AECOM

Mitigating PFAS Transport within Water Reclamation Facilities

NEW ENGLAND WATER ENVIRONMENT ASSOCIATION
NEWEA
WORKING FOR WATER QUALITY

1/23/24

Christopher Curran, PE

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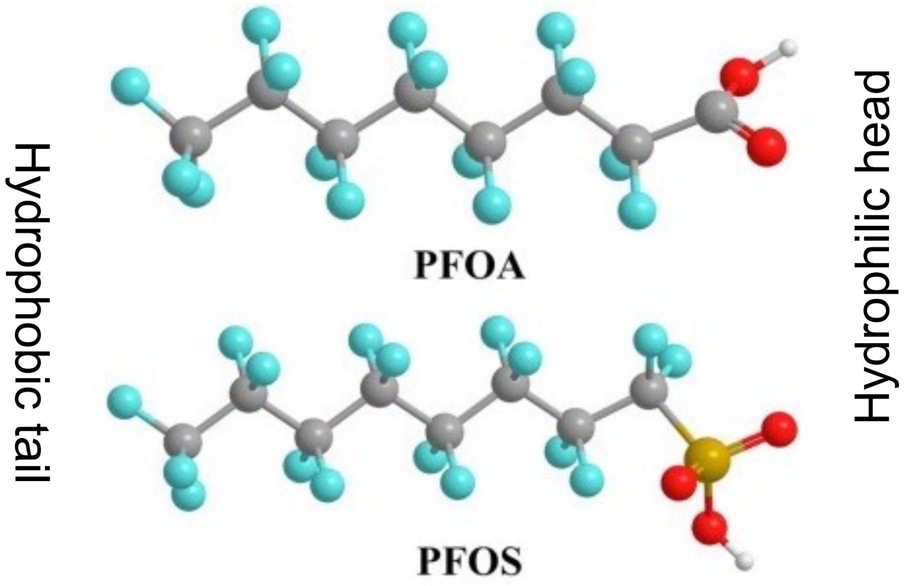
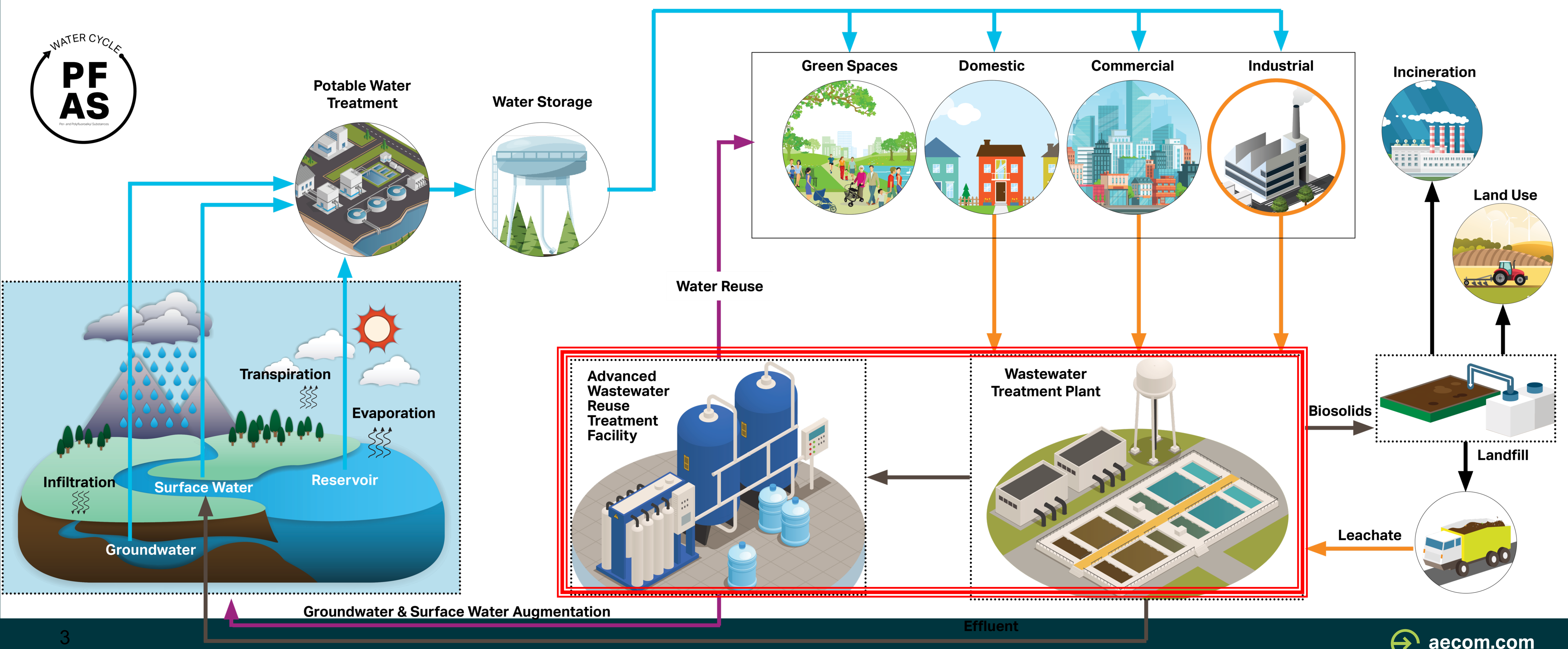
Agenda

- Regulatory drivers
- PFAS in WRF Effluent: Michigan and other study findings
- PFAS in Potable Reuse
- Carbon-Based Reuse PFAS Treatment Approaches
- Emerging PFAS Destruction Approaches

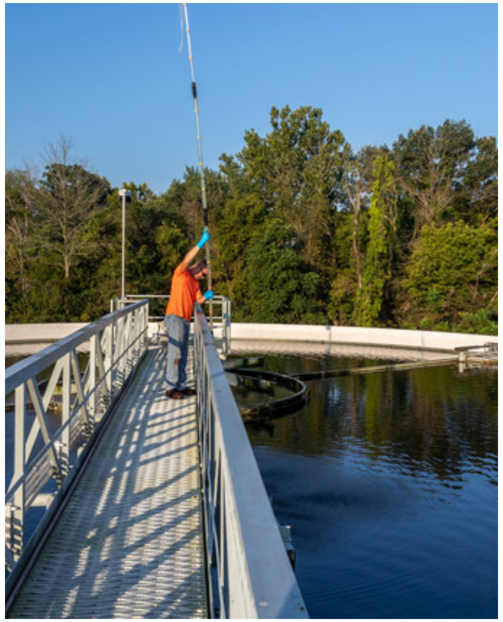


PFAS in the One-Water Cycle – Wastewater Treatment Plants



Regulatory Drivers

Regulatory Drivers



Drinking Water Systems – Draft MCLs and UCMR5 Data Summary

Reuse Systems – subject to State MCLs and Forthcoming EPA MCLs

Implications of ***National Pollution Discharge Elimination Permit (NPDES)***

New guidance Dec 2022 to state permitters

Hazardous Waste Designation

USEPA intends to:

- Add PFOA, PFOS, PFBS, and GenX as RCRA hazardous constituents under 40 CFR Part 261 Appendix VIII
- First step toward formal rulemaking to regulate as listed hazardous wastes
- Subject to RCRA corrective action requirements at hazardous waste treatment, storage, and disposal facilities

USEPA elected NOT to list PFAS as a class as a Subtitle C hazardous waste

RCRA hazardous wastes are automatically hazardous substances under the CERCLA

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PFAS in WRF Effluent

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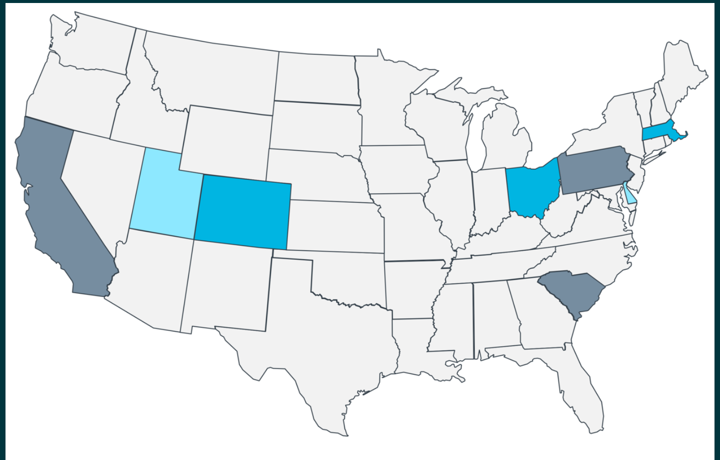
PFAS in Wastewater - Michigan, AECOM, and California Studies

