Advanced PFAS-Specific Separation and Concentration Technologies

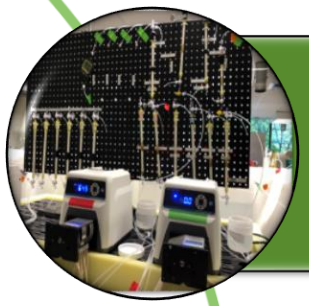
Dr. Kent Sorenson, PE (Denver, CO)

7/20/2020

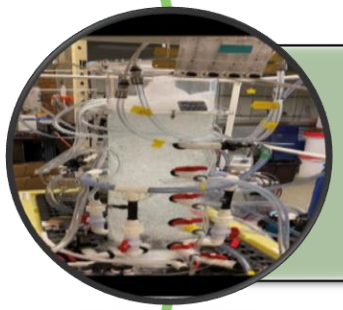
CDM Smith

NEWMOA Events

What will you learn?



Opportunities for improved separation and concentration technologies



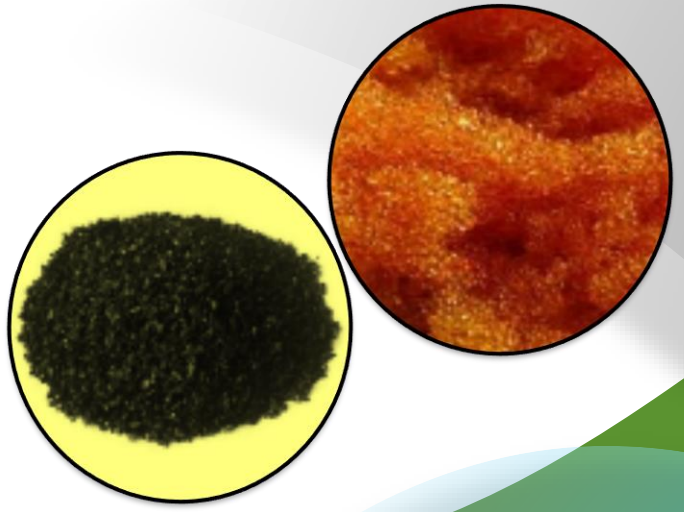
Principles of surface active foam fractionation for water treatment

Potential for complete on-site treatment and destruction of PFAS

Agenda

- Limitations of conventional PFAS treatment
- Overview of foam fractionation
- Potential for “closed loop” process

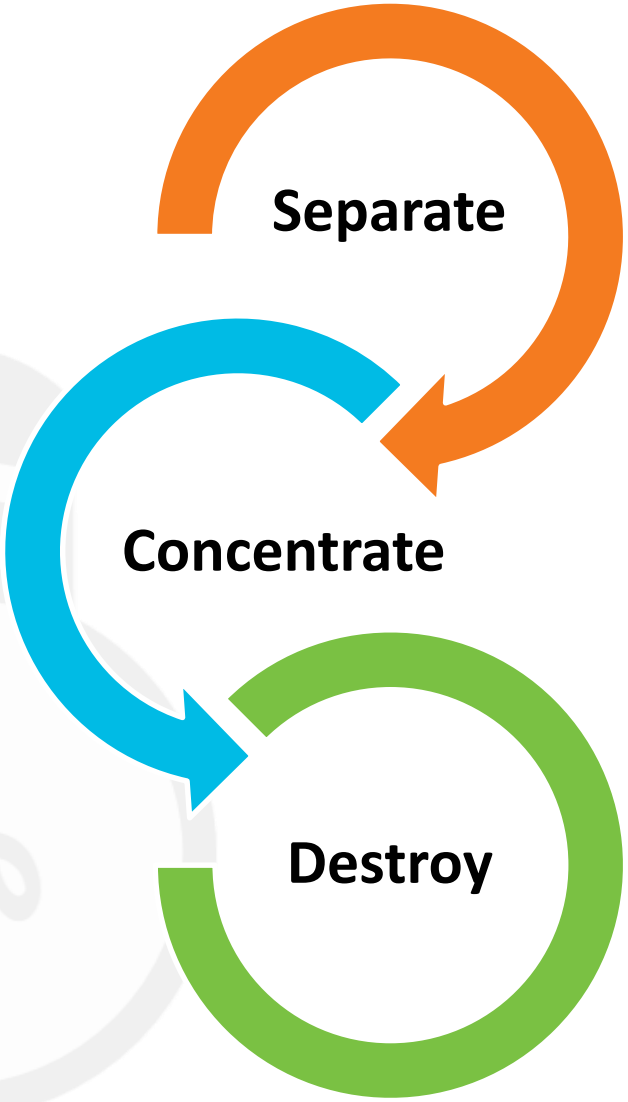
CONVENTIONAL PFAS TREATMENT CONSIDERATIONS/ LIMITATIONS



Limitations of “Conventional” Treatment for PFAS

- High volume of spent media or waste stream requiring waste management
- Significant pretreatment often required to remove competing solutes
- High concentrations of PFAS can lead to inefficient removal of target compounds
- Overall high costs for removing small mass of contamination (down to trace ppt levels)

Comprehensive PFAS Treatment Solution

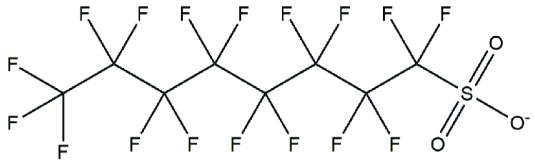


Treatment Goals	Example Treatments
• Protect human health and the environment • Meet safe drinking water and discharge requirements	• GAC, AIX, RO (demonstrated) • NF • Surfactant or coagulant separation • Foam Fractionation
• Reduce waste stream volume	• Regenerable media → regenerant waste • Surfactant or coagulant separation → PFAS laden flocs • Foam fractionation → foam concentrate
• Zero PFAS waste discharge	• High temp thermal, electrochemical, plasma, sonolysis

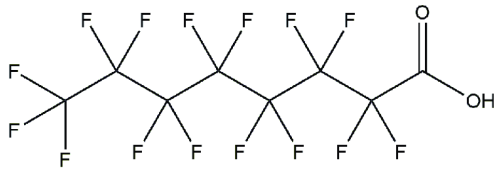
SURFACE ACTIVE FOAM FRACTIONATION

How foam fractionation works

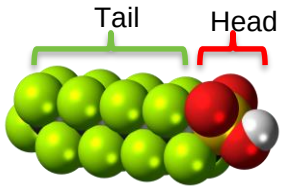
- Molecular structure creates affinity for air-water interfaces
- PFAS separated from water as bubbles
- Foam captured for further concentration

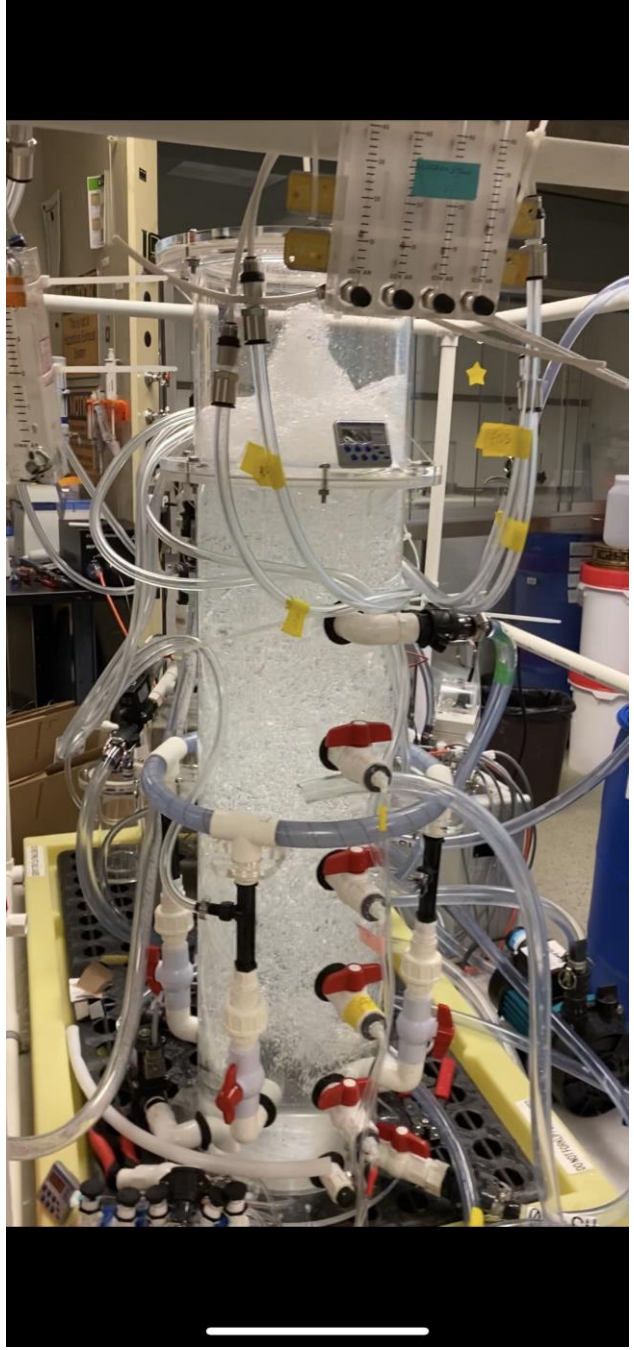


Perfluorooctane sulfonate (PFOS)



