Electrochemical Destruction of of PFAS in High Strength Wastes

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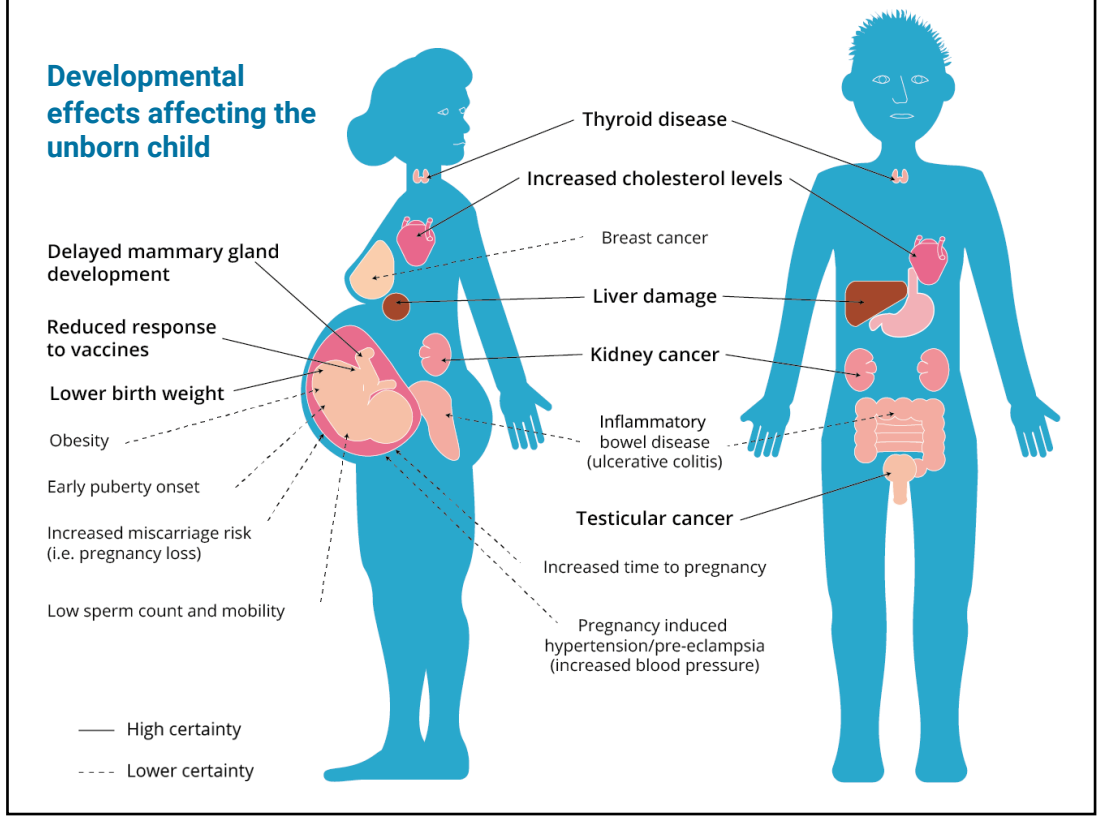
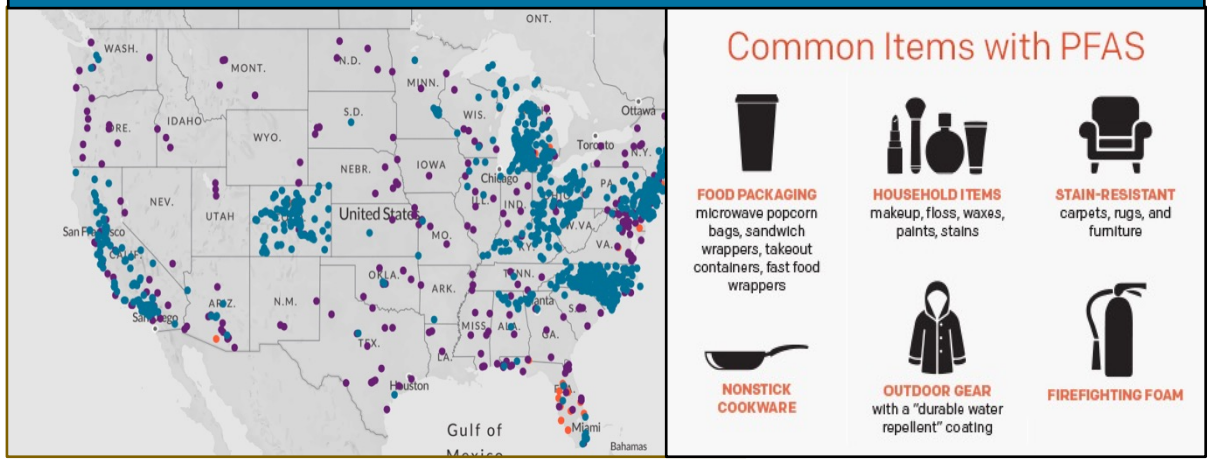
PFAS IS HARMFUL and FOREVER