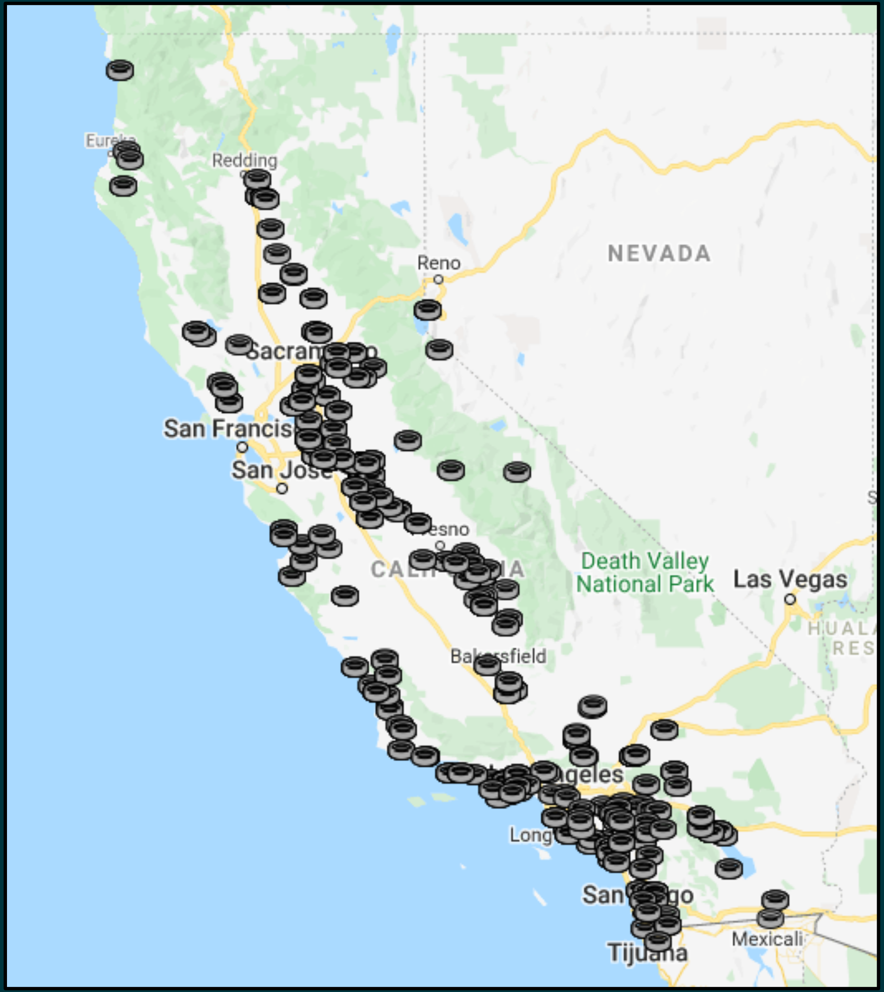
- **AECOM Study – 2021**
  - 19 WWTPs
- **California Study – 2021 (Q1,Q2, and Q3)**
  - 180 WWTPs
  - 1 MGD dry weather design
- **Michigan Study - 2018**
  - 42 WWTP
  - 20 largest (10-930 MGD)
  - 22 various treatment processes (0.2-9 MGD)



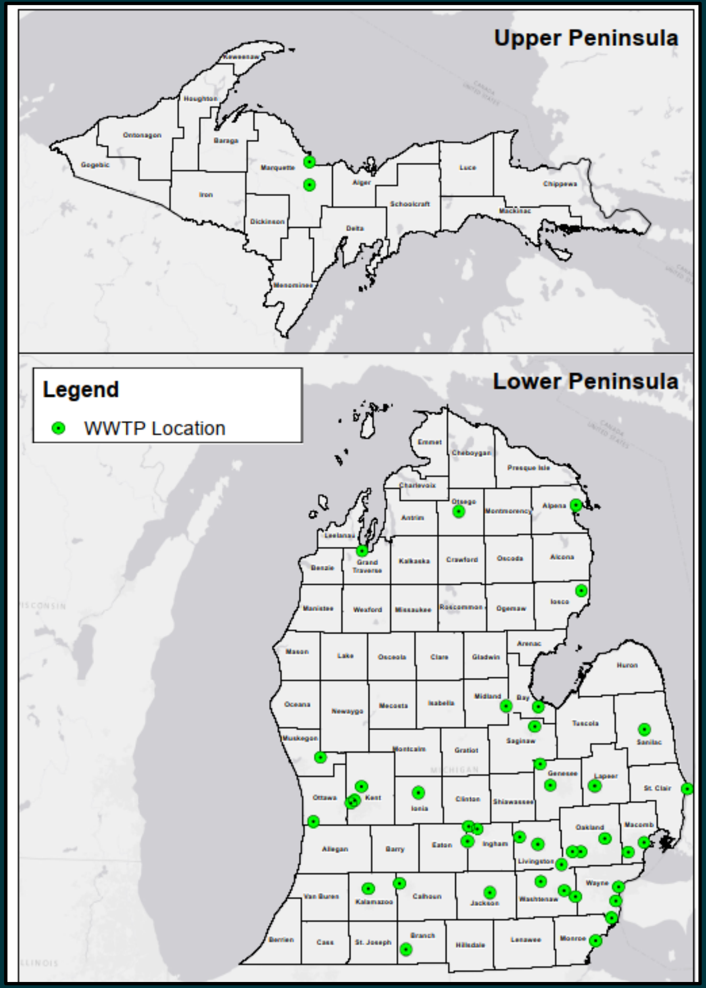
Number of Participants (19 total in 8 states)

1 participant | 2 participants | 3+ participants

California WWTPs



Michigan WWTPs



https://www.michigan.gov/documents/egle/wrd-pfas-initiatives-statewide-full-report_722902_7.pdf

https://www.waterboards.ca.gov/pfas/

AECOM PFAS Analytes

Large group of compounds (>9,000)

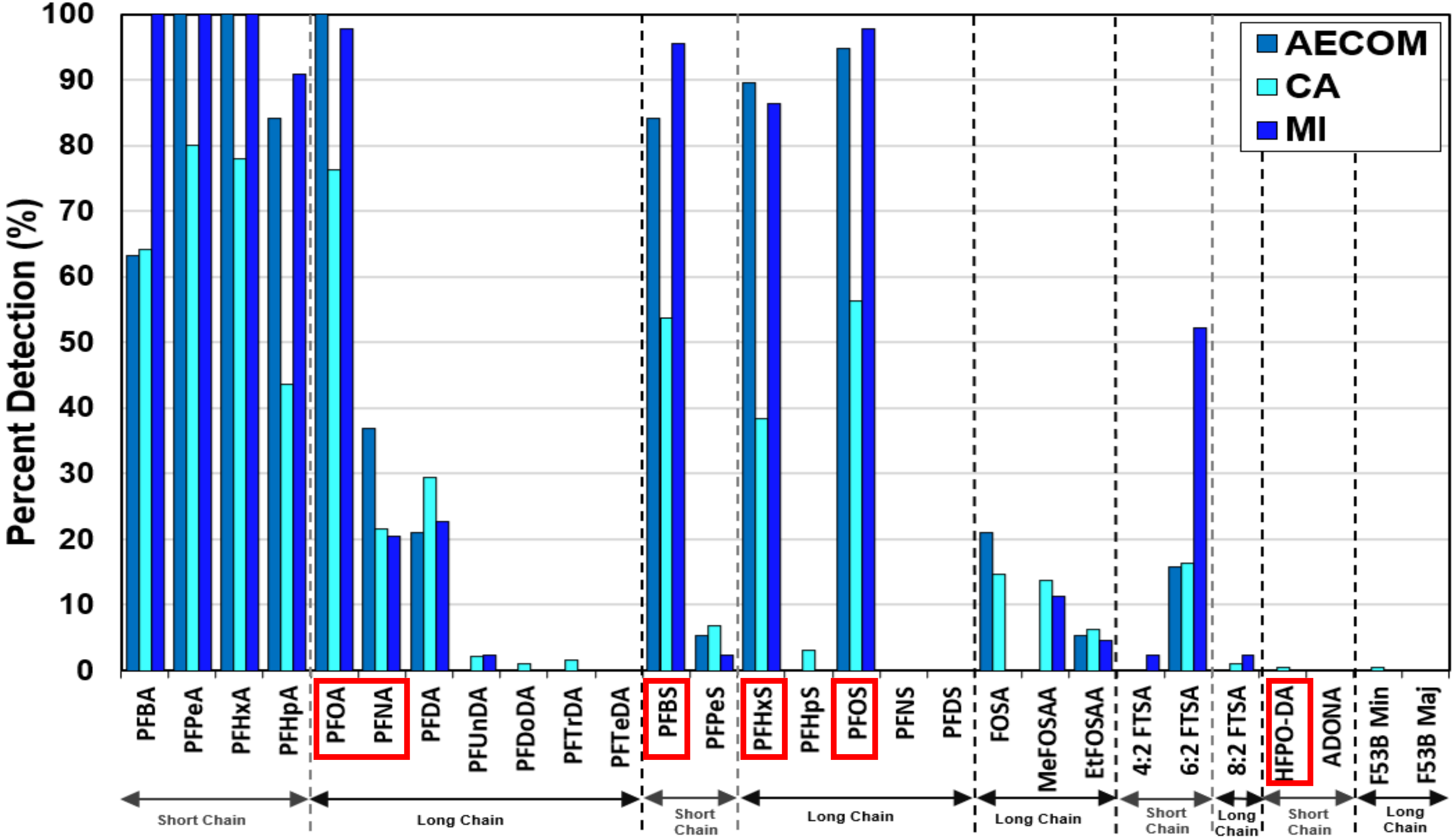
28 PFAS Analyte List

- 18 PFAS/2 Families – Do not degrade
- 3 PFAS / 3 Families – PFOS Precursors
- 3 PFAS / 1 Family – PFCAs Family Precursors
- 4 PFAS / 3 Families – Replacement Chemistry

