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

Mei Sun[1], Detlef Knappe[2], Zackary Hopkins[2], Yen-ling Liu[1], Vivek Pulikkal[1]

[1]Department of Civil and Environmental Engineering, University of North Carolina at Charlotte

[2]Department of Civil, Construction and Environmental Engineering, North Carolina State University

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NORTH CAROLINA PFAS Testing Network

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PFAST Team 3
PFAS removal from drinking water sources

Orlando Coronell, PhD
Associate Professor
UNC, Chapel Hill

Membrane treatment

Mei Sun, PhD
Assistant Professor
UNC, Charlotte

Ion exchange treatment
Electrochemical treatment

Detlef Knappe, PhD
Professor, North Carolina State University

Activated carbon treatment

Frank Leibarth, PhD
Assistant Professor
UNC, Chapel Hill

Novel resin treatment

Heather Stapleton, PhD
Associate Professor
Duke University

Home filter treatment

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)

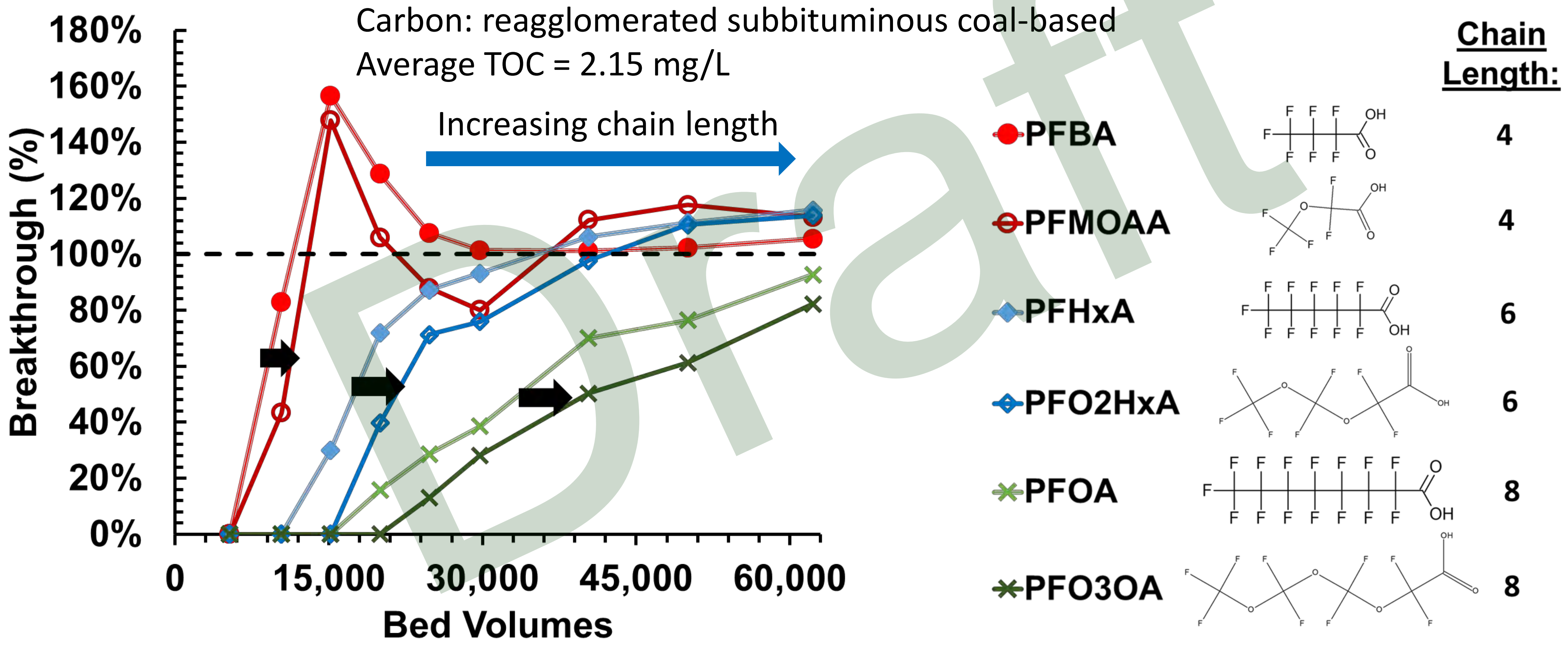
Adsorbates:

