Electrified PFAS Mitigation and Degradation Research Initiative at EPA

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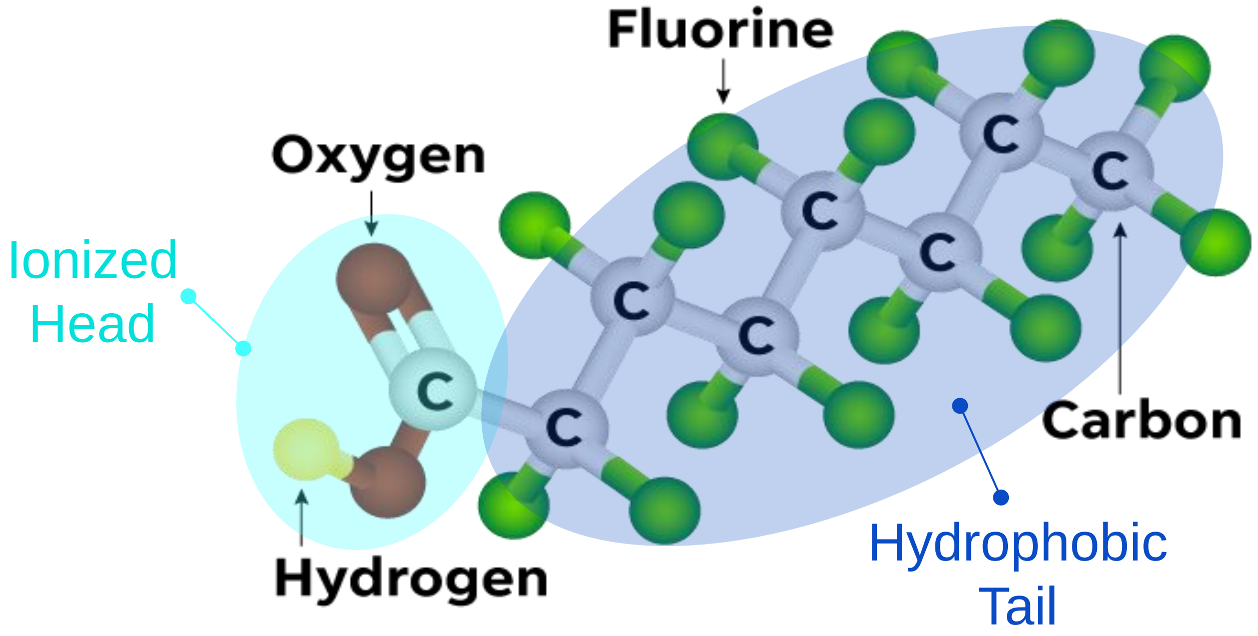
Objectives

- Review PFAS treatment technologies
- Identify promising developments for PFAS technologies
- Propose electrochemical systems for PFAS treatment
- Investigate PFAS removal via electrocoagulation
- Study PFAS degradation via photo-assisted oxidation / reduction

PFAS have unique properties that can impact removal and degradation.



- Expansive chemical group
- Diverse structures
- Highly soluble
- Stable and persistent

Wang. W. et al, Chem Eng Journal 2019

PFAS Regulation in Drinking Water

Chemical	Maximum Contaminant Level Goal (MCLG)	Maximum Contaminant Level (MCL)
PFOA	0	4.0 ppt
PFOS	0	4.0 ppt
PFHxS	10 ppt	10 ppt
HFPO-DA (GenX chemicals)	10 ppt	10 ppt
PFNA	10 ppt	10 ppt
Mixture of two or more: PFHxS, PFNA, HFPO-DA, and PFBS	Hazard Index of 1	Hazard Index of 1

Public water systems have five years (by 2029) to implement solutions that reduce these PFAS if monitoring shows that drinking water levels exceed these MCLs.

https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

Many technologies have been proposed for PFAS treatment.

REMOVAL

- More studied, generally simpler
- Produce concentrated waste streams

Adsorption

Reverse osmosis (RO)

DEGRADATION

- Promise complete destruction
- Eliminate waste streams
- Unknown, incomplete degradation products

Incineration

Photolysis

More developed ⟷ ***Less developed***

Electrochemical systems are promising but require further development.

