November 6, 2025

Plasma’s Role in PFAS Remediation

Selman Mujovic, PhD

Purafide CEO

Outline

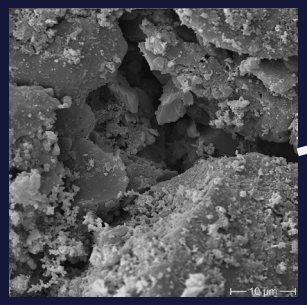
- Problem: PFAS
- Solution: Destruction (Plasma)
- Purafide’s Approach
- Experimental Design
- Previous & Pending Studies
- Takeaways & Next Steps

Problem: PFAS

- Separation is current state-of-practice for PFAS management
  - Produces hazardous waste
    - Concentrate
    - Spent media
  - Disposal is costly and introduces long-term liabilities
- Sustainable destruction is needed

Ion Exchange (IX) Resin

Granular Activated Carbon (GAC)

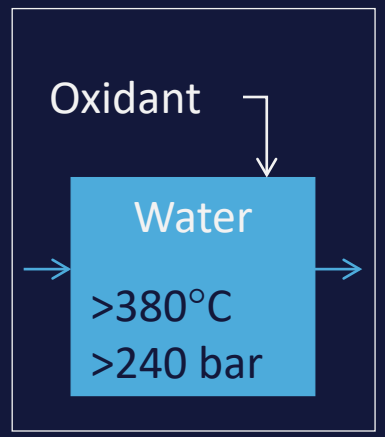


Landfill

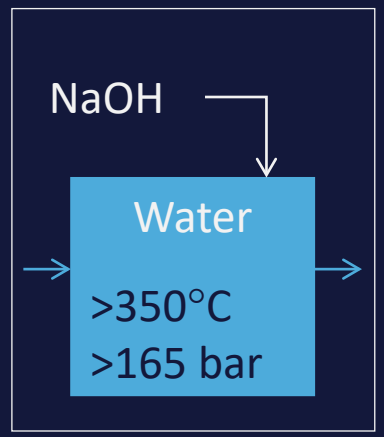
Solution: Destruction

- Thermal and non-thermal approaches (Examples below)
  - Each has benefits & limitations — cost, scale, resource recovery, etc.
    - Universally, scavenging capacity of background matrix hinders efficacy

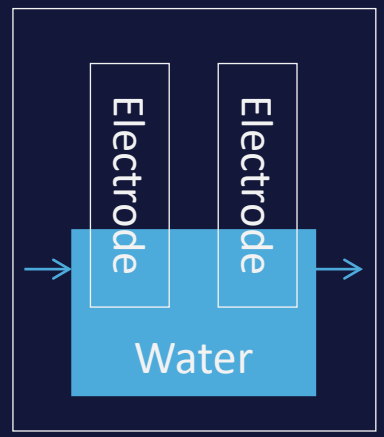
Supercritical Water Oxidation (SCWO)



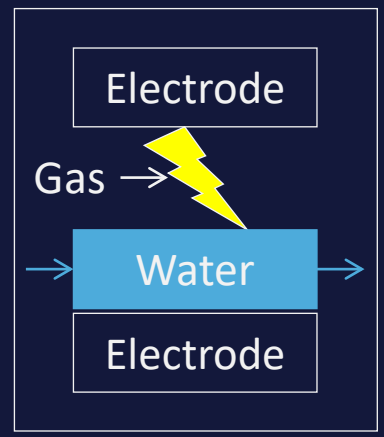
Hydrothermal Alkaline Treatment (HALT)



Electrochemical Oxidation (ECO)



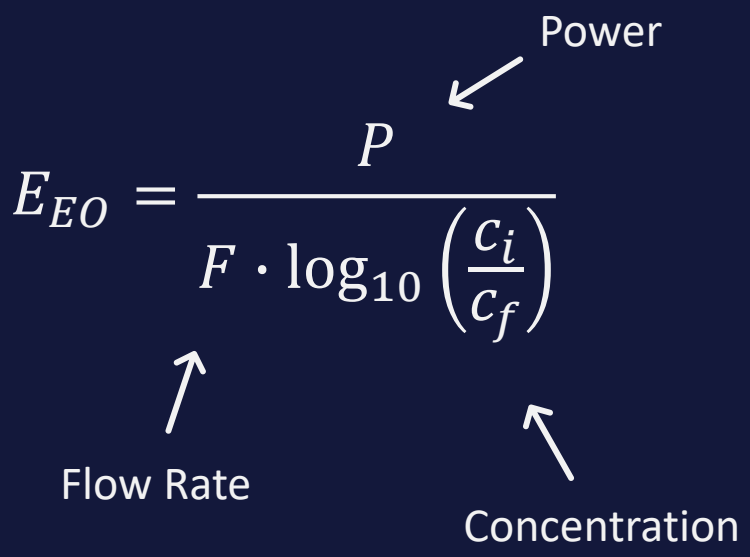
Plasma



Hao, 2022, ES&T
Vadillo, 2013, I&ECR

Energy Efficiency per Order

- Typically, thermal requires greater energy than non-thermal
- Plasma can be efficiently produced to destroy contaminants

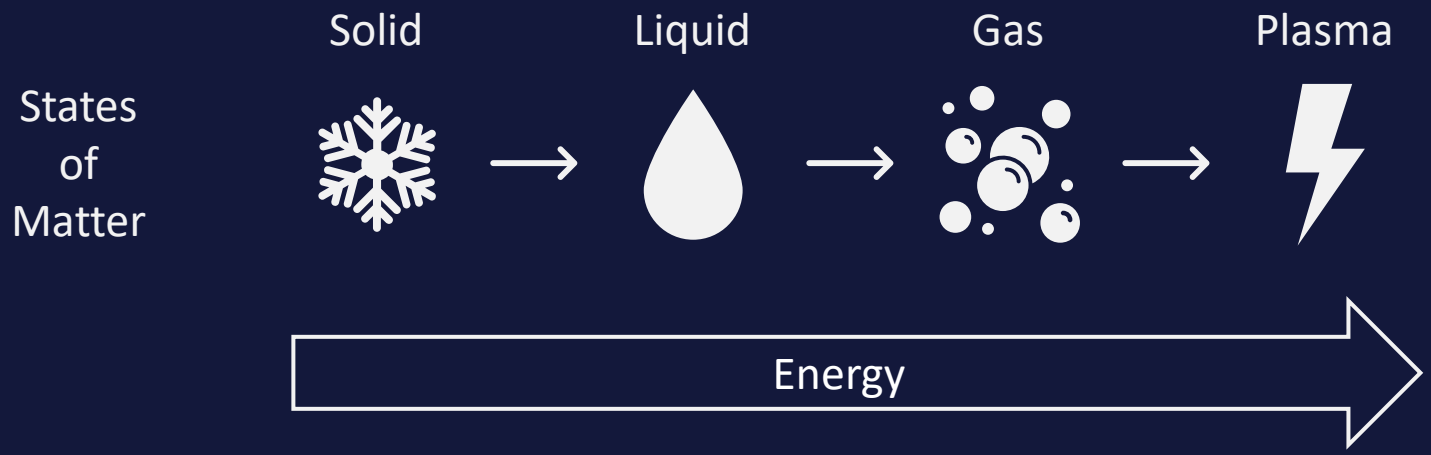


Technology	PFOA E_{EO} (kWh/m^3)
Incineration	440
HALT	130
ECO	15
Plasma	4.0

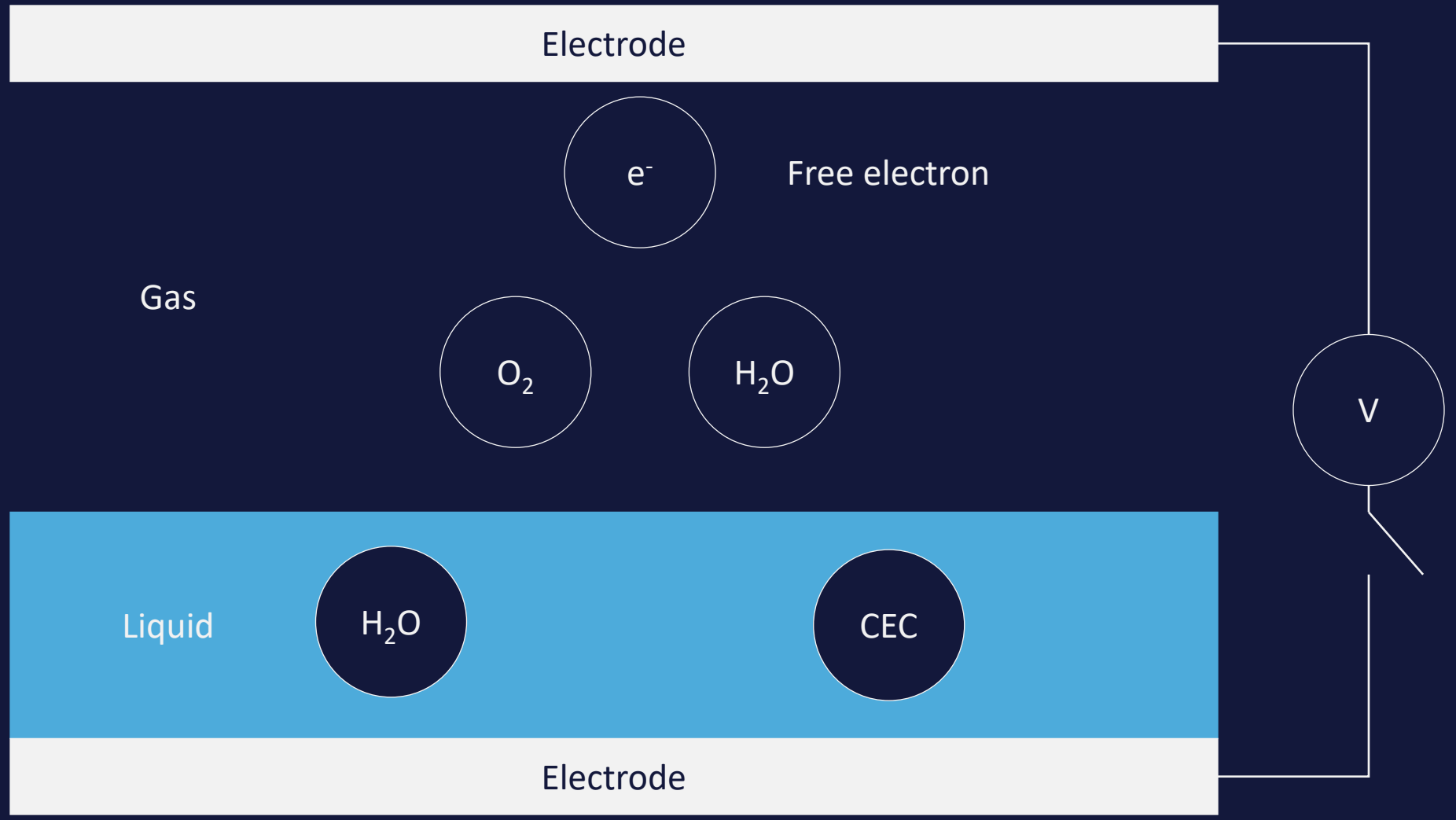
Bolton, 2001, IUPAC
Hao, 2021, ES&T
Thagard, 2017, JPD

