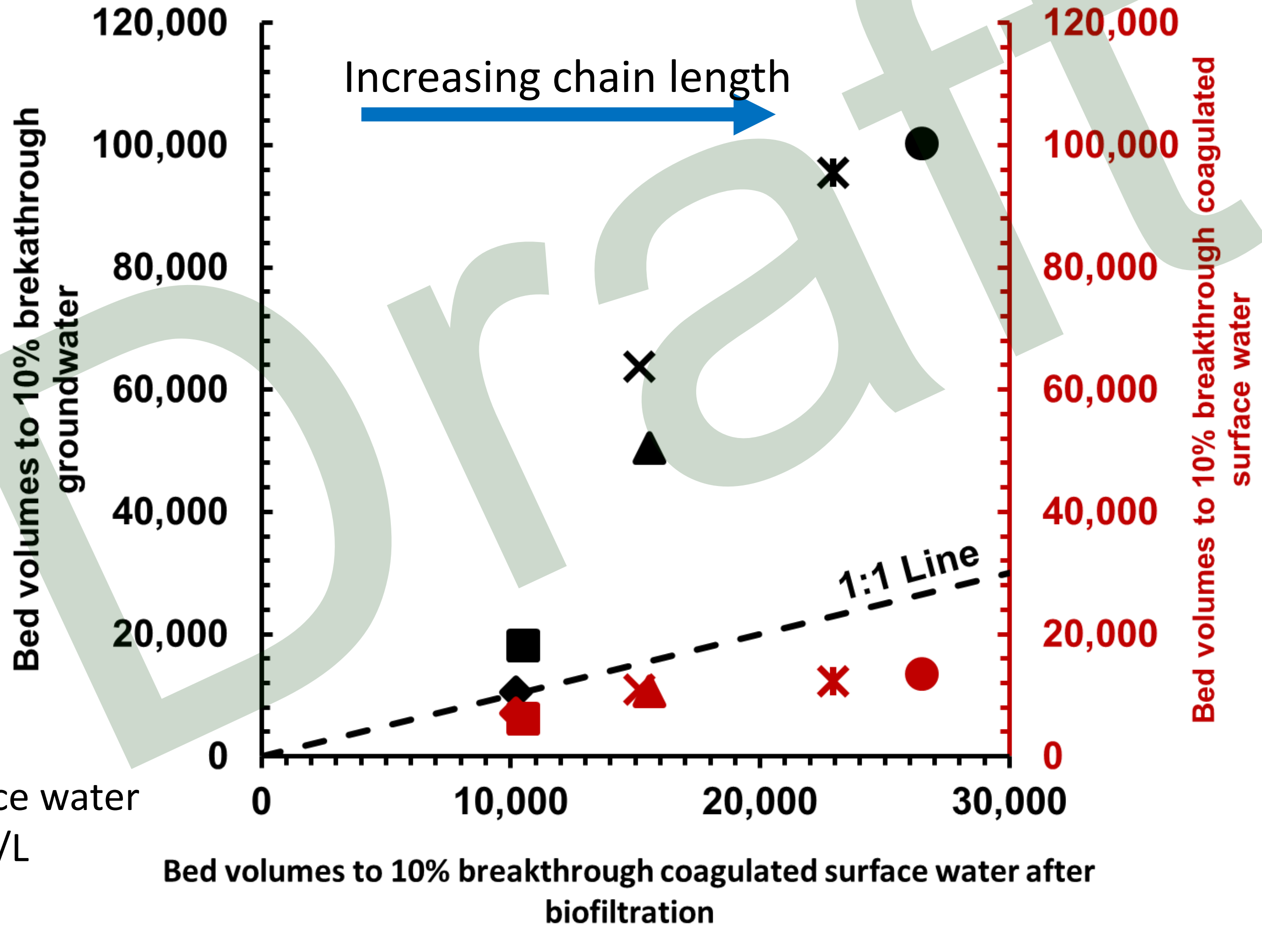
Complete PFAS removal achieved initially, but GAC lost capacity for short chain PFAS quickly