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

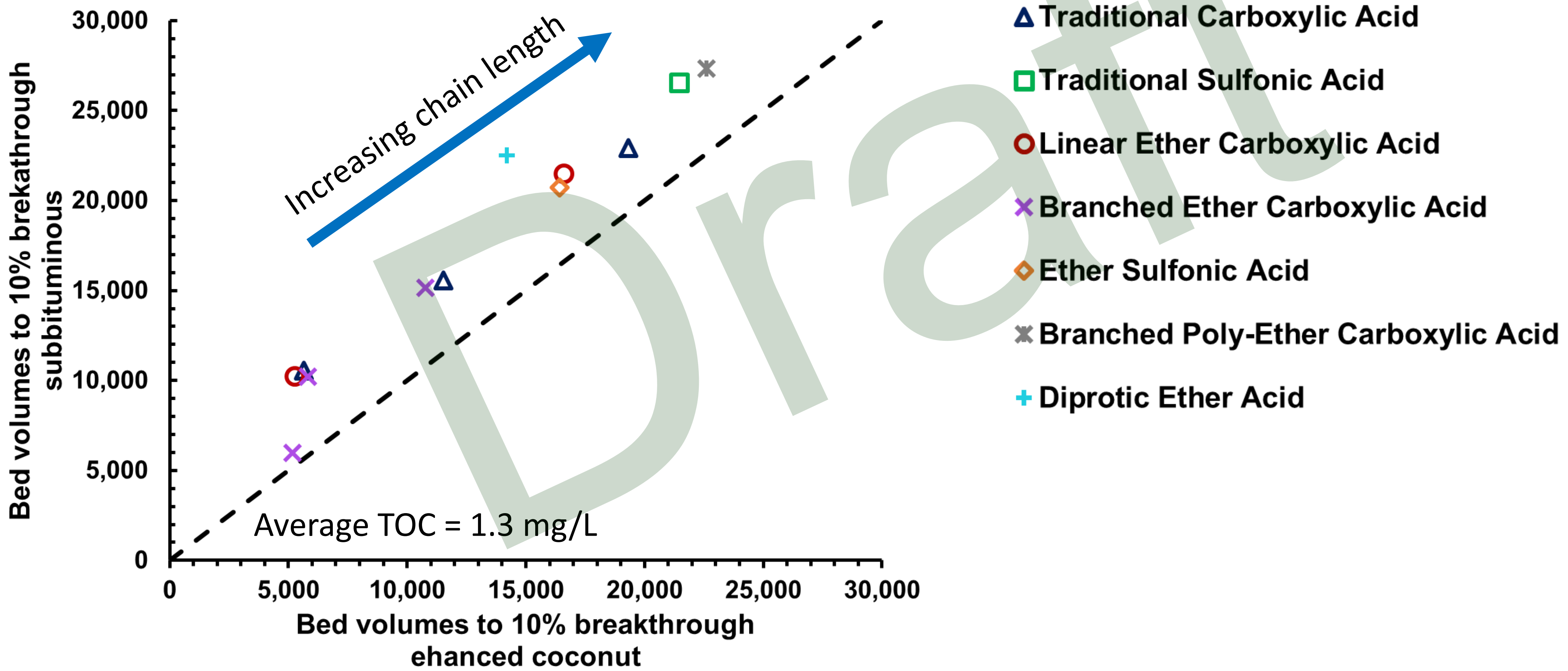
Analysis:

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

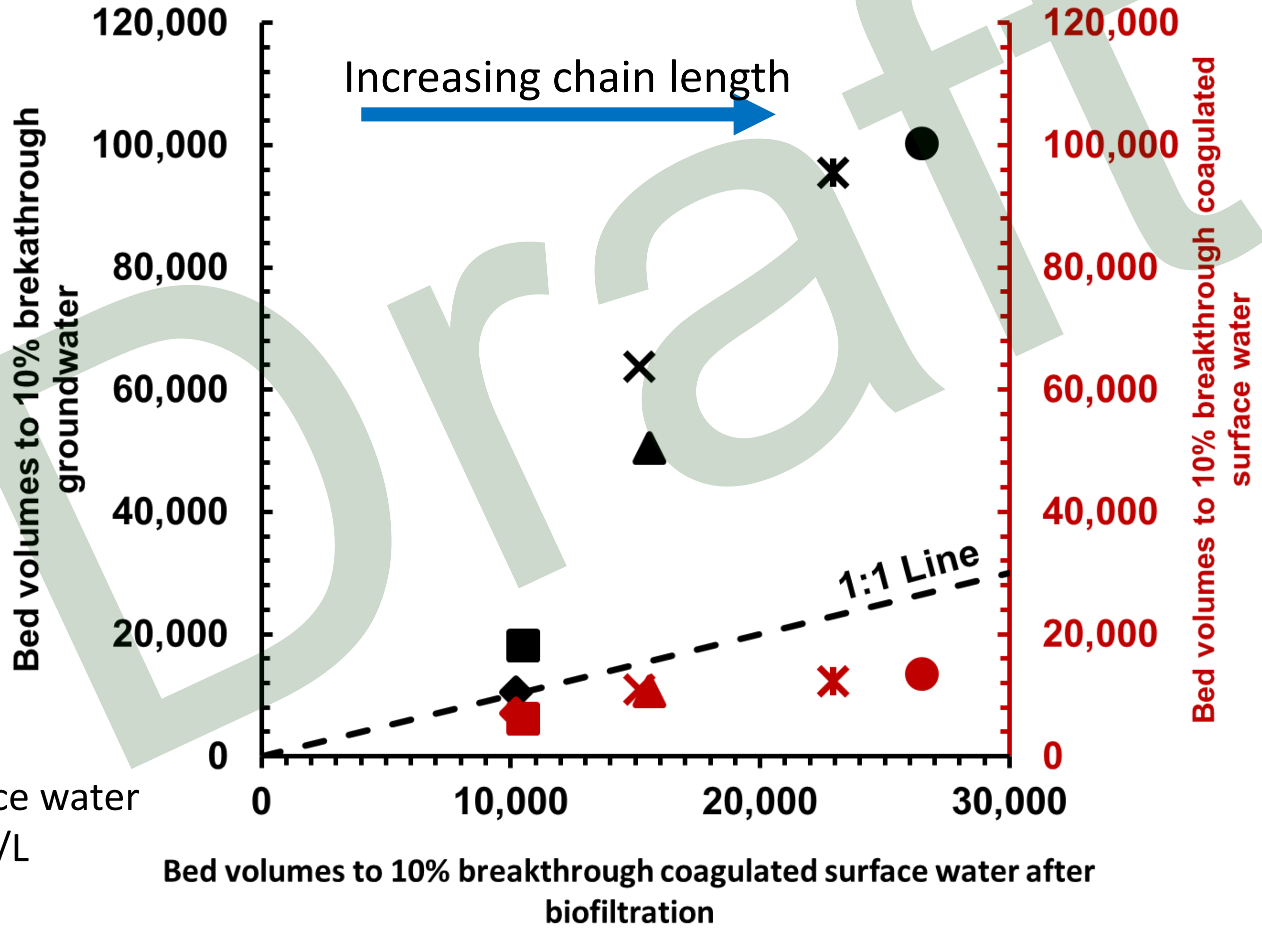


Coal-based GAC has longer service life than coconut shell-based GAC



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

Key Findings and Ongoing Work

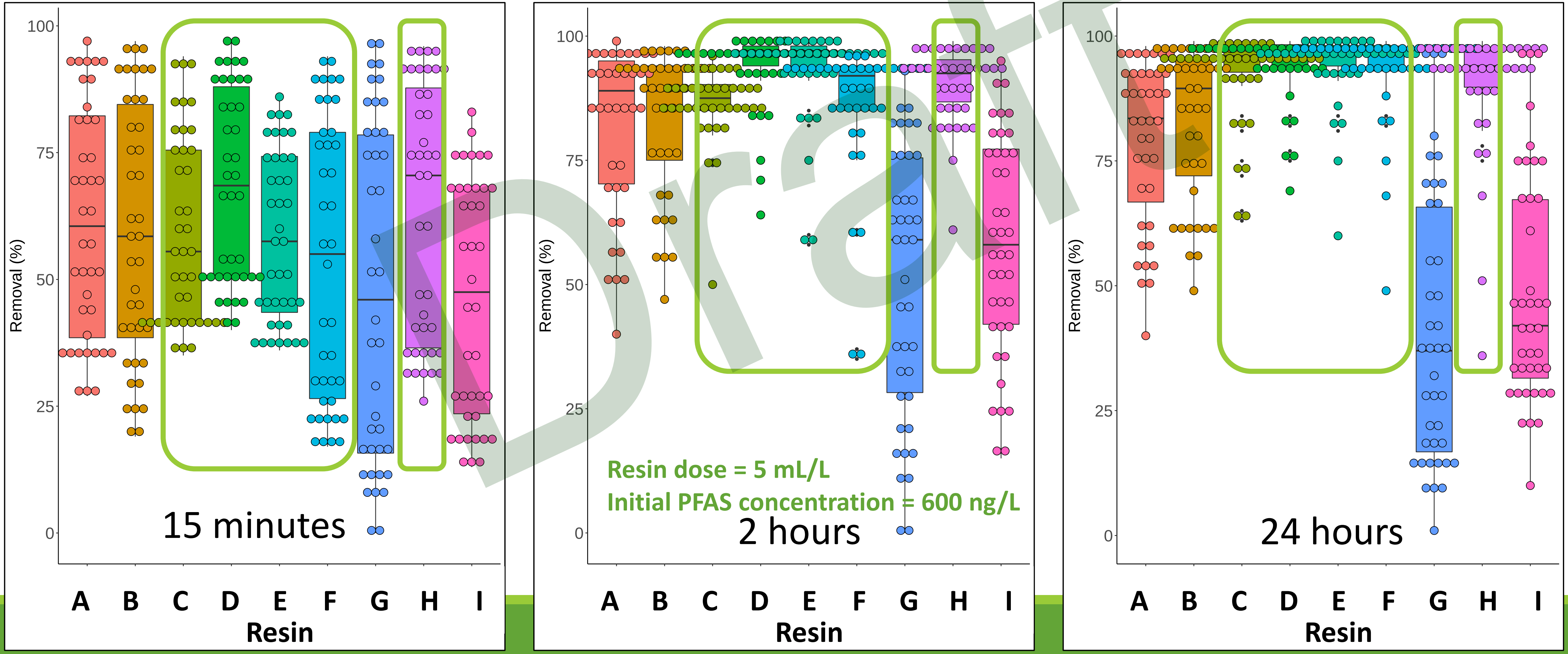
- In coagulated surface water, granular activated carbon service life ranged from 5,000 to 30,000 bed volumes for most PFAS
- PFAS adsorbability impacted by:
  - ↑ Chain length → ↑ GAC service life
  - Incorporation of ether oxygen → ↑ ↓ GAC service life
  - Branching → ↓ GAC service life
  - ↑ Background 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)

