Jacobs Challenging today. Reinventing tomorrow.

PFAS in Recycled Wastewater and RO Reject

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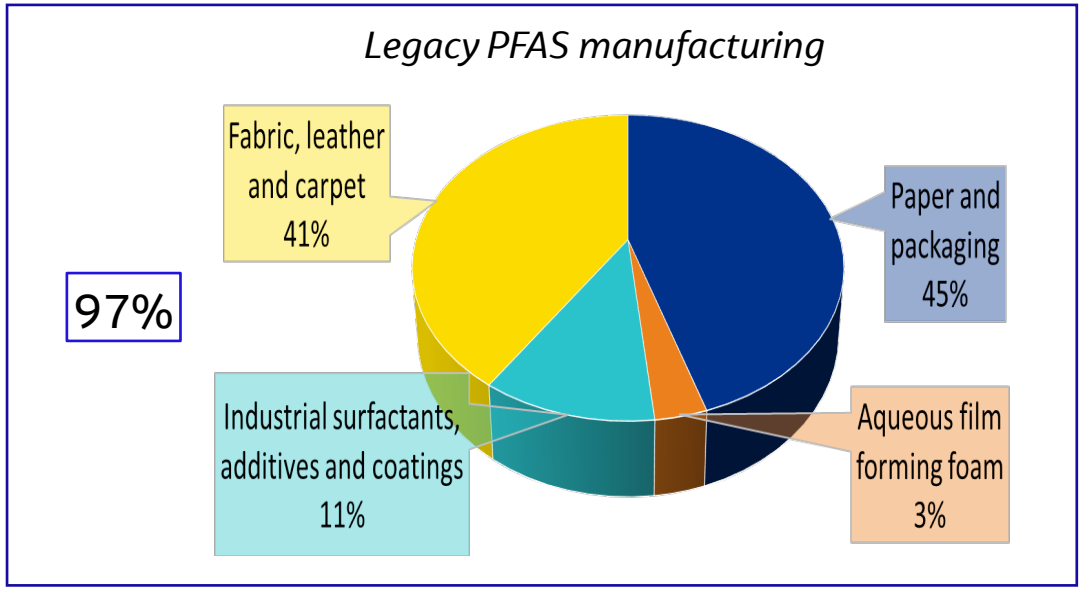
Global Technology Leader – Drinking Water & Reuse

WateReuse – Northern California Chapter Meeting
August 26, 2022

PFAS are used in a variety of everyday items



Recent EPA Updates

Health Advisory Values

What: Updated Health Advisory values for PFOA and PFOS (interim). New Health values for PFBS and GenX (final).

When: Released June 2022

Ambient WQ Criteria

What: EPA proposed aquatic life criteria for PFOA and PFOS.

Values for fresh and marine waters.

For protection of aquatic life, not food chain or human consumption. Additional criteria are expected.

When: Draft released April / May 2022

NPDES

What: Use authority on existing permits and issue guidance for new permits to require sampling, best management practices, pretreatment, and notification.

The memo details how the EPA will address PFAS discharges in EPA-issued NPDES permits.

It is likely that monitoring requirements will be triggered at a time after EPA's multi-lab validated methods are made available to the public.

When: Updated Memo April 2022

Drinking Water EPA Health Advisories

- Provides information on contaminants that can cause health effects which occur in drinking water
- **Non-enforceable and non-regulatory**
- **New HA's are not measurable**
- EPA Maximum Contaminant Level (MCLs) are anticipated in late 2022.
  - What are they likely to be?

PFAS	PREVIOUS EPA Health Advisory (ng/L)	EPA Health Advisory [June 2022] (ng/L)	EPA Minimum Reporting Level (MRL) (ng/L)	Analytical Detection Limit (ng/L)
PFOA	70 (provisional)	0.004 (interim)	4	0.2
PFOS	70 (provisional)	0.02 (interim)	4	0.2
PFBS	---	2,000 (final)	3	0.2
GenX	---	10 (final)	5	0.6

Drinking Water MCLs ?

- Measurable
- Cost-benefit justification
- Finalization
  - MCLG
  - Draft MCL
  - Final Ruling
  - 5 year compliance window

PFAS	EPA Health Advisory (ng/L)	California NL / RL (ng/L)	State Level Regulations
PFOA	0.004	5.1 / 10	3.3* (8) - 70
PFOS	0.020	6.5 / 40	3.3* (13) – 70
PFBS	2,000	500 / 5000	93 – 500
GenX	10	NA / NA	140 – 370
PFHxS	---	2 (prop) / NA	3.3* (18) – 93

EPA Draft Aquatic Life Ambient Water Quality Criteria (AWQC)

	Acute Water Column (ng/L)		Chronic Water Column (ng/L)	
PFAS	Fresh Water	Marine	Fresh Water	Marine
PFOA	49,000	7,000	94	Under Development
PFOS	3,000	550	8.4	Under Development