Perfluorooctanoic acid (PFOA)





Oakey Results

SAFF™ + AIX
Commissioned 19th May 2019

- 20 ML Treated
- 500L PFAS Waste Concentrate
- CF 42,000x, (CF 442,000x tested)
- New CF 1-10Mx in-development

SAFF™ + AIX

- Contract <0.07μg/l
- Aust. DoD website reporting <0.01μg/l

OPEC SYSTEMS

www.opecsystems.com

Performance Data: Rates of Removal

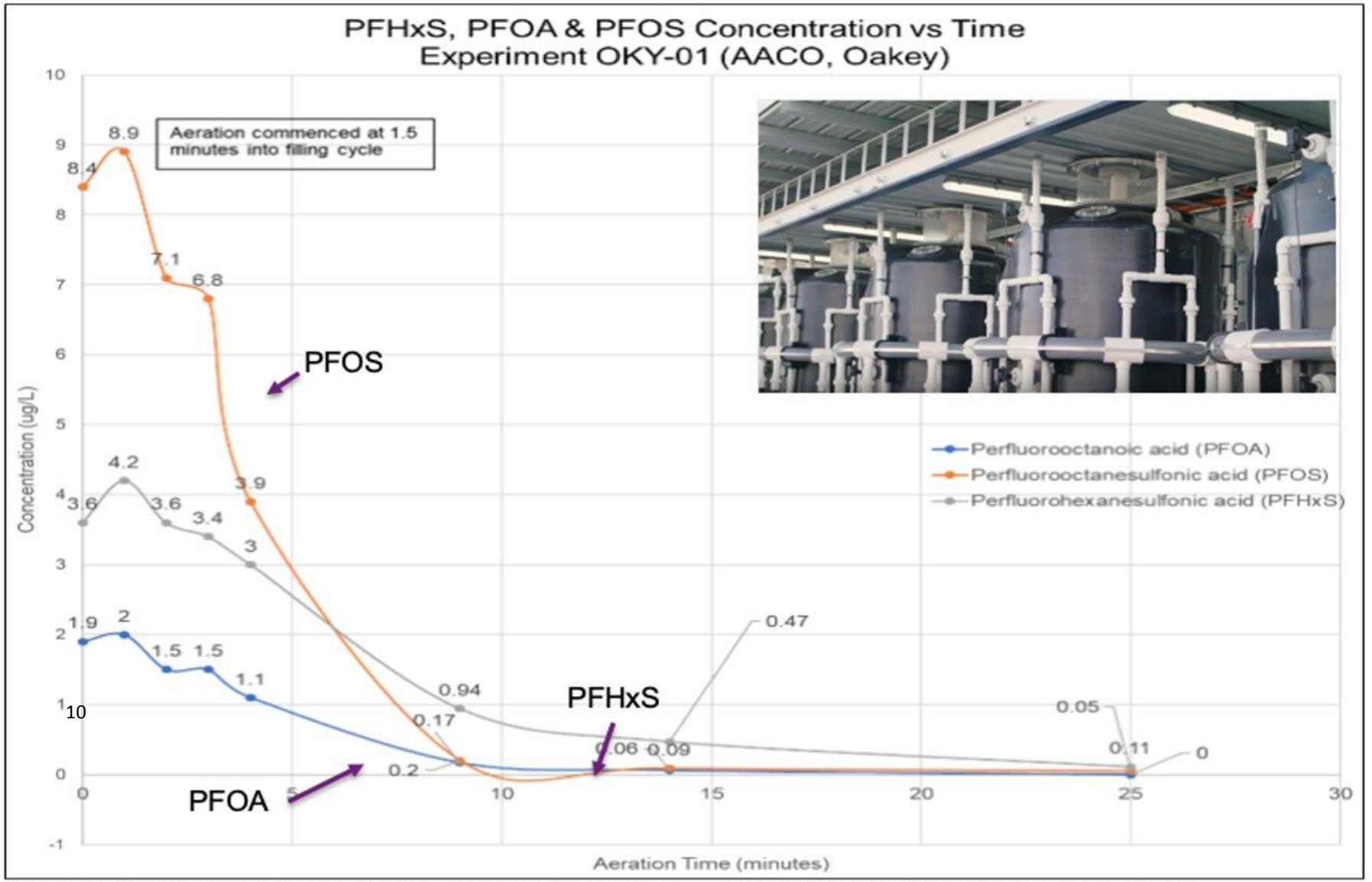


Chart-3: PFOS, PFHxS and PFOA removal Rates from AACO WTP (Commissioning Data 2019).