Harmful



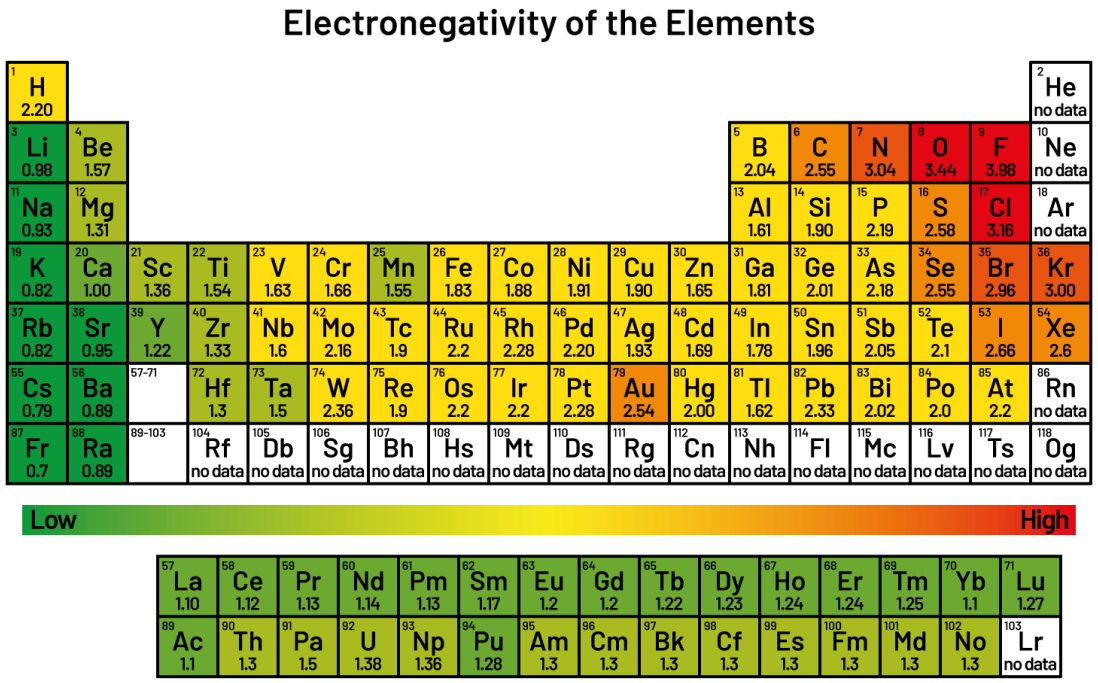
Widespread



How it Works

Electrochemical Oxidation 101

PFAS is "FOREVER"



(Helmenstine, 2021)

PFAS	E^0 anion (V/SHE)	E^0 acid (V/SHE)
PFBA	2.96	3.65
PFHxA	2.97	3.70
PFHpA	2.96	3.58
PFOA	2.91	3.71
PFNA	3.12	3.76
PFBS	3.71	3.96
PFHxS	3.72	4.00
PFOS	3.74	4.02
Source: Radjenovic et al., ES&T, 2020		

E^0 of OH• = 2.59(V/SHE)