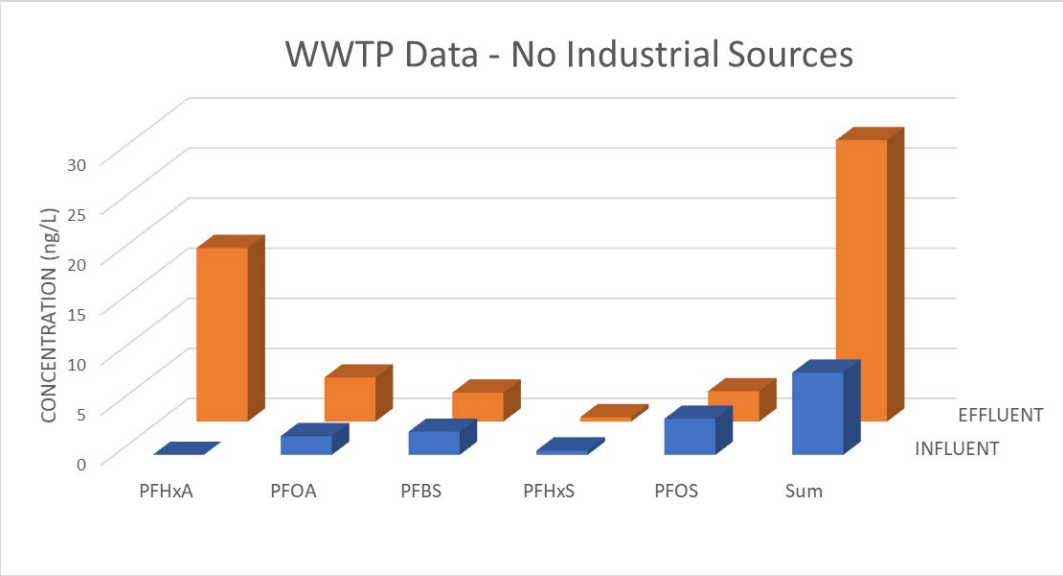
EPA - NPDES Updates for PFAS

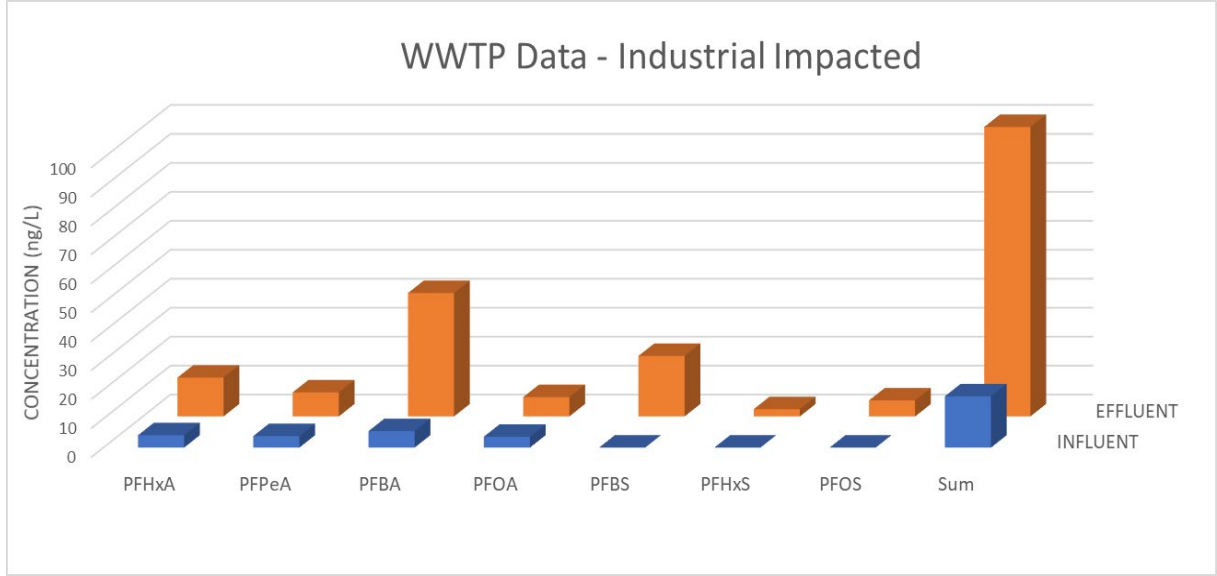
- Ultimately use NPDES to restrict PFAS discharges to water bodies
- Requirements to monitor for PFAS under new/updated NPDES permits
  - Includes increased focus / analysis / monitoring of biosolids
- Identify Sources to WWTP / Conduct Pollutant Minimization Plan (PMP)
  - Good examples MI / WI
- No numerical limits established
  - EPA will use data to inform Effluent Limitation Guidelines (ELG) actions

HAZARDOUS WASTE UPDATES

- EPA did not designate PFAS as a class of chemicals to be considered hazardous waste under **RCRA**
- EPA did outline plans to initiate rulemaking to designate PFOA, PFOS, PBS, and HFPO (GenX) as hazardous constituents under **RCRA**. This would classify these compounds as characteristically hazardous.
- EPA to list PFOA and PFOS under **CERCLA** – also known as the Superfund law. Concerns about the potential implications and liabilities for municipalities since they are passive receivers.