REMOVE

Electrocoagulation

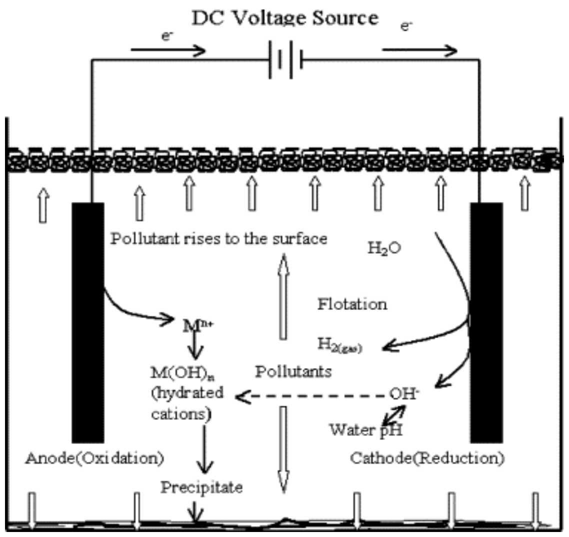
Electrodialysis

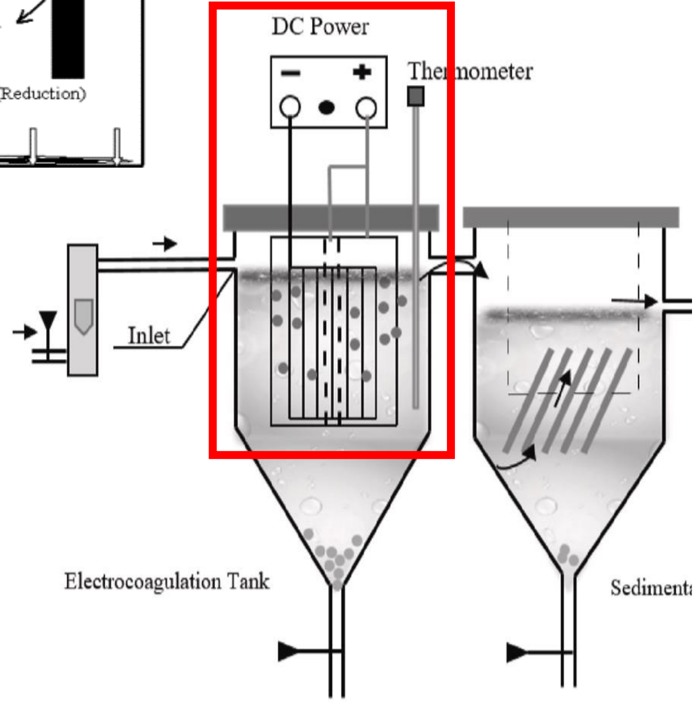
DEGRADE

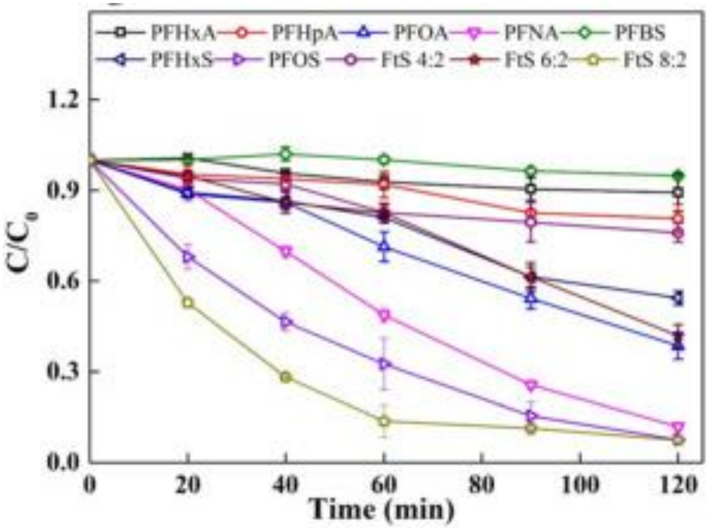
Electro-oxidation / reduction

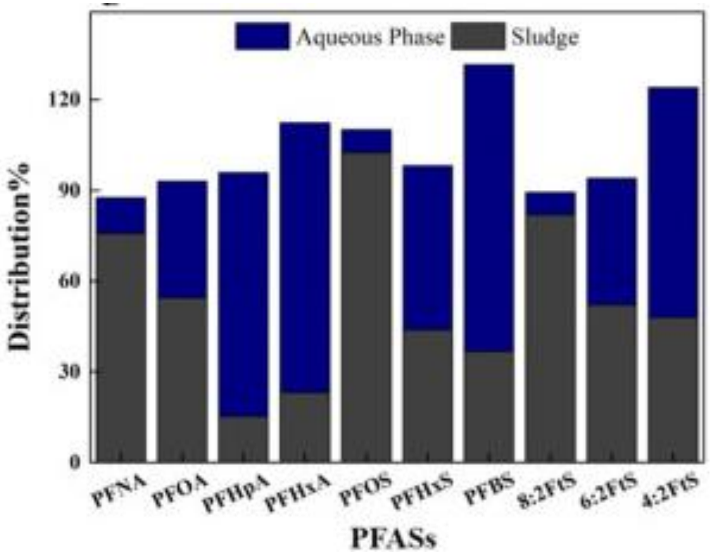
- Electricity drives chemical reactions
- Varied mechanisms
- Modular and scalable
- Minimal chemical input
- Minimal mechanical energy loss