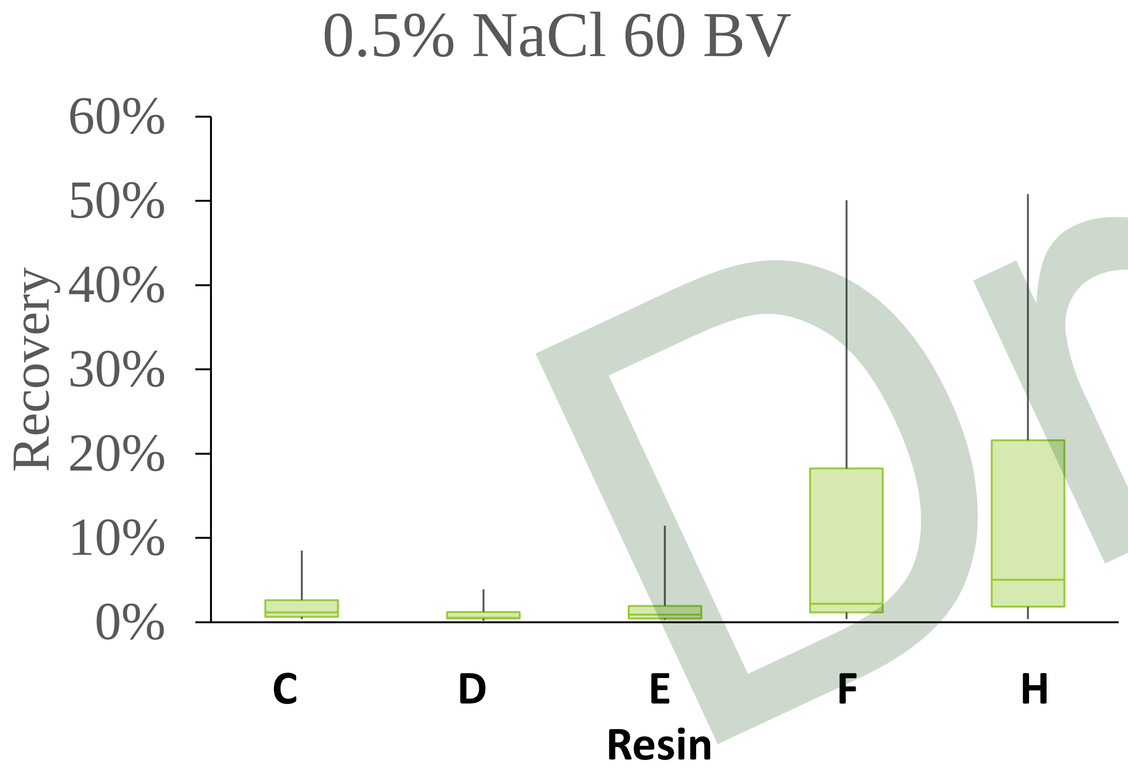
Objectives

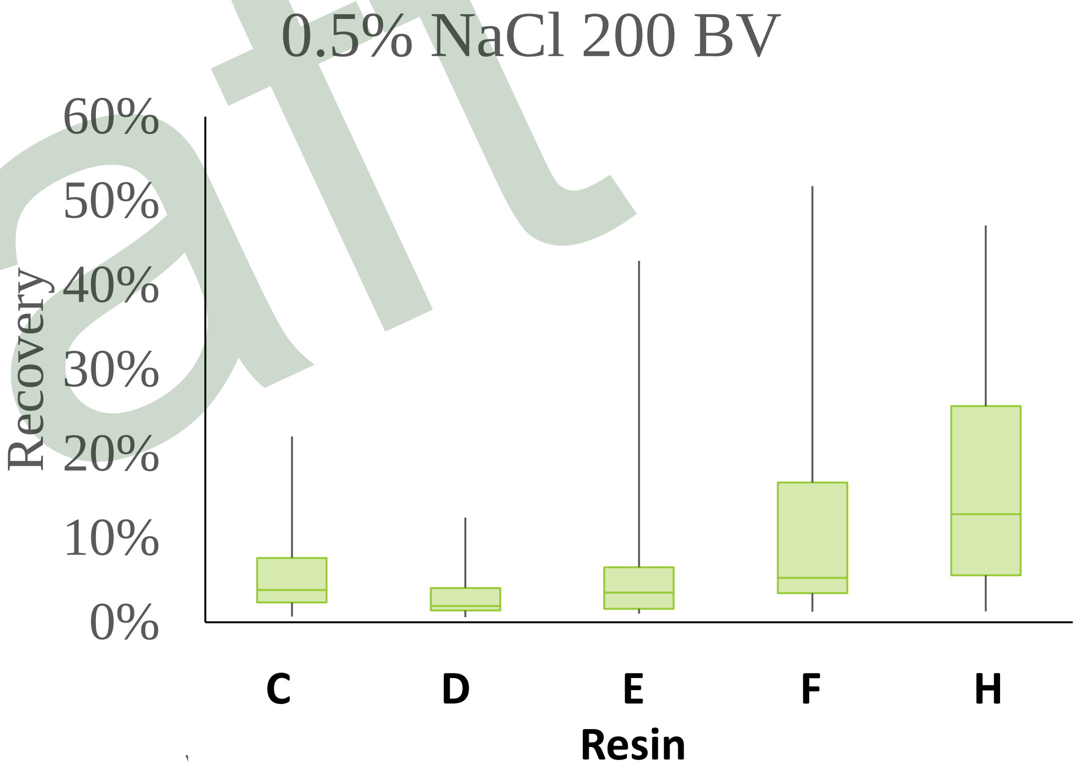
- Assess removal efficiency for the emerging PFAS
- Optimize treatment and regeneration under practical conditions
- Evaluate water matrix effects

