AECOM

PFAS

IDENTIFY. RESOLVE.

Coupling Regenerable Ion Exchange Resin with Electrochemical Oxidation for Onsite Separation & Destruction of PFAS in Groundwater

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Project Objectives

- Demonstrate Regenerable ion exchange resin (IXR) effluent meets drinking water health advisory levels for PFOS and PFOA
- Confirm the destruction of PFAS in the still bottom via electrochemical oxidation (EO) treatment
- Optimize the operation conditions of IX-R and EO processes
- Demonstrate the regenerable IX-R+EO treatment train through operation of a pilot-scale treatment system
- Examine the effort needed to complete the closed loop IXR+EO treatment process

Project Team

- AFCEC BAA 108 Project Team
  - PI: Shangtao Liang, PhD, AECOM
  - Co-PI: Jack Huang, PhD, University of Georgia
  - PM: Rebecca Mora, AECOM
  - Technical Advisor: Rachael Casson, AECOM

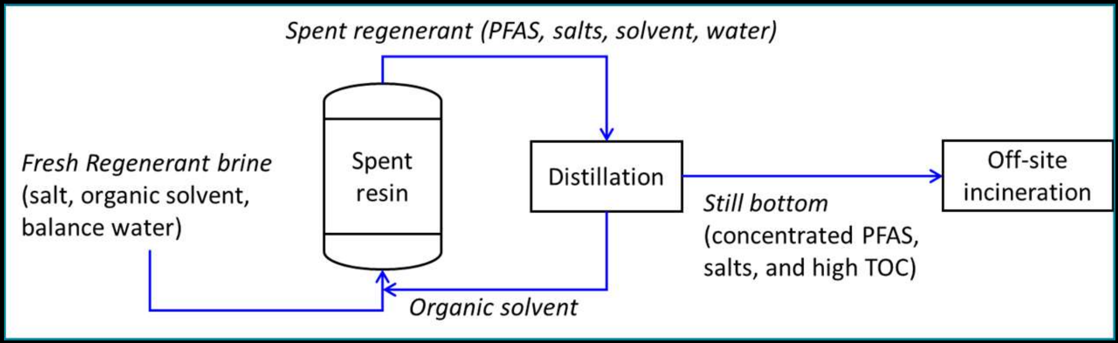
IX-R Technology Supplier
  - ECT2

Analytical Laboratory
  - Pace Analytical - Gulf Coast
  - Eurofins Lancaster (TOP analysis)