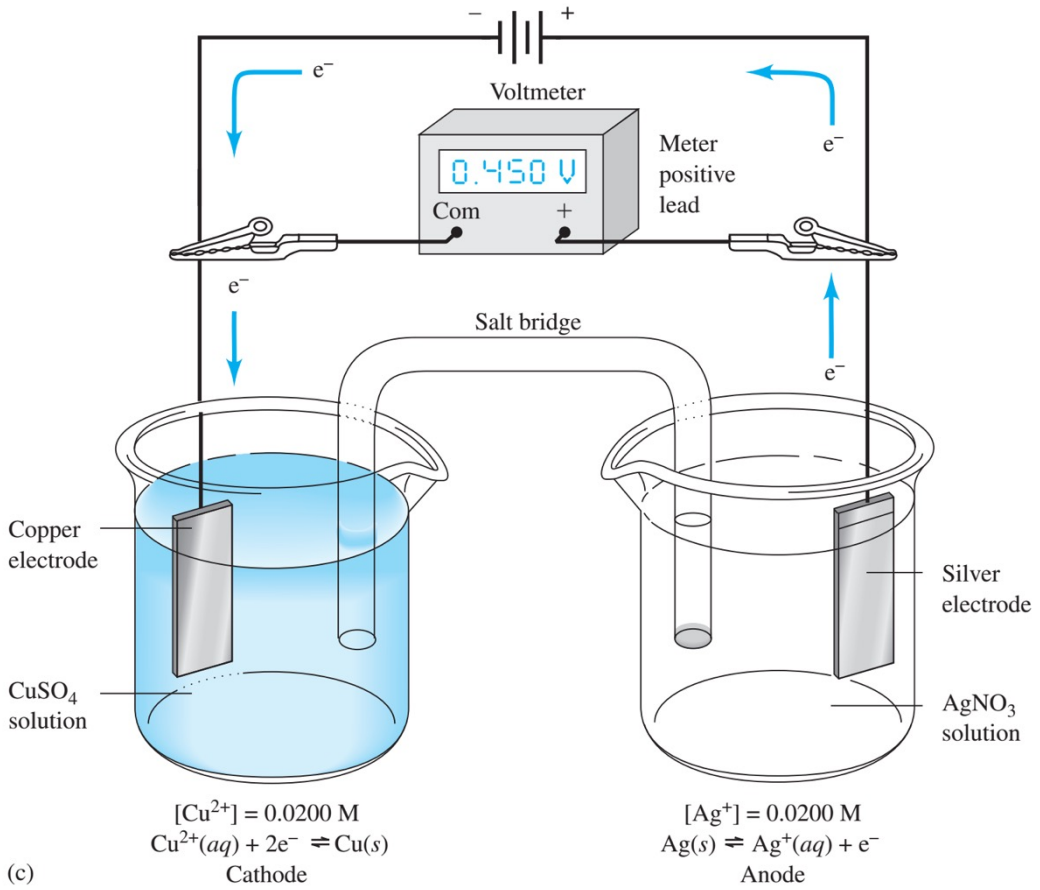
DESTRUCTION of PFAS

Destructive Technologies for PFAS:

-Electrochemical Oxidation (EOx)
-Supercritical Water Oxidation
-Plasma Oxidation
-Hydrothermal Alkaline Treatment
-Reductive Defluorination
-Photochemical

Overpotential at anode EOx allows for destruction of PFAS.

(Skoog, 2005)

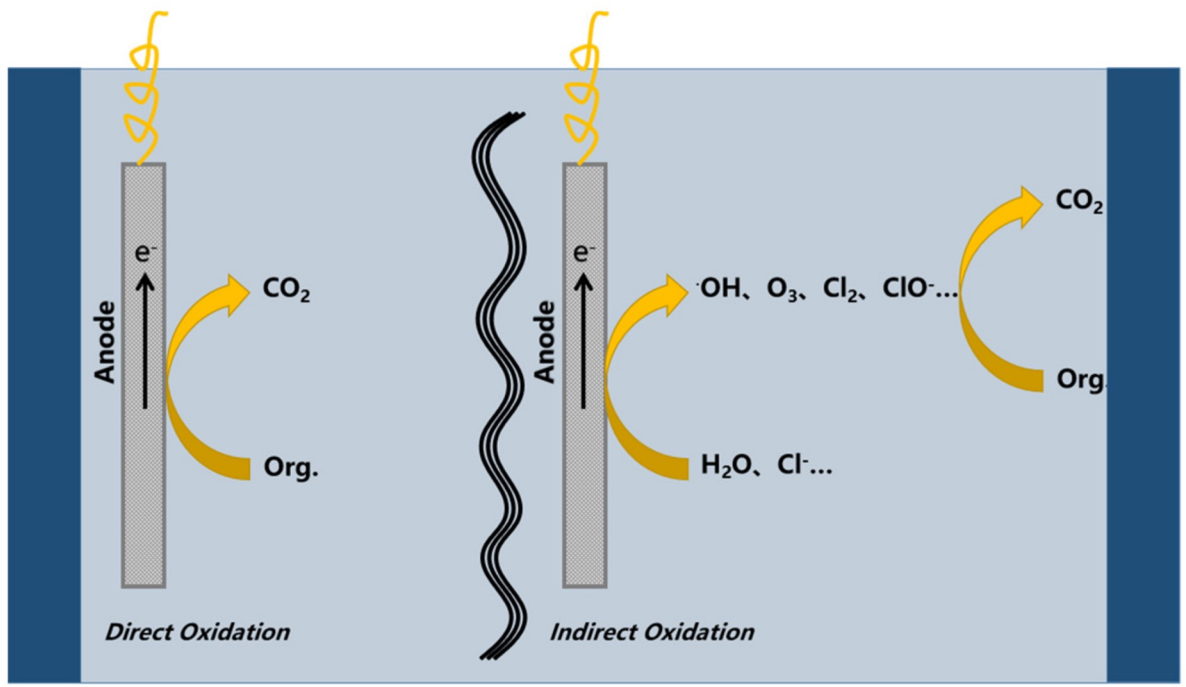


PFAS DESTRUCTION MECHANISM

(1) Direct Oxidation: Potential (V) at anode greater than E^0 of PFAS. Anode "takes" e^- from PFAS resulting in PFAS• and other oxidized forms.

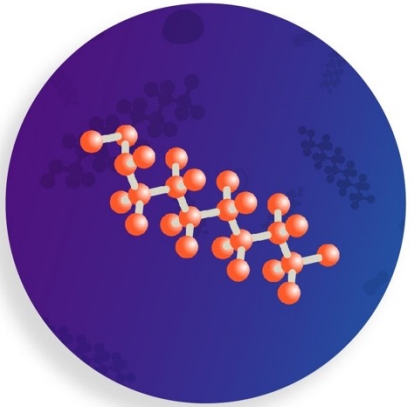
(2) Indirect Oxidation: Anode "takes" electron from other constituents in the water (e.g., OH^-), generating radicals *in situ* (e.g. OH•). Oxidizes PFAS• and other pollutants at relatively low power.

Both mechanisms combine for PFAS destruction!