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

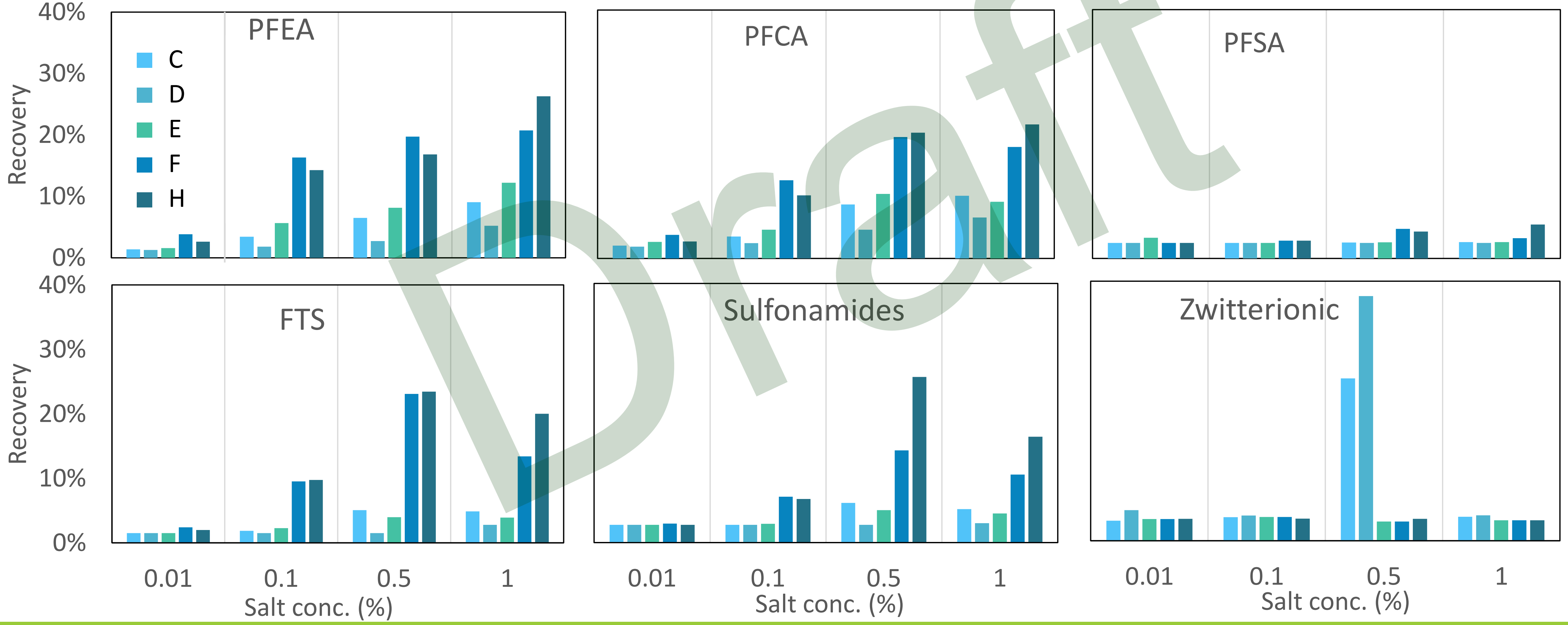


PFAS are hard to be released from resins using simple salt solutions