PFAS Analyte List

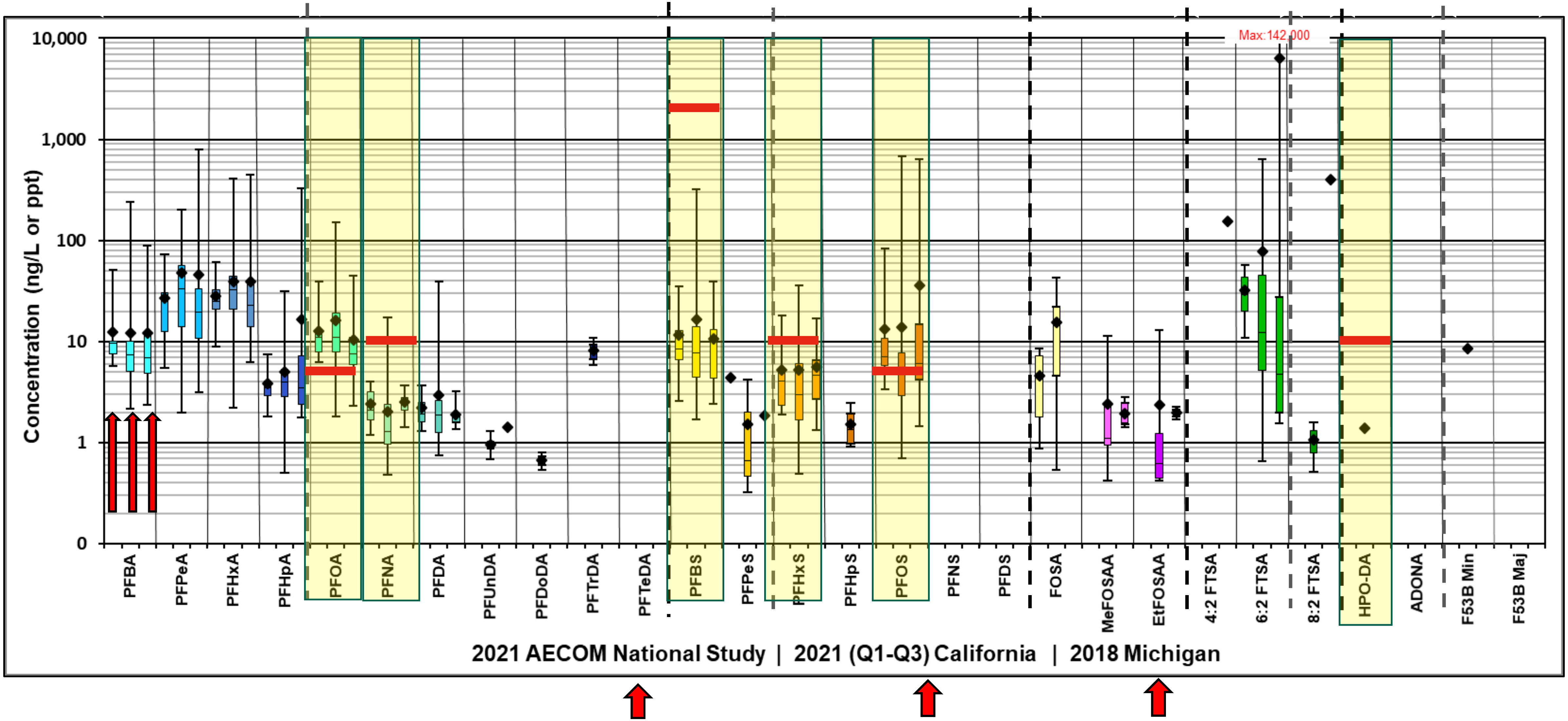
#	PFAS Name	Acronym	CAS #	(Carbon #) Chain Length
Perfluoroalkyl carboxylic acids (PFCAs)				
1	Perfluorobutanoic Acid	PFBA	375-22-4	(4) Short-chain
2	Perfluoropentanoic Acid	PFPeA	2706-90-3	(5) Short-chain
3	Perfluorohexanoic Acid	PFHxA	307-24-4	(6) Short-chain
4	Perfluoroheptanoic Acid	PFHpA	375-85-9	(7) Short-chain
5	Perfluorooctanoic Acid	PFOA	335-67-1	(8) Long-chain
6	Perfluorononanoic Acid	PFNA	375-95-1	(9) Long-chain
7	Perfluorodecanoic Acid	PFDA	335-76-2	(10) Long-chain
8	Perfluoroundecanoic Acid	PFUnDA	2058-94-8	(11) Long-chain
9	Perfluorododecanoic Acid	PFDoDA	307-55-1	(12) Long-chain
10	Perfluorotridecanoic Acid	PFTrDA	72629-94-8	(13) Long-chain
11	Perfluorotetradecanoic Acid	PFTeDA	376-06-7	(14) Long-chain
Perfluoroalkane sulfonic acids (PFSAs)				
12	Perfluorobutane Sulfonic acid	PFBS	375-73-5	(4) Short-chain
13	Perfluoropentanesulfonic acid	PFPeS	2706-91-4	(5) Short-chain
14	Perfluorohexane Sulfonic acid	PFHxS	355-46-4	(6) Long-chain
15	Perfluoroheptane Sulfonic acid	PFHpS	375-92-8	(7) Long-chain
16	Perfluorooctane Sulfonic acid	PFOS	1763-23-1	(8) Long-chain
17	Perfluorononanesulfonic acid	PFNS	68259-12-1	(9) Long-chain
18	Perfluorodecane Sulfonic acid	PFDS	335-77-3	(10) Long-chain
Precursors to PFOS				
19	Perfluorooctane sulfonamide[1]	FOSA	754-91-6	(8) Long-chain
20	N-methylperfluorooctanesulfonamidoacetic acid[2]	MeFOSAA	2355-31-9	(8) Long-chain
21	N-ethylperfluorooctanesulfonamidoacetic acid[3]	EtFOSAA	2991-50-6	(8) Long-chain
Precursors to PFCA Family				
22	4:2 Fluorotelomer Sulfonic Acid[4]	4:2 FTS	757124-72-4	(6) Short-chain
23	6:2 Fluorotelomer sulfonic acid[4]	6:2 FTSA	27619-97-2	(8) Long-chain
24	8:2 Fluorotelomer sulfonic acid[4]	8:2 FTSA	39108-34-4	(10) Long-chain
PFAS Replacement Chemistry				
25	Hexafluoropropylene Oxide Dimer Acid	HFPO-DA	13252-13-6	(6) Short-chain
26	4,8-Dioxa-3H-perfluorononanoic acid	ADONA	919005-14-4	(7) Short-chain
27	9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	F53B Minor	756426-58-1	(8) Long-chain
28	11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	F53B Major	763051-92-9	(10) Long-chain

PFAS Effluent Percent Detection - All 3 Studies



Effluent PFAS Concentrations – All 3 Studies

PFAS included in EPA Draft Rule and MCL



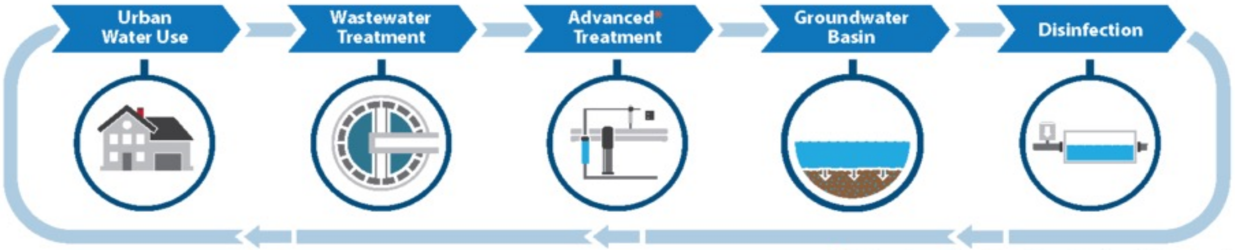
PFAS in Potable Reuse

Recycled Water Types and Terminologies

Municipal Water Reuse of Biological Secondary Effluent

- Non-Potable Reuse Filtration (GMF or MF/UF) and Disinfection (UV or Chlorine)
  - Landscape Irrigation, Environmental Restoration, & Industrial Uses
- Purified Recycled Water for Drinking including GMF, MF/UF, Ozone-BAC, RO, GAC, UV AOP and Others
  - Indirect Potable Reuse (IPR):
    - Groundwater Augmentation
    - Reservoir Augmentation
  - Direct Potable Reuse (DPR):
    - Raw Water Augmentation
    - Treated Drinking Water Augmentation