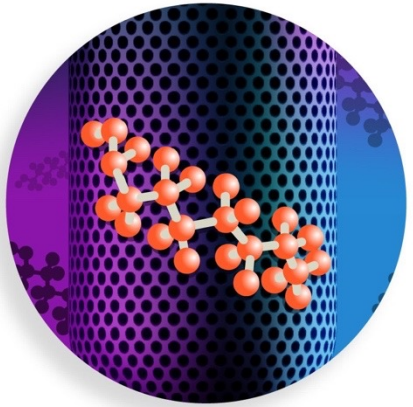
Direct and Indirect Oxidation, (Liu et al., 2022)

THE ACLARITY SOLUTION



1

PFAS in liquid waste



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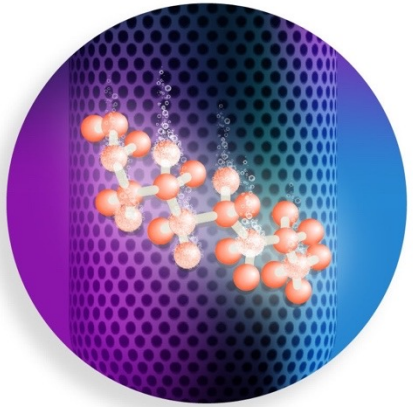
The PFAS are adsorbed onto anode surface



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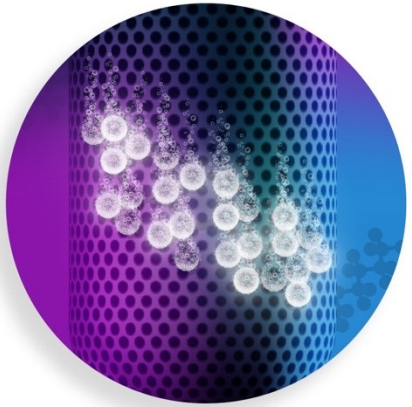
Free electrons break C-F bonds resulting in CO2, HF, F-



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Oxidant radicals generated through electrochemical process

5

PFAS are permanently destroyed

IDEAL for CONCENTRATED MATRICES

Present Focus

- Landfill leachates
- AFFF
- Foam Fractionate
- RO/NF concentrate

Under Investigation

- Direct treatment of IX Resin

50% of PFAS in the environment is sourced from landfills

PFOA and PFOS as hazardous compounds via CERCLA “soon”

SIMPLE STEPS for FULL-SCALE DEPLOYMENT

Mobile Bench System
Batch Treatment

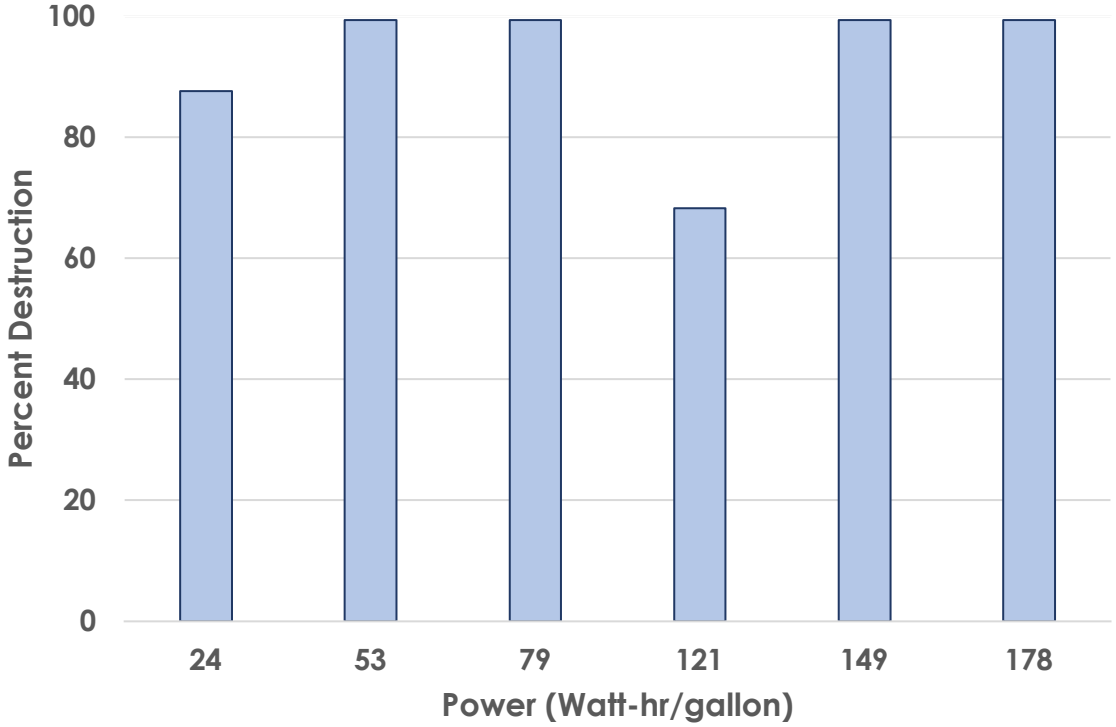
Full-Scale Reactor Field
Deployment System
Continuous Flow

Multi-Reactor, Multi-Skid Installation
Destruction as a Service™
Permanent Install