Plasma

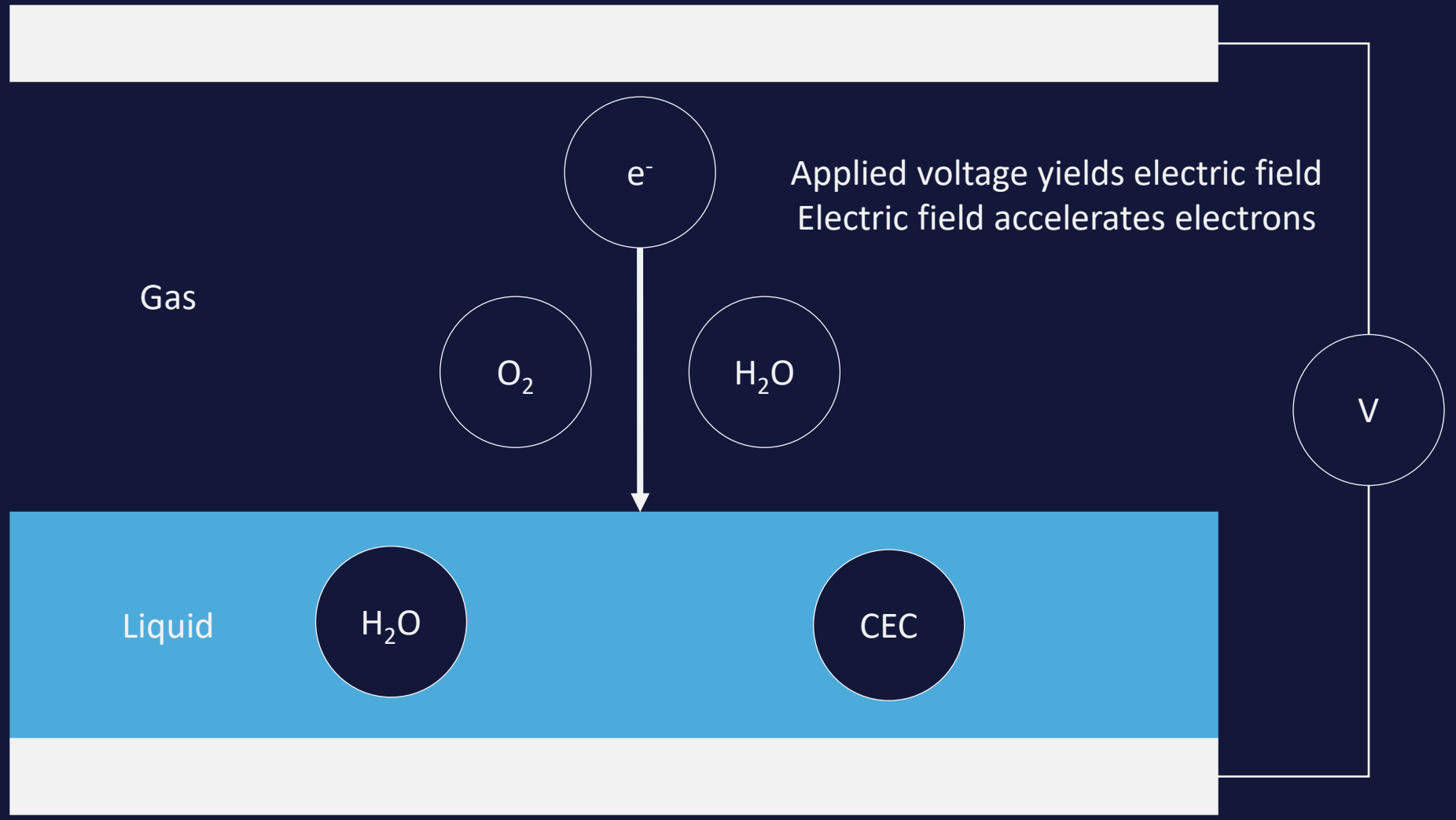
- Plasma = ionized gas
- Commercially available plasma: UV and ozone
  - Both do not take advantage of short-lived, very potent radicals
- Plasma interacting with water enhances reduction/oxidation