Example WW Eff With and Without Confirmed Industrial Contributions

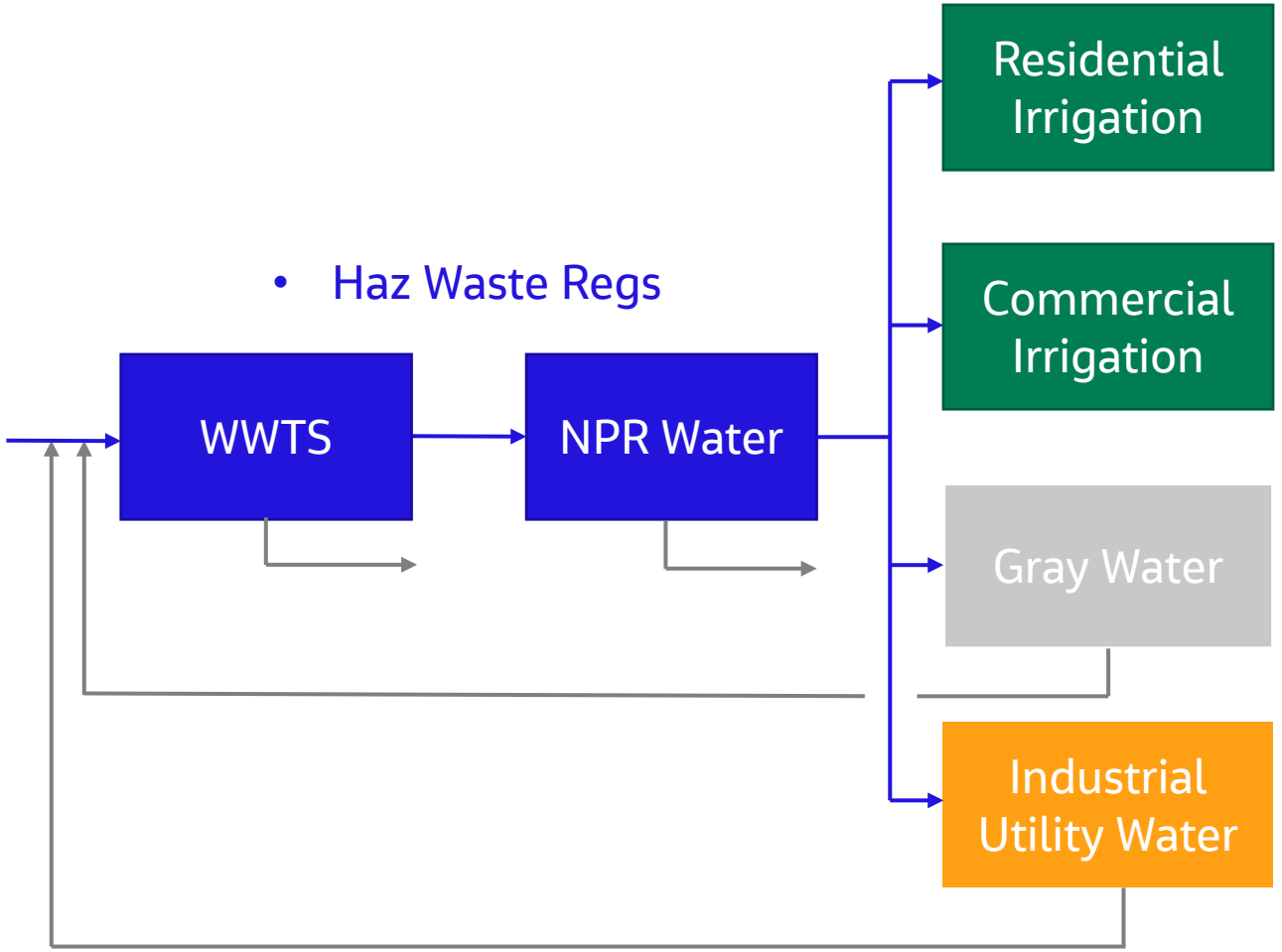




New studies show that significant precursors likely remain after biological treatment of wastewater