Regenerable Ion Exchange Resin for PFAS Treatment

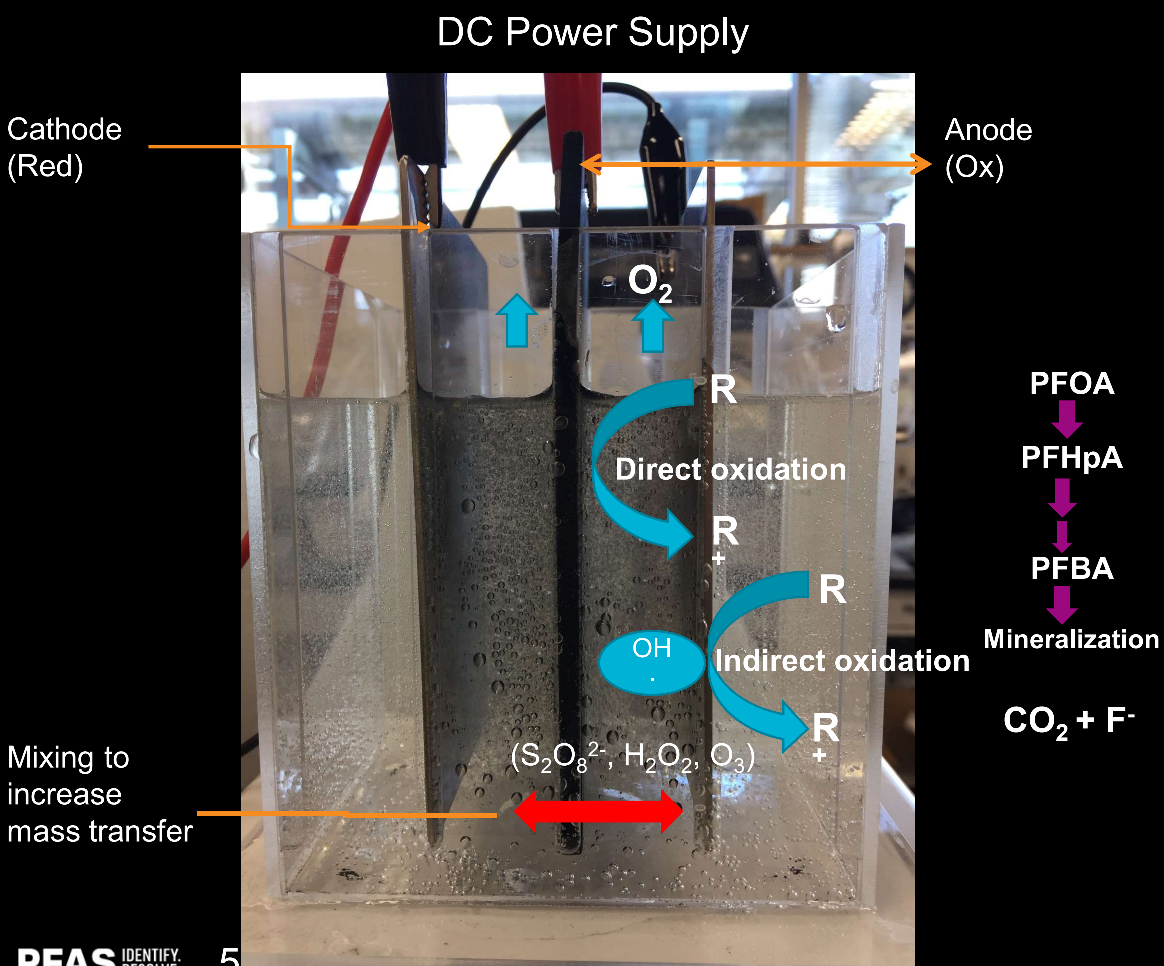
- Uses an on-site process to regenerate spent IXR
  - Significantly reduces spent media for off-site incineration
  - Most applicable for treatment of higher concentrations
- Regeneration solution: brine, organic solvent
  - Organic solvent is reclaimed through distillation
  - Still bottom is the only waste stream requiring disposal

This project used electrochemical treatment to destroy PFAS in the still bottom



Regeneration of ion exchange resin

Electrochemical Oxidation of PFAS – Proof of Concept



PUBLICATIONS

- Lin, Hui, et al. "Development of macroporous Magnéli phase Ti4O7 ceramic materials: As an efficient anode for mineralization of poly-and perfluoroalkyl substances." **Chemical Engineering Journal** 354 (2018): 1058-1067.
- Liang, Shangtao, et al. "Electrochemical oxidation of PFOA and PFOS in concentrated waste streams." **Remediation Journal** 28.2 (2018): 127-134.
- Schaefer, Charles E., et al. "Electrochemical Transformations of Perfluoroalkyl Acid (PFAA) Precursors and PFAAs in Groundwater Impacted with Aqueous Film Forming Foams." **Environmental science & technology** (2018).
- Niu, Junfeng, et al. "Electrochemical oxidation of perfluorinated compounds in water" **Chemosphere** 146 (2016) 526-538
- Schaefer, Charles E., et al. "Electrochemical treatment of perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) in groundwater impacted by aqueous film forming foams (AFFFs)." **Journal of hazardous materials** 295 (2015): 170-175.
- Lin, Hui, et al. "Highly efficient and mild electrochemical mineralization of long-chain perfluorocarboxylic acids (C9–C10) by Ti/SnO2–Sb–Ce, Ti/SnO2–Sb/Ce–PbO2, and Ti/BDD electrodes." **Environmental Science & Technology** 47.22 (203): 13039-13046.
- Niu, Junfeng, et al. "Theoretical and experimental insights into the electrochemical mineralization mechanism of perfluorooctanoic acid." **Environmental Science & Technology** 47.24 (2013): 14341-14349
- Niu, Junfeng, et al. "Electrochemical mineralization of perfluorocarboxylic acids (PFCAs) by Ce-doped modified porous nanocrystalline PbO2 film electrode." **Environmental Science & Technology** 46.18 (2012): 10191-10198.