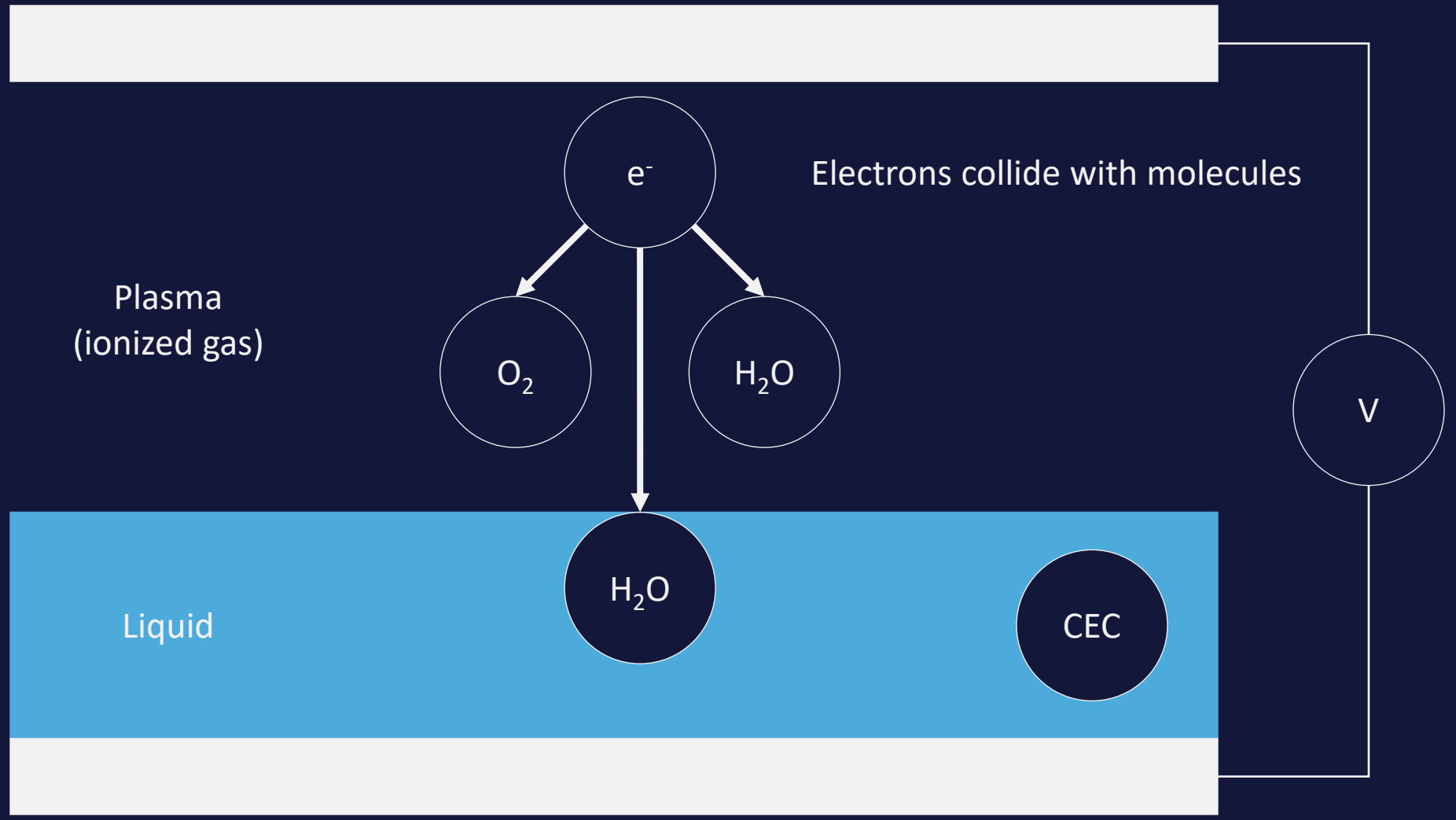
How Plasma Works



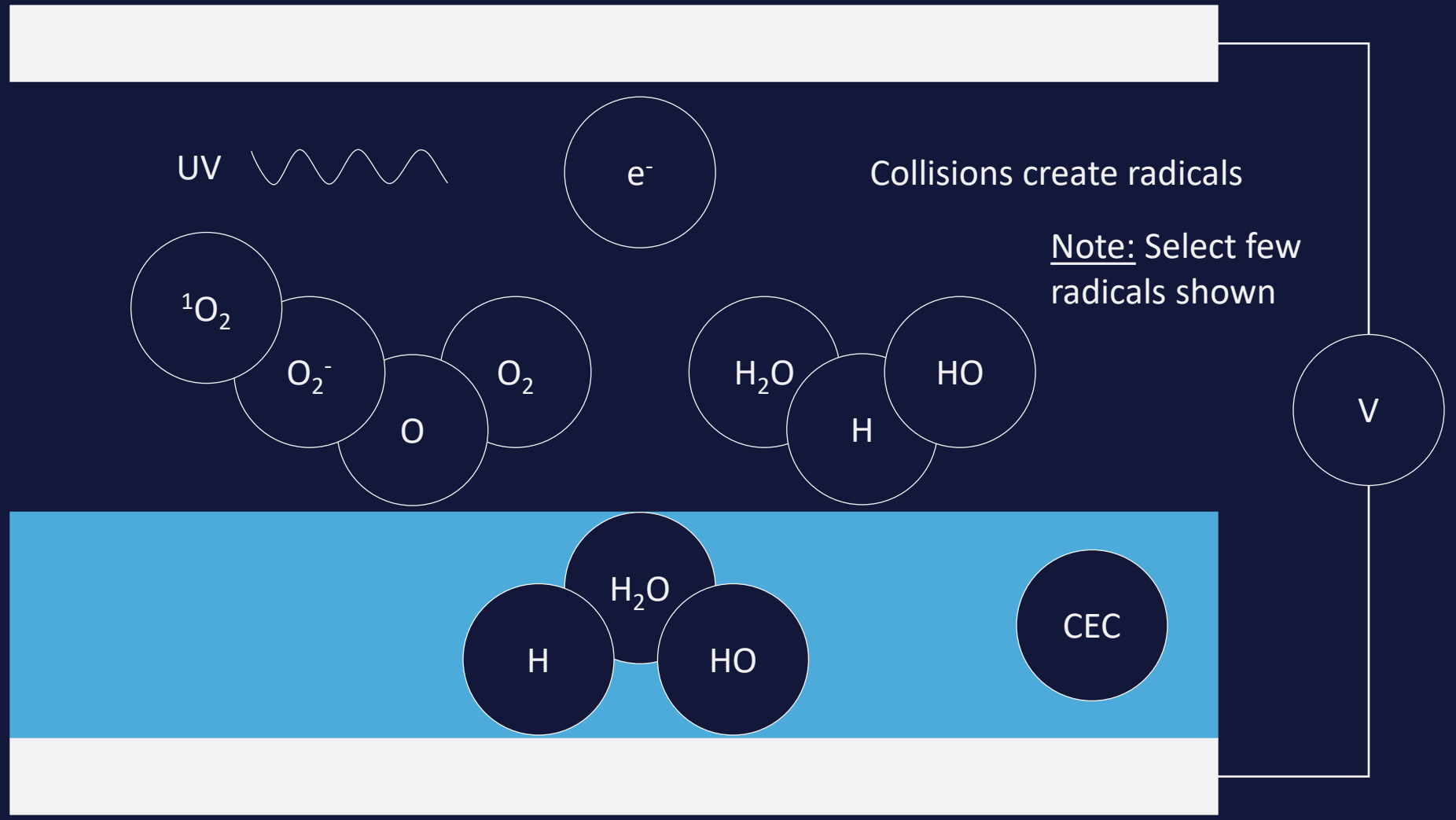
How Plasma Works



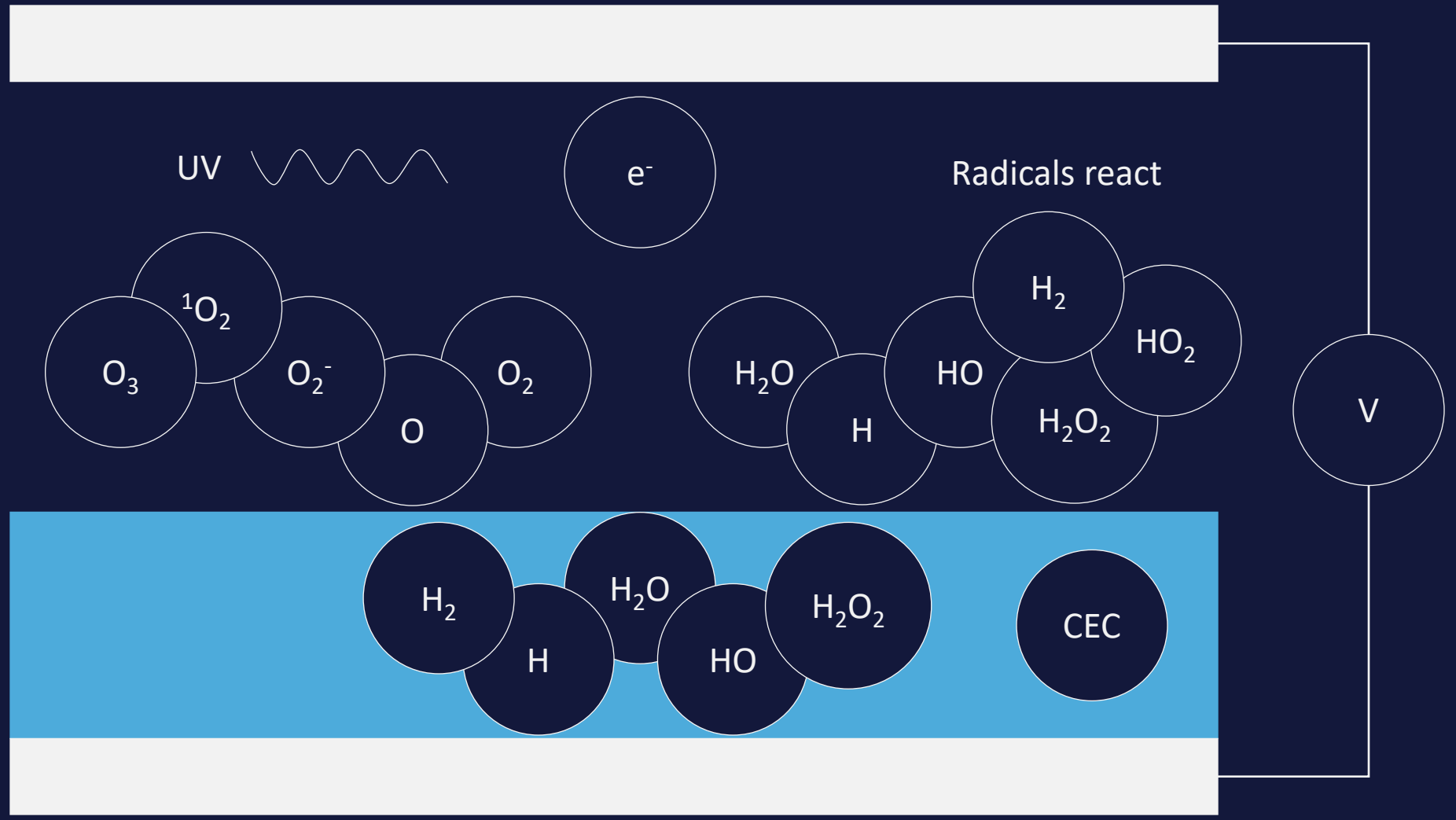
How Plasma Works



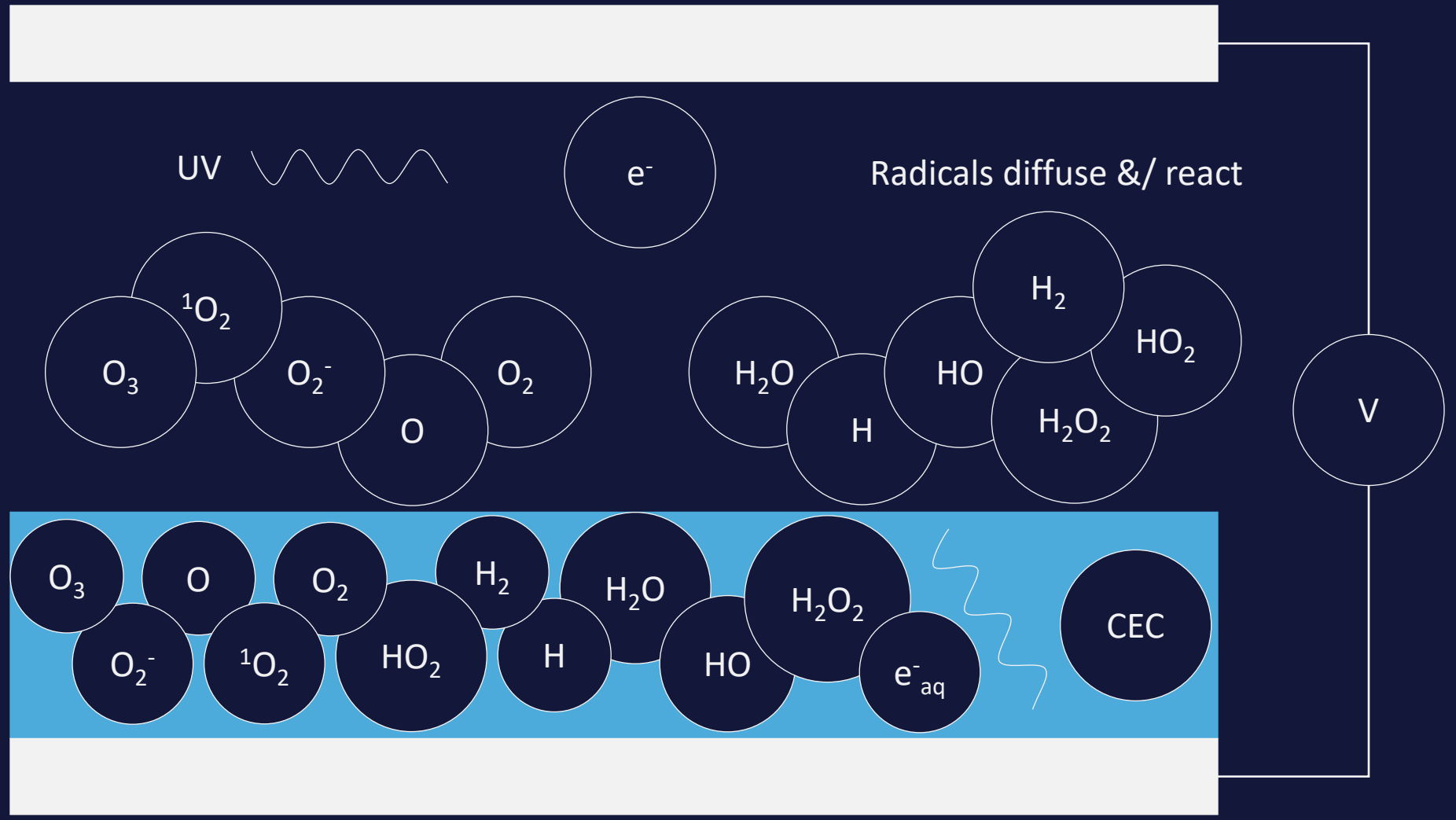
How Plasma Works



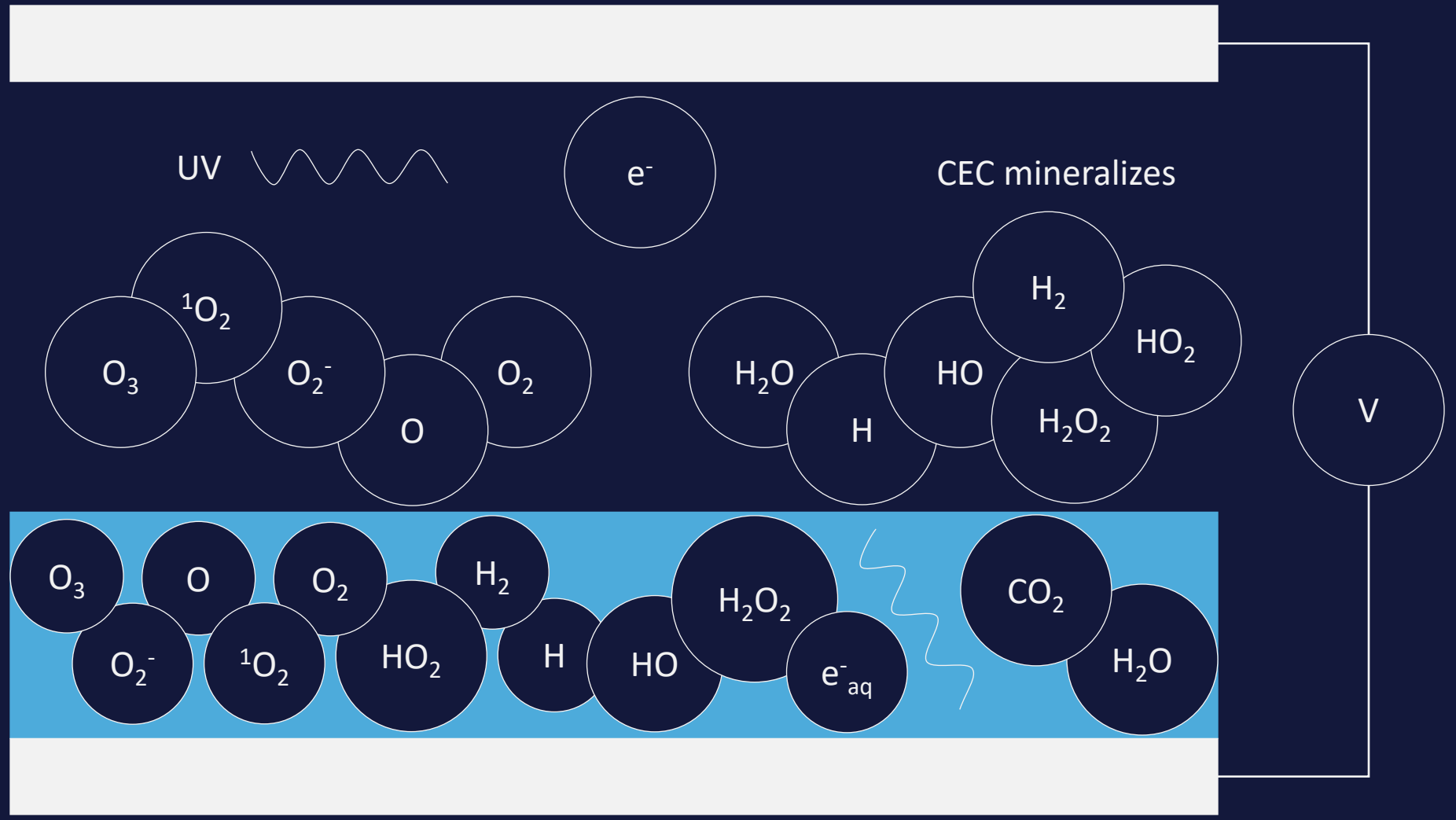
How Plasma Works



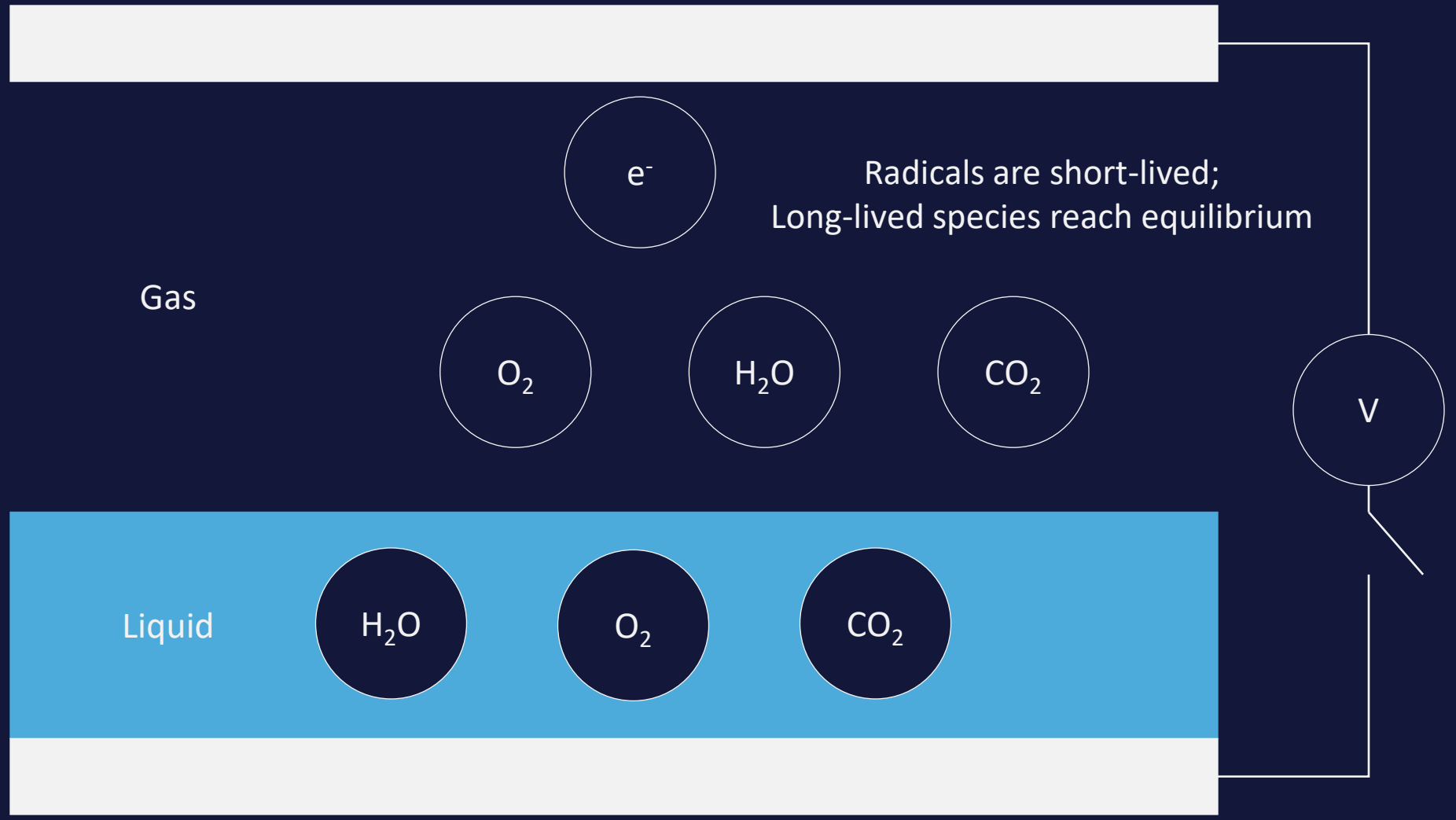
How Plasma Works



How Plasma Works

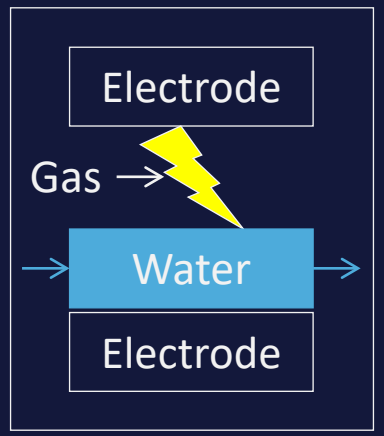


How Plasma Works



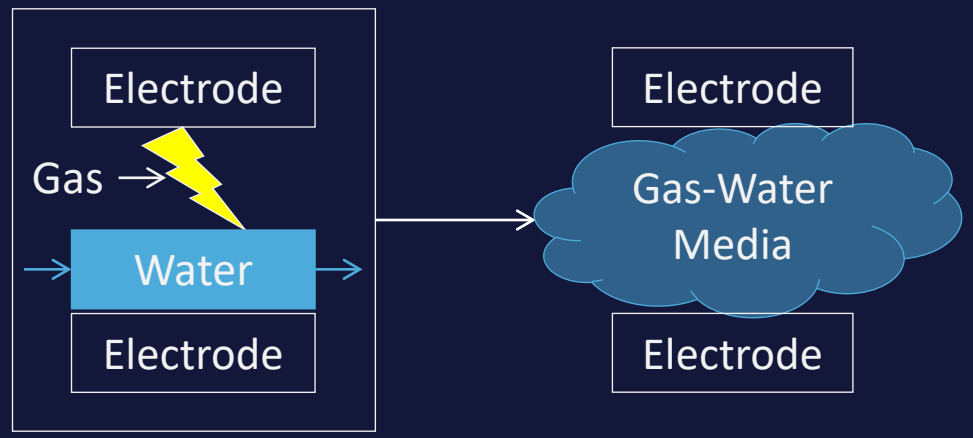
Purafide's Approach

- *Goal:* more plasma on water, same power



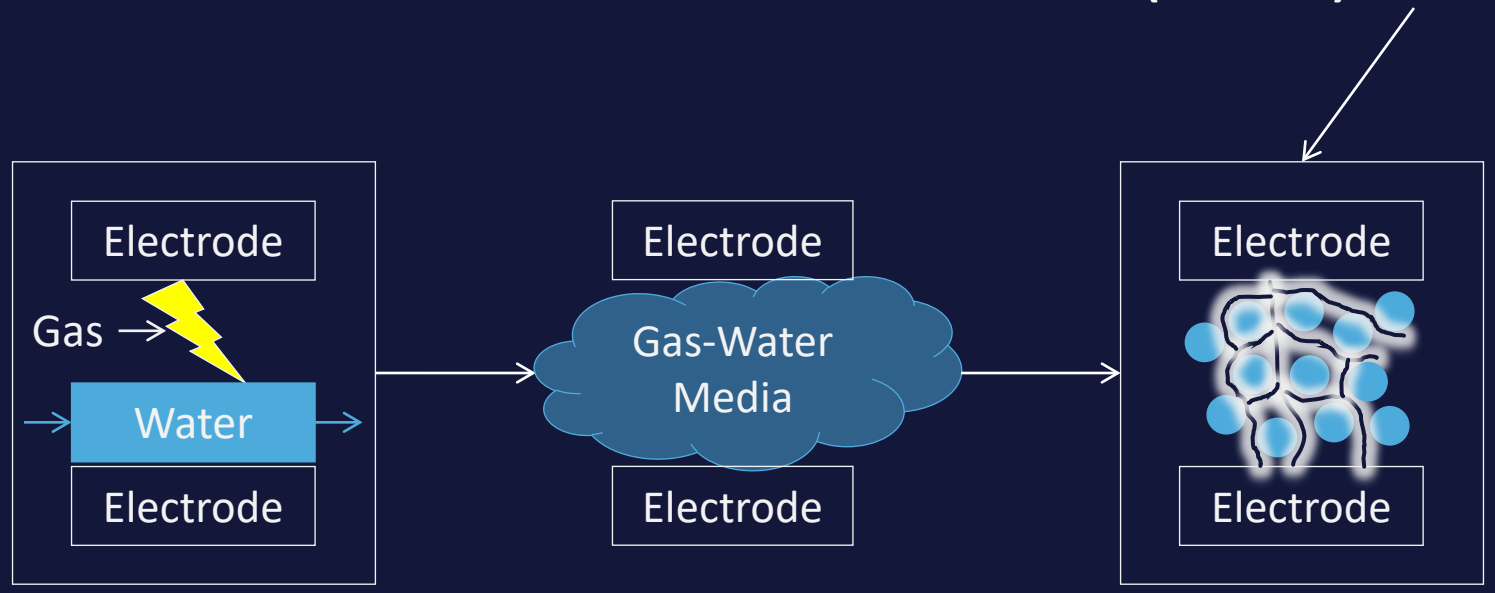
Purafide's Approach

- *Goal:* more plasma on water, same power
- *Method:* manipulate geometry



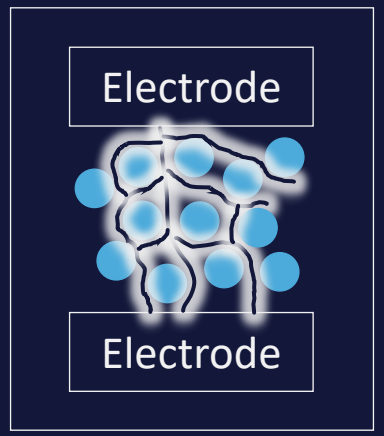
Purafide's Approach

- *Goal:* more plasma on water, same power