1. Groundwater Augmentation

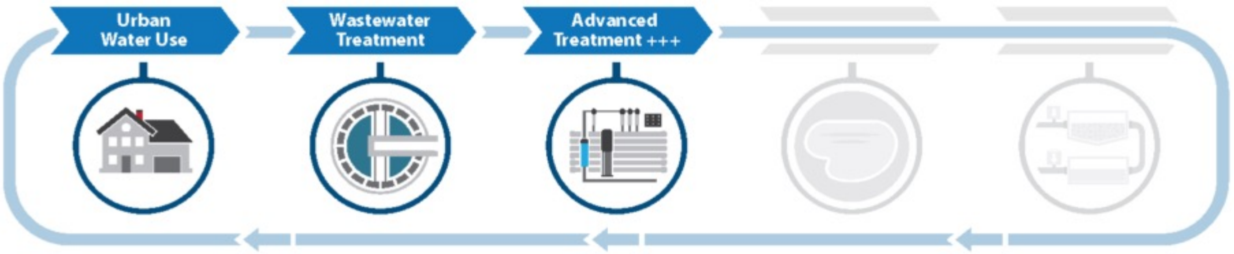


*Includes advanced treatment through soil aquifer treatment

2. Reservoir Water Augmentation

3. Raw Water Augmentation

4. Treated Drinking Water Augmentation



PFAS - Key One Water Planning Drivers

Wastewater effluent containing PFAS being discharged to a river

- Potential for PFAS regulation under permitting

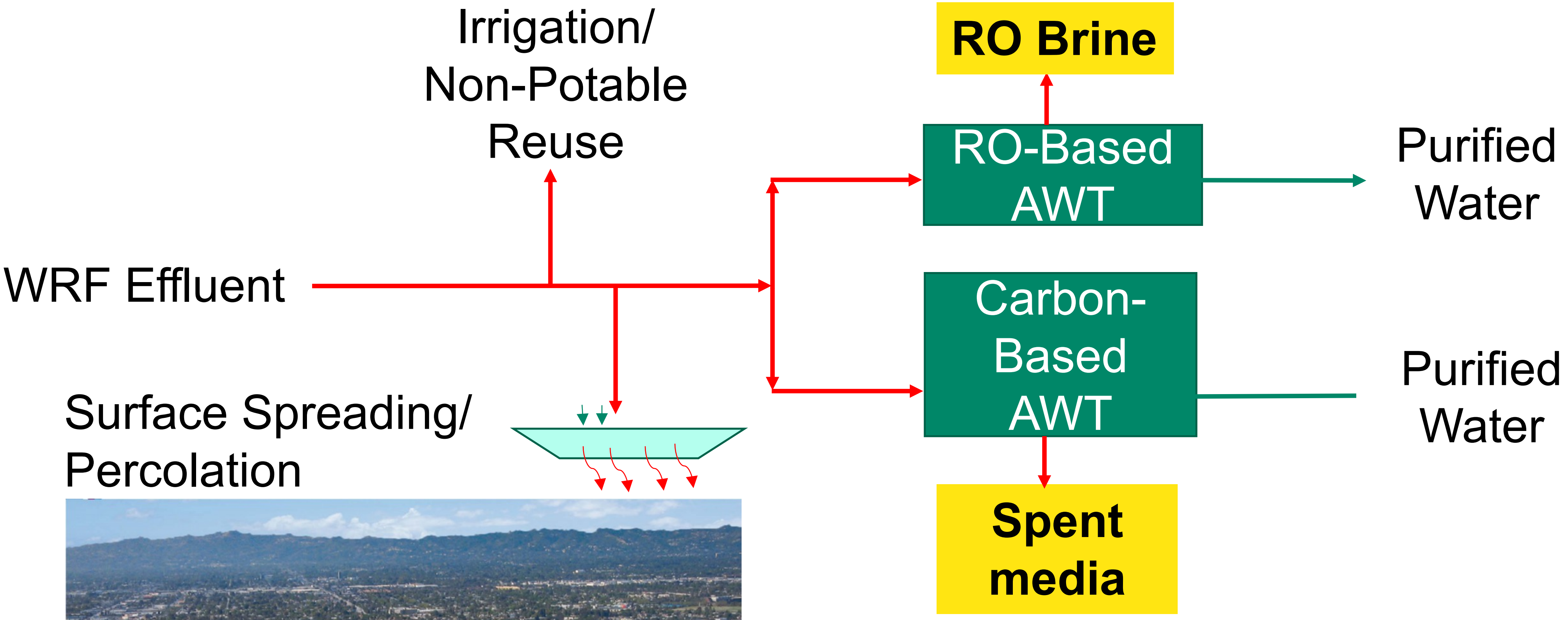
River influenced with PFAS is used as source water for drinking water

- Impending USEPA rule making for PFAS in drinking water

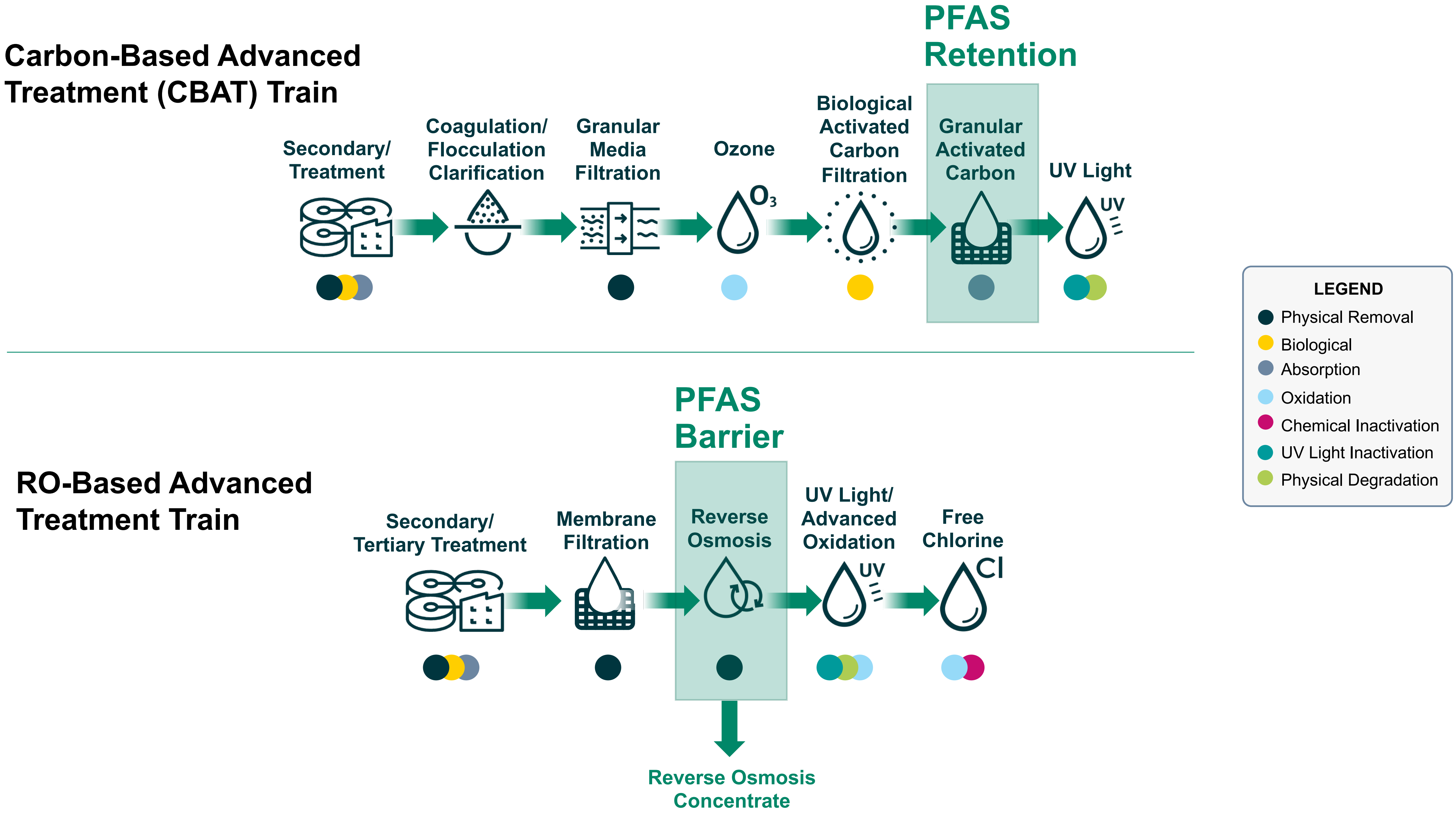
Potable reuse

- Potential solution to treat PFAS at water plant

PFAS Impact on Water Reuse

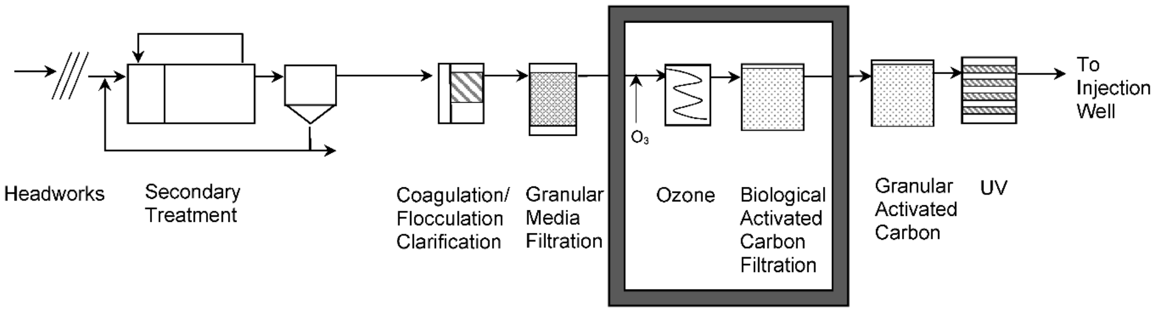


Potential PFAS
in Groundwater


Carbon-Based Advanced Treatment (CBAT) Train
PFAS Retention
Secondary/ Treatment
Coagulation/ Flocculation Clarification
Granular Media Filtration
Ozone
O_3
Biological Activated Carbon Filtration
Granular Activated Carbon
UV Light
UV
RO-Based Advanced Treatment Train
PFAS Barrier
Secondary/ Tertiary Treatment
Membrane Filtration
Reverse Osmosis
UV Light/ Advanced Oxidation
UV
Free Chlorine
Cl
Reverse Osmosis Concentrate
LEGEND
Physical Removal
Biological
Absorption
Oxidation
Chemical Inactivation
UV Light Inactivation
Physical Degradation