KEY POINTS

(1) Robust, Proven & Rapid

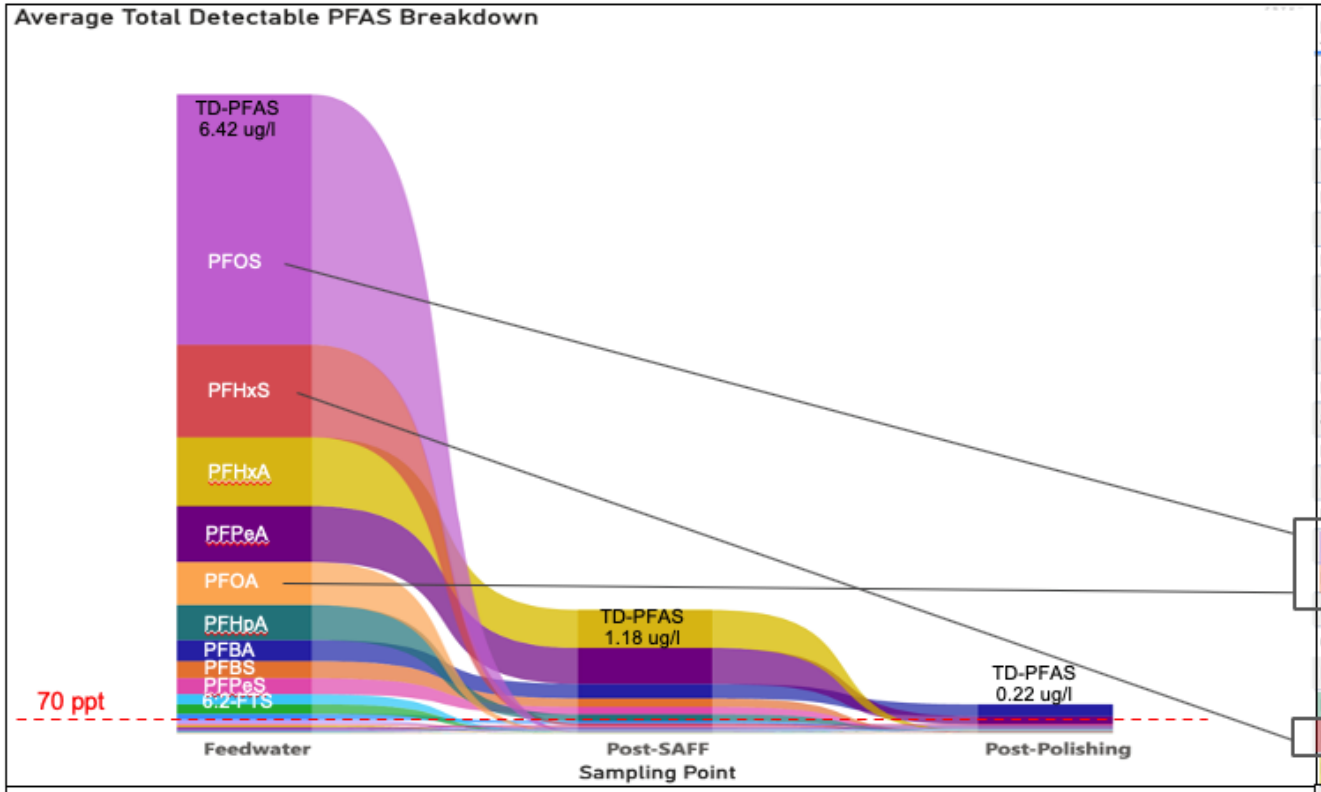
(2) PFOS: 3-4 mins

(3) PFOA: 3-4 mins

(4) PFHxS: 10-12

Monitoring 30+ PFAS Compounds

PFAS Ribbon Graph: AACO's 3M Lightwater Signature



Reportable	Feedwater	Post-SAFF	Post-Polishing
PFTeDA (µg/L)	< 0.001	< 0.001	< 0.001
PFTrDA (µg/L)	< 0.001	< 0.001	< 0.001
PFDoDA (µg/L)	< 0.001	< 0.001	< 0.001
EtFOSE (µg/L)	< 0.005	< 0.005	< 0.005
EtFOSAA (µg/L)	< 0.005	< 0.005	< 0.005
10:2 FTS (µg/L)	< 0.010	< 0.010	< 0.010
PFUnDA (µg/L)	< 0.001	< 0.001	< 0.001
MeFOSAA (µg/L)	< 0.005	< 0.005	< 0.005
PFDS (µg/L)	< 0.001	< 0.001	< 0.001
PFDA (µg/L)	0.003	< 0.001	< 0.001
EtFOSA (µg/L)	< 0.005	< 0.005	< 0.005
8:2 FTS (µg/L)	0.022	< 0.010	< 0.010
PFNS (µg/L)	0.014	< 0.001	< 0.001
PFNA (µg/L)	0.044	< 0.001	< 0.001
MeFOSA (µg/L)	< 0.005	< 0.005	< 0.005
PFOS (µg/L)	2.539	0.002	0.002
PFOA (µg/L)	0.435	0.003	0.002
FOSA (µg/L)	< 0.005	< 0.005	< 0.005
6:2 FTS (µg/L)	0.100	< 0.005	< 0.005
PFHpS (µg/L)	0.097	0.002	0.002
PFHpA (µg/L)	0.355	0.071	0.002
PFHxS (µg/L)	0.939	0.020	0.002
PFHxA (µg/L)	0.697	0.386	0.004
4:2 FTS (µg/L)	< 0.010	< 0.010	< 0.010
PFPeS (µg/L)	0.162	0.074	0.002
PFPeA (µg/L)	0.565	0.363	0.077
PFBS (µg/L)	0.173	0.087	0.002
PFBA (µg/L)	0.215	0.147	0.124
PFPrS (µg/L)	0.060	0.021	< 0.001

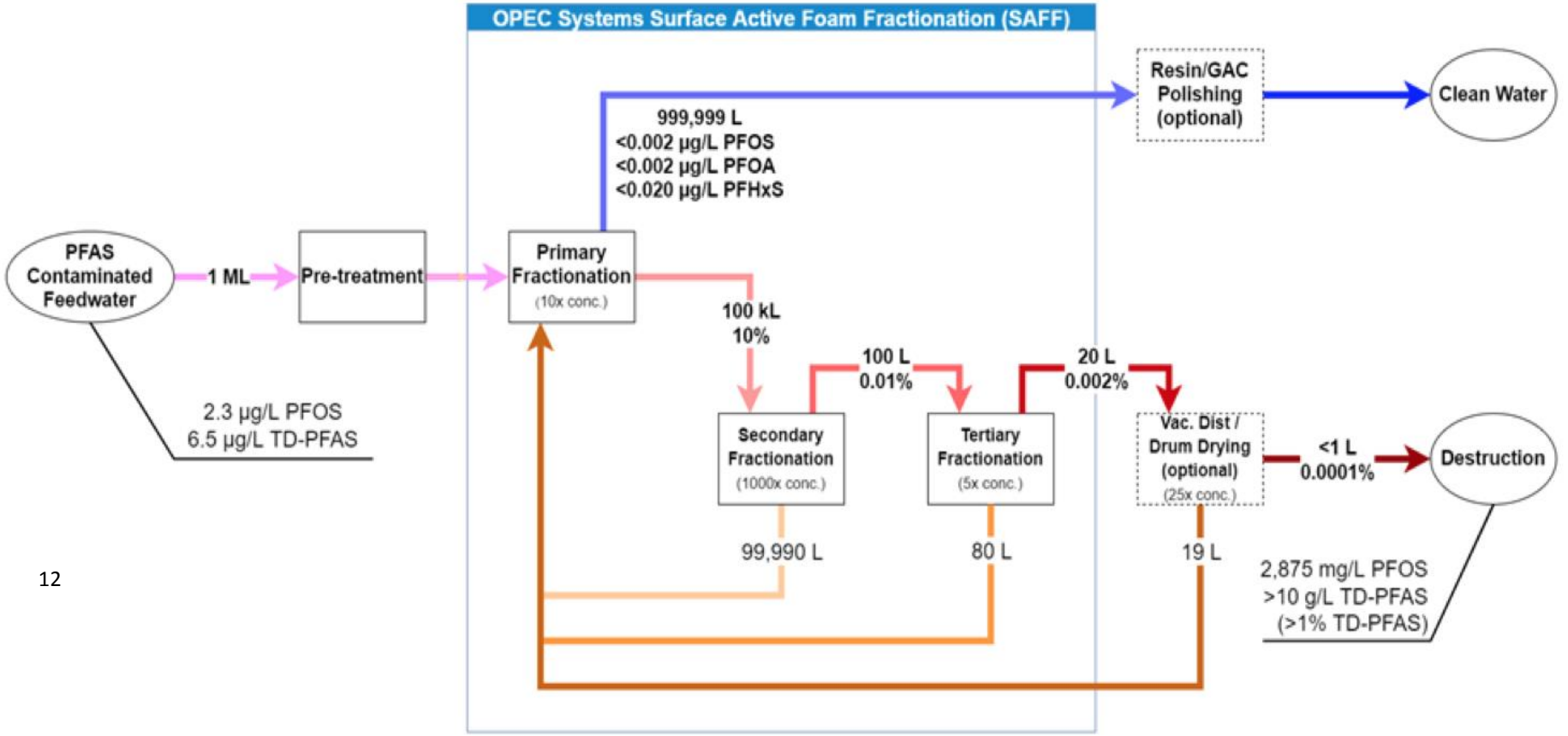
SAFF Removes 81.7% of Bulk PFAS from GW's
Impacted with 3M Lightwater AFFF prior to AIX Polishing

Key Points:

- SAFF removes PFOS/PFOA completely
- Very effective for C6 and greater
- Less effective for shorter chains (polish might be required)
- Very low operating cost

Concentration Factors

Triple SAFF™ Process



12

KEY POINTS

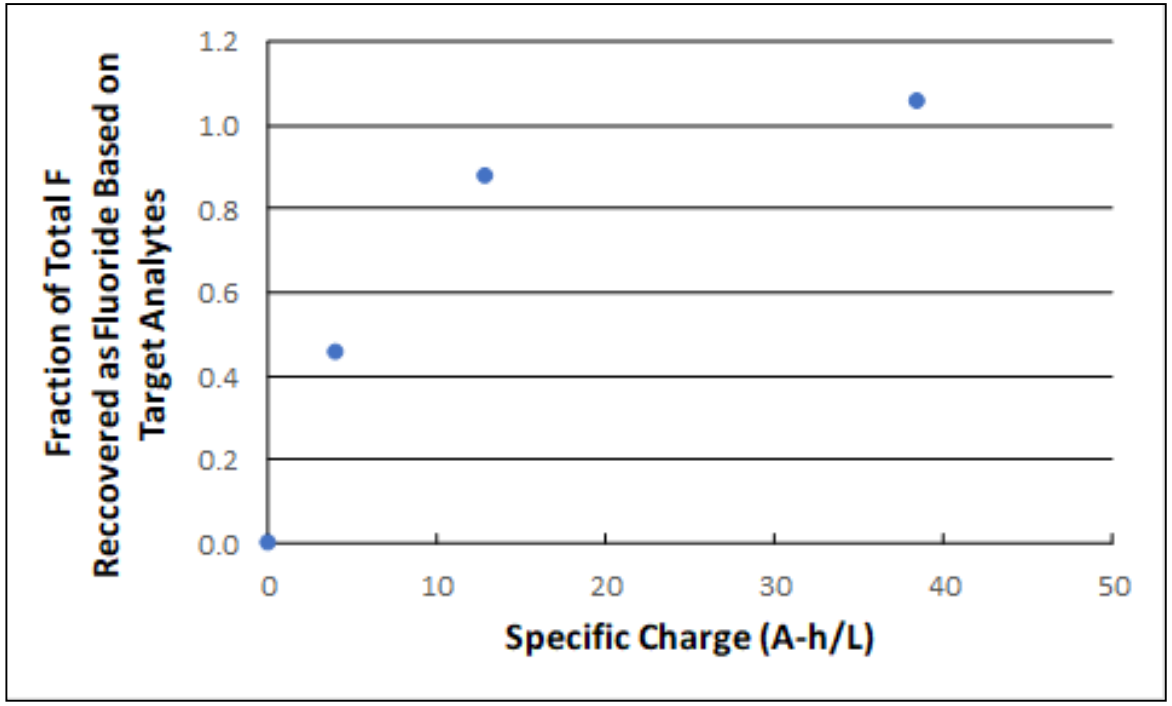
(1) Primary stage achieves discharge criteria.