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

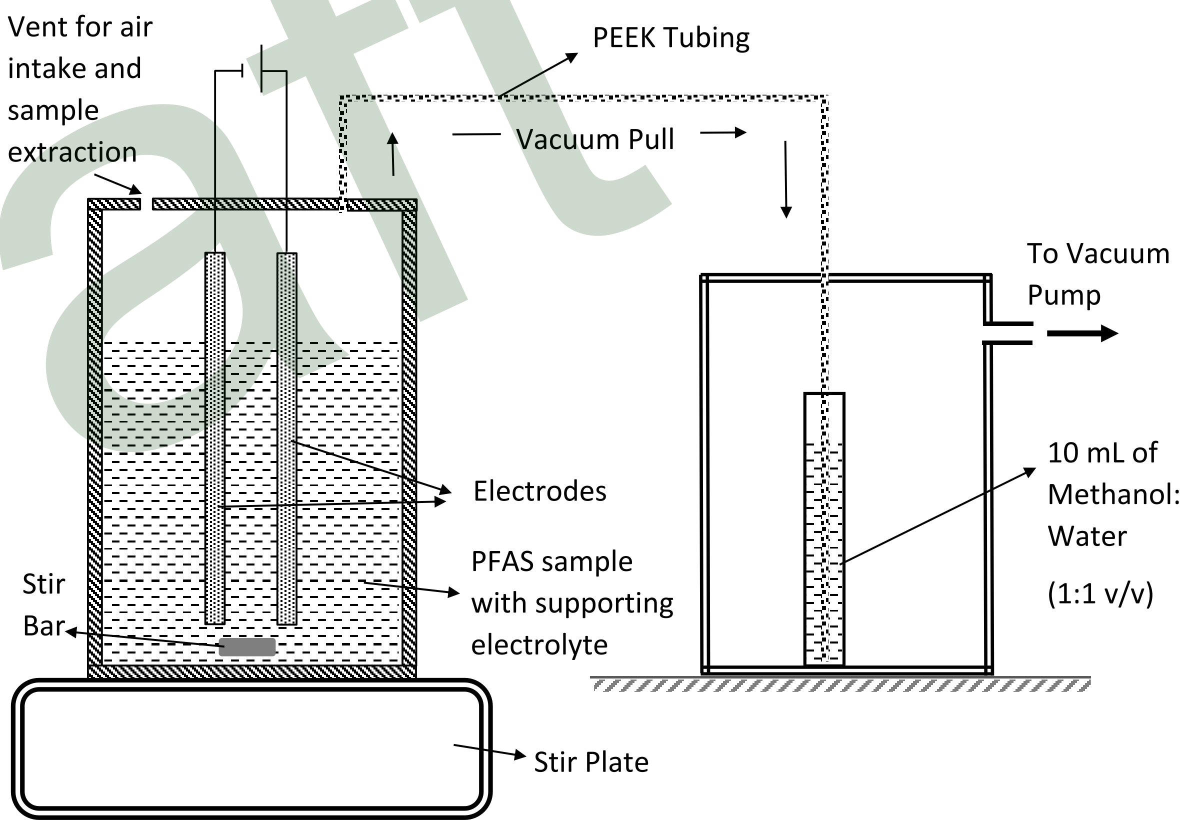
PFAS removal by electrochemical oxidation

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

mei.sun@uncc.edu