PFAS Impact on Water Reuse – Carbon-based AWT

OneWater Nevada South Truckee Meadows WRF Pilot Testing



xylem Let's Solve Water

OneWater Nevada
Our Sustainable Water Future

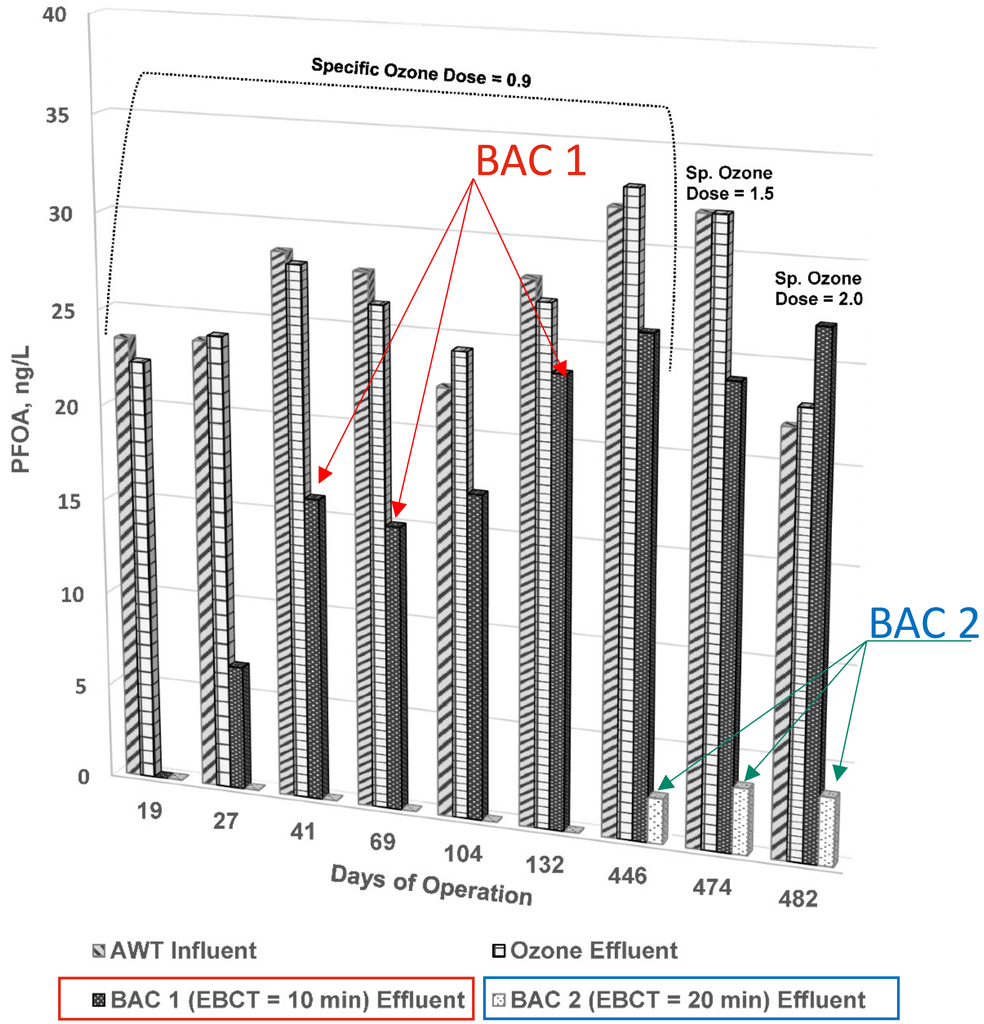
University of Nevada, Reno

PFAS Impact on Water Reuse – Ozone-BAC Process

– Lower removal PFOA removal capacity in BAC relative to clean water GAC applications attributed to:
  - Very high levels of competitive adsorbates
  - Higher surface loading and particulate blinding
  - Pore plugging due to biological growth

– PFOA Removal in BAC: Longer contact time improved performance (10 vs 20 min)
  - Allows longer term carbon-based (primary) removal mechanisms
  - Lighter loaded BAC 2 contained lower biomass density and demonstrated higher PFOA removal capacity than heavily loaded BAC with shorter EBCT (BAC 1).

– **A PFAS removal step is recommended**



Source: Sundaram,V., Pagilla, K., Guarin, T., Lin, L., Marfil-Vega, R., Bukhari, Z. (2020) Extended field investigations of ozone-biofiltration advanced water treatment for potable reuse, Water Research, Vol 172. https://doi.org/10.1016/j.watres.2020.115513

Maximizing PFAS and TOC Removals in Carbon-Based Treatment

- With impending PFAS MCL, **use of single step GAC for TOC and PFAS removal may limit operational flexibility**
- GAC for TOC and a specific treatment approach for PFAS may help with maximizing performance and ease of operation

PFAS Treatment for Water Reclamation / Reuse Applications

Need a Media that is Selective for PFAS and not TOC

Existing sorbent technologies

- Subject to fouling
- Short life span
- Space intensive
- Non-selective

Novel sorbents

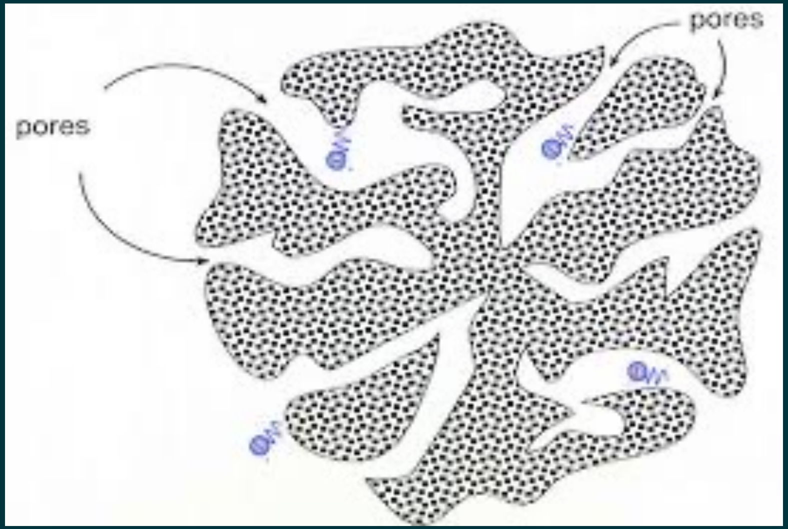
- ✓ PFAS selectivity and rapid kinetics
- ✓ Benefit – Working with organics present
- ✓ Fouling resistance / Oxidant Tolerant
- ✓ Media regeneration opportunities

Novel Sorbents in Development

MINERALS TECHNOLOGIES CETCO

Background – Novel Adsorbents

- Novel adsorbents is a broad category for different selective media
- Characterized by high capacity, highly selective, and rapid kinetics
- Size exclusion of other organic foulants
- Available in both powder and granular forms