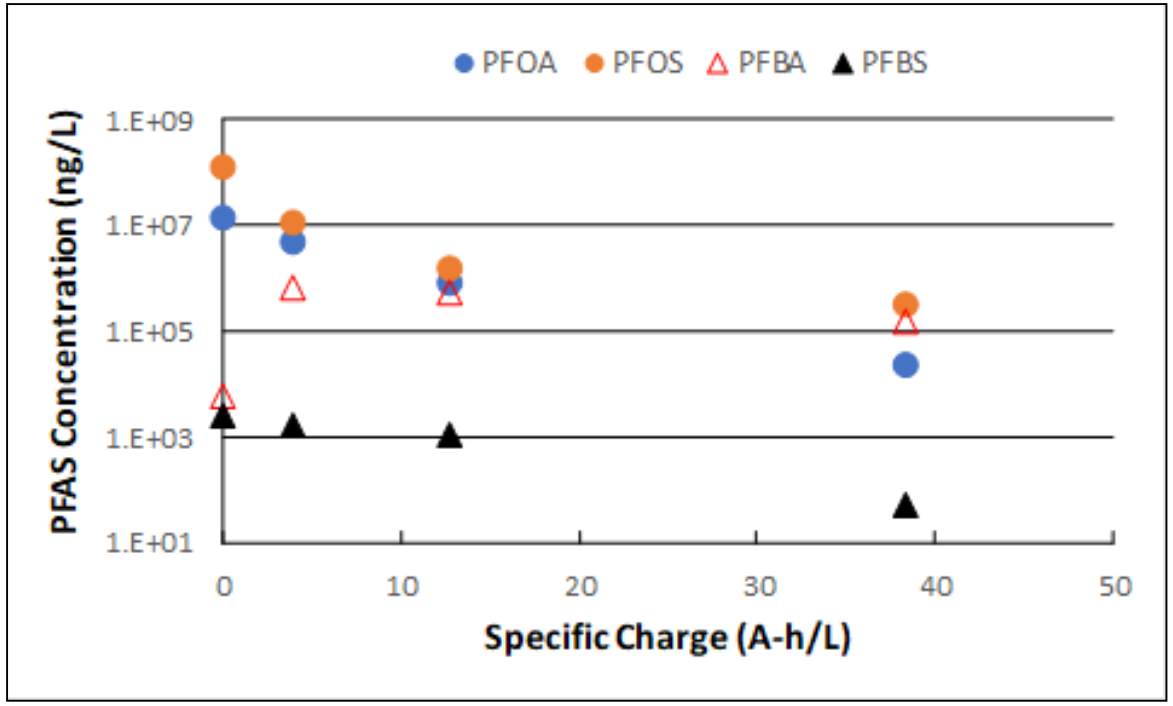
(2) Secondary & Tertiary stages minimize waste volumes

(3) PFAS Waste 0.001% (+1% Concentrate)

CLOSED LOOP TREATMENT?

Electrochemical Treatment of SAFF Hyper-Concentrate

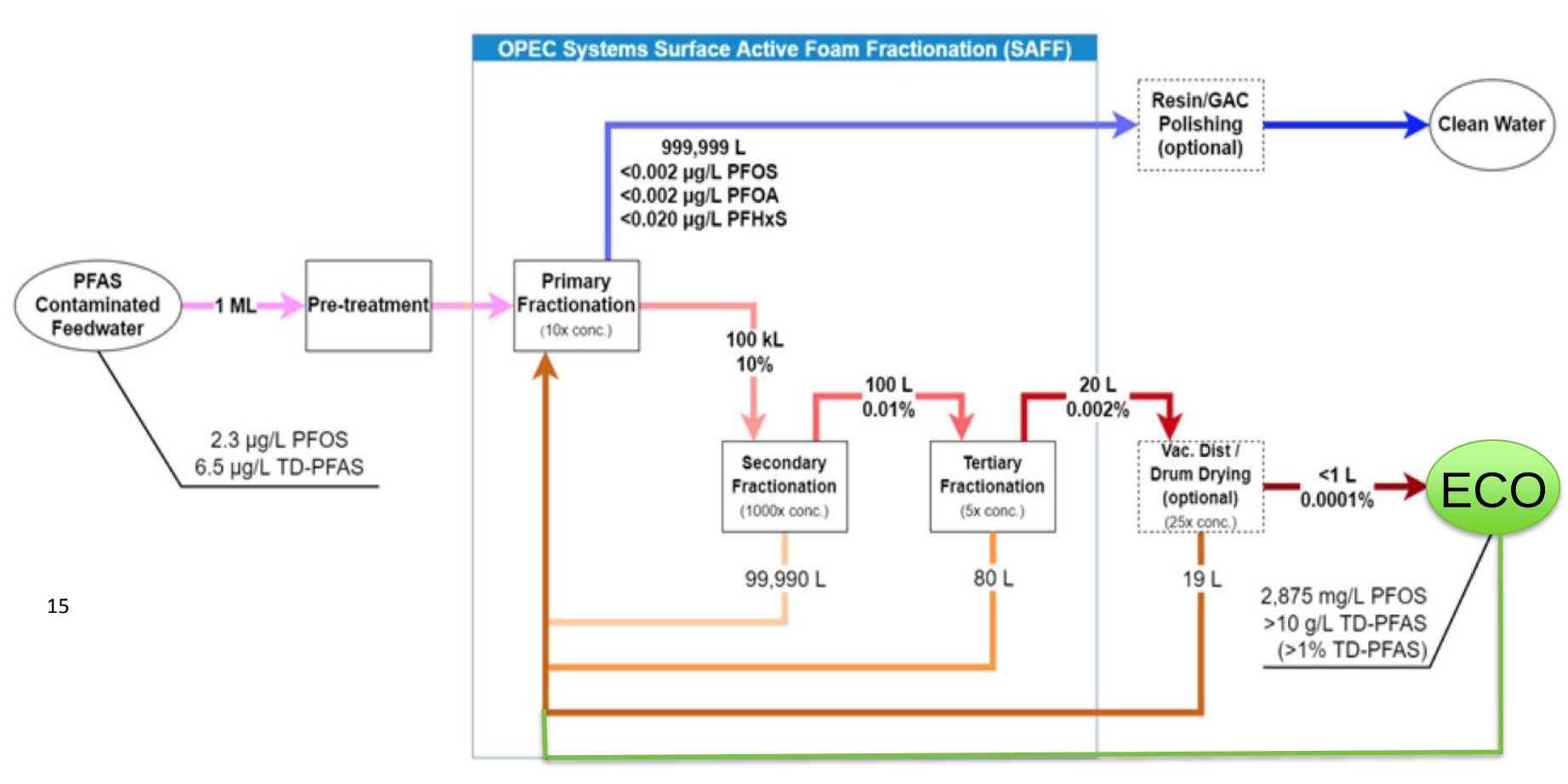




Current density of 40 mA/cm2 for 24 hr reaction time

The Breakthrough – Potential for Closed Loop Treatment

Triple SAFF™ Process + ECO



15

KEY POINTS

(1) Primary stage achieves discharge criteria.