- *Method:* manipulate geometry
- *Innovation:* Plasma Water Reactor (PWR)



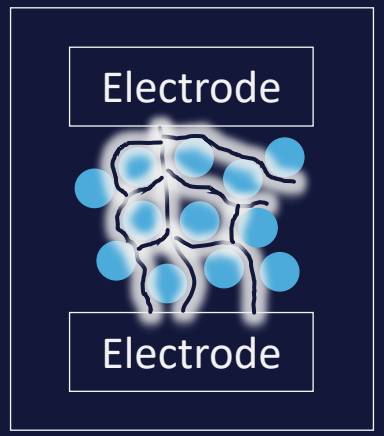
Purafide's Approach

- *Goal:* more plasma on water, same power
- *Method:* manipulate geometry
- *Innovation:* Plasma Water Reactor (PWR)
  - Plasma self-propagates along water surfaces



Purafide's Approach

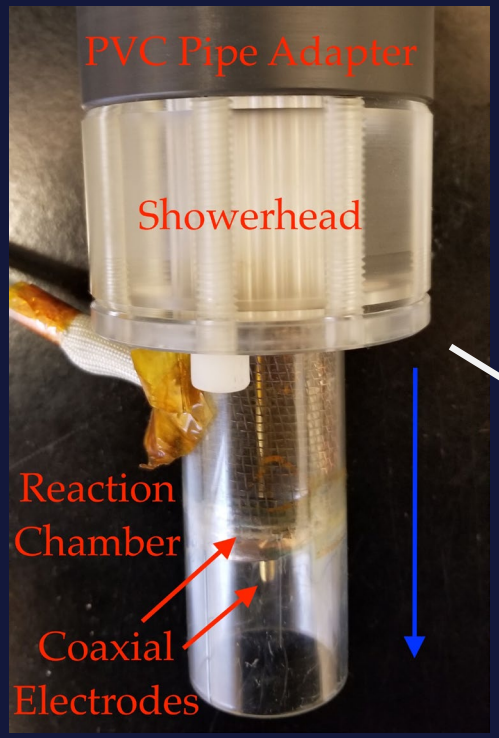
- *Goal:* more plasma on water, same power
- *Method:* manipulate geometry
- *Innovation:* Plasma Water Reactor (PWR)
  - Plasma self-propagates along water surfaces

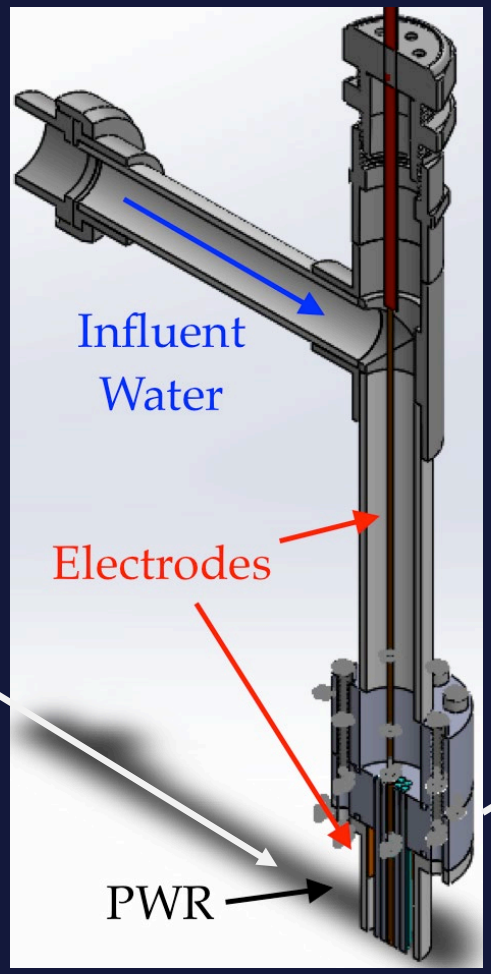


Purafide's Approach

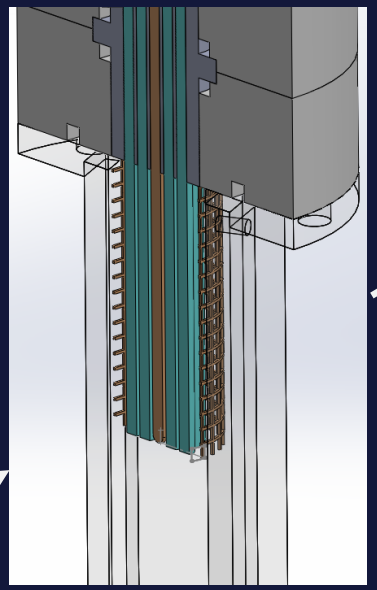
- *Goal:* more plasma on water, same power
- *Method:* manipulate geometry
- *Innovation:* Plasma Water Reactor (PWR)
  - Plasma self-propagates along water surfaces