GAC Adsorption Mechanism

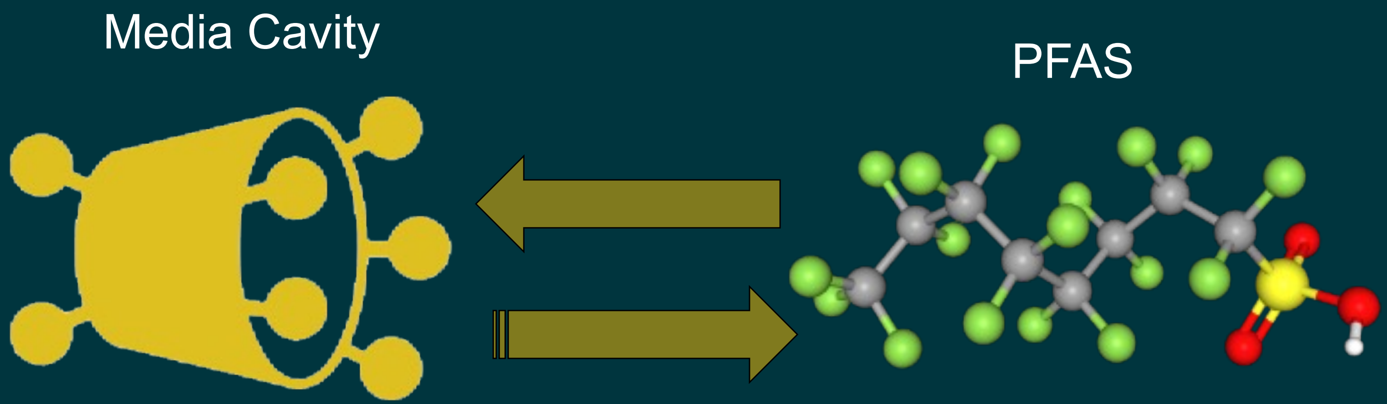
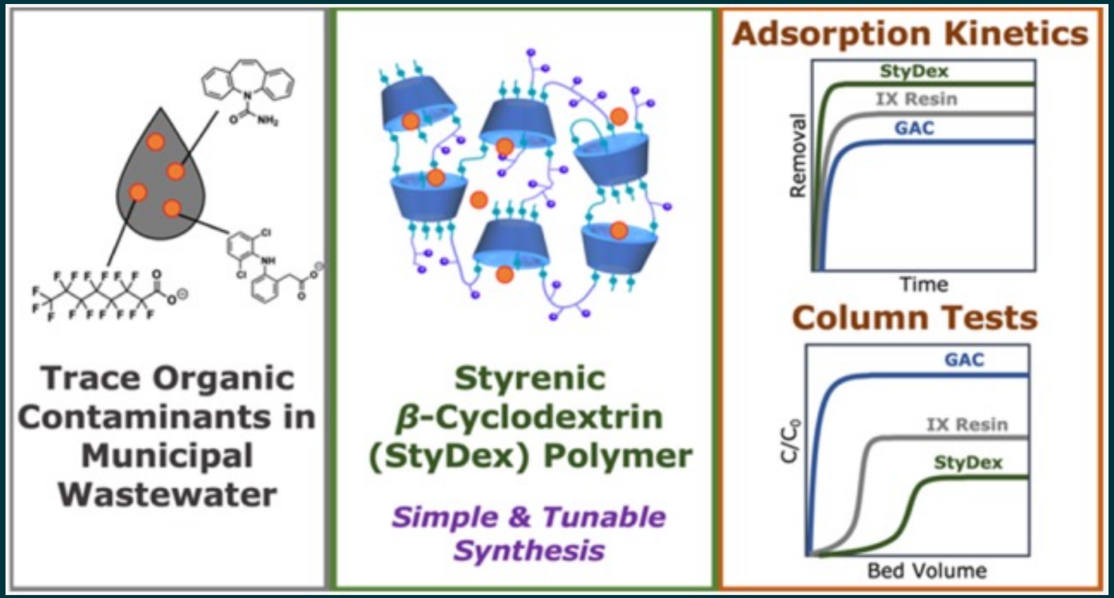
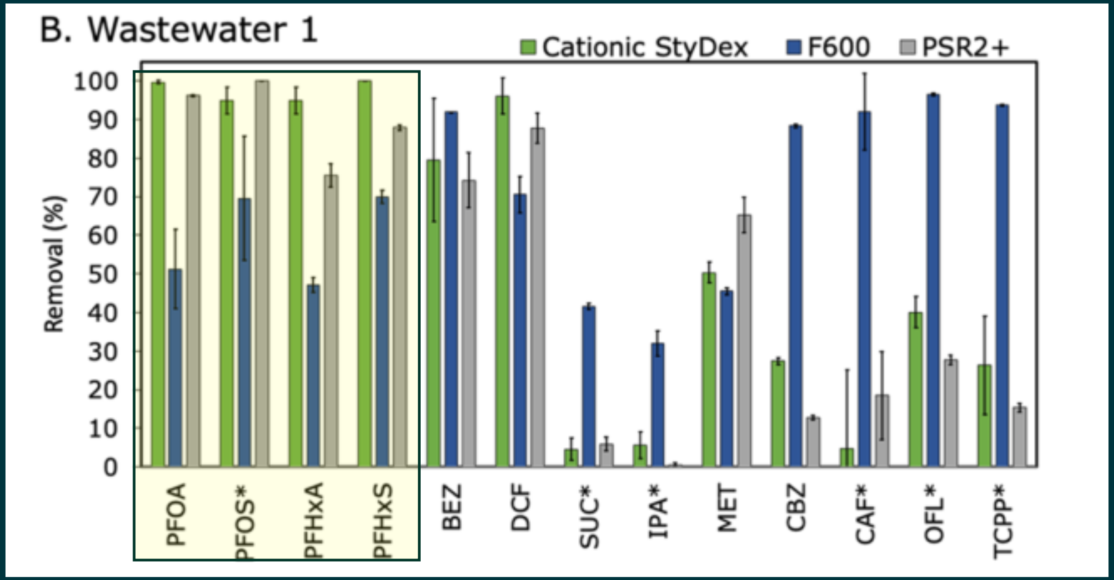


*Figure provided by Cyclopure

Novel Adsorbent Benefits

- Less adsorption inhibition than GAC in wastewater.
- Exhibits faster adsorption kinetics than GAC and ion exchange (IX) resin
- Higher adsorption affinity for PFAS than GAC
- Rapid small-scale column tests show that the polymer exhibits later breakthrough times compared to GAC and IX resin.
- Regenerable by solvent wash without significant decrease in removal performance





*Trace Organic Contaminant Removal from Municipal Wastewater by Styrenic β-Cyclodextrin Polymers (2023), https://doi.org/10.1021/acs.est.3c04233
Zhi-Wei Lin, Emma F. Shapiro, Francisco J. Barajas-Rodriguez,et al

One Water Nevada – Integrating PFAS Treatment into Reuse

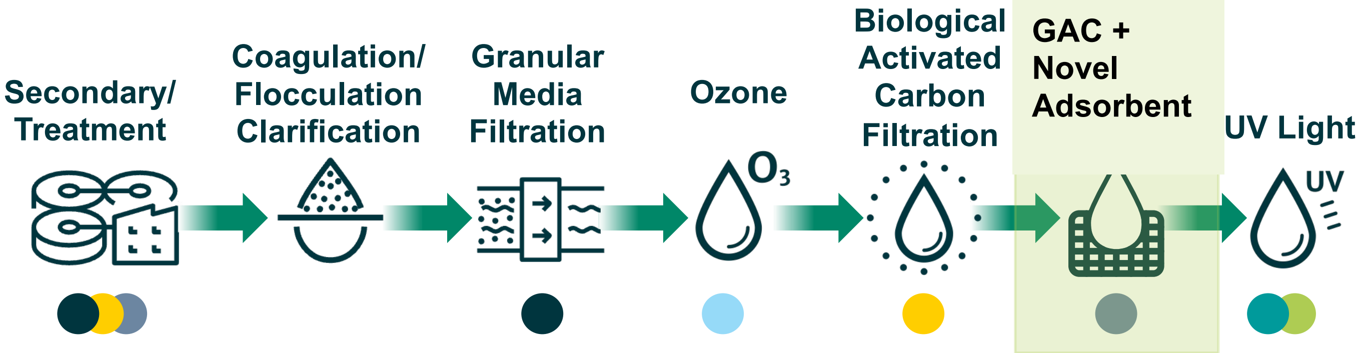
Advanced Purified Water - Indirect Potable Reuse

- One Water Considerations – NPDWR Draft MCLs
- Balancing TOC & PFAS Treatment Considerations
- Use of PFAS Selective Adsorbents
  - Modified bentonite based
  - Cyclodextrin based
  - Others in development

Carbon-Based Advanced Treatment (CBAT) Train

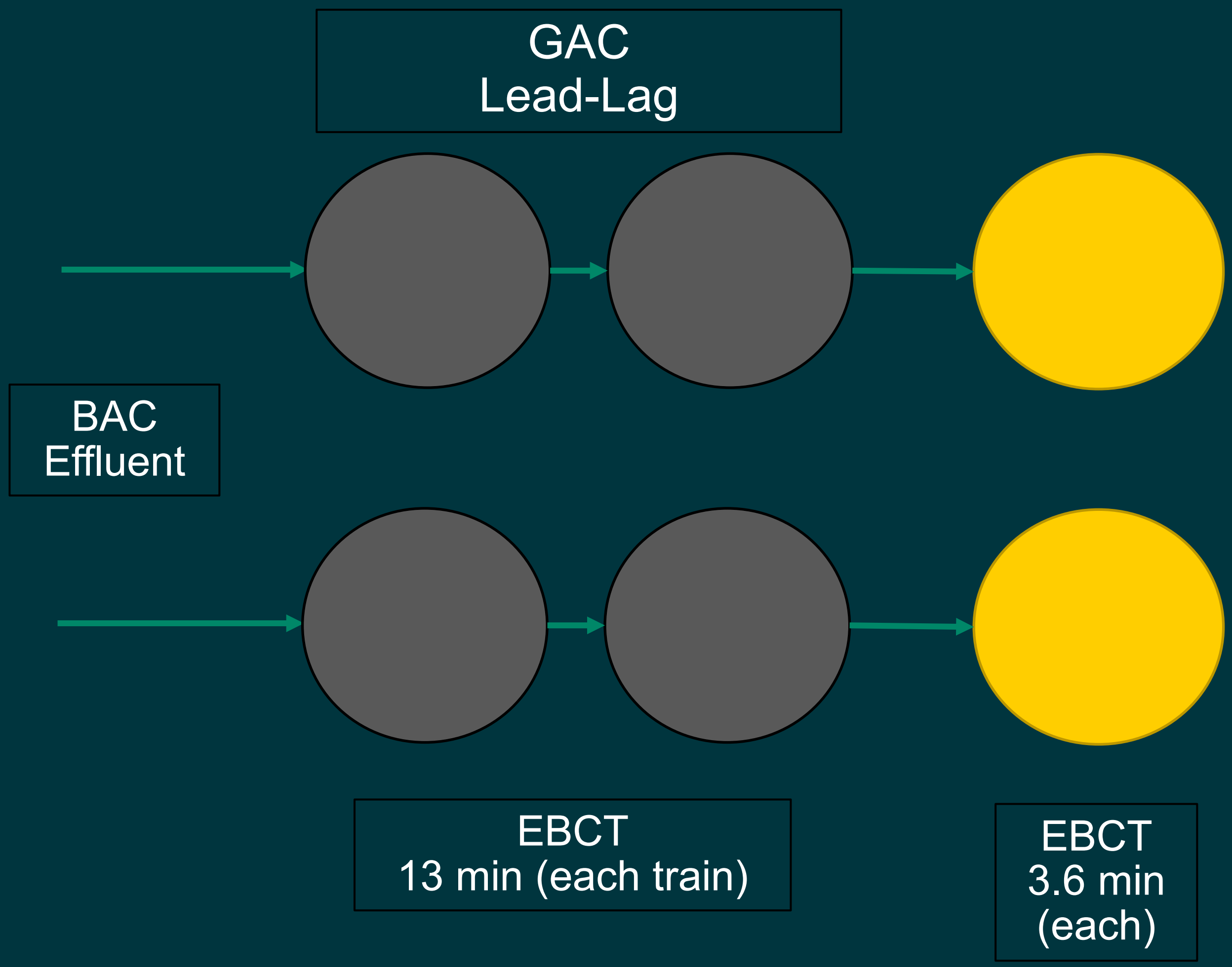
LEGEND

- Physical Removal
- Biological
- Absorption
- Oxidation
- Chemical Inactivation
- UV Light Inactivation
- Physical Degradation