(2) Secondary & Tertiary stages minimize waste volumes

(3) PFAS Waste 0.001% (+1% Concentrate)

(4) ECO destroys 99 – 99.9% of PFAS, recycles remainder to Primary stage

Summary

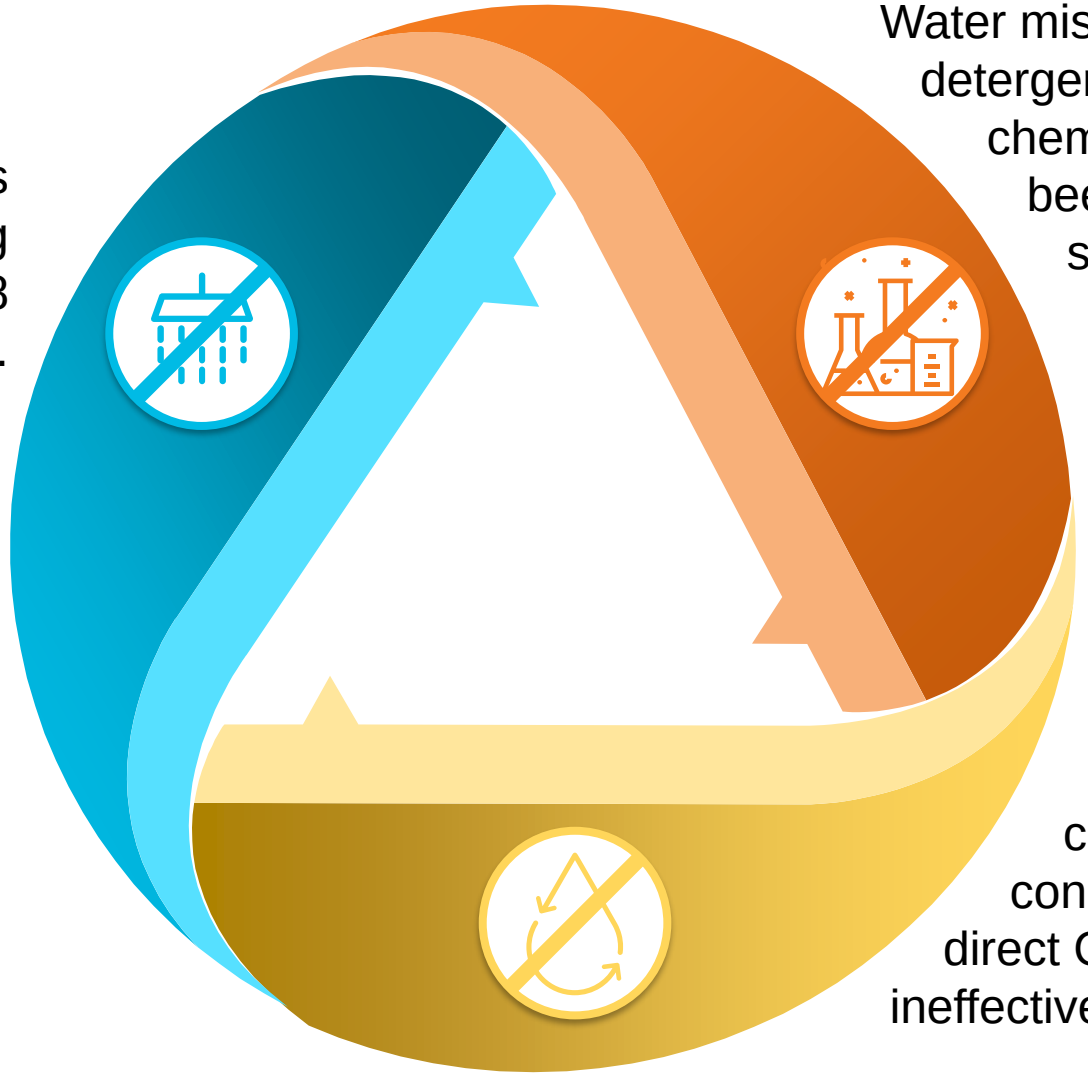
- SAFF is not DAF
- How SAFF & ECO works:
  - Separation via primary fractionation
  - Concentration via 2nd and 3rd fractionation
  - On-site destruction (ECO)

- Benefits:
  - No chemical addition
  - Low CAPEX & OPEX
  - Little to no waste
  - Lowest $/g PFAS removed

PERFLUORAD®

Problem Statement

Triple water rinsing is NOT effective, leaving significant residual C8 PFAS.

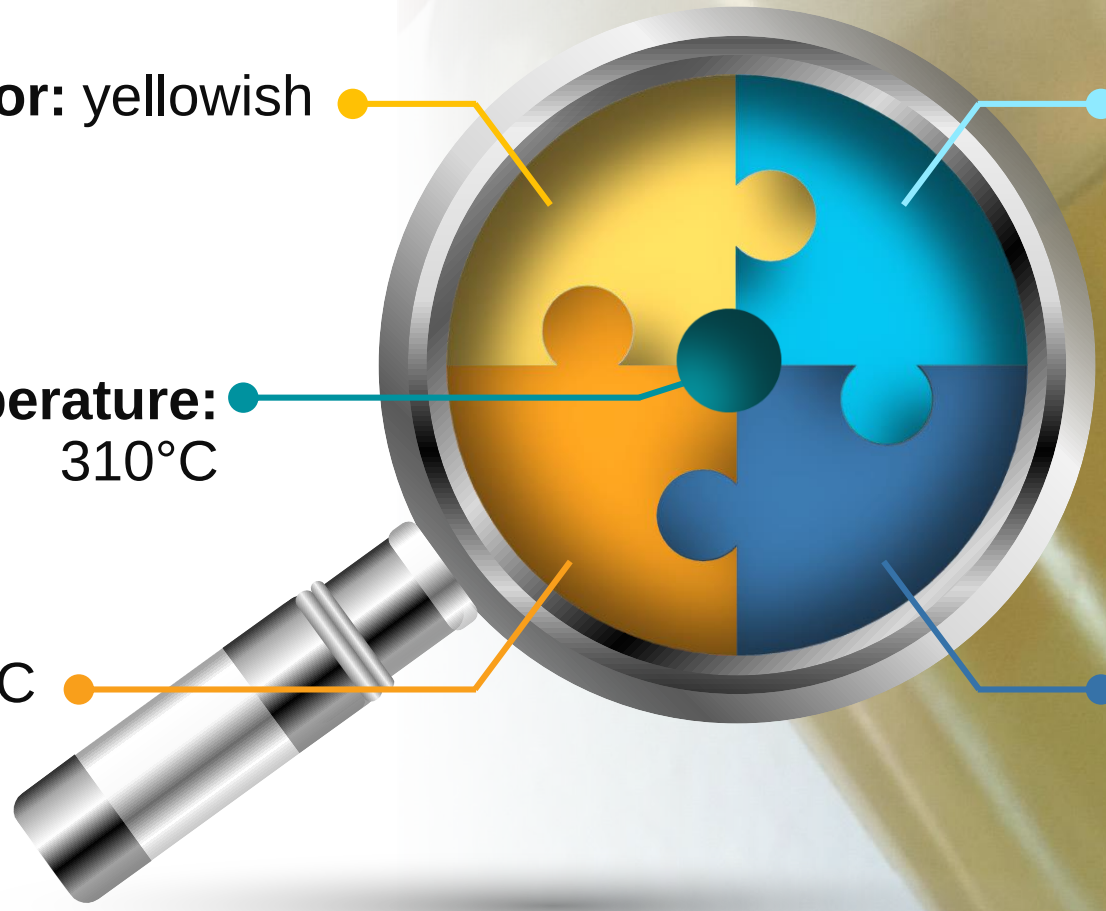


Water miscible solvents, steam, detergents, and proprietary chemical amendments have been assessed with limited success.

Wastewater generated during foam replacement contains high PFAS concentrations (ppb) making direct GAC or AIX treatment either ineffective or very inefficient.

What is PerfluorAd?