PWR Prototypes





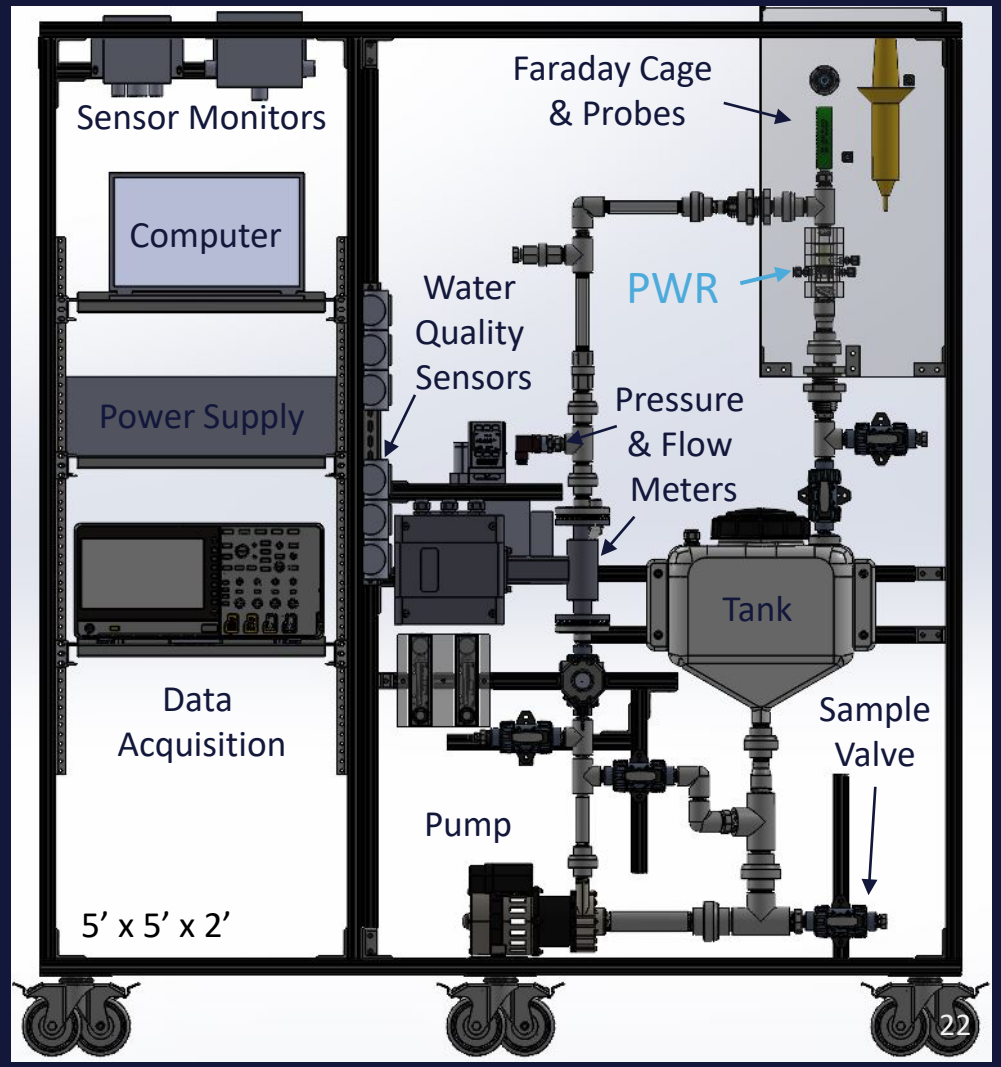
Section Cut of Active Region



Video of Active Region

Experimental Design

- Parametrically assess the PWR:
  1. Matrix
  2. Operating conditions
  3. Reactor geometry
- Operate first in batch-mode
  - Sample at various treatment times
  - Monitor plasma & water quality
    - Applied power, voltage, current, imaging
    - pH, Cond., ORP, DO, DO_3, H_2O_2, UVT, Turb.
    - PFAS (1633) and 1,4-dioxane (8270E-SRM)
- Design and deploy pilot



Confirming PFAS Destruction

Targeted Analysis:

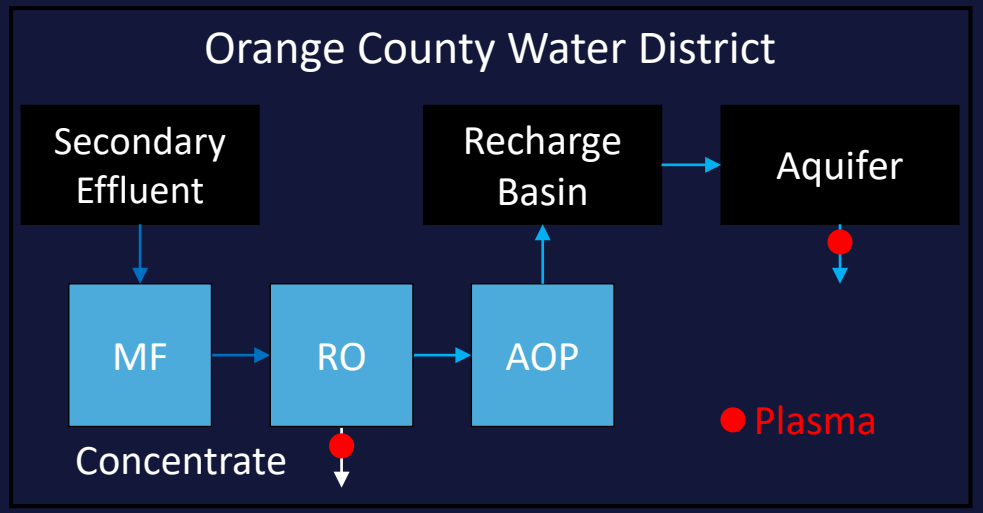
- EPA Method 537.1
  - 18 analytes; drinking water
- EPA Method 533
  - 25 analytes; drinking water
- EPA Method 1633
  - 40 analytes; water (drinking water – leachate), soil, biosolids, tissue

Non-Targeted Analysis:

- Total Oxidizable Precursor (TOP) Assay
- Total Organic Fluorine
  - EPA Method 1621: Adsorbable Organic Fluorine

Preliminary Studies

- Groundwater – Drinking Water (DW)
- Groundwater – Remediation Sites (GW-R)
- Groundwater – Leachate-Impacted (LGW)
- Ion Exchange Regenerant
- Leachate (LL)
- RO Concentrate – Indirect Potable Reuse
- RO Concentrate – Leachate (LROC)
- Wastewater – Influent
- Wastewater – Effluent
- Wastewater – Centrate



Preliminary Results

Percent Removal (%)

CEC	DW	GW-R	LROC
1,4-D	>99.7	66	
PFNA	>91	>97	
PFOA	80	>99.8	>99
PFOS	85	94	>93
PFHxS	68		>97
PFHpA	61		>98
PFBS	29		14

Electric Energy Per Order (kWh/m^3)

CEC	DW	GW-R	LROC
1,4-D	13	210	
PFNA	47	30	
PFOA	97	47	8
PFOS	34	51	7
PFHxS	130		5
PFHpA	300		14
PFBS	1500		120

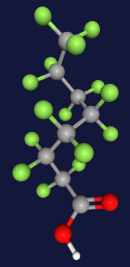
Note: ECO was ineffective for GW-R & LROC

Example Site: Michner Plating

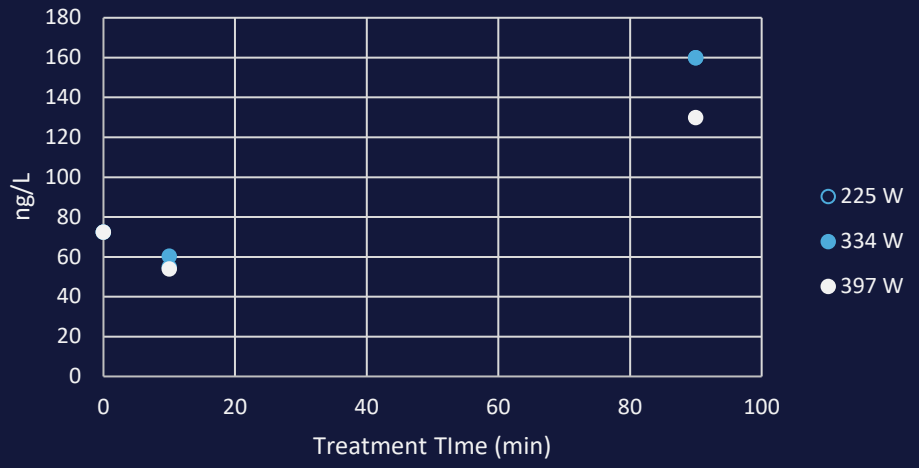
- Operated as an electroplating facility (1930s - 2007)
- 19 of 31 samples from monitoring wells exceeded 70 ppt of PFOA+PFOS (Oct 2019)

Courtesy of MPART (Michigan.gov)

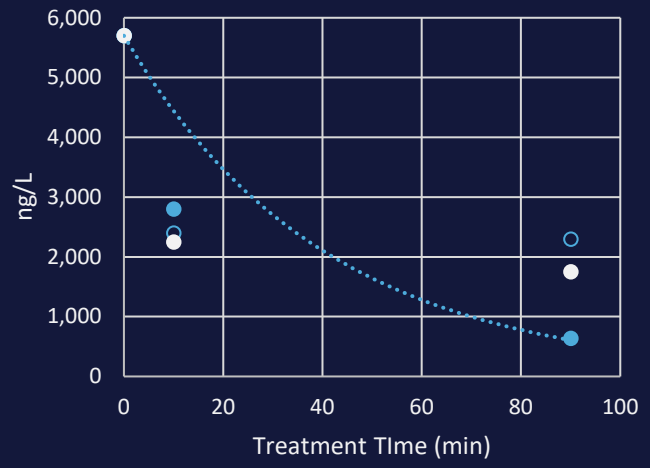
Highlighted Michner PFAS Results



PFOA

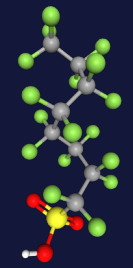


PFOS

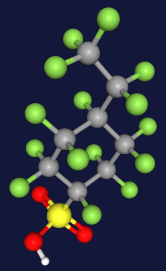


$y = 5700e^{-0.025x}$

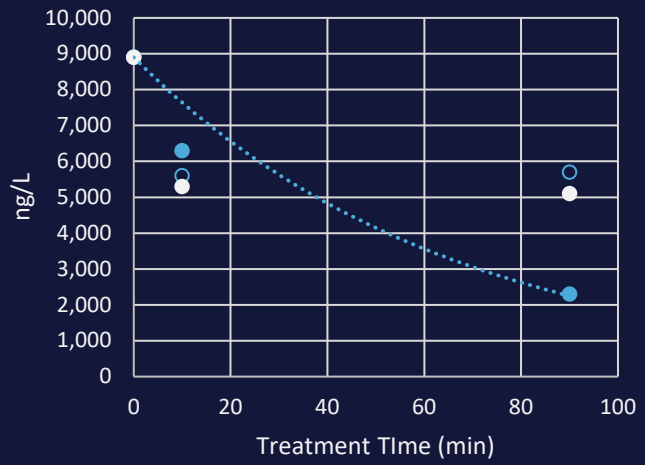
$R^2 = 0.8699$



225 W
334 W
397 W
Expon. (334 W)



PFecHS

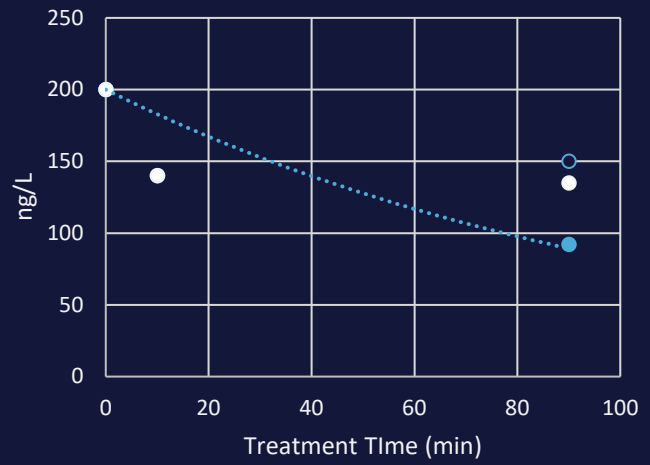


$y = 8900e^{-0.015x}$

$R^2 = 0.9514$

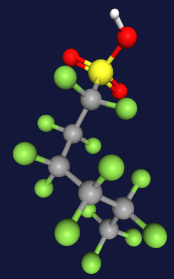
225 W
334 W
397 W
Expon. (334 W)