Electrocoagulation (EC) provides partial PFAS removal.









Mollah, M. et al. J. of Haz. Mater. 2004; Jaism, M. et al. Heliyon 2023.

Shi, H. et al. Sci. of Tot. Environ. 2021.

Pilot system will study long-term EC feasibility in challenging water.

WIGWAM, CO – Site Support & Analysis

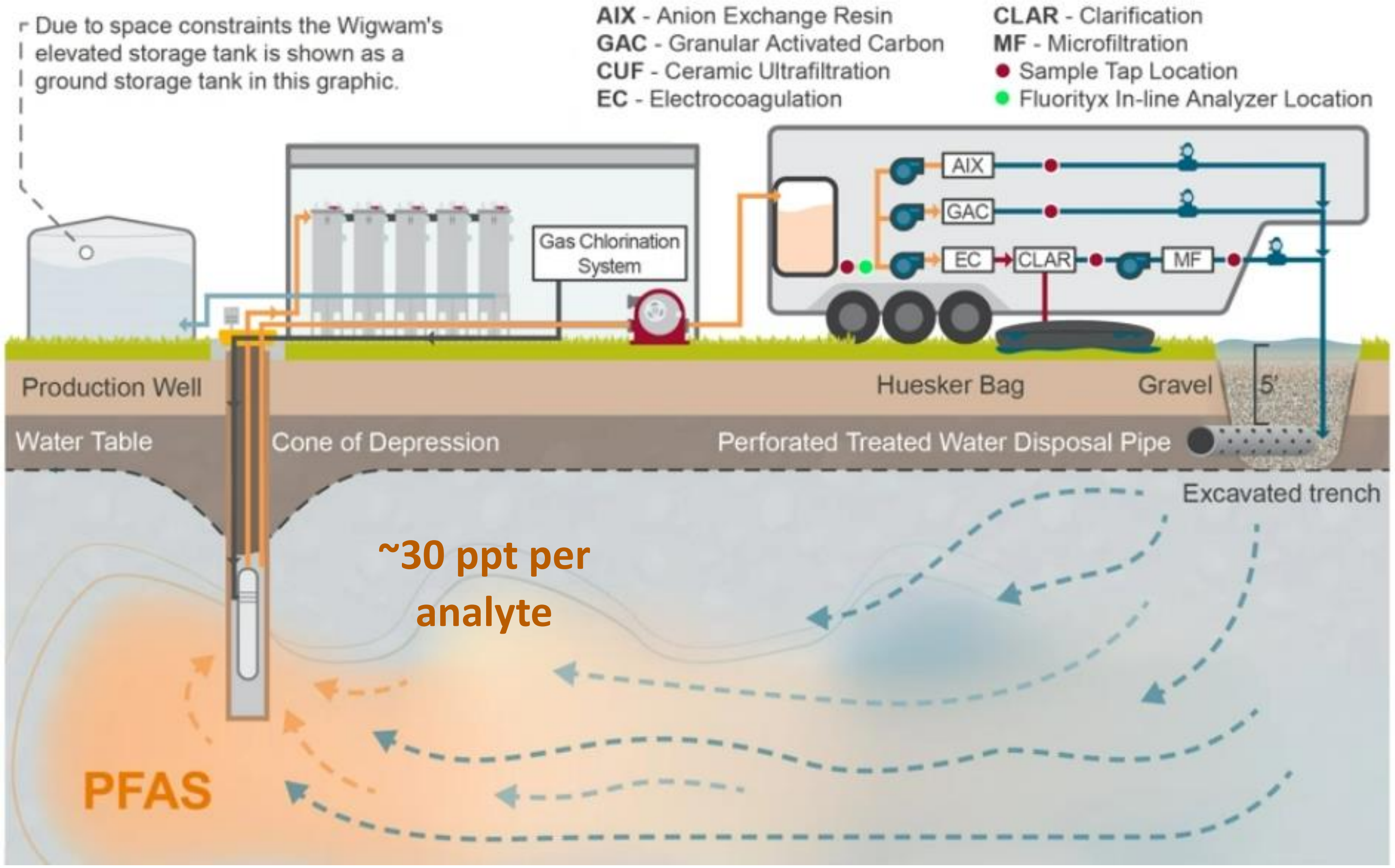