Field Demonstration at Wright-Patterson AFB

Field Pilot at WPAFB

Tested technology at 2 sites that have groundwater contaminated with PFAS from use of aqueous film-forming foam (AFFF)

- Sites: Hangar, Fire Training Area (FTA)
- Elevated PFAS concentrations at both sites
- Generate performance data for different water quality

Field Pilot – Operation

- IX-R groundwater treatment flow rate: 2 to 5 gpm
- Designed to treat 5,000 – 15,000 ppt total PFAS
- Treatment goal: PFOS + PFOA < 70 ppt (Hangar) and ND for PFOS (FTA)
- Treated ~500,000 gallons of groundwater over 5 months at two sites

Field Pilot – Separation & Concentration

Feed Groundwater

Discharge

Resin Regeneration and Distillation Equipment

Still Bottom Waste

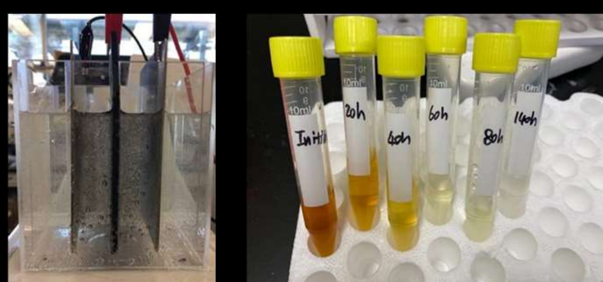
Field Pilot – Destruction

Still Bottom Waste

On-site pilot treatment

Pilot EO Reactor

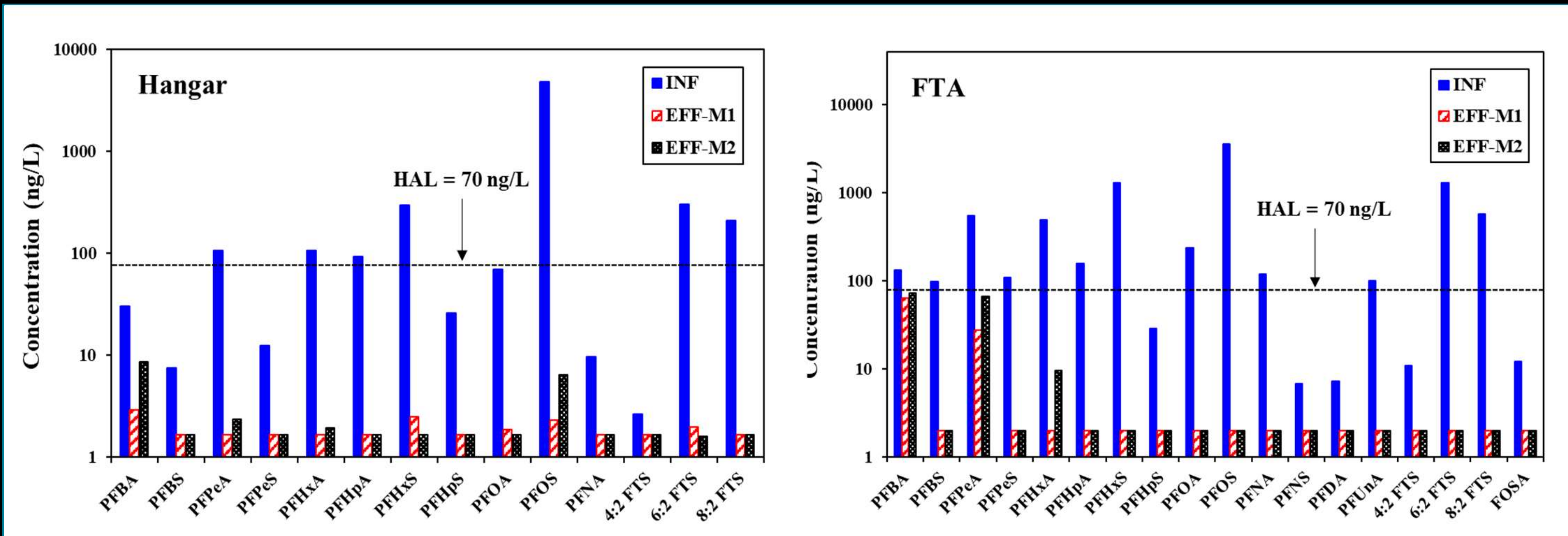
UGA Bench Treatment



Bench EO Reactor

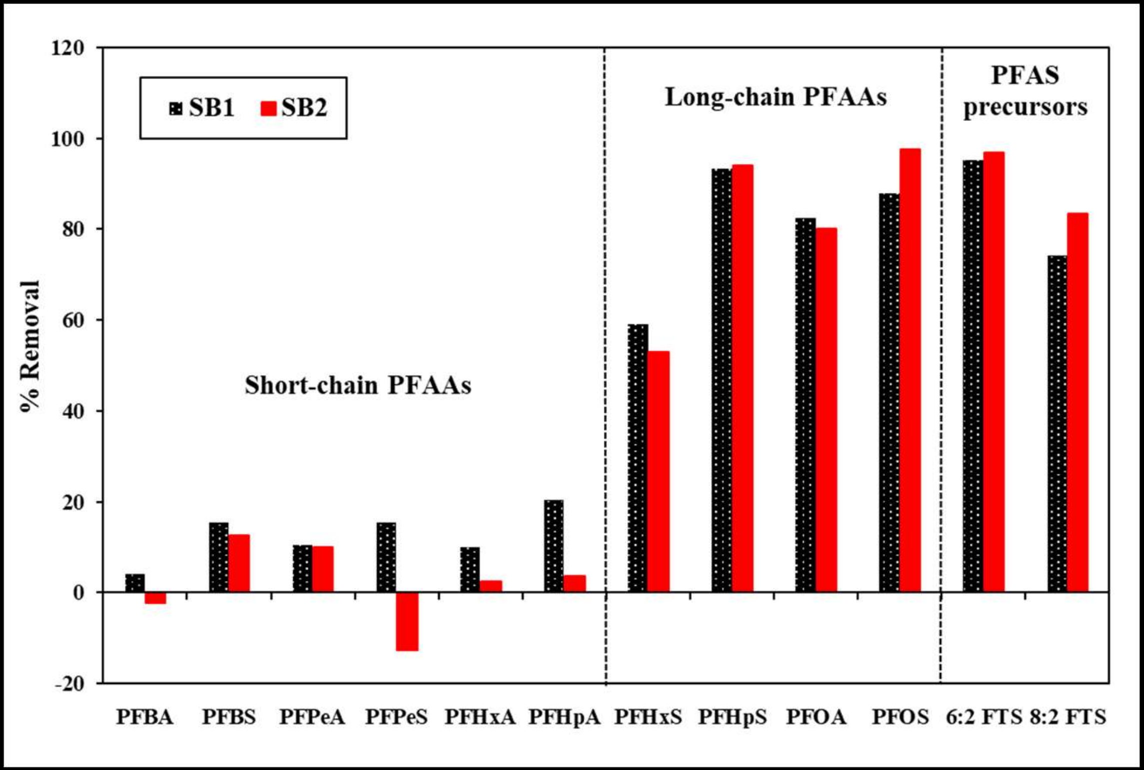
Results and Discussion

Field Pilot – IXR Results



- Only PFAS detected in feed water are shown
- PFOA and PFOS are below 70 ng/L in IXR effluent
- 15 out of 18 PFAS are not detected in IXR effluent
- Resins were regenerated before PFAS saturation

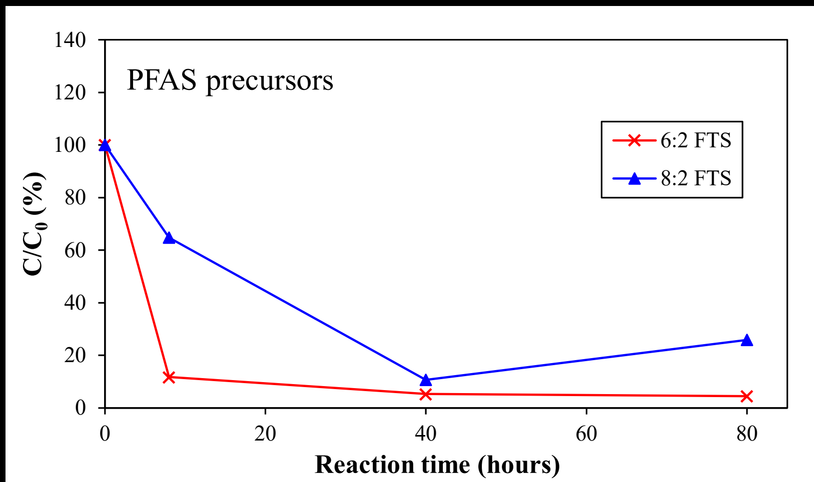
Field EO Pilot Results – PFAS Degradation