Data Source: Jacobs, 2020; SHVUA, 2018

NPR & PFAS: Potential Risks & Regulations: Conventional Technology



- Haz Waste Regs

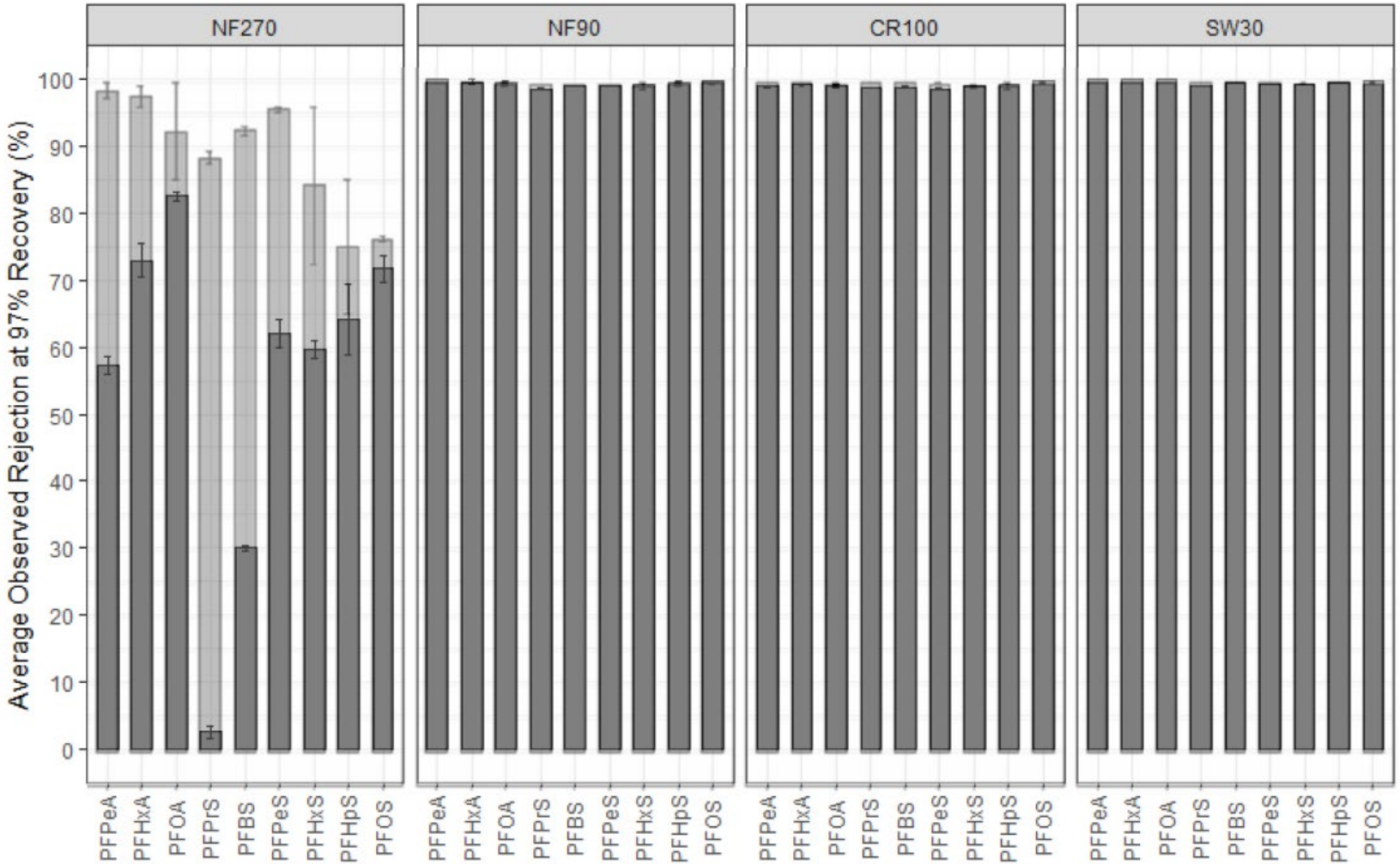
- Crop uptake

- Aquatic toxicity
- Migration to GW

- Cooling Tower (Mist and Drift)