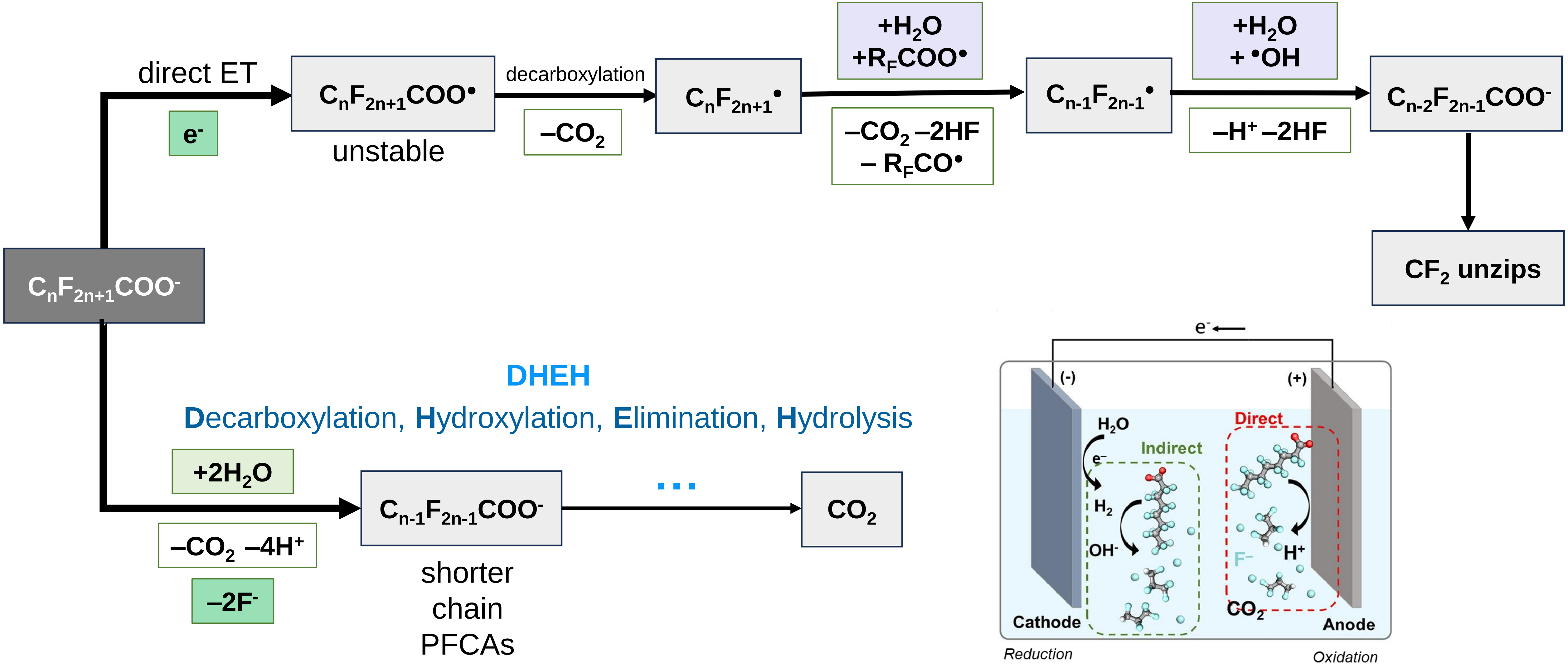


Figure courtesy of Kimley-Horn.

- Alluvial aquifer, shallow, AFFF contaminated
- Very hard water (510 mg/L $CaCO_3$)
- Operated 24/7 for one year with bi-weekly sampling events
- Compared to three adsorbents under same conditions
- Electrodes (“blades”) with frequent polarity reversal and cleaning in place