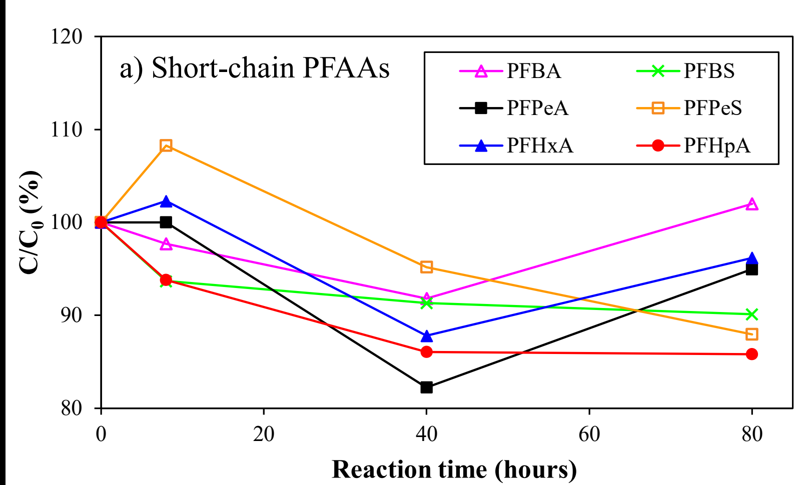


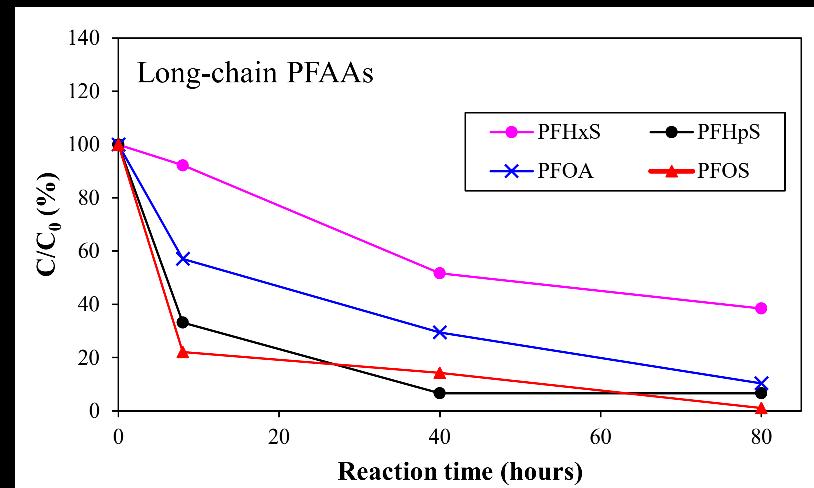
Degradation rate $(C_t-C_0)/C_0$		
	SB1	**SB2**
PFBA	-4%	2%
PFBS	-15%	-13%
PFPeA	-10%	-10%
PFPeS	-16%	13%
PFHxA	-10%	-2%
PFHpA	-20%	-4%
PFHxS	-59%	-53%
PFHpS	-93%	-94%
PFOA	**-82%**	**-80%**
PFOS	**-88%**	**-98%**
6:2 FTS	-95%	-97%
8:2 FTS	-74%	-83%

- Greater than 80% reductions for PFOA and PFOS
- Greater than 70% reductions for precursors
- Degradation of short-chains was slower due to decarboxylation of long-chains and precursors
- Good replicability between batches