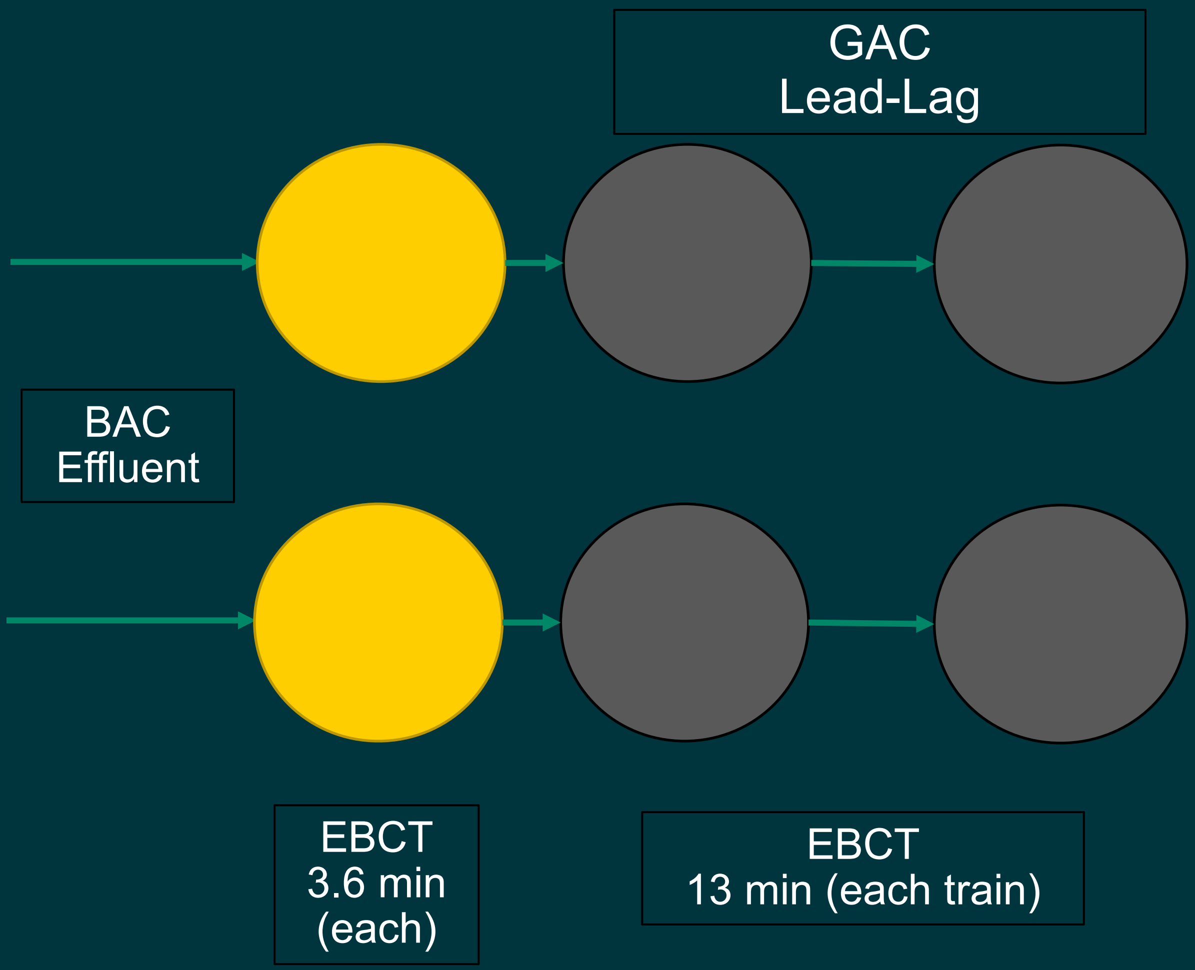


Operation Modes: GAC / Novel Adsorbent Configurations

GAC followed by Novel Adsorbent Vessels

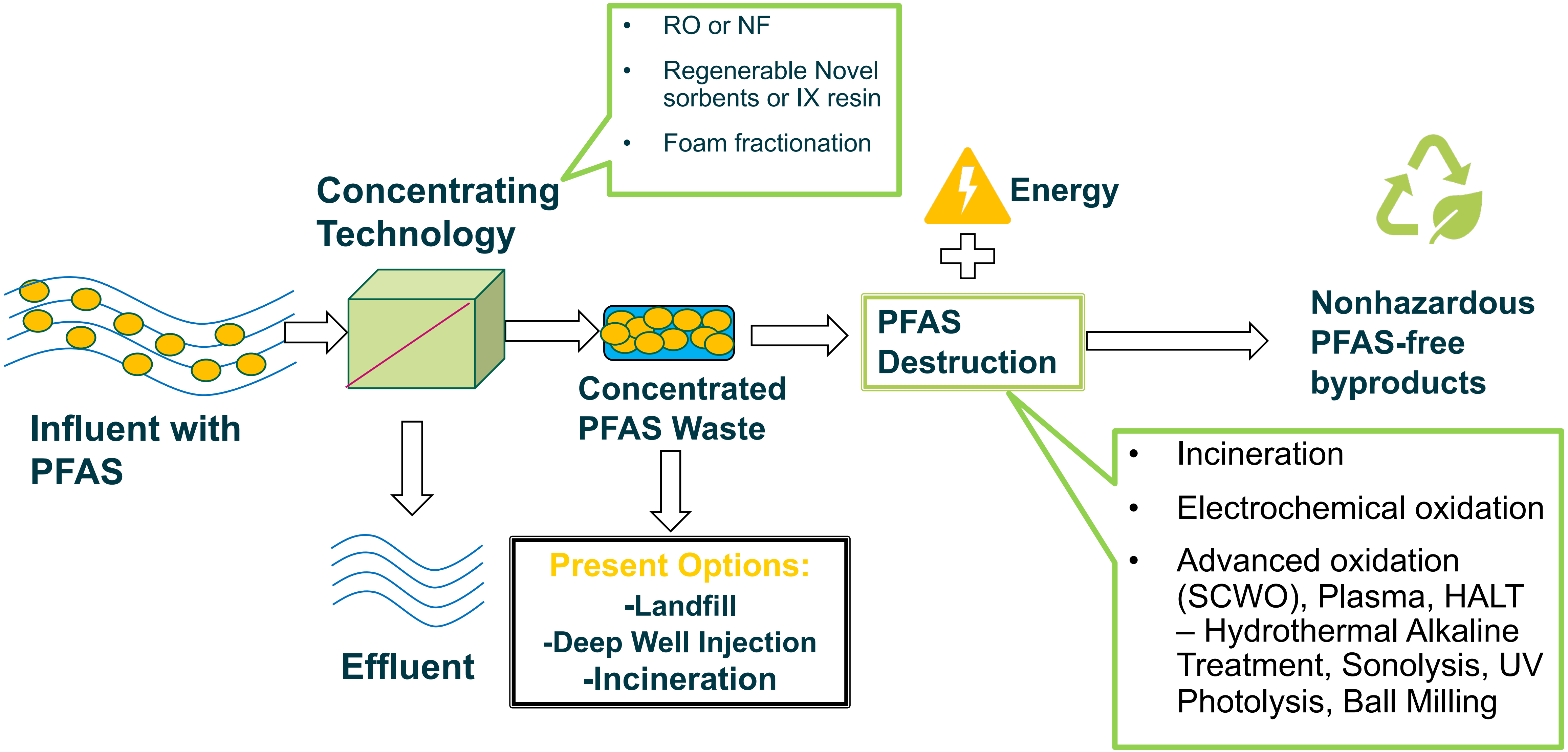


Novel Adsorbent Vessel followed by GAC

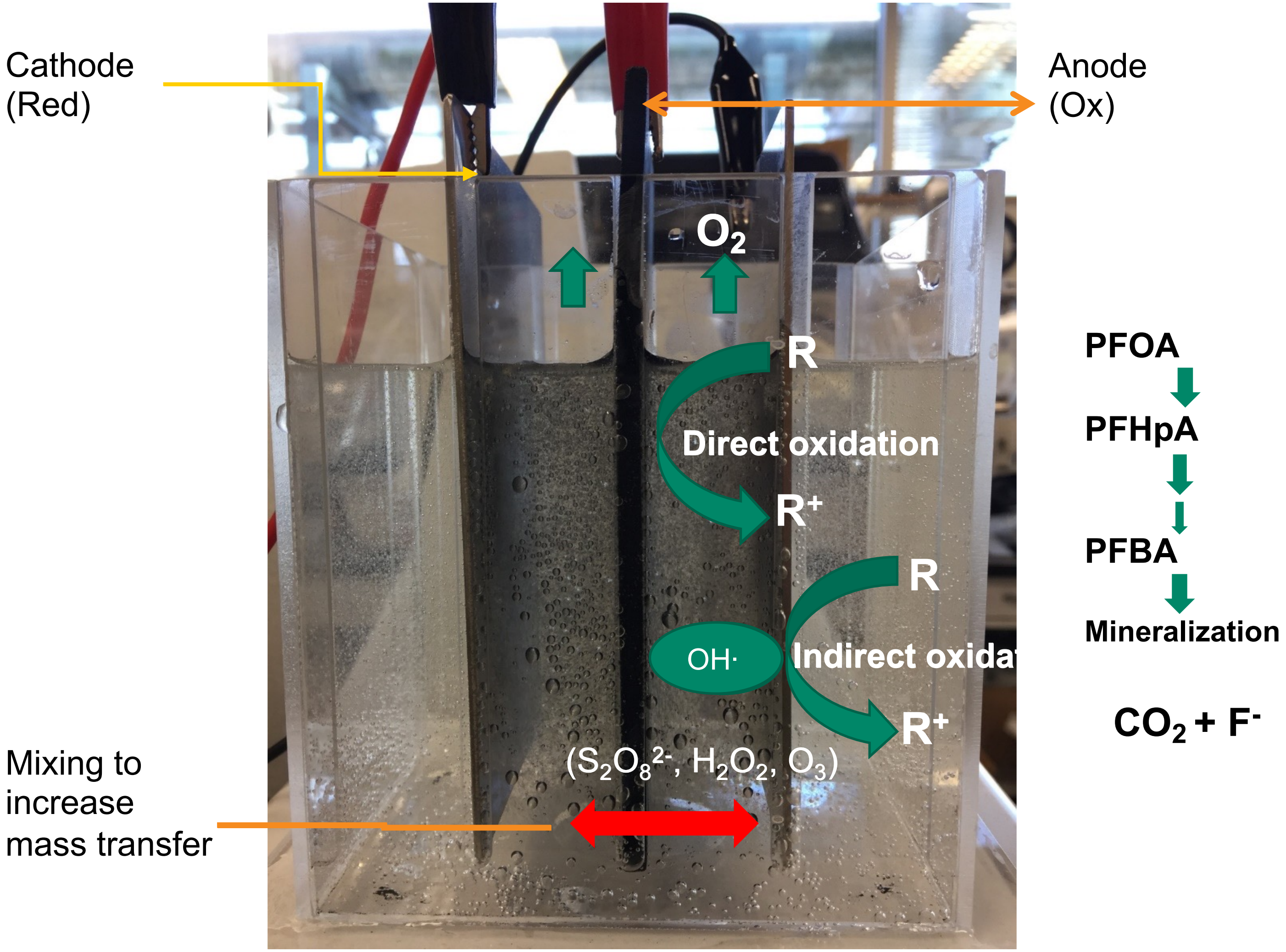


Emerging PFAS Destruction Considerations

Treatment Approach – Add Destruction for PFAS-free Solution



Emerging Technologies: Electrochemical Oxidation



Anodic oxidation

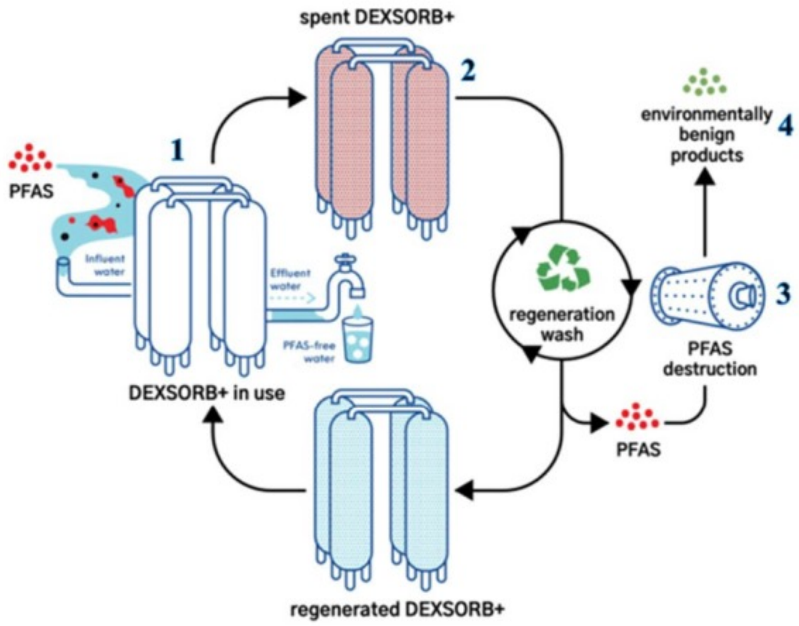
- **Direct electrolysis (at the electrode)**
- **Indirect electrolysis (in bulk liquid)**
- **Various electrode materials**
  - Boron-doped diamond
  - Lead dioxide
  - Titanium oxide and titanium suboxide
  - Tin oxide

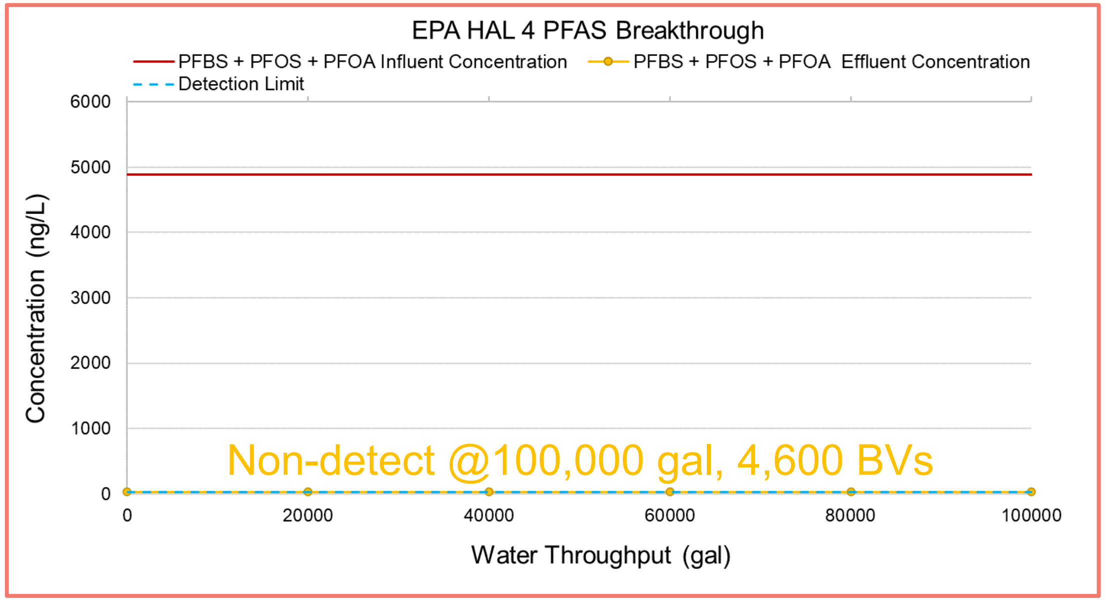
EO performance has been proven from bench-scale to field demonstration.

Emerging Approaches in Development: Novel Adsorbents + DE-FLUORO™ PFAS DESTRUCTION TECHNOLOGY

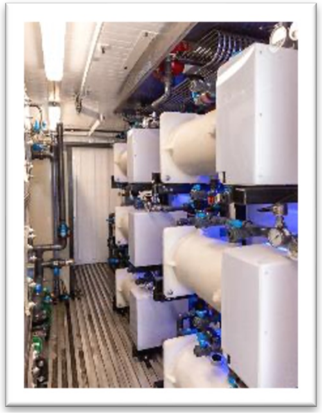