Bench Testing Results

Leachate, foam fractionate, & more

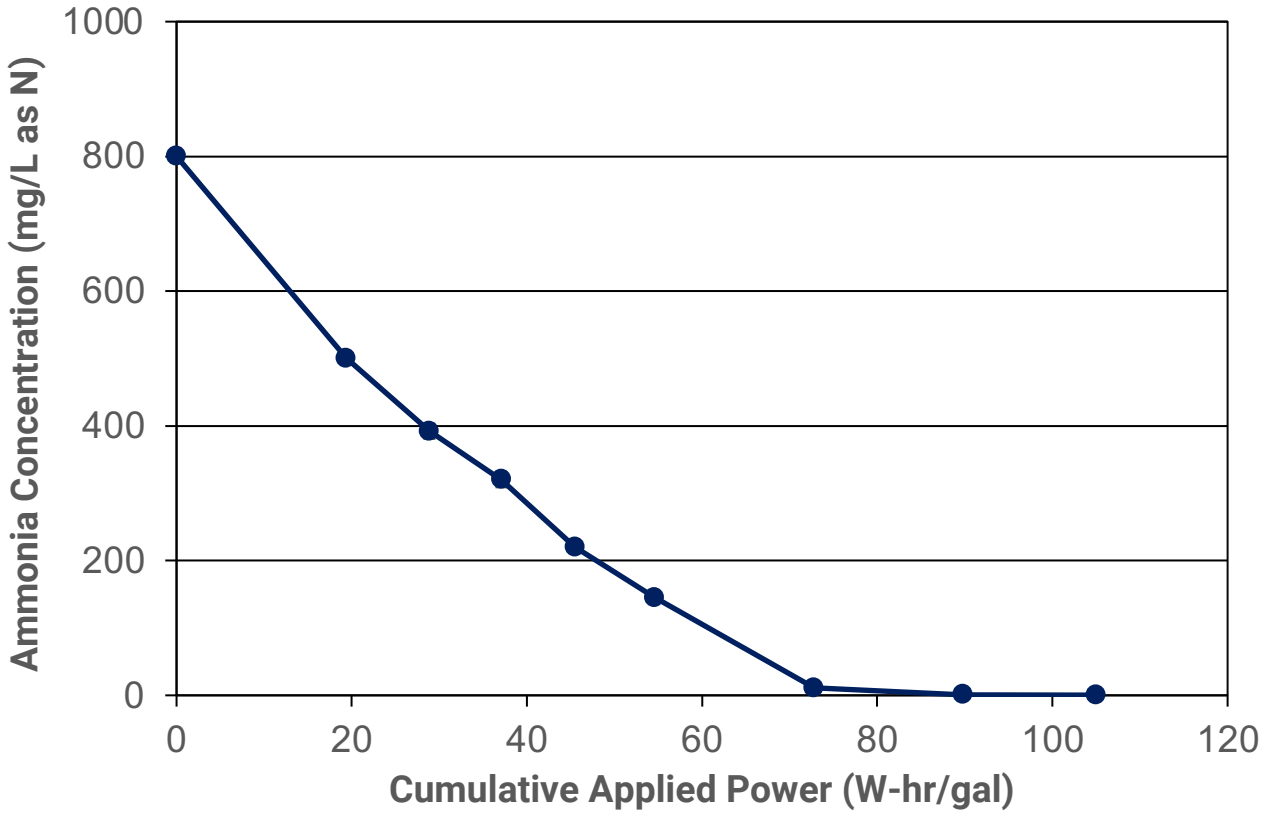
PFAS DESTRUCTION in LANDFILL LEACHATE

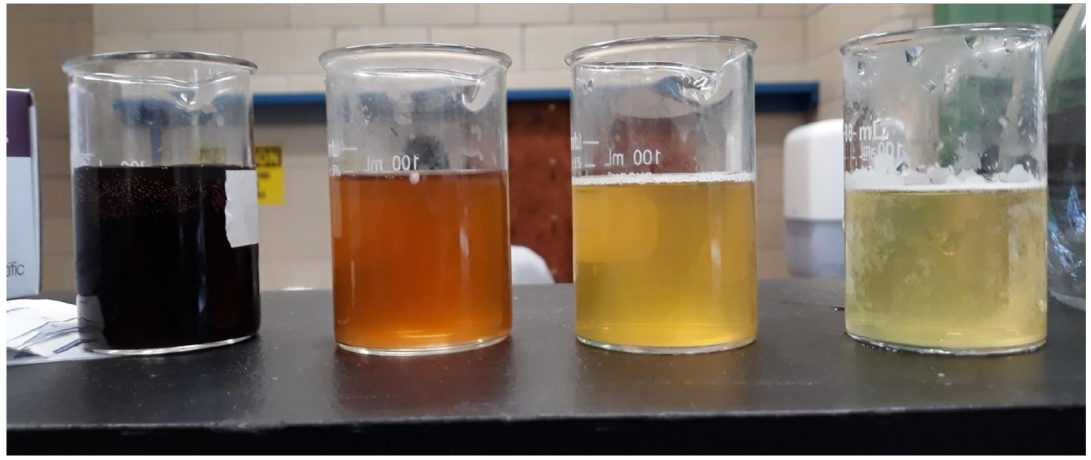


Compound	% Destruction at 53 watt-hr/gallon	Decay Rate (min^{-1})
PFOA	99.9%	0.024
PFOS	96.6%	0.012
PFNA	95.2%	0.011
PFHxS	98.4%	0.015
PFDA	95.9%	0.012
PFHpA	99.4%	0.019