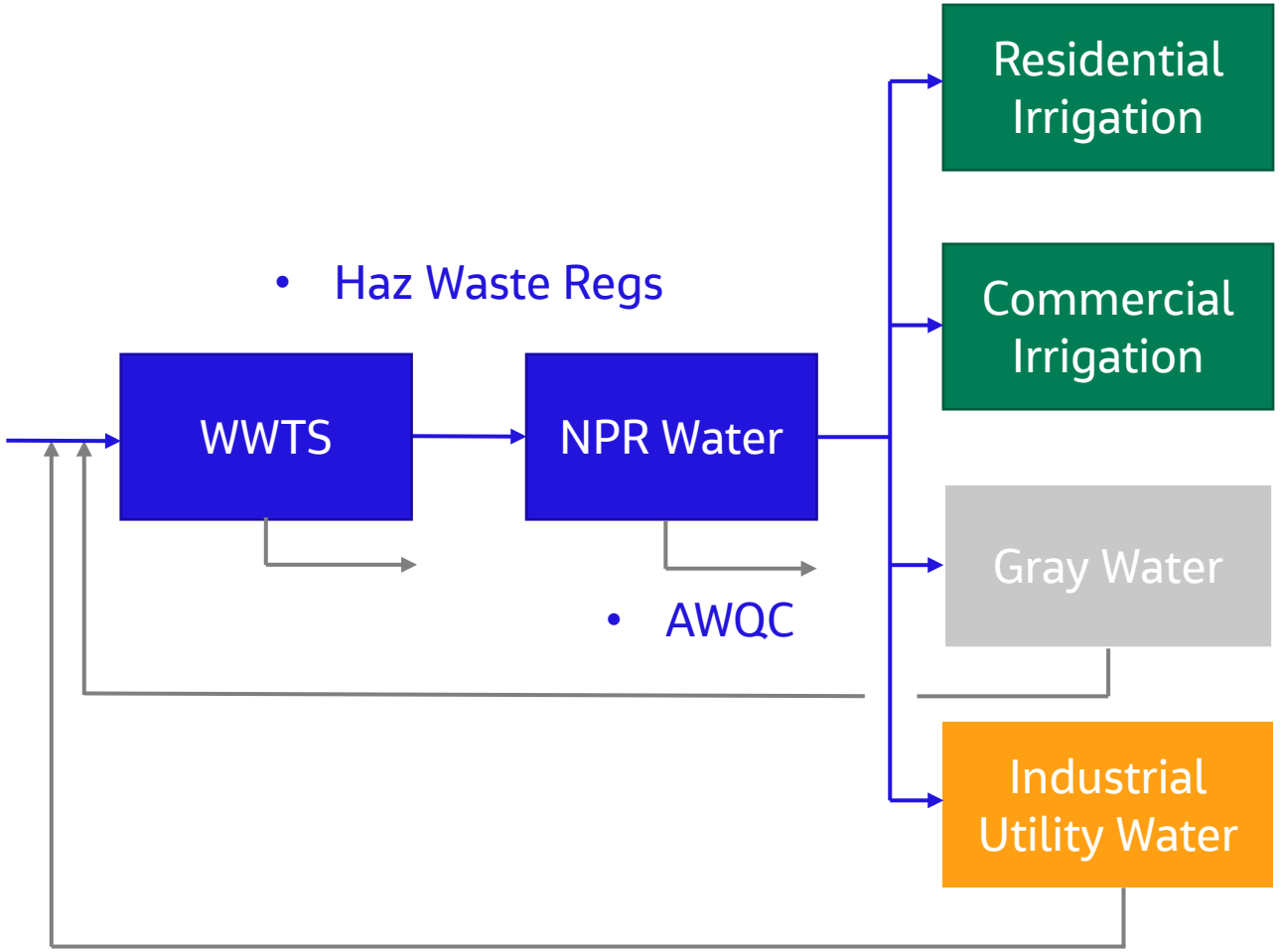
NF / RO Performance for Terminal PFAS

Light Gray – 75% recovery
Dark Gray – 97% recovery



Source: Closed-Circuit High-Pressure Membrane Systems for the Separation of Per and Polyfluoroalkyl Substances, Safulko, A. et. al., Membrane Technology Conf 2022.

NPR & PFAS: Potential Risks & Regulations: Advanced Technology (RO)



- Crop uptake
- Aquatic toxicity
- Migration to GW
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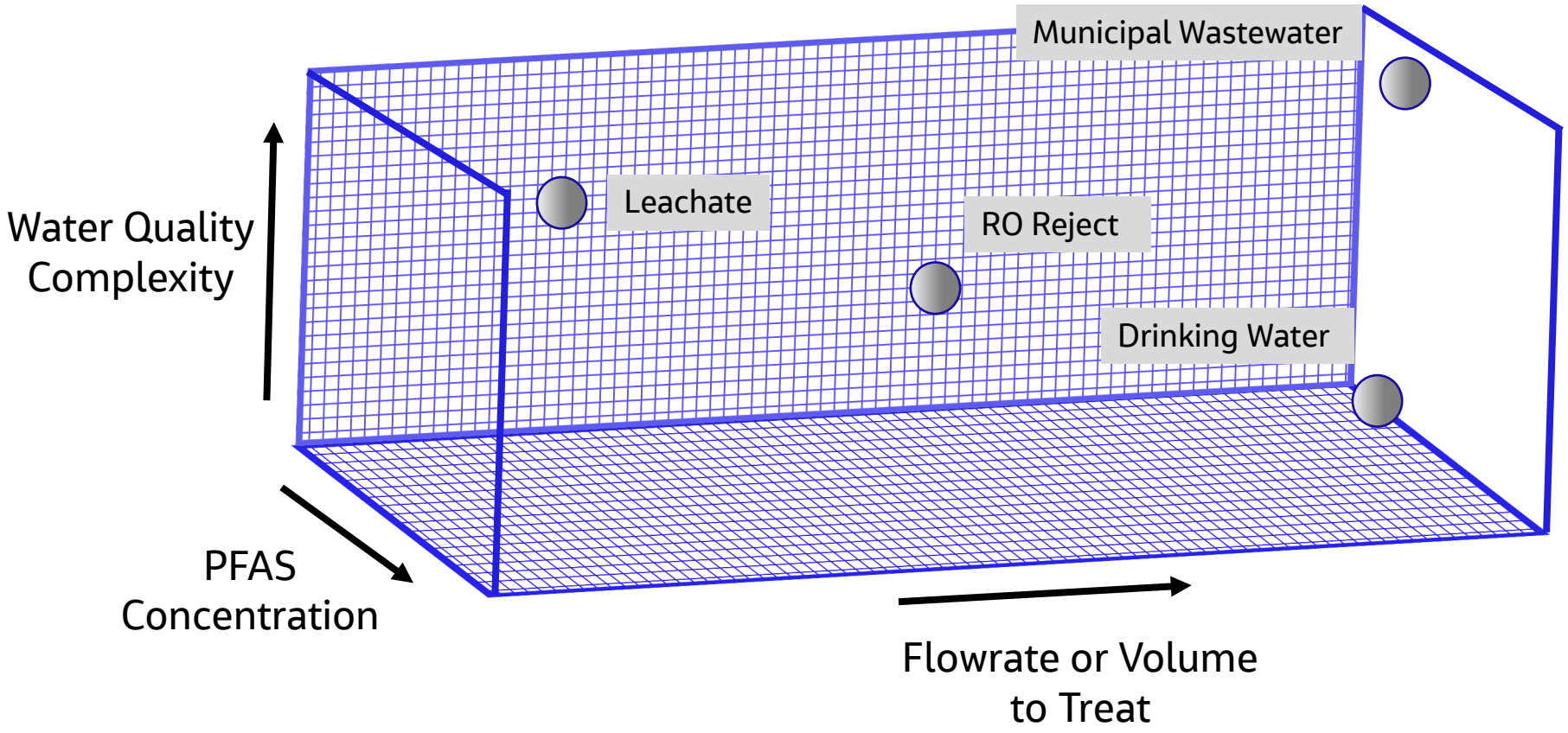
PFAS, Flowrate, and Water Complexity