Coal-based GAC has longer service life than coconut shell-based GAC



GAC service life decreases with increasing background organic matter



TOC = <0.5 mg/L
EBCT: 10 minutes

Coagulated/filtered surface water: 2.15 mg/L
EBCT: 15 minutes

Coagulated/filtered surface water after biofiltration: 1.3 mg/L
EBCT: 10 minutes

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Key Findings and Ongoing Work

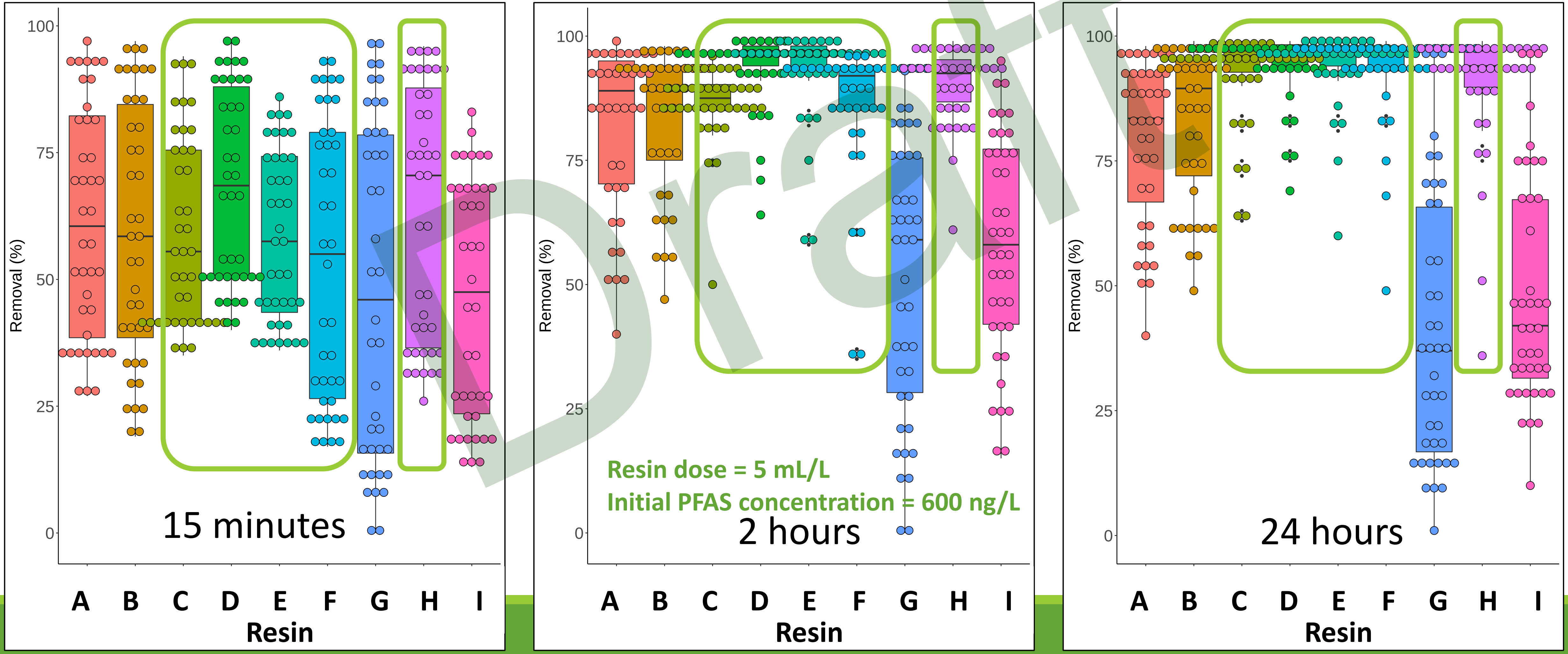
- In coagulated surface water, granular activated carbon service life ranged from 5,000 to 30,000 bed volumes for most PFAS
- PFAS adsorbability impacted by:
  - ↑ Chain length → ↑ GAC service life
  - Incorporation of ether oxygen → ↑↓ GAC service life
  - Branching → ↓ GAC service life
  - ↑ Background organic matter → greatly ↓ GAC service life
- Additional tests
  - Additional GACs
  - Cape Fear River water with a background organic matter level that matches CFPUA pilot plant