Field EO Pilot Results – PFAS Degradation

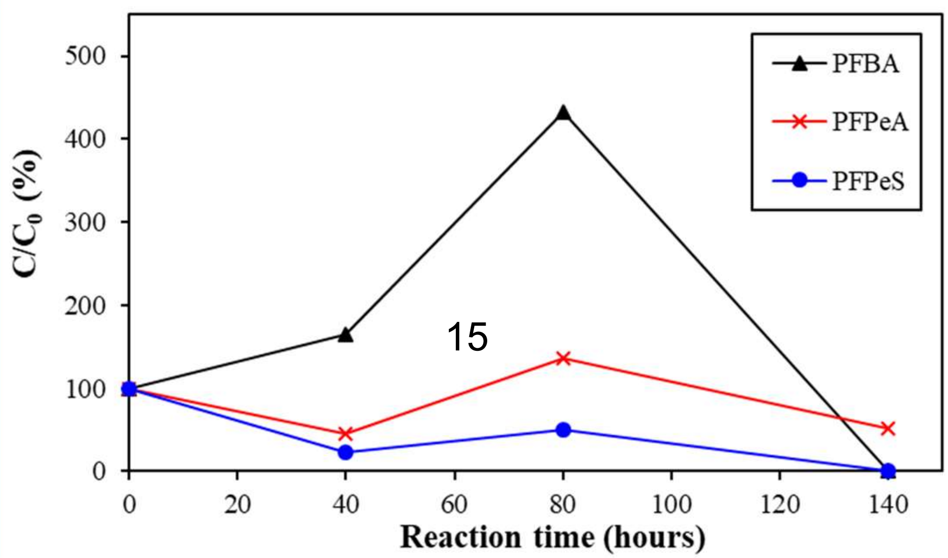


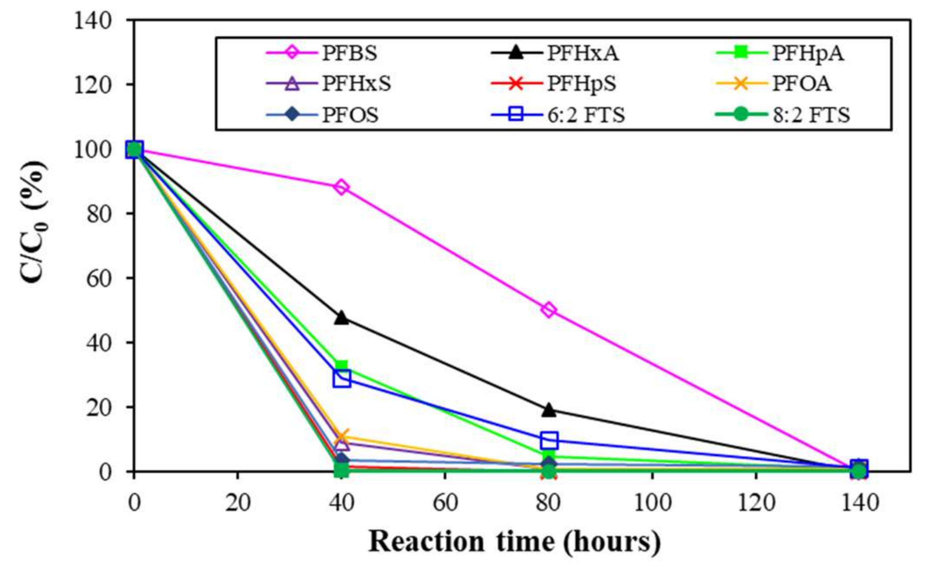




- Rapid degradation was observed for PFAS precursors and long-chain PFAAs within the first 8 hours of treatment
- Short-chain PFAAs were generated as intermediate degradation products

Supplemental Bench – Extended Treatment Time





- 89% PFOA reduction and 96% PFOS reduction achieved within 40 hours
- 99% PFOA reduction and 98% PFOS reduction achieved at 80 hours
- >98% reduction of total PFAS after 140 hours of treatment

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- Examine the amount of effort (energy, cost, additional pre-treatment or post-treatment) needed to complete the closed loop IXR+EO treatment process

Liang et al., 2022. *Field demonstration of coupling ion-exchange resin with electrochemical oxidation for enhanced treatment of per- and polyfluoroalkyl substances (PFAS) in groundwater.* Chemical Engineering Journal Advances V9, 100216

DE-FLUORO – Technology Development Progress

ANZ Field Demonstration

Complete: Large-scale batch reactor

US Air Force Field Demonstration

Underway: Large-scale flow through reactor

Questions?

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