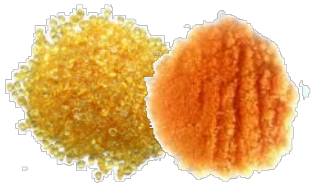
PFAS Technologies

Category	Transfer	Destructive
Effective & Practiced	- GAC / PAC - Ion Exchange - Reverse Osmosis (RO)	- Incineration
Maturing & Demonstrated	- Foam Fractionation - Specialty Adsorbents - Electrocoagulation	- Supercritical H_2O Oxidation
Developing	- Regenerable adsorbents	- Electro-oxidation - Non-thermal plasma - Advanced Red/Ox

Adsorbents for PFAS Removal

- Activated carbon
- Ion Exchange
- CETCO Fluoro-Sorb

Granular Activated Carbon (GAC)



Ion Exchange (IX) Resin

Alternative Adsorbents

TOC Increase in Reject Water has a significant impact on GAC

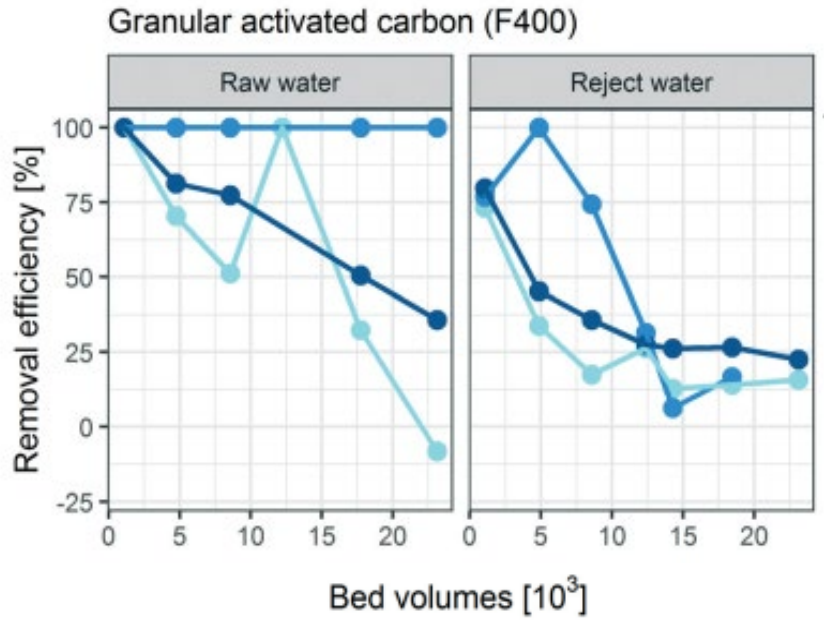
TOC
Raw water: 2.8 mg/L
Reject: 14 mg/L

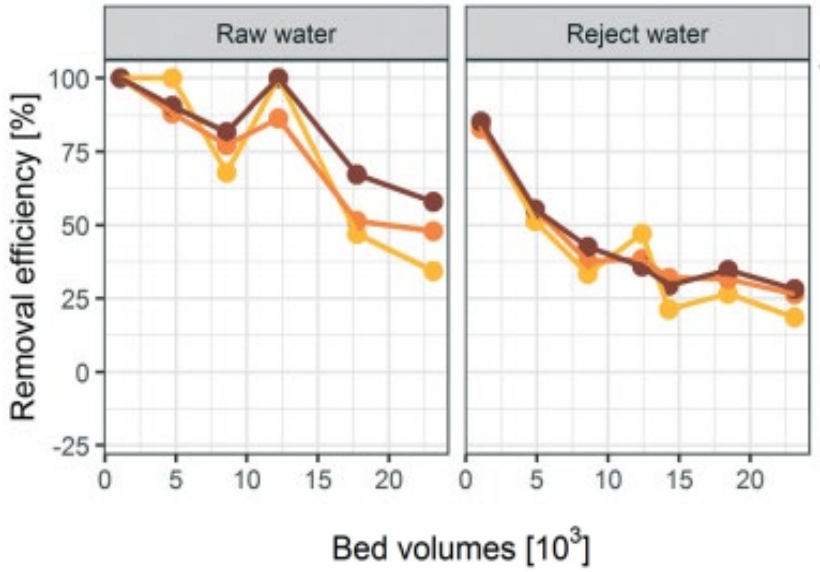
Alk (HCO3-)
Raw water: 333 mg/L
Reject: 566 mg/L