PFAS removal by ion exchange (IX)

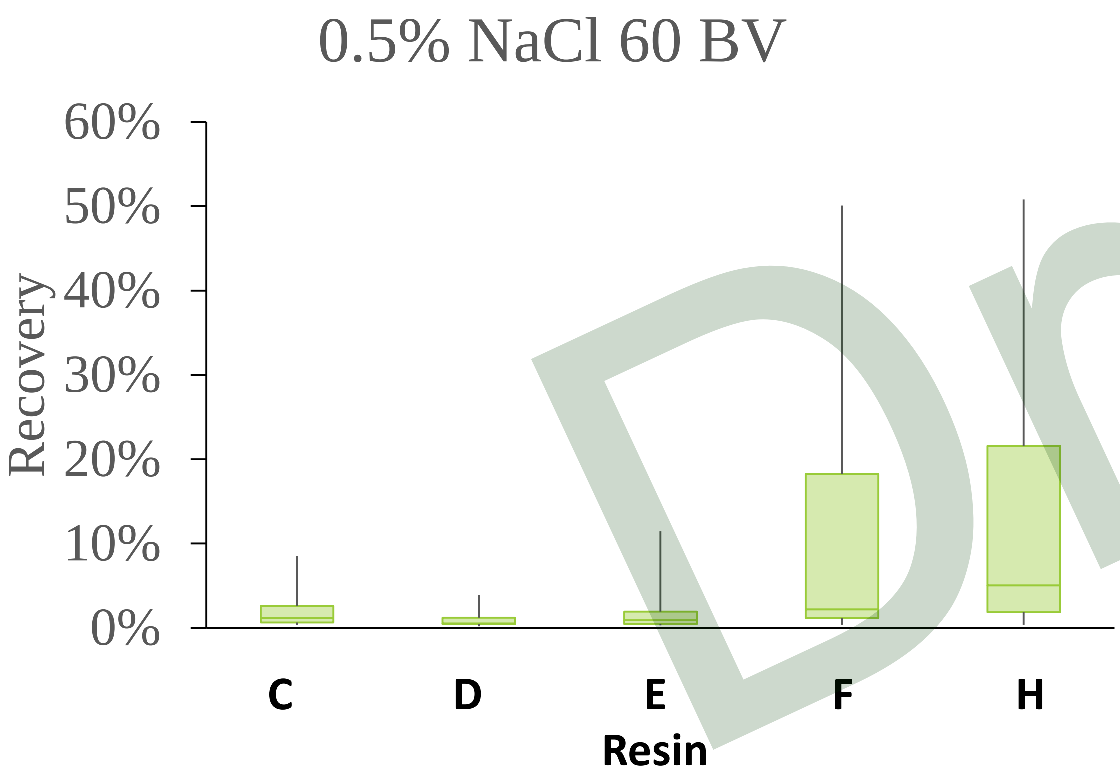
Objectives

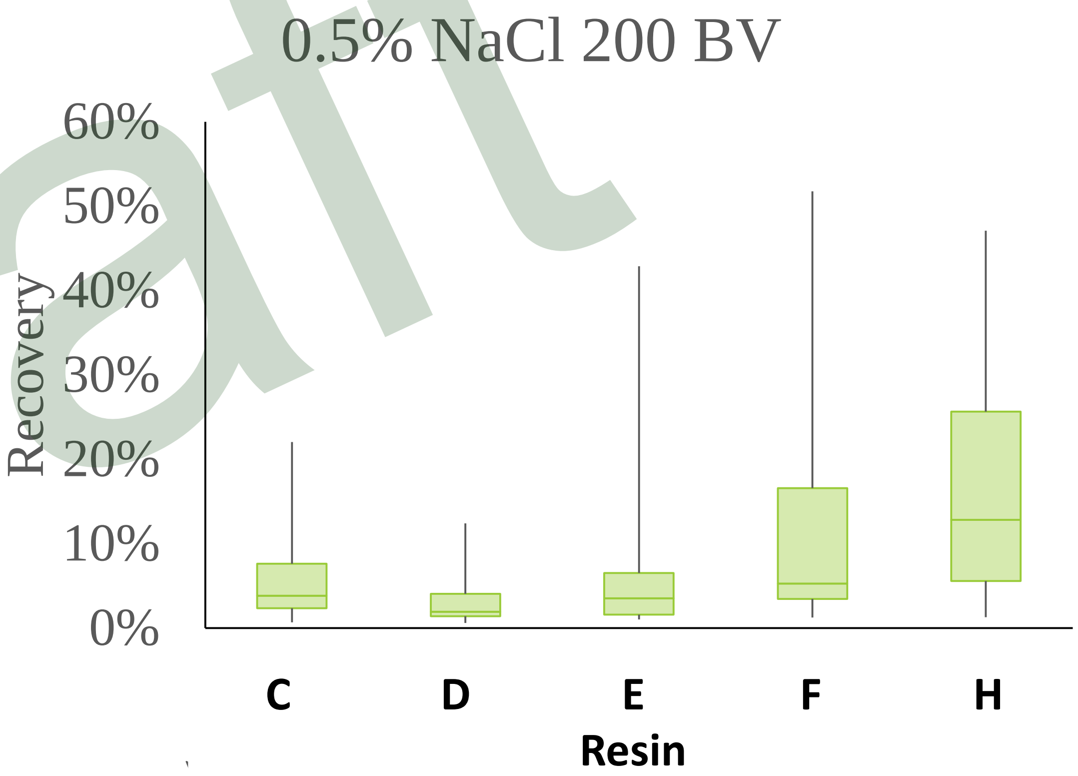
- Assess removal efficiency for the emerging PFAS
- Optimize treatment and regeneration under practical conditions
- Evaluate water matrix effects

Removing 42 PFAS from Fayetteville groundwater with nine resins: Five resins removed majority of PFAS in 2 hours