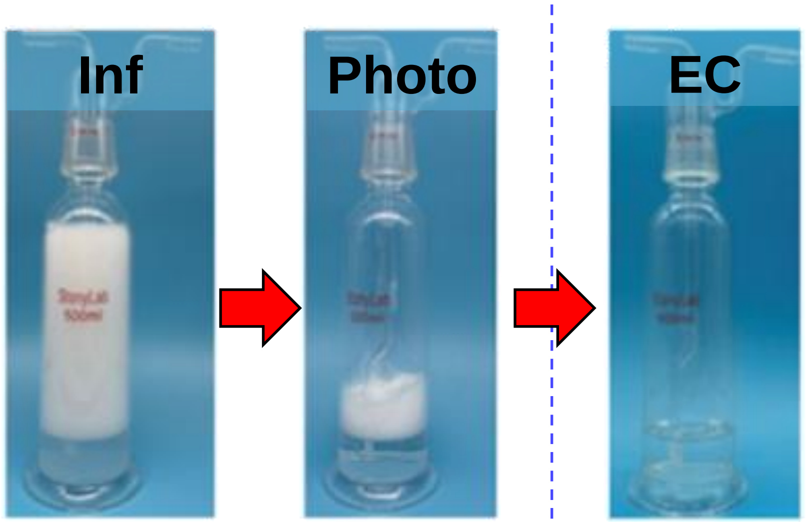
Electrochemical oxidation (EO) provides PFAS degradation.

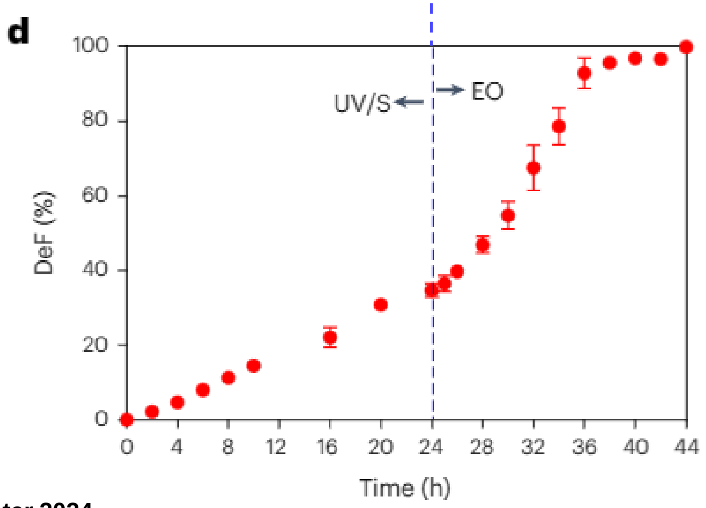


Santiago, A. et al. *Electrochimica Acta* 2022

Photo-assisted EO systems promise improved PFAS degradation.

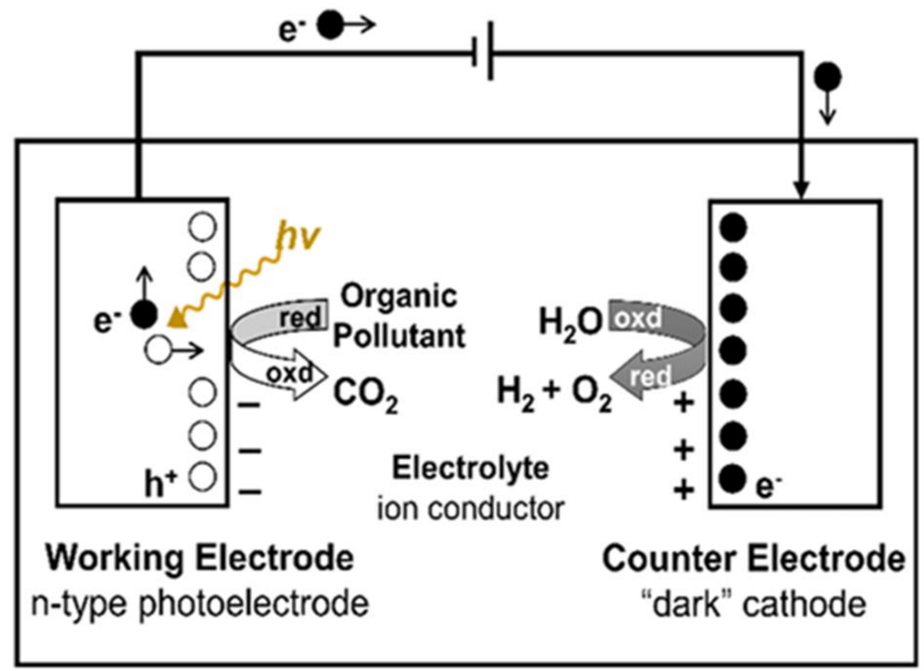
1) Multiple units in series





Guan, Y. et al. Nature water 2024.

2) Single unit



Butzlaff, A. et al. RSC Advances 2023.