Cl
Raw water: 39 mg/L
Reject: 40 mg/L

SO4
Raw water: 39 mg/L
Reject: 180 mg/L

NO3
Raw water: 4 mg/L
Reject: 4 mg/L



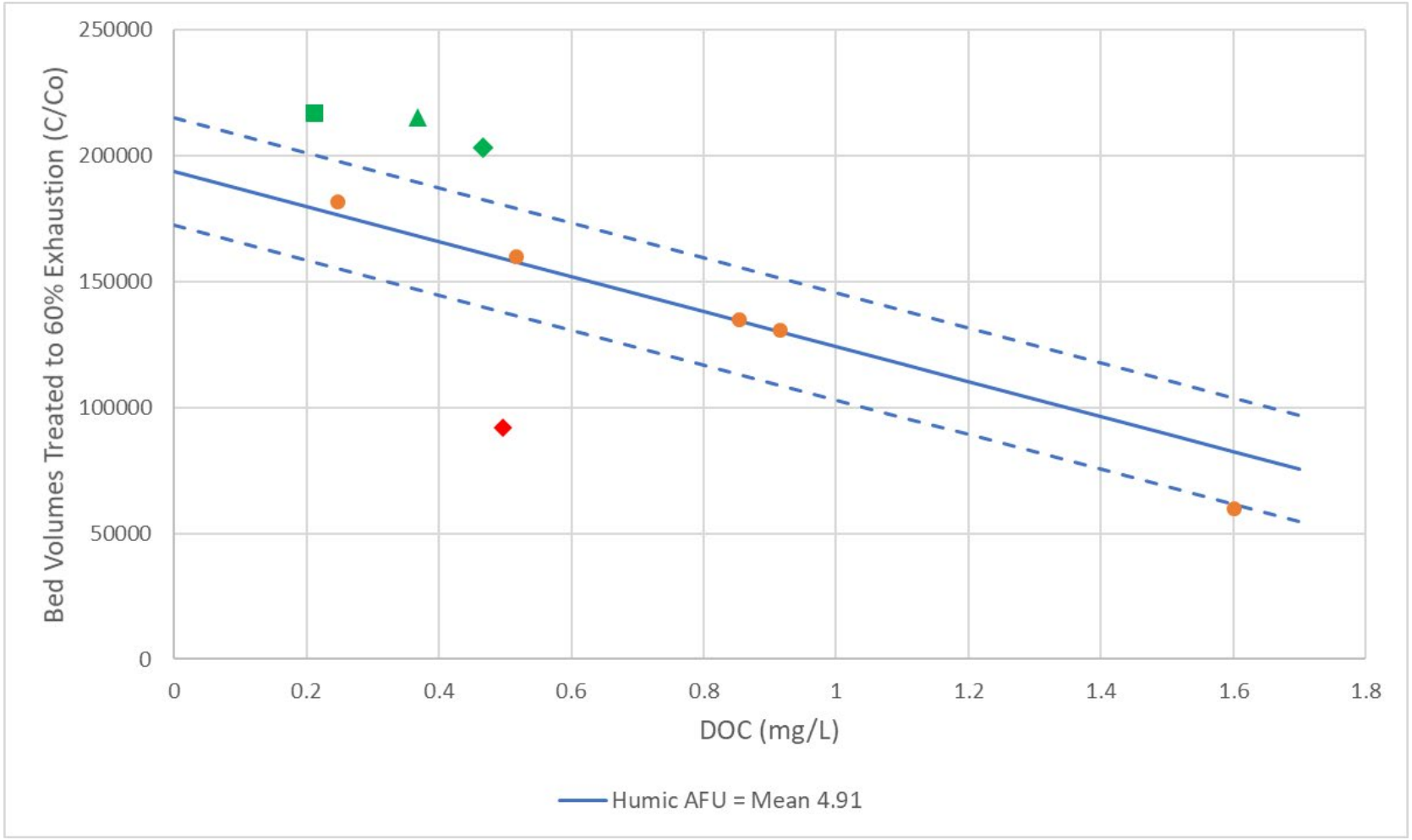


PFHxA PFHpA PFOA PFBS PFHxS PFOS

Source: Franke, V., et. al. (2019). Efficient removal of per-and polyfluoroalkyl substances (PFASs) in drinking water treatment: nanofiltration combined with active carbon or anion exchange. Env Sci: Water Res & Tech, 5(11), 1836-1843.