Liquid active substance derived from plant-based fatty acid



Color: yellowish

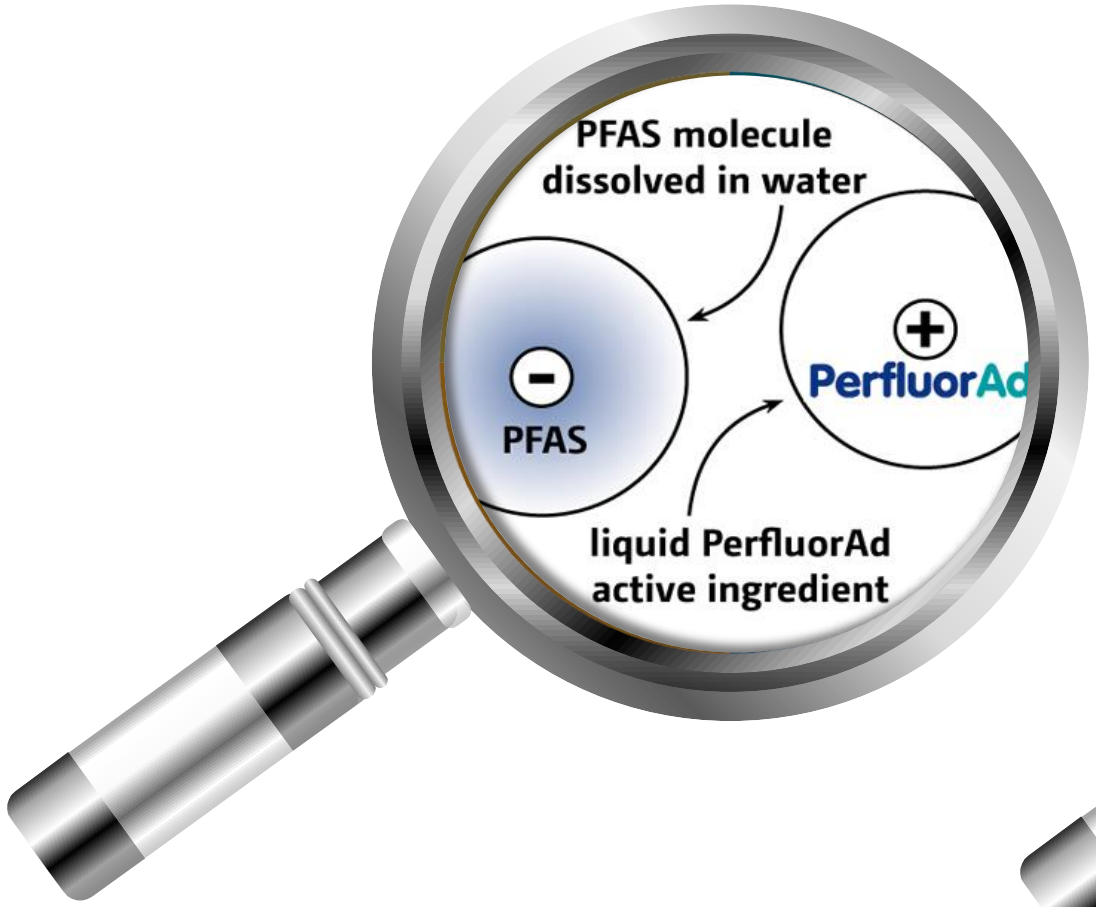
Density: approx. 0.98 g/cm³ @ 20°C

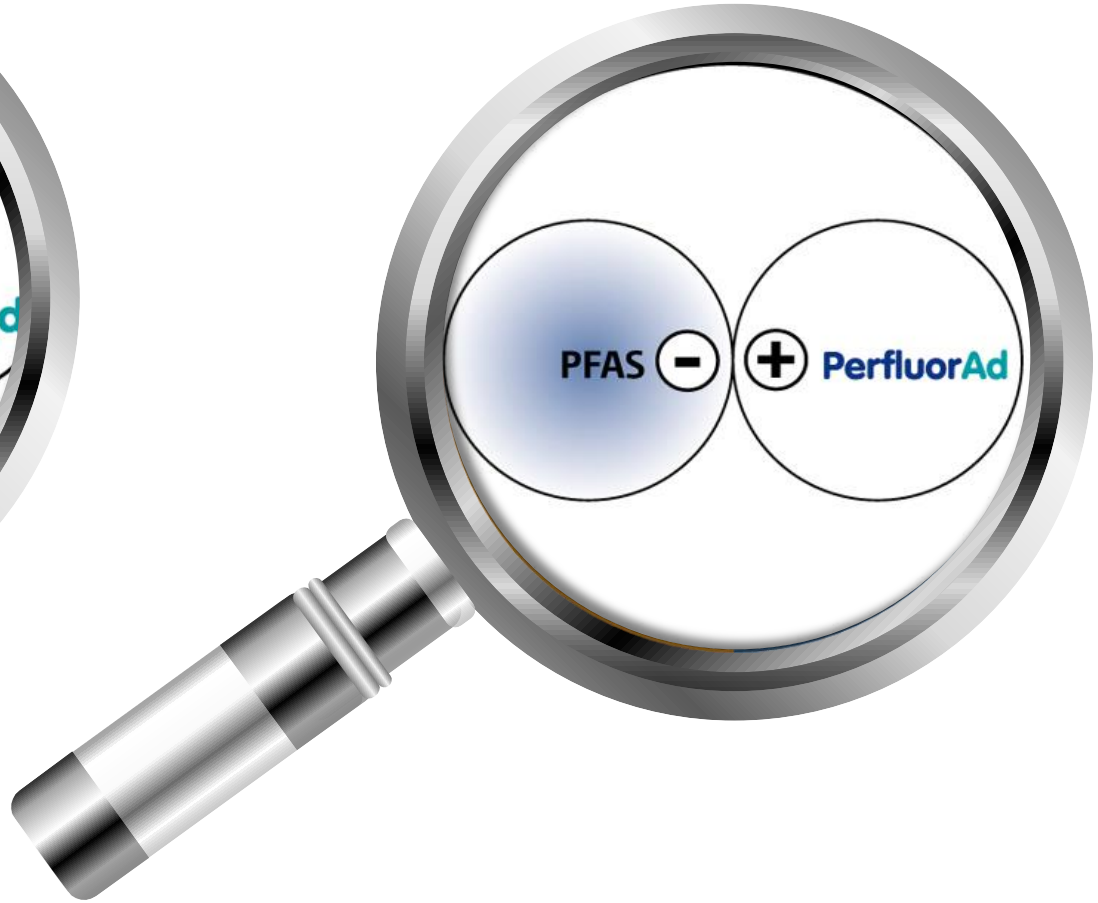
Ignition temperature: 310°C

Flash point: >100°C

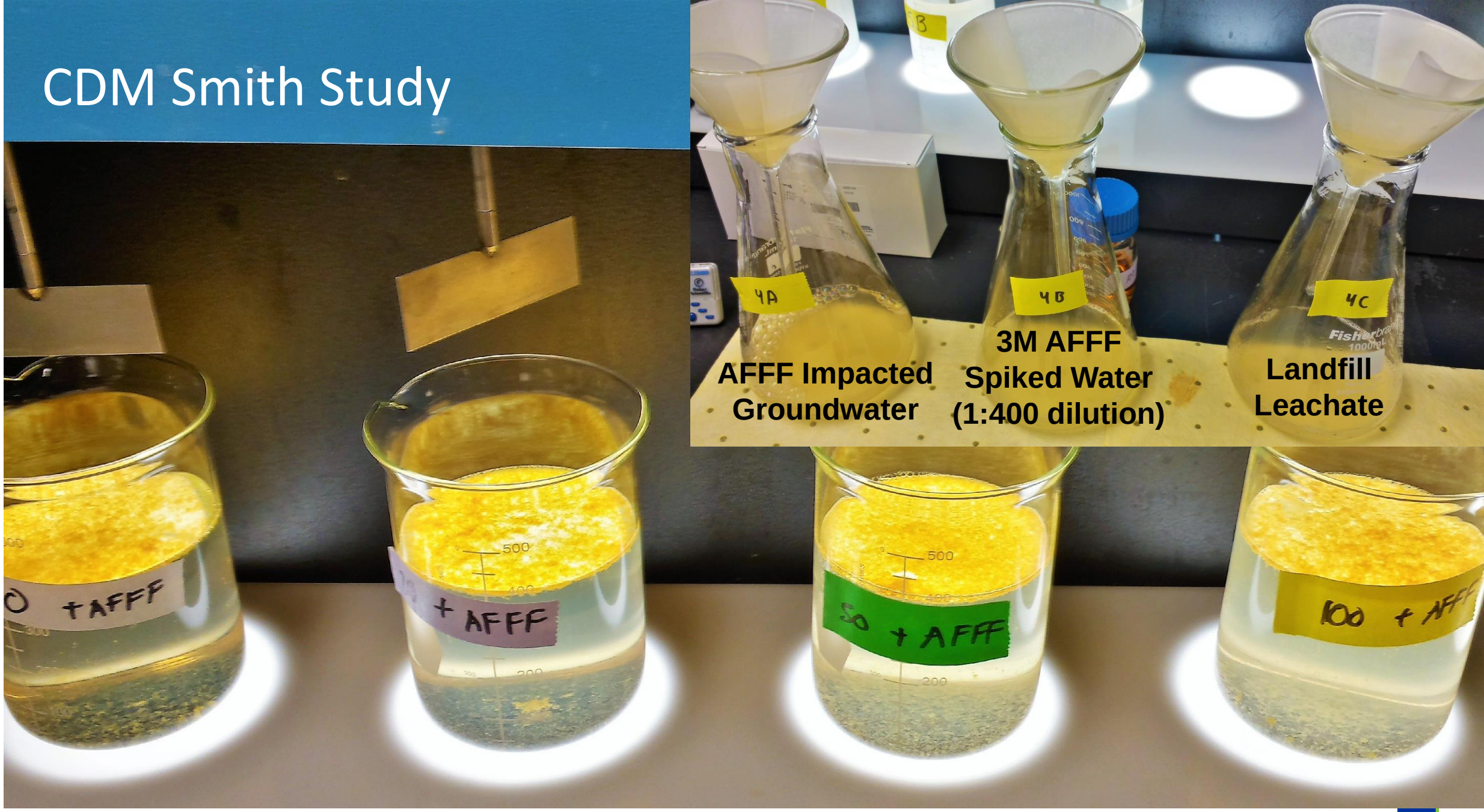
Viscosity: 100 mPas @ 40°C

What is PerfluorAd?