Systems will be developed from a holistic approach and evaluated under real conditions.

Reaction environment

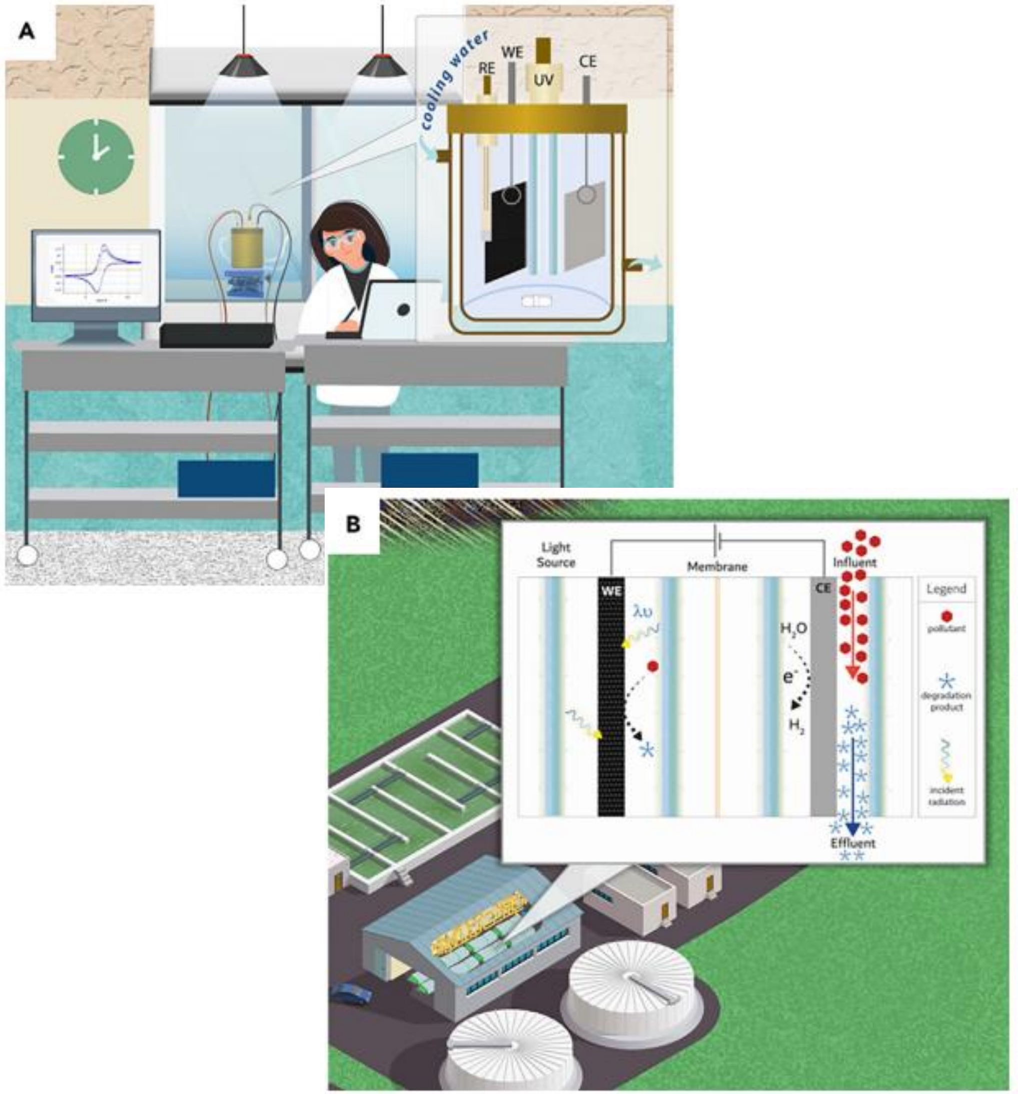
- Competing components
- By-product identification
- Reactive species formation

Design

- Reactor design
- Tailored materials
- Cathode contributions
- Flow configuration

Operation

- Long-term stability
- Electrode fouling
- Energy consumption
- Voltammetric techniques

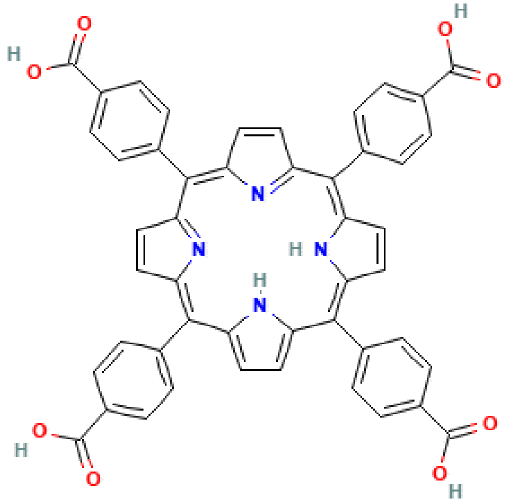


Butzlaff, A. and Ateia, M. *Chem Catalysis* 2024.