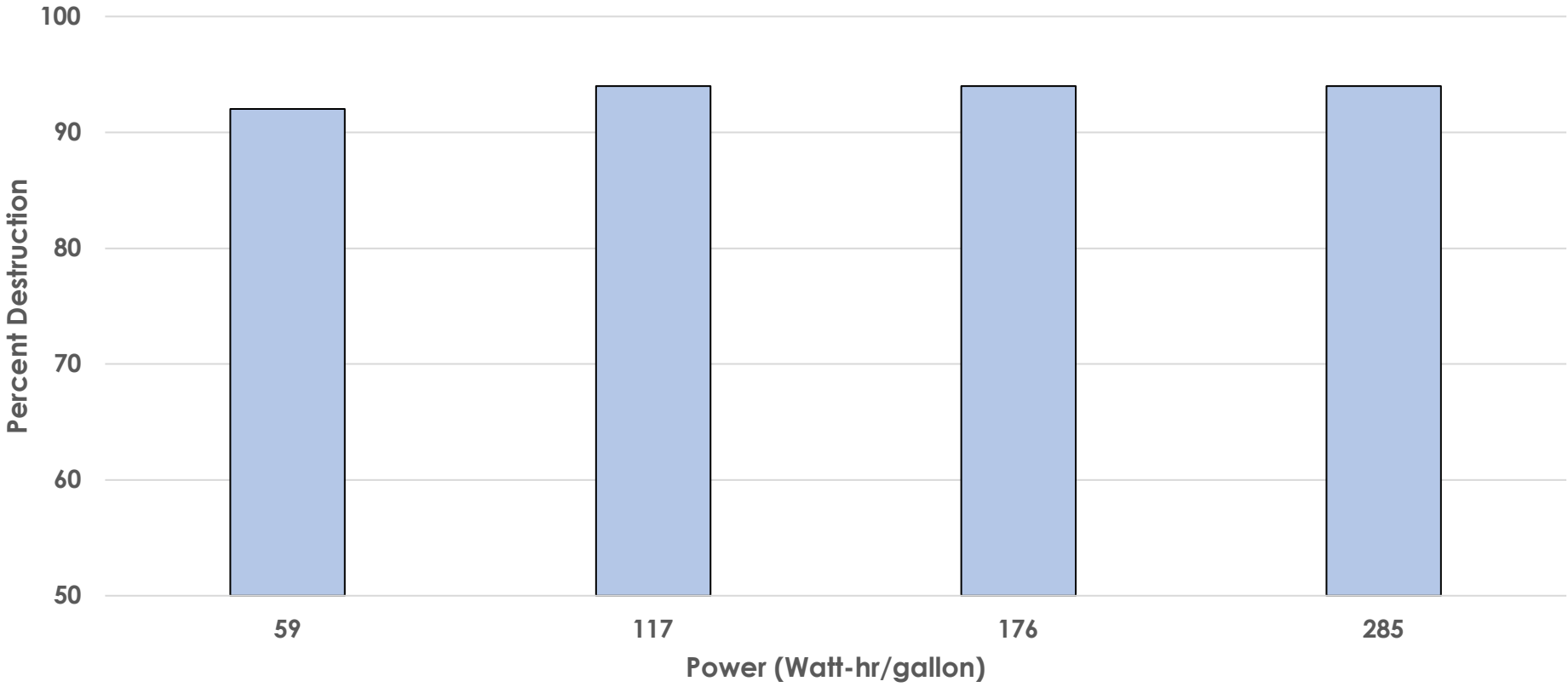
Starting PFAS6 Concentration: 11,000 ppt

DESTROYS AMMONIA and COLOR





PFAS Destruction in Foam Fractionate



Starting PFAS6 Concentration: 520,000 ppt

Recent Field Testing Results

In the field with production ready reactors

PROJECT OVERVIEW

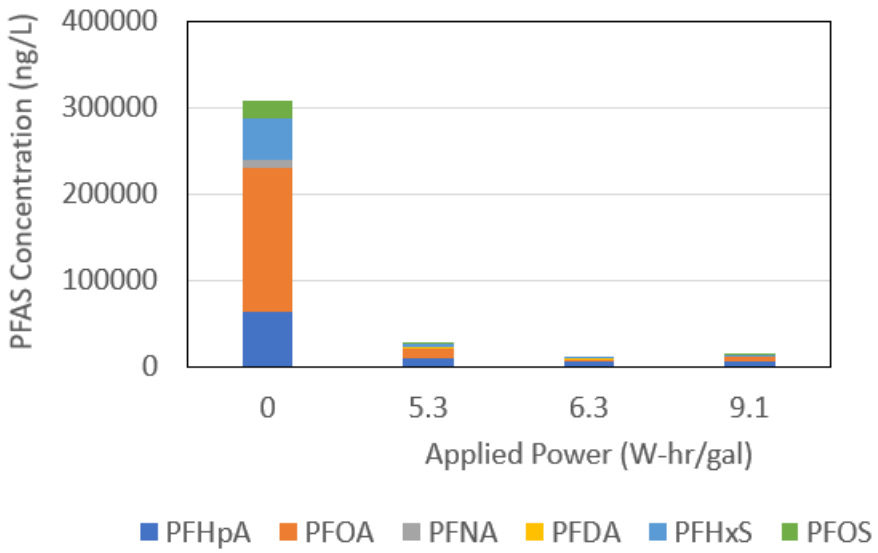
- Type: Landfill
  - Tested five leachates and RO Concentrate