CDM Smith Study

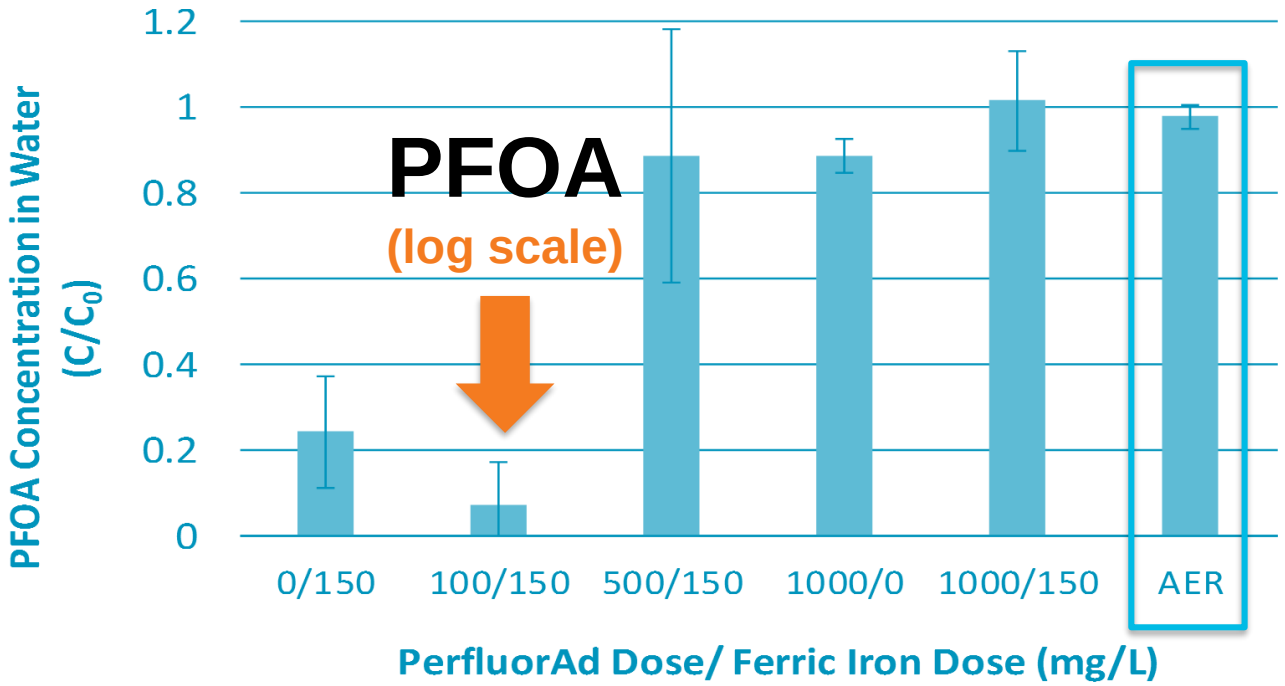


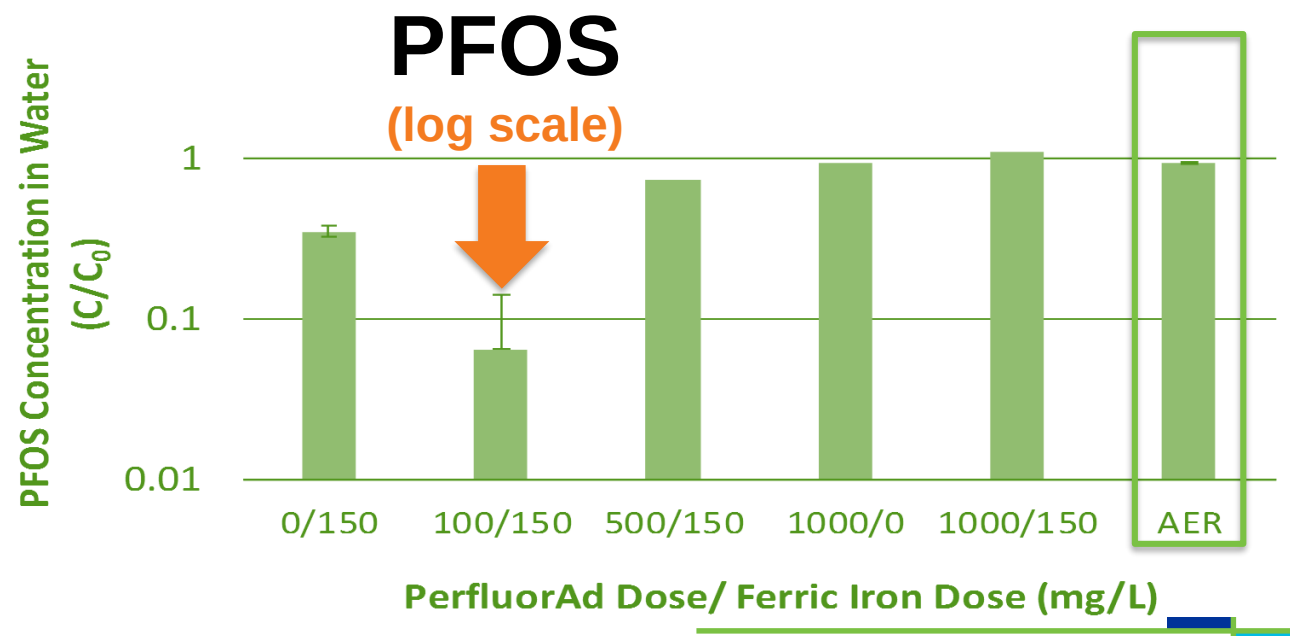
3M AFFF Spiked Water (1:400 dilution)

PFAA concentrations(µg/L)

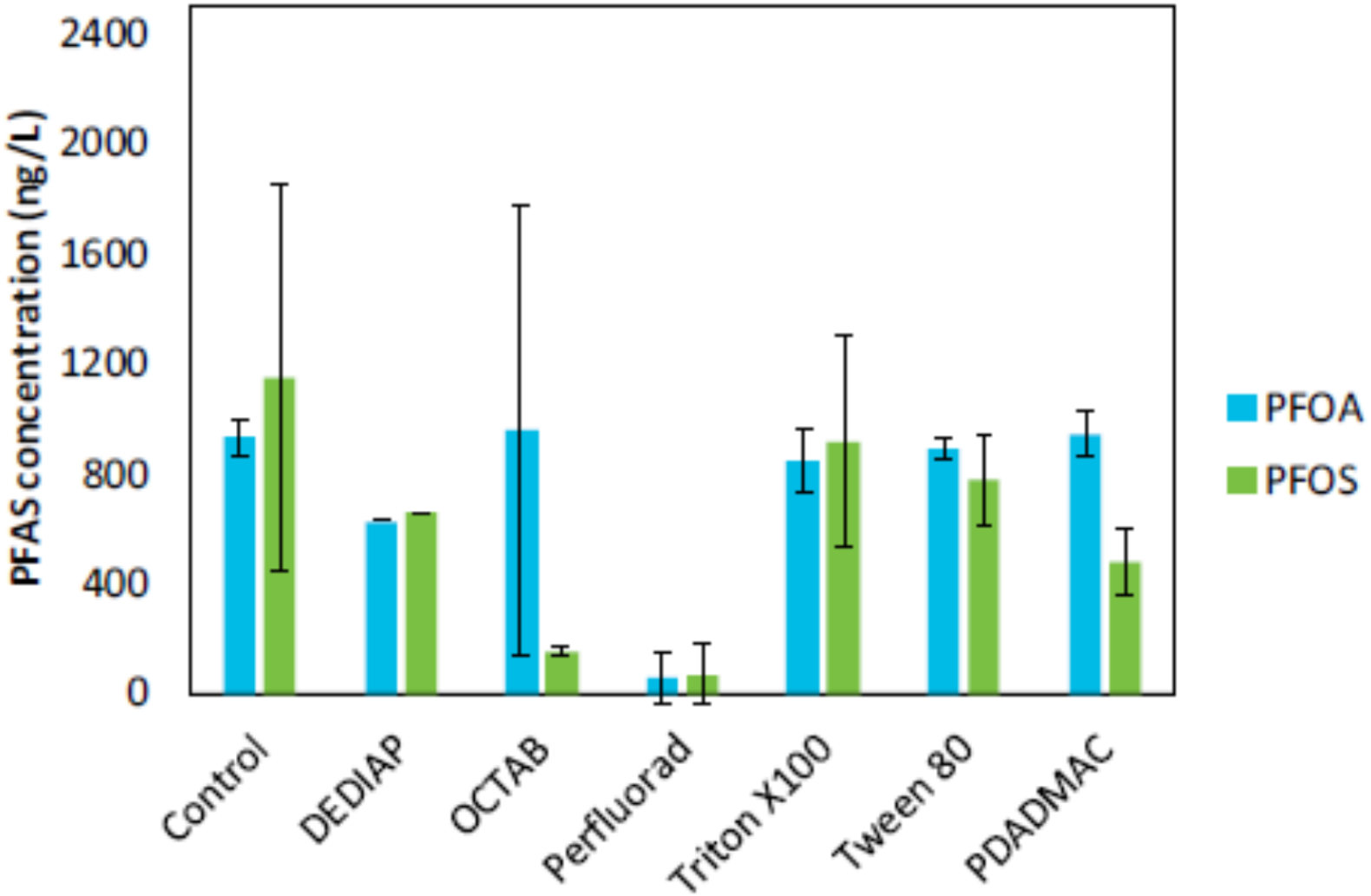
PFPeA	149
PFHxA	362
PFHpA	122
PFOA	**428**
PFPrS	225
PFBS	505
PFPeS	530
PFHxS	2461
PFHpS	211
PFOS	**5050**