Flexible photocatalysts have been identified and synthesized.

Dr. Tin Le

Organic linker



tetrakis(4-carboxyphenyl) porphine (TCPP)

+

Metal

Zirconyl chloride octahydrate

OR

Cobalt nitrate hexahydrate

OR

Iron (III) chloride hexahydrate

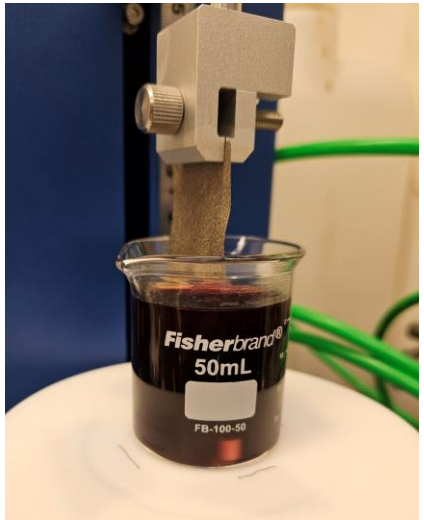
=

PCN-222

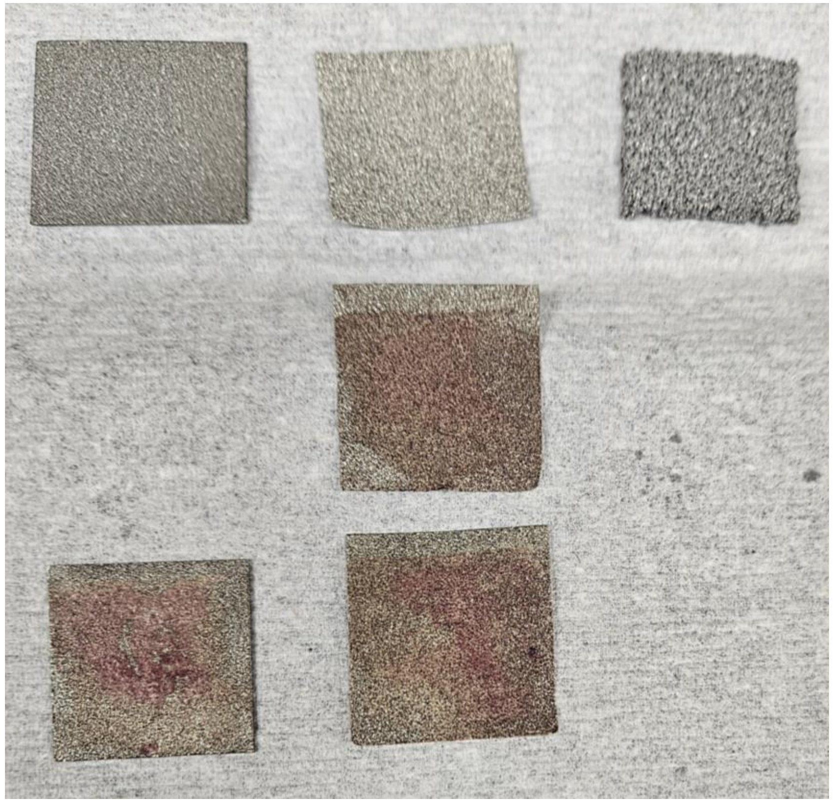
- Electroactive
- Photoactive
- Hard-Soft Acid-Base stable

Multiple modification pathways will be explored to identify most robust material.