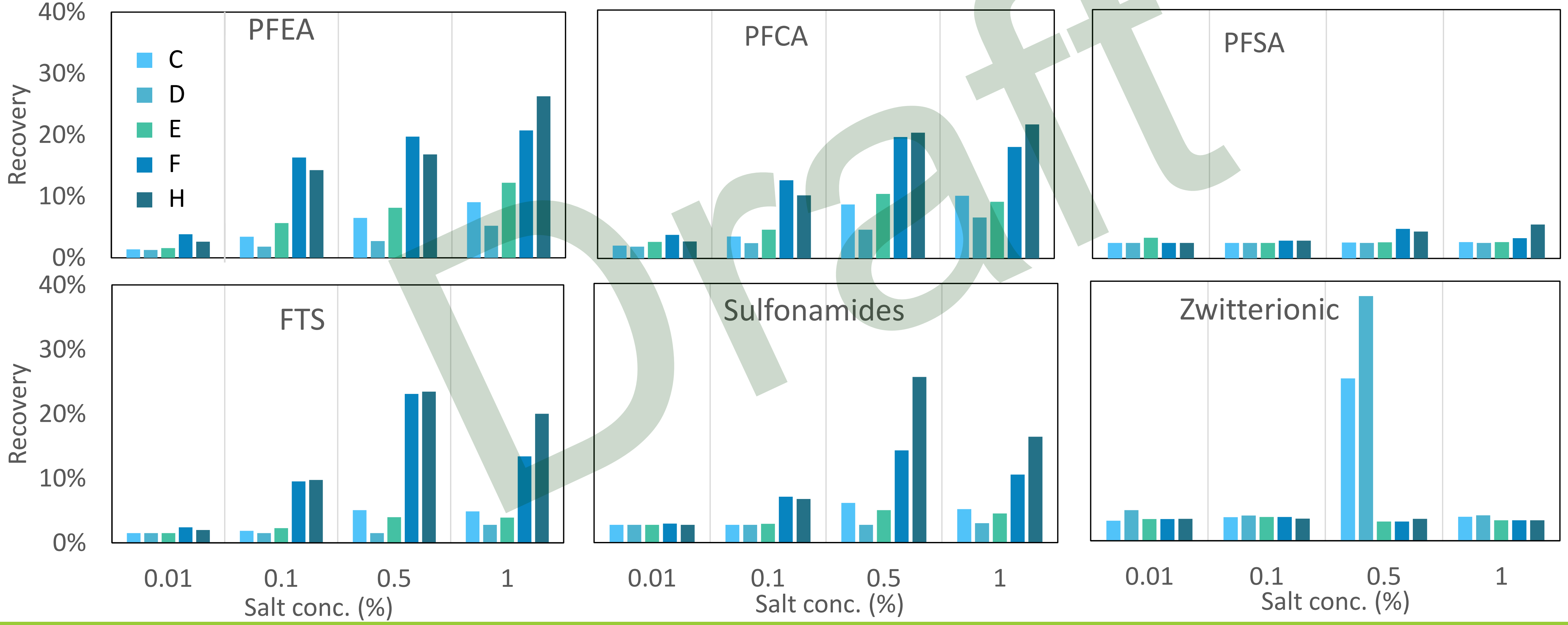


PFAS are hard to be released from resins using simple salt solutions





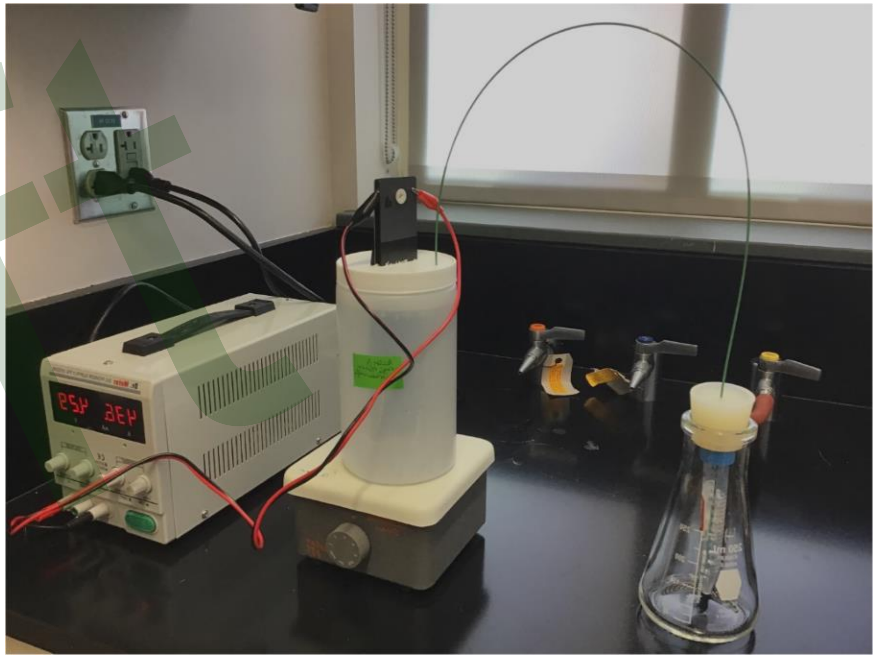
Increasing salt concentration helps regeneration to a limited extent



Key Findings and Future Work

- Among the nine resins, five can achieve >90% removal in 2 hours for 22 PFAS out of 42 tested
- These five resins are not easily regenerated by simple salt solutions, but two are regenerated better than the other three
  - Additional tests
    - Optimizing regeneration methods
    - Characterizing the treatment of the best resin
    - Evaluating the impact of water matrices