Parameter (units)	Value
Aluminum (mg/L)	0.773
Calcium (mg/L)	847
Chromium (mg/L)	0.637
Iron (mg/L)	54.8
Magnesium (mg/L)	829
Manganese (mg/L)	4.9
Ammonia (mg/L as N)	20.7
COD (mg/L)	8620
NO2+NO3 (mg/L as N)	626
Total Nitrogen (mg/L as N)	1110
TDS (mg/L)	50900
TKN (mg/L as N)	482
TOC (mg/L)	2960
UV254 (1/cm)	88

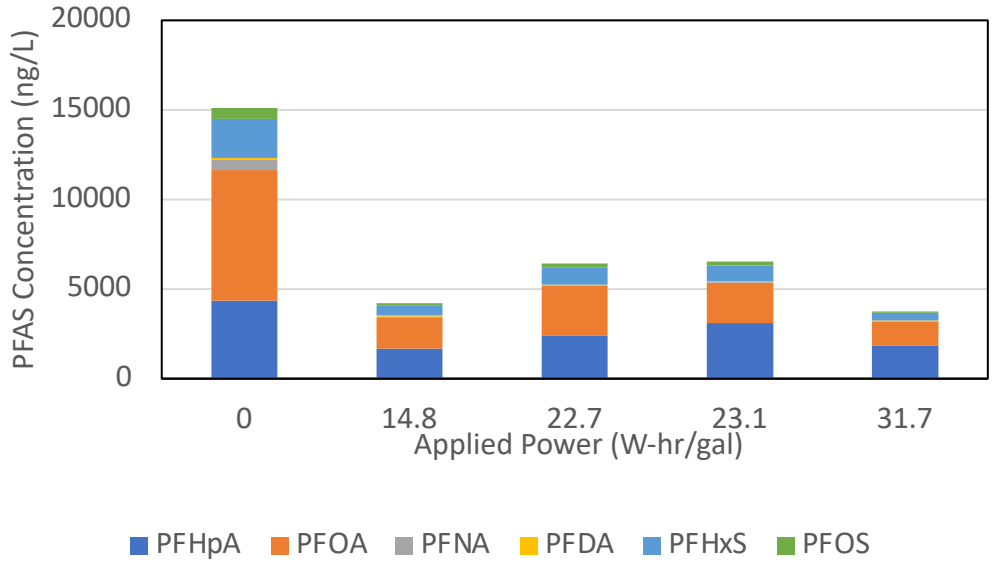
LONG AND SHORT CHAIN PFAS ARE DESTROYED

Destroys PFAS with Low Power

Thermal Concentrate from Landfill Leachate – continuous flow



RO Concentrate from Landfill Leachate – continuous flow

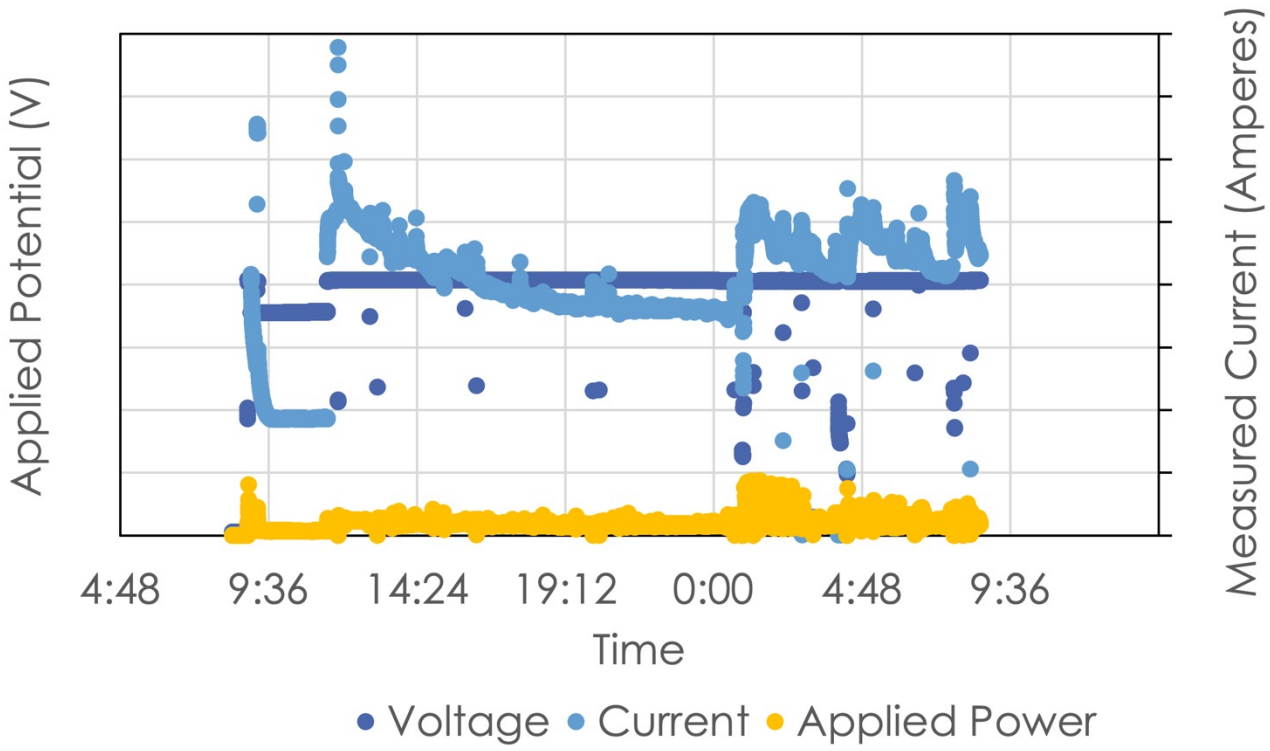


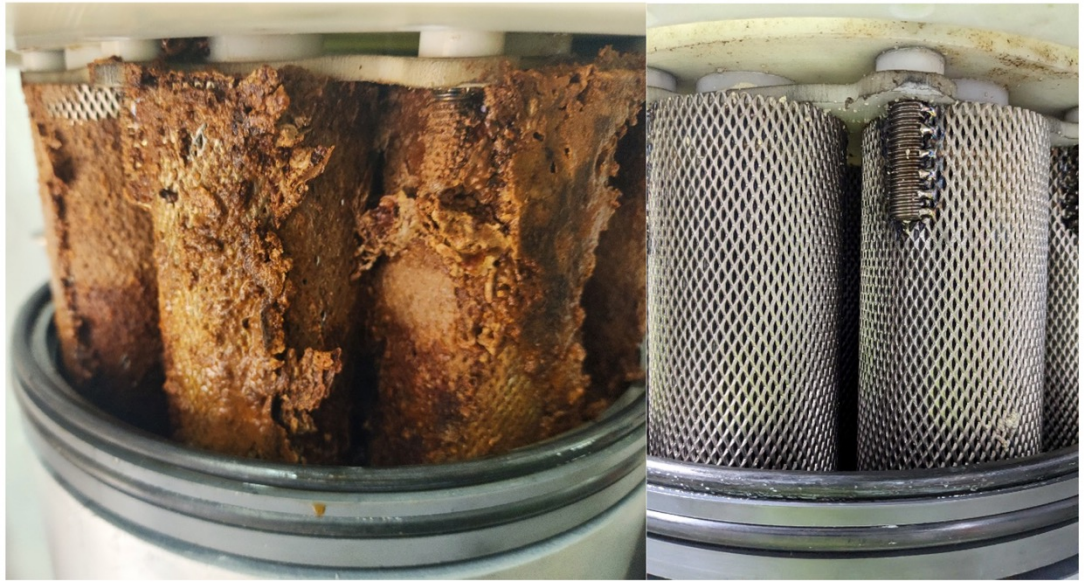
DESTRUCTION IN DIFFERENT WATER MATRICES

	Synthetic Brine		Raw Leachate		Thermal Concentrate		Foam Fractionate	
	Initial Conc (ng/L)	Decay Rate (min^{-1})	Initial Conc (ng/L)	Decay Rate (min^{-1})	Initial Conc (ng/L)	Decay Rate (min^{-1})	Initial Conc (ng/L)	Decay Rate (min^{-1})
PFOA	21,500	0.020	1,118	0.025	168,000	0.024	4,510,000	0.011
PFOS	33,500	0.024	486	0.022	22,200	>0.02	147,000	0.016
PFDA	---	---	---	---	6,790	>0.0125	43,000	0.017
PFNA	---	---	---	---	8,420	>0.018	96,400	0.014
PFHxS	---	---	---	---	47,000	0.02	50,700	0.008
PFHpA	---	---	---	---	62,700	0.008	9,370	0.0014

FOULING with RO CONCENTRATE

24-hour fouling test run. Cleaned with ~2% acid soln.





Fouled Electrodes **Clean Electrodes**

CONCLUSIONS and KEY FINDINGS

- Destruction of long and short chain PFAS compounds
- Continuous flow steady state operation
- Low power (<50 W-hr/gal)
- Ambient temperatures and pressures
- Long lasting electrodes (years)
- Cleaning allows for fouling removal and the recovery of original performance
- Remote operation
- No waste produced

OTHER APPLICATIONS and FUTURE WORK

- Future Development
  - Ion Exchange Brine
  - Spent IX Resin
  - Regenerable GAC waste
  - Biosolids

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THANK YOU!

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