1) Dip-coated



Titanium **Nickel** **Aluminum**



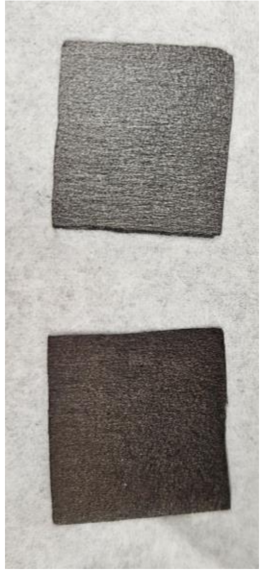
Control

1 dip coat

3 dip coats

2) Electrochemical

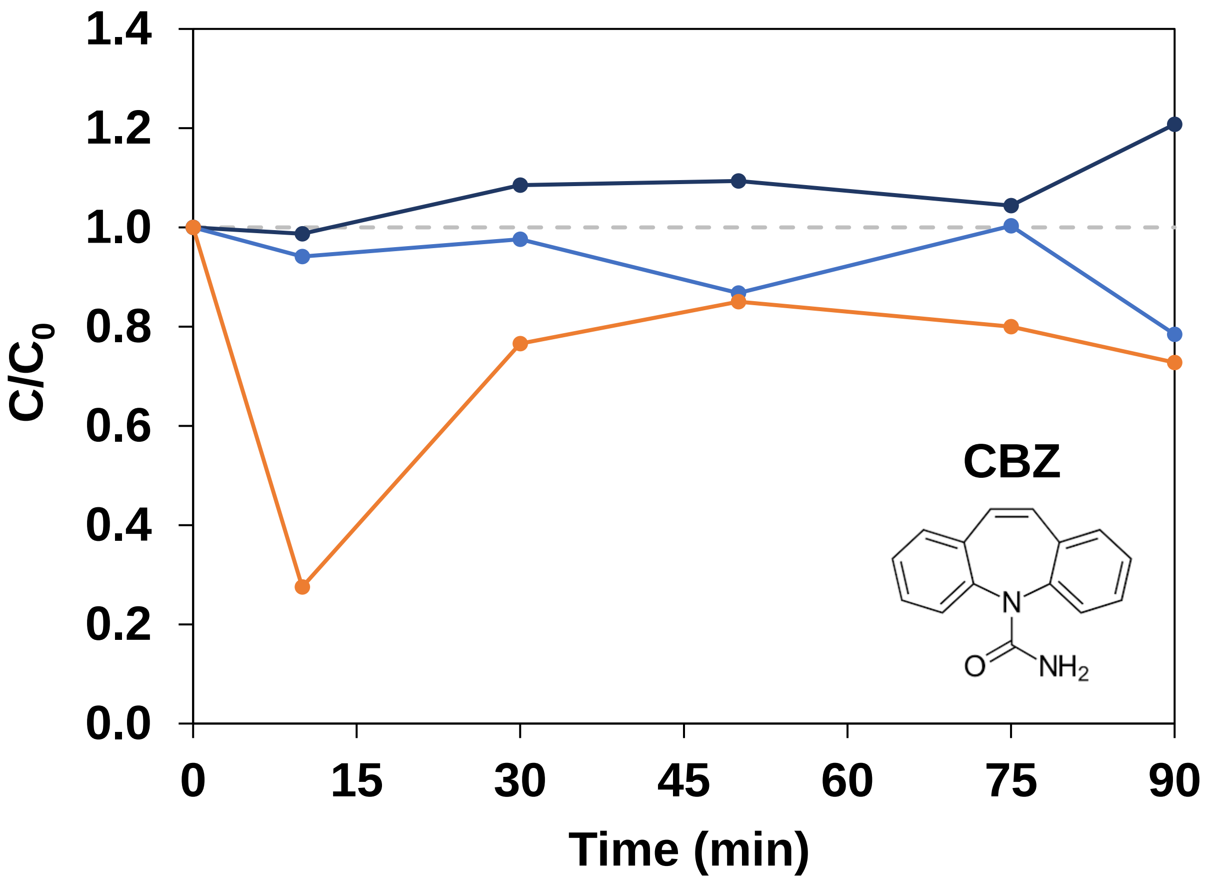
Titanium **Carbon**



Control

Modified

Initial characterization and experiments motivate continued investigation.



- MOF crystallinity improved from reported literature
- MOFs water stable after multiple washes
- MOF-modified electrodes demonstrate oxidation activity toward organic contaminants

Electrolyte: 5 ppm phosphate buffer purged with N2;
Contaminant: 12 ppm carbamazepine; +1.2 V vs Ag/AgCl

Future Efforts

- Continued photo-electrode optimization
- Photo-assisted electrochemical PFAS degradation experiments
- Pilot scale (photo)electrochemical evaluation
- Site support and PFAS analysis for Wigwam, CO
- Identify additional utilities interested in electrochemical treatment methods

Questions?

BIL Water Infrastructure – Safe Drinking Water

https://www.epa.gov/infrastructure/water-infrastructure-investments

Pathway Innovation Projects (PIP)

https://www.epa.gov/innovation/pathfinder-innovation-projects

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