PFHxS



$y = 200e^{-0.009x}$

$R^2 = 0.816$



225 W
334 W
397 W
Expon. (334 W)

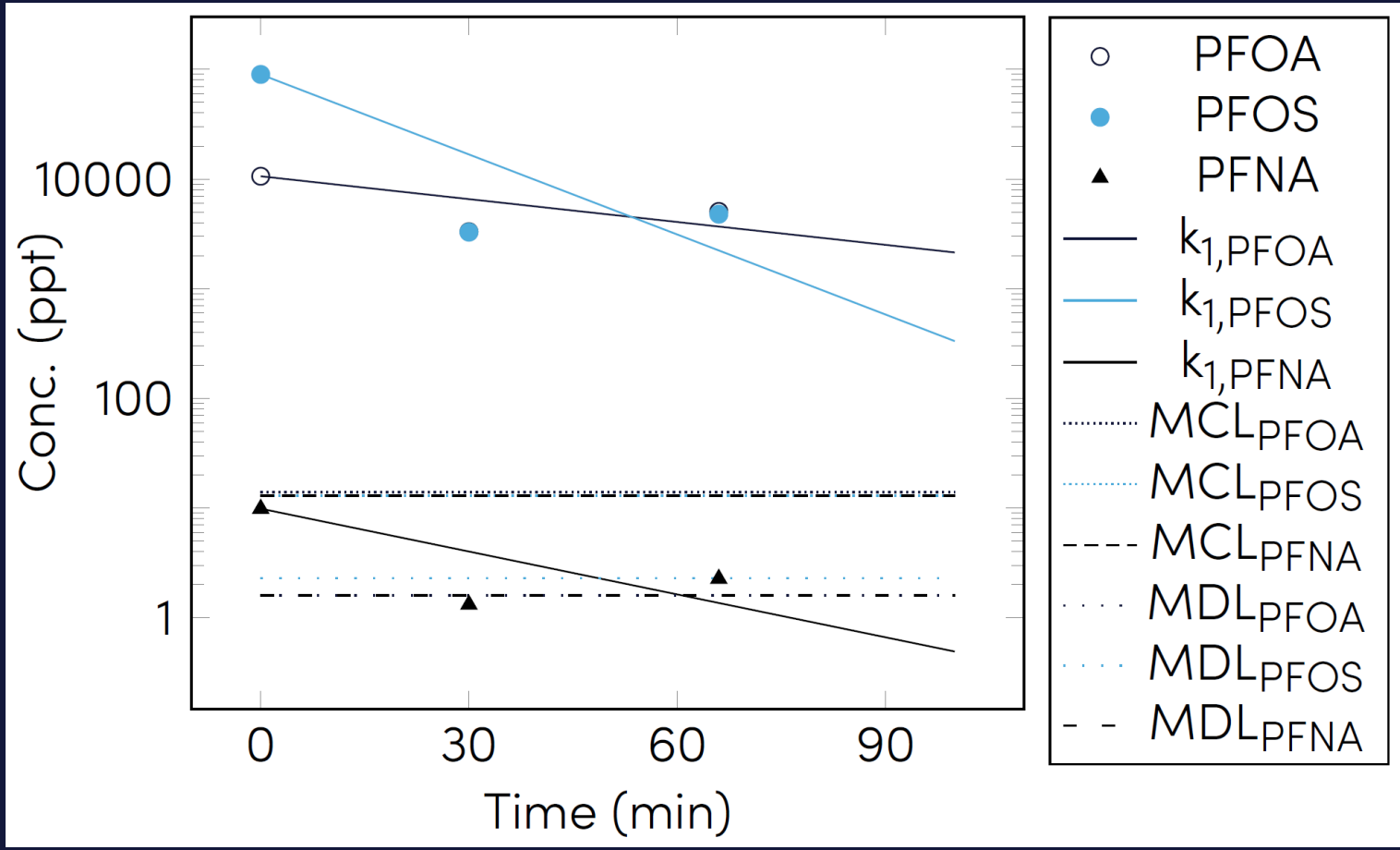
Example Sites: NJDEP

Analyte	MDL	SDWA MCL	NJ MCL	LGW	LL
1,4-D	0.16 ppb		0.4 ppb*	2.8 ppm	89 ppb
PFOA	0.23 ppt	4 ppt	14 ppt	10.6 ppb	2.07 ppb
PFOS	2.9 ppt	4 ppt	13 ppt	89.9 ppb	444 ppt
PFNA	0.28 ppt	10 ppt	13 ppt	9.87 ppt	137 ppt

*MCL for groundwater. Draft MCL of 0.33 ppb for drinking water.

Leachate-Impacted Groundwater

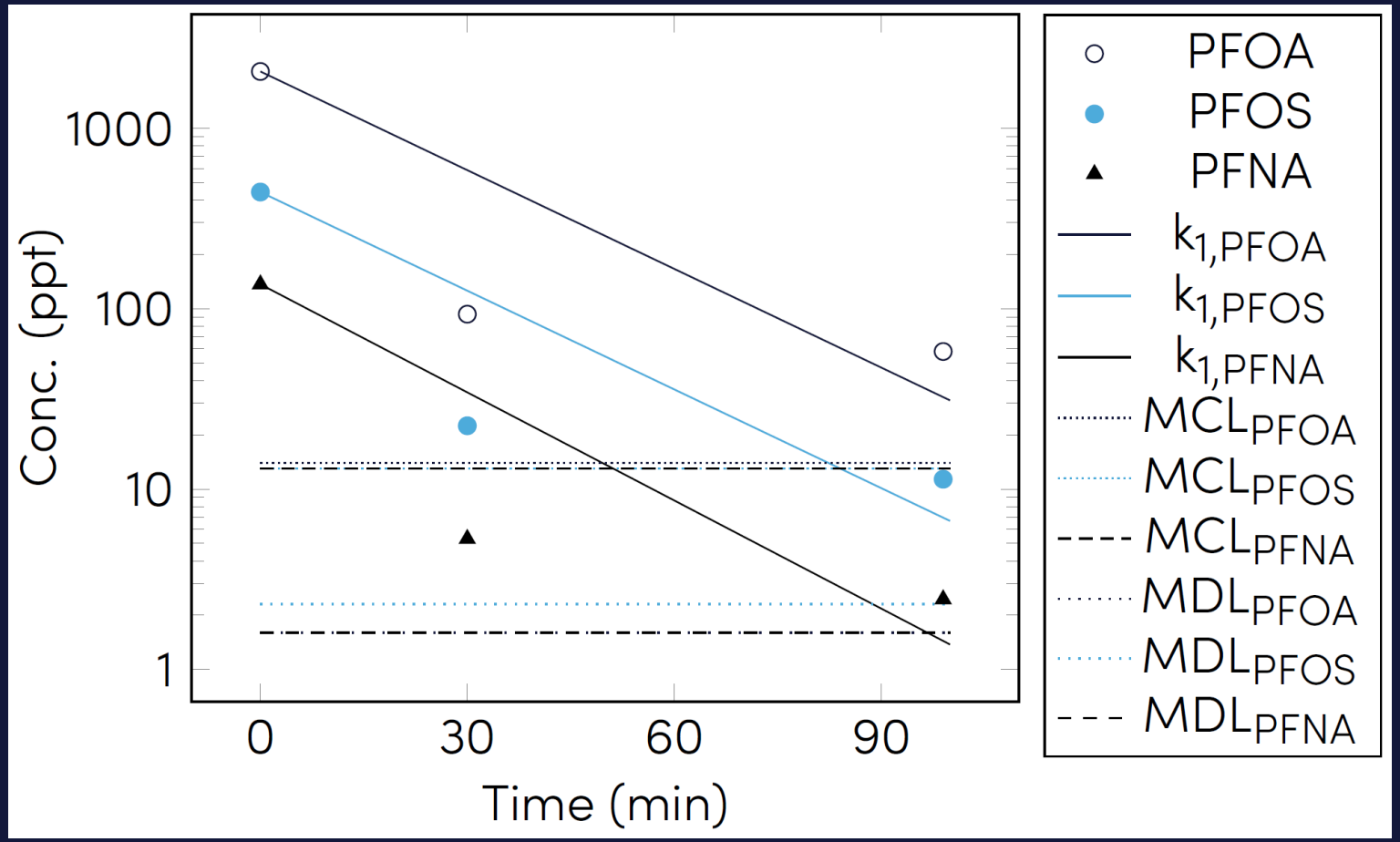
E_{EO}
17-170 kWh/m^3



Electric Cost
$32-240/kgal

Landfill Leachate

E_{EO}
27-64 kWh/m^3



Electric Cost
$14-69/kgal

Takeaways

- Long-chain PFAS easier to destroy than short-chain PFAS
- Optimization is critical
  - E_{EO} can vary order of magnitude
  - Most cost-effective matrix is not always what you think it is
- Kinetics unexpectedly exhibited non-first-order behavior
  - Scavengers & precursors play pivotal roles
- Real-time measurements of species & water quality may serve as surrogates to suggest sufficient treatment

Pending Studies

Bench-Scale

- Groundwater
  - Drinking water source
- Surface Water
- Wastewater
  - Biosolids
  - Industrial
  - Utility
- GAC Regenerant
- Spent Media

Pilot-Scale

- Industry-impacted groundwater
- Leachate

Flow Configurations:

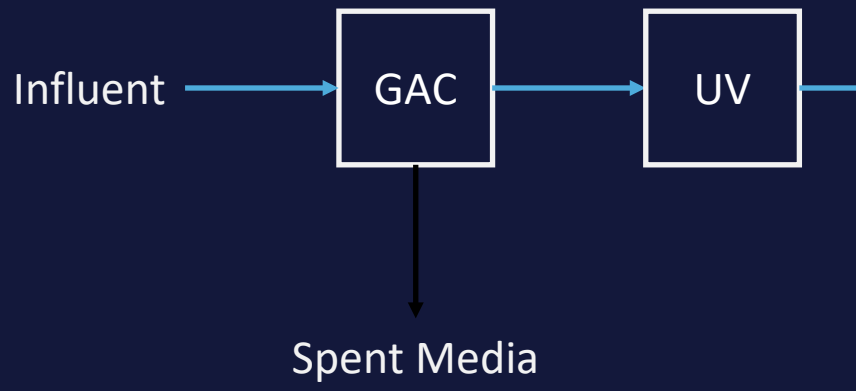
Batch, Semi-batch, Continuous

Applications

- Explore synergy in advanced treatment trains
  - Eliminate emerging contaminants in effluent and reject streams
  - Enhance electrocoagulation, biodegradation, and inactivation
  - Create technoeconomic model for pipe parity
  - Real-time monitor and dynamically treat water