Novel PFAS adsorbents Regeneration Field Pilot Demonstration (on-going)

- EBCT: 5 + 5 minutes (Lead-Lag configuration)
- Average Flow Rate: 2.5 gpm
- TOC > 7.0 mg/L
- Total PFAS Level = 16,287 ng/L





DE-FLU•RO™ Available Systems



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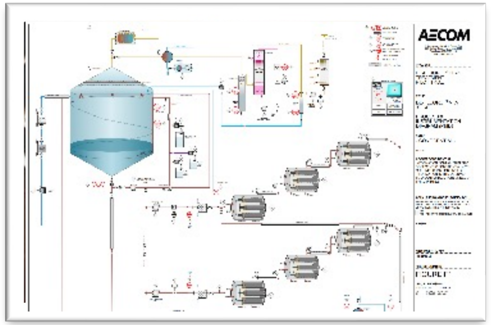
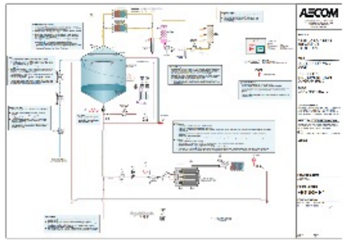


BLUE FIN

BARRACUDA

PIKE

PENGUIN



DE-FLU•RO
PFAS DESTRUCTION TECHNOLOGY
MANTA

Take Away Points

- EPA PFAS MCLs are imminent
- PFAS in WRF Effluent:
  - Short-chain PFAS: tendency to remain in liquid
- Carbon-based systems can be configured to maximize both PFAS and TOC removals
  - PFAS-Selective Novel Adsorbents are key
- Developing destruction technologies are on the horizon for managing certain concentrate streams

Thank you.

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PFAS

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