PFAS removal by electrochemical oxidation

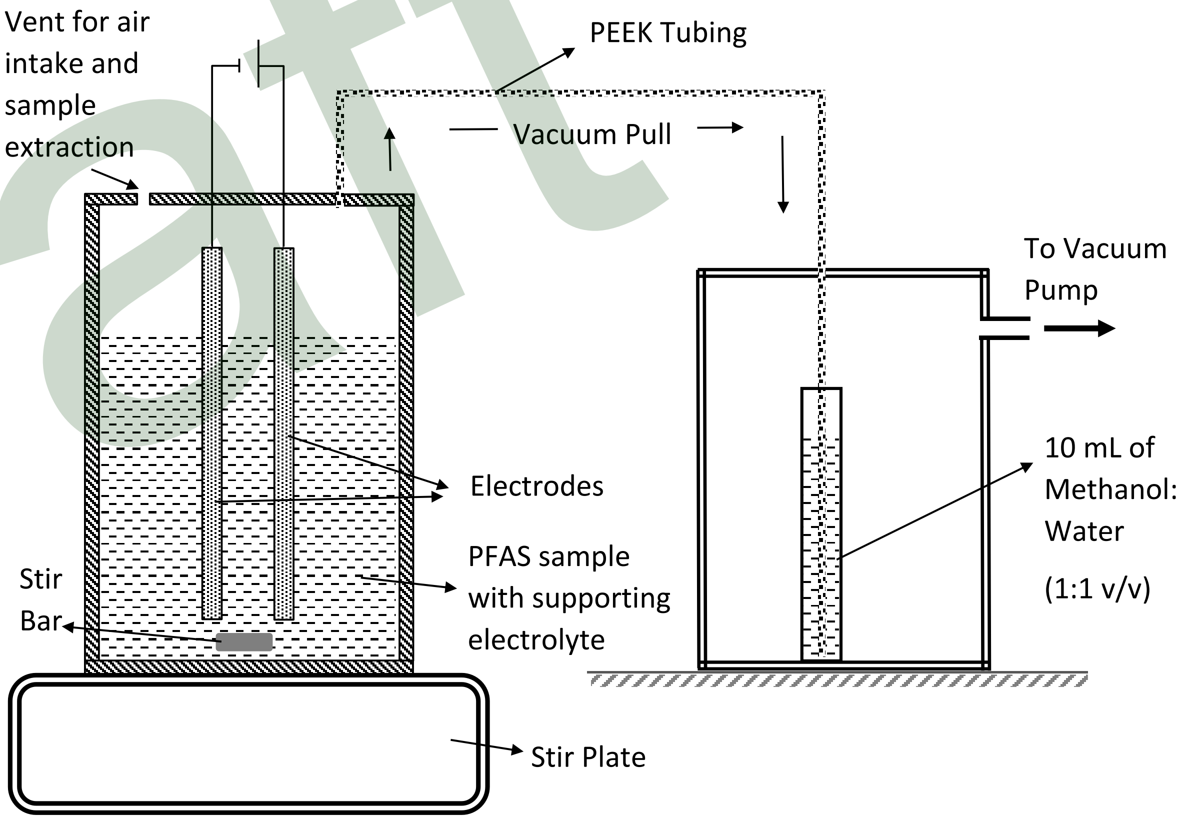


Objectives

- Converts PFAS to non-toxic bicarbonate, fluoride and sulfate ions with complete fluorine mass balance
- Sustainable disposal method for waste streams from membrane and IX treatments

Electrochemical Mineralization- Experiment Design

- PFAS - PFOA, PFOS, GenX
- Anodes - Ebonex Plus (Titanium-ceramic composite), Graphene, Ti/RuO_2 , Boron doped diamond
- Supporting electrolytes - Sodium sulfate, sodium bicarbonate
- Current Density - 0.1(Ebonex Plus) , 1, 5, 10, 20, 30, 40 mA/cm^2



Key Findings

- Titanium-ceramic composite, Graphene and Ti/RuO_2 are not effective anodes for PFAS electrochemical degradation
- PFAS loss through aerosols during electrochemical treatment is substantial
- Additional tests
  - Other electrode materials such as boron doped diamond
  - More PFAS species
  - Impact of water matrix

Final take home message

- PFAS removal from water using either GAC or resins is possible
- Proper selection of processes/products can make the treatment more cost-effective
- Various problems still exist in reality – we don’t have a perfect treatment option yet
- Managing the waste streams after treatment and completely destruct PFAS is challenging

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