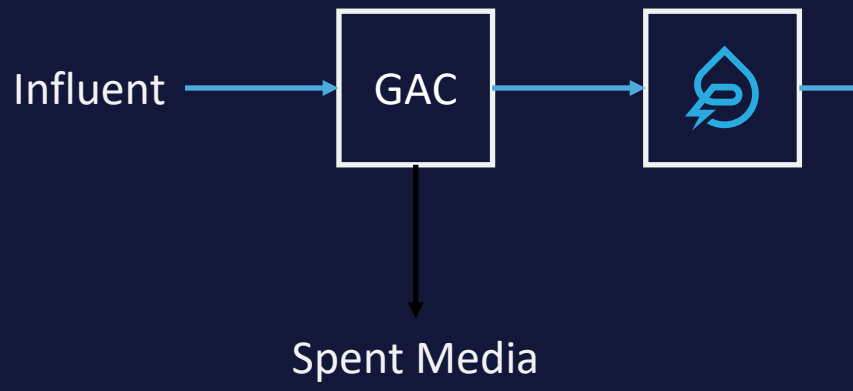
- Examples:
  - Remediation (Pump-and-Treat)
  - Source Control (Industrial Pretreatment Program)
  - In-/Effluent Control (Point of Entry or Use Treatment)

GAC-based Reuse



GAC: Granular Activated Carbon
UV: Ultraviolet light

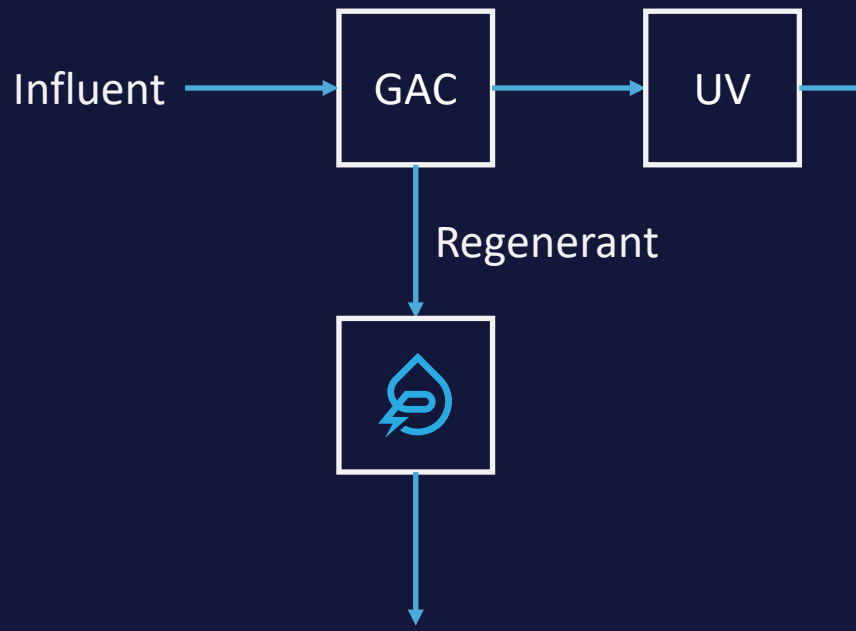
GAC-based Reuse



Added Benefits:

- CEC destruction
  - Short-chain PFAS
  - Trace organics (ie. 1,4-D)
- Pathogen inactivation

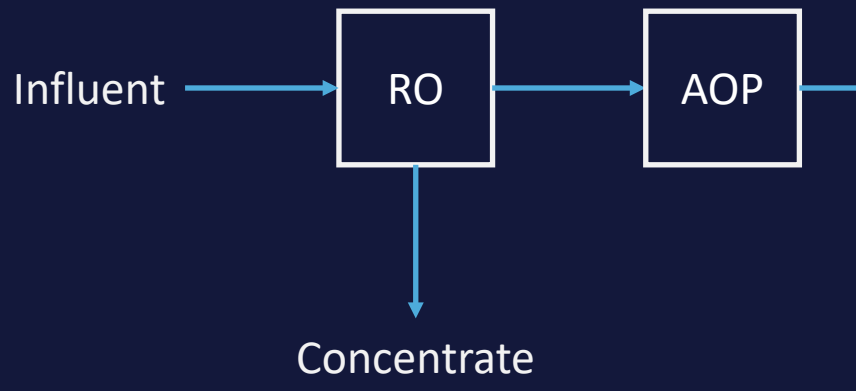
GAC-based Reuse



Added Benefits:

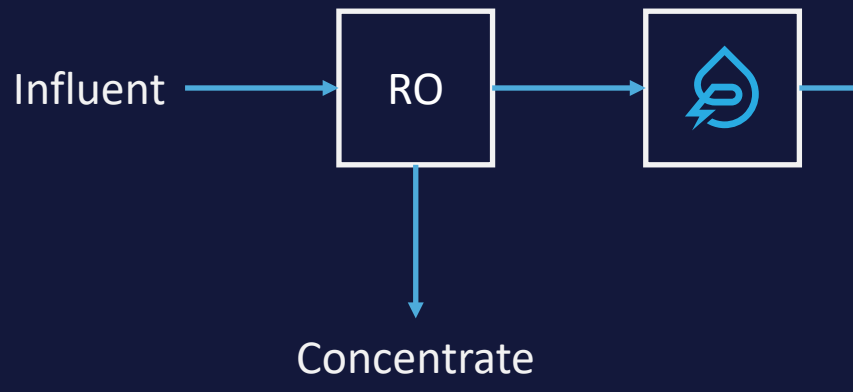
- Regenerant management
  - Recycle spent media
- CEC destruction
  - Long-chain PFAS
  - Organics

RO-based Reuse



RO: Reverse Osmosis
AOP: Advanced Oxidation Process

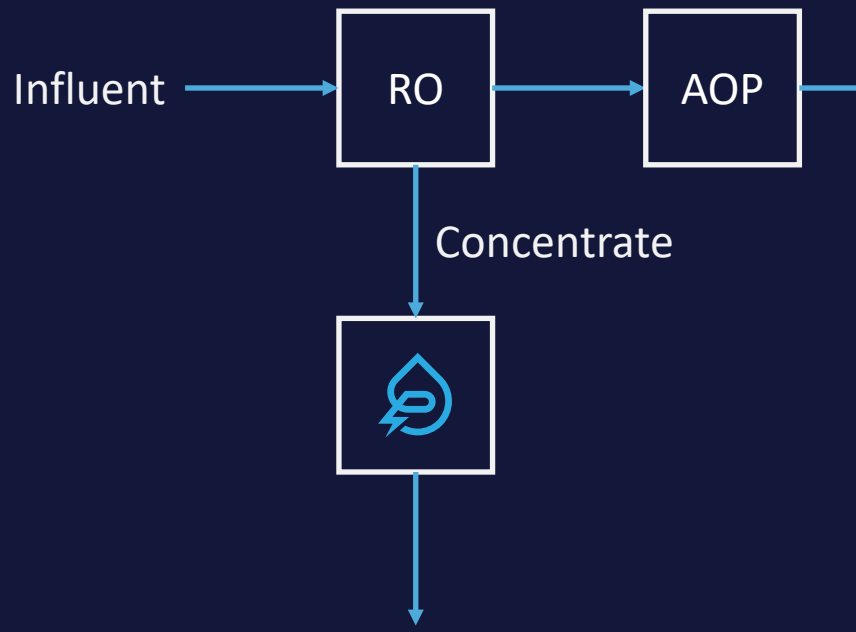
RO-based Reuse



Added Benefits:

- CEC destruction
  - Trace organics (ie. 1,4-D)
- Pathogen inactivation

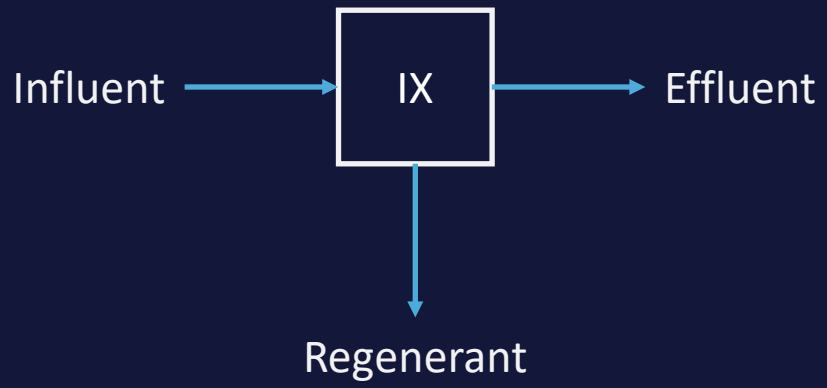
RO-based Reuse



Added Benefits:

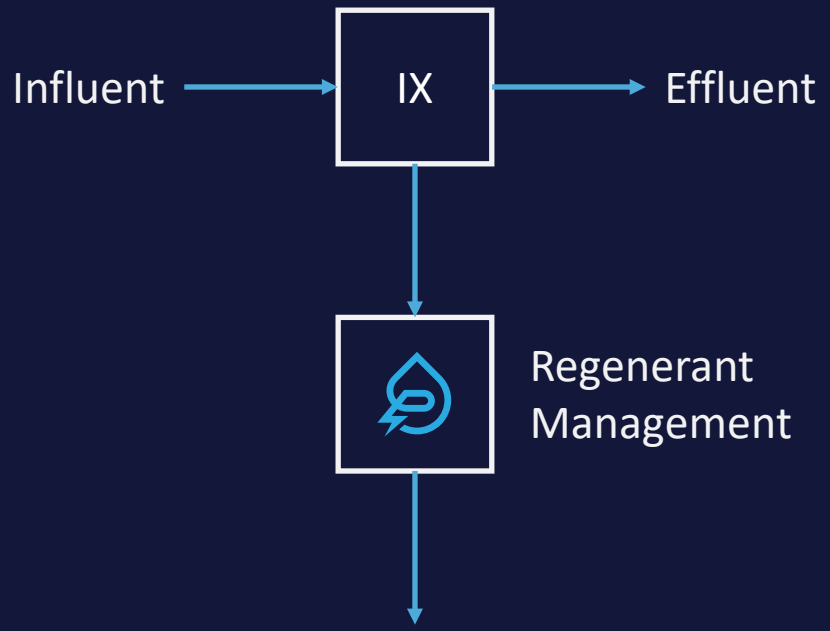
- Concentrate management
- CEC destruction
  - PFAS
  - Trace organics (ie. 1,4-D)