AER: Anion Exchange Resin, 100 mg/L





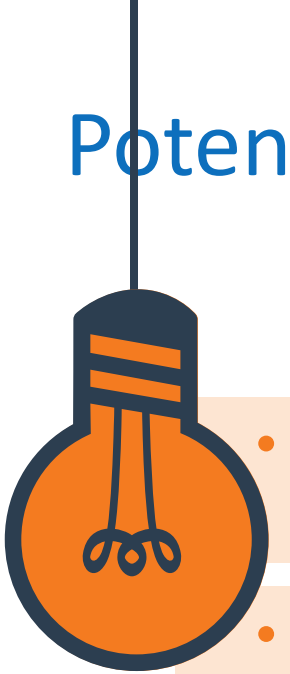
PFAS Removal by PerfluorAd and Several Commercially Available Surfactants



PerfluorAd Data Summary

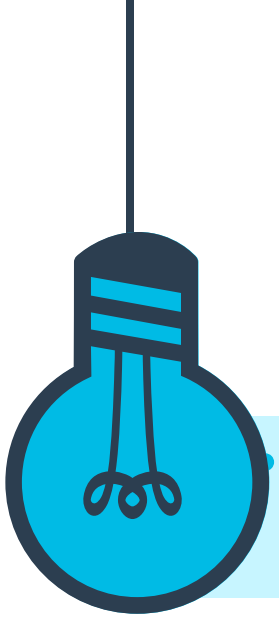
A viable treatment option for PFAS removal
Iron (II) chloride improves removal efficiency
Effective for different water types at high PFAS concentrations
Most effective for anionic long-chain PFAS
Most effective for sulfonates
PFAS treatment performance can be comparable or even better than resin
Subject to treatment goals, PerfluorAd can be standalone or coupled with other treatment technologies

Potential Applications



Contaminated Sites

- **Groundwater in the AFFF source areas**
- **Pretreatment for GAC or IX**
- Contaminated surface water
- IDW
- In-situ sediment remediation with PerfluorAd and immobilization reagents

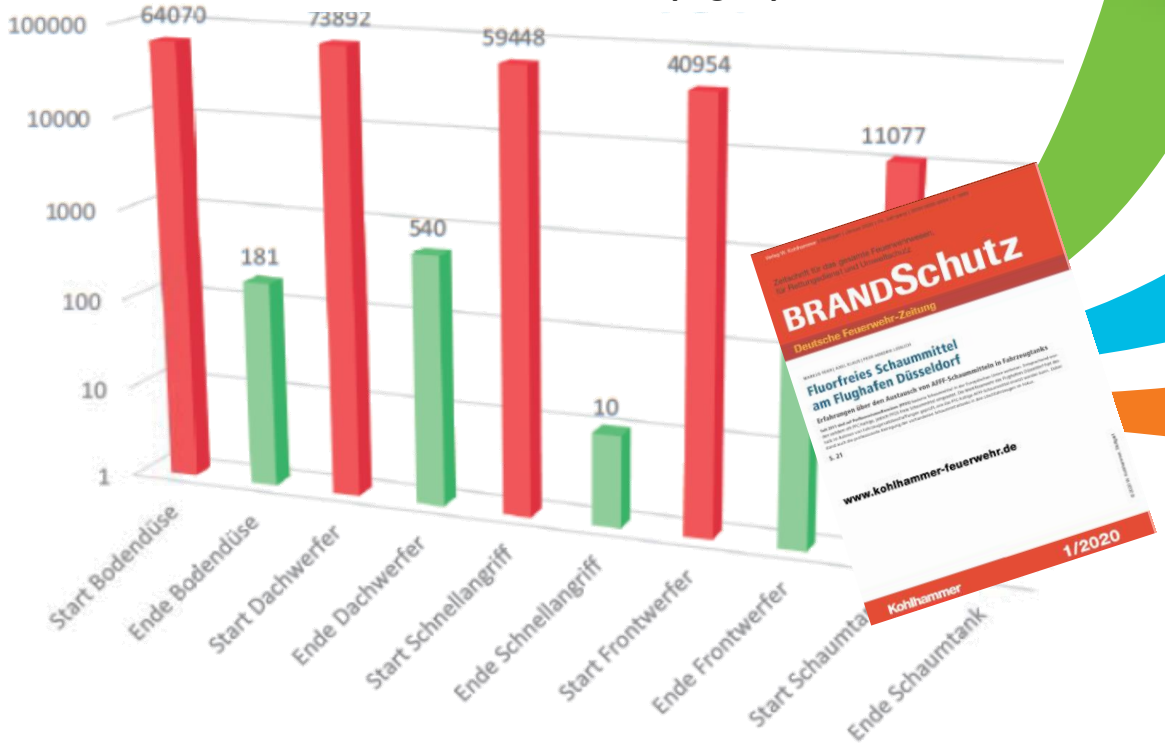


Water and Wastewater

- **Treatment of wash/decon water during AFFF replacement**
- Pretreatment
- Treatment of RO rejected concentrate
- Treatment of landfill leachate
- Treatment of high PFAS waste streams

Cleaning Out a Firetruck in Germany

Article Published Last January For Dusseldorf Project in Germany



01

Before and after PerfluorAd cleanout data for a fire truck for the sum of 6 PFAS compounds

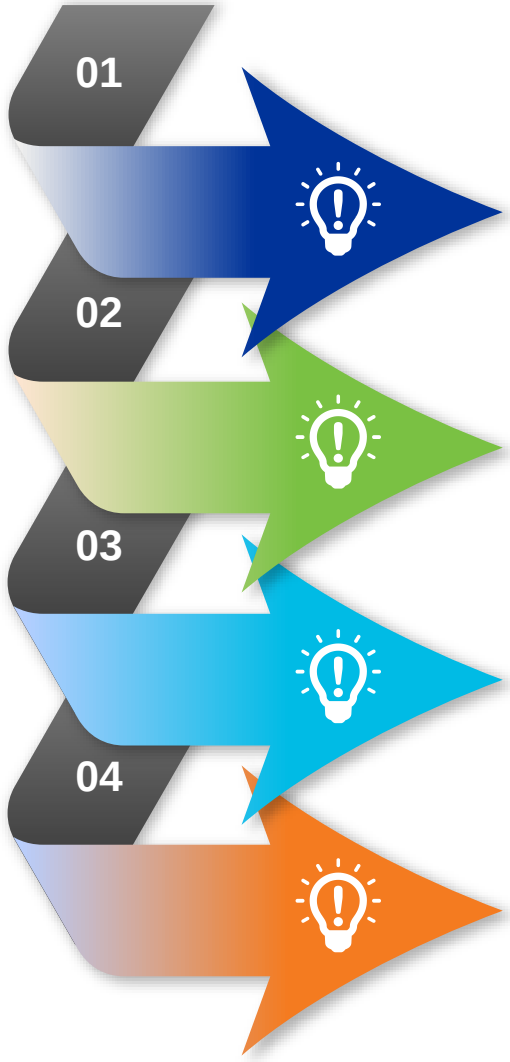
02

Greater than two order of magnitude reduction for all

03

Greater than three orders of magnitude reduction for some

PerfluorAd Key Points:



Finalizing contract with ESTCP for demonstration now

Planning to conduct laboratory validation phase this year

Rigorous field demonstration with a fire truck next year

Looking for other treatability or demonstration opportunities

Find more insights:
www.cdmsmith.com/pfas

Questions?

Kent Sorenson, PhD, PE
Environment Strategy Leader
303-383-2430
sorensonks@cdmsmith.com

CDM Smith