Point-of-Use Treatment

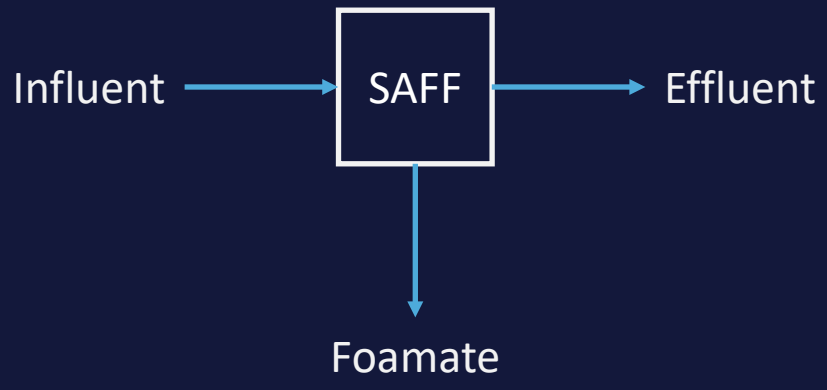


IX: Ion Exchange

Point-of-Use Treatment

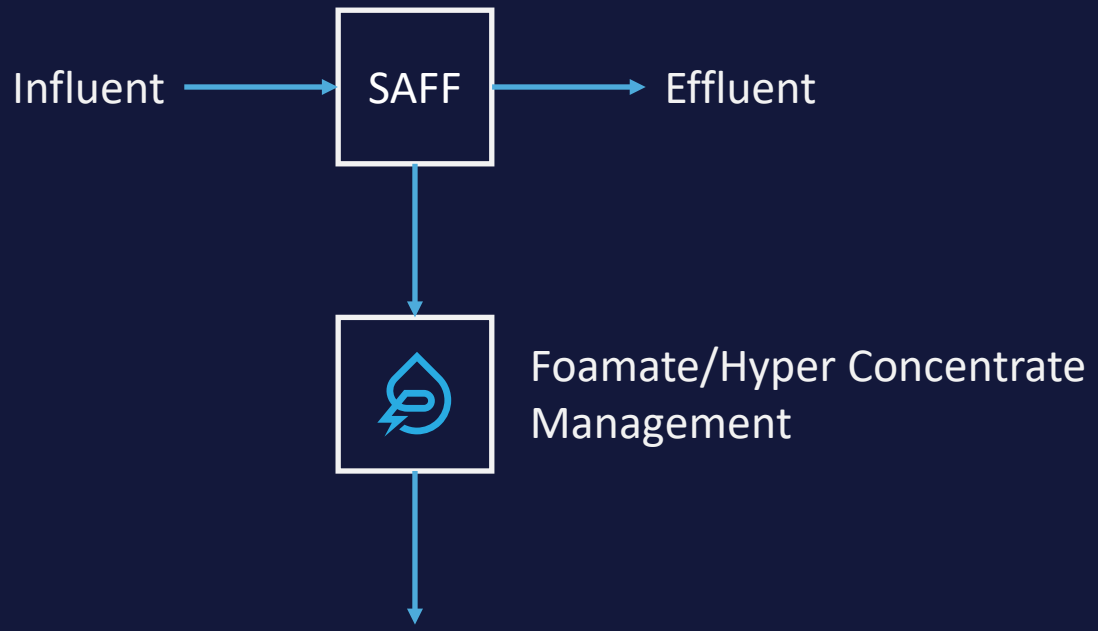


Concentrate & Destroy



SAFF: Surface Active Foam Fractionation

Concentrate & Destroy



Summary

Key Results: Plasma can operate regardless of background matrix to achieve sufficient & efficient destruction

Best Applications: Decentralized advanced water treatment

Goal: Tailor plasma to optimize kinetics

Vision: Online monitoring of species & surrogates coupled to dynamic water treatment enables real-time remediation

Acknowledgements

- Michigan Department of Environment, Great Lakes, & Energy
- National Science Foundation
- New Jersey Department of Environmental Protection
- U.S. Environmental Protection Agency

Purafide

- Early-stage startup
  - Develop analytical tools and plasma-based treatment technologies
  - Implement environmental justice-oriented business models
    - A portion of profits are allocated to our Water Equity Fund

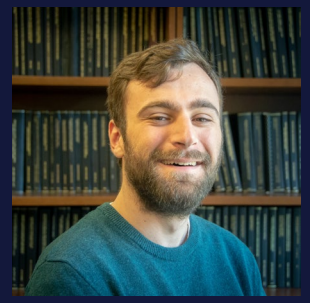
Luis Arias
Chief Technician

Jensen Bouzi
Software Developer

Ashleigh Bowie
Operations Chief

Jenelle Gustave
Chief Chemist

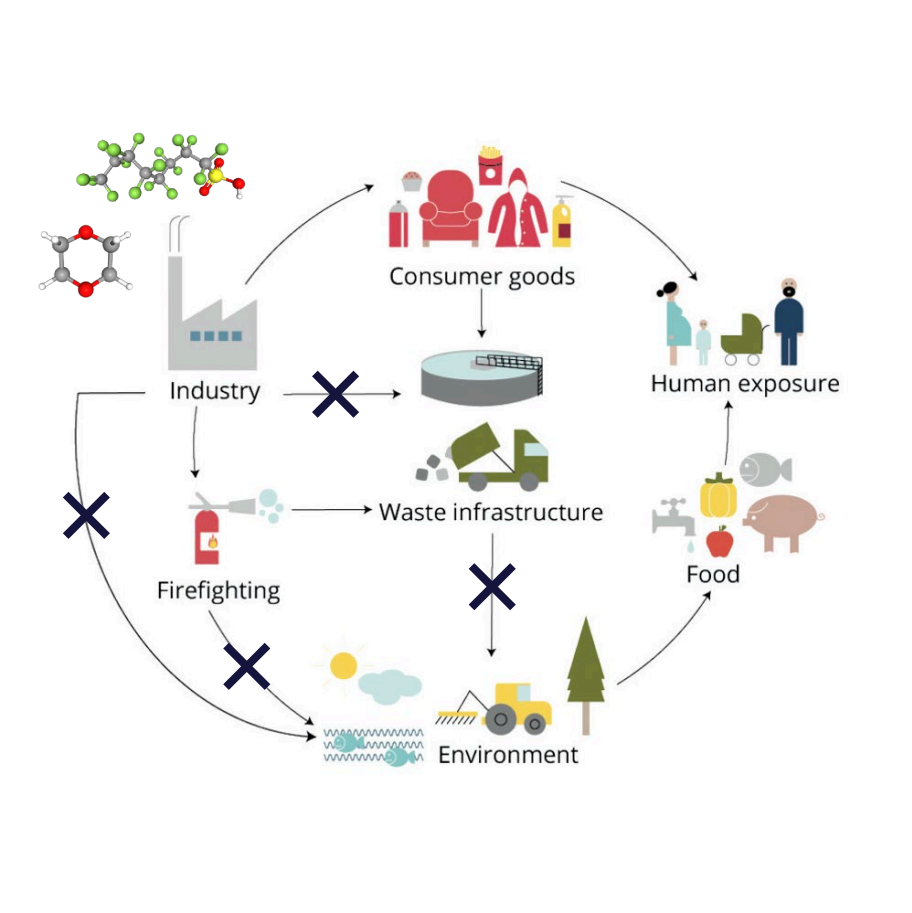
Vladimir Khin
Data Scientist



Selman Mujovic
CEO

Our Mission

Break the contamination cycle



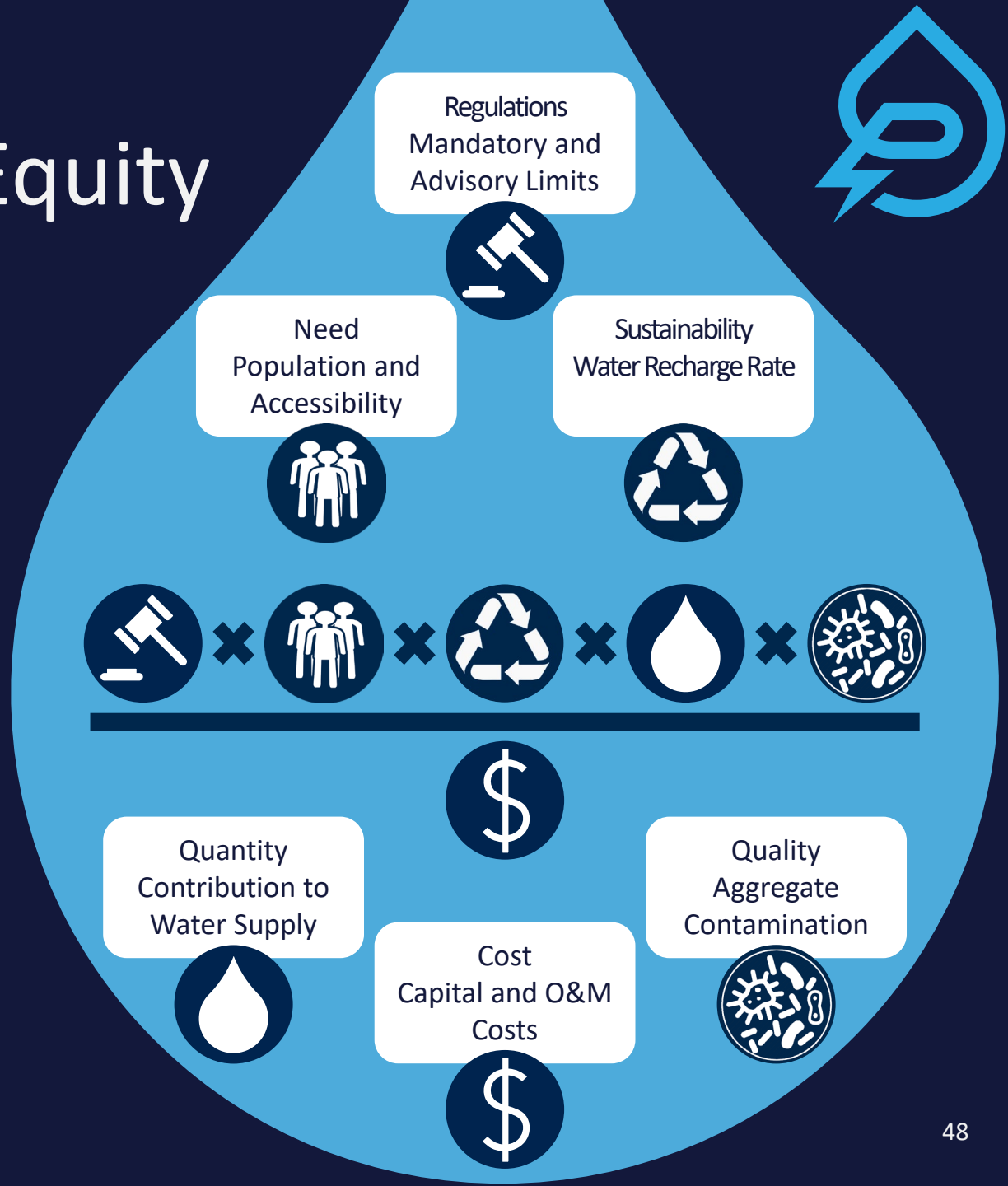
Water Equity

Pay-It-Forward

Marginalized communities receive pro bono analysis

Buy 1, Donate 1

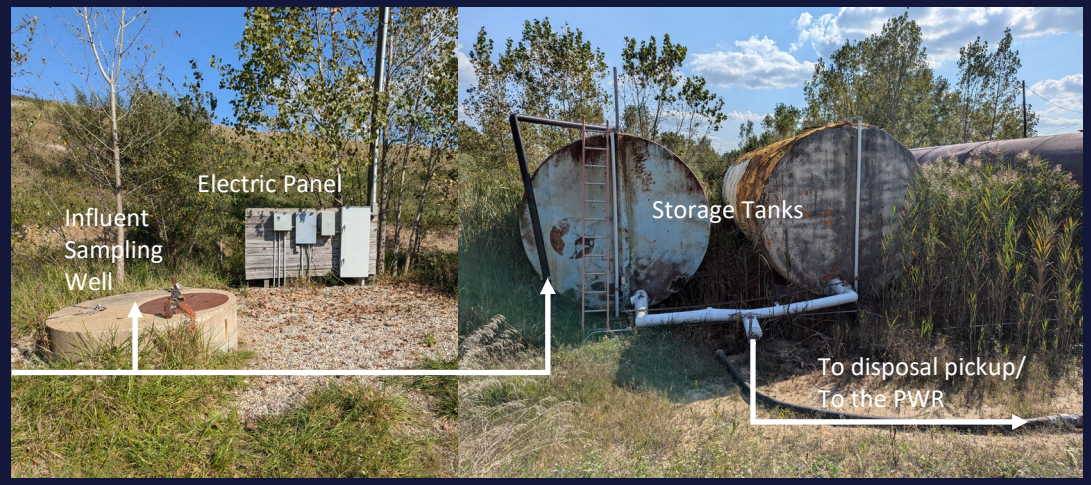
Proceeds from product sales go towards installing treatment systems



Next Steps

- Continue treatment studies
  - Deploy pilots at landfill and superfund site
  - Identify other sites with problematic matrices
- Partner with those in need of analysis
  - Monitor pollution in Tribal Nations
  - Develop methods: 6PPD-Q, microplastics, etc.
- Apply for matching funds
  - Gather letters of support

Landfill Pilot



Thank You for Your Interest

Questions?
Selman Mujovic, PhD
CEO
selman@purafide.info
+1 (347) 840-0150

Purafide
1205 Manhattan Ave, Ste 146B
Brooklyn, NY 11222

Want to Collaborate on a Project?

https://forms.gle/gsVL2A6YXdMhQi9A7