DOC composition has a significant influence on adsorption

- GAC – Greatest impact
- IX – Lesser impact
- FS – Minimal impact



Impacts of TOC and Inorganics on IX

TOC
Raw water: 2.8 mg/L
Reject: 14 mg/L

Alk (HCO3-)
Raw water: 333 mg/L
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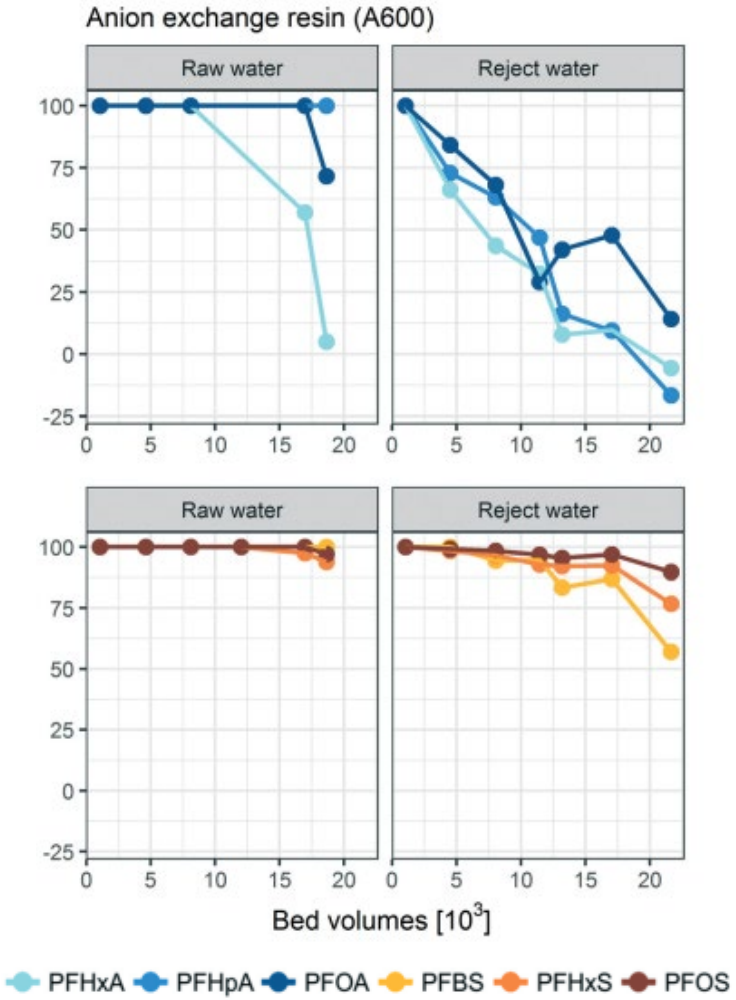
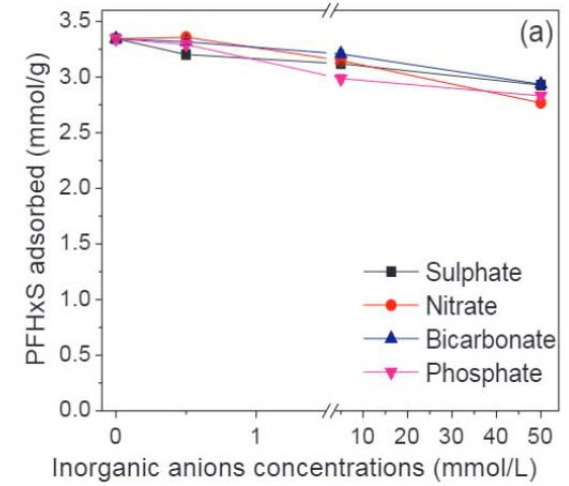
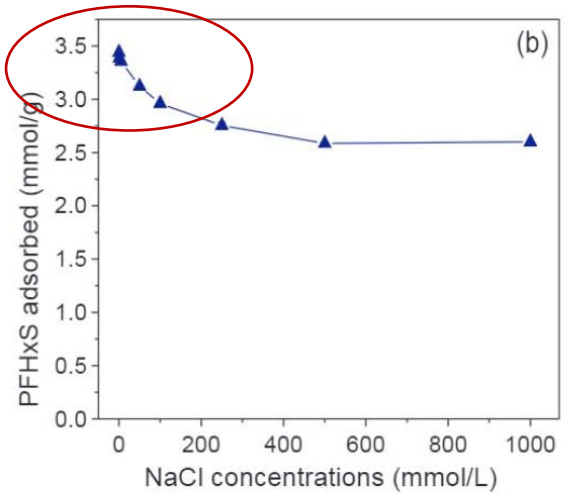




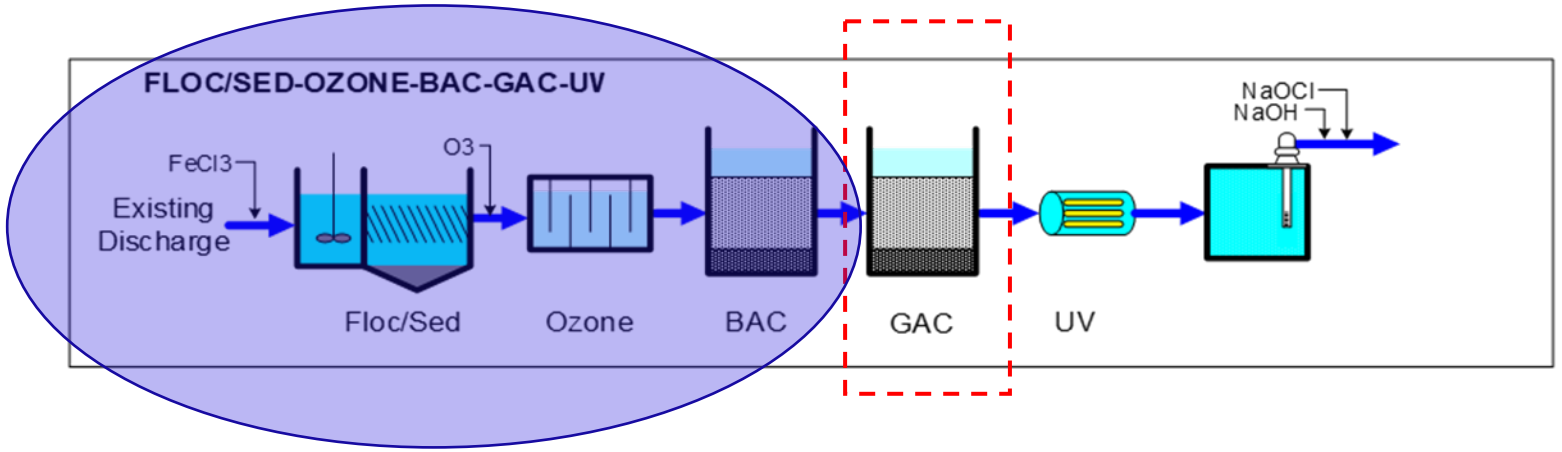


1 mmol/L:

HCO3-	61 mg/L
NaCl	59 mg/L
SO4	96 mg/L
NO3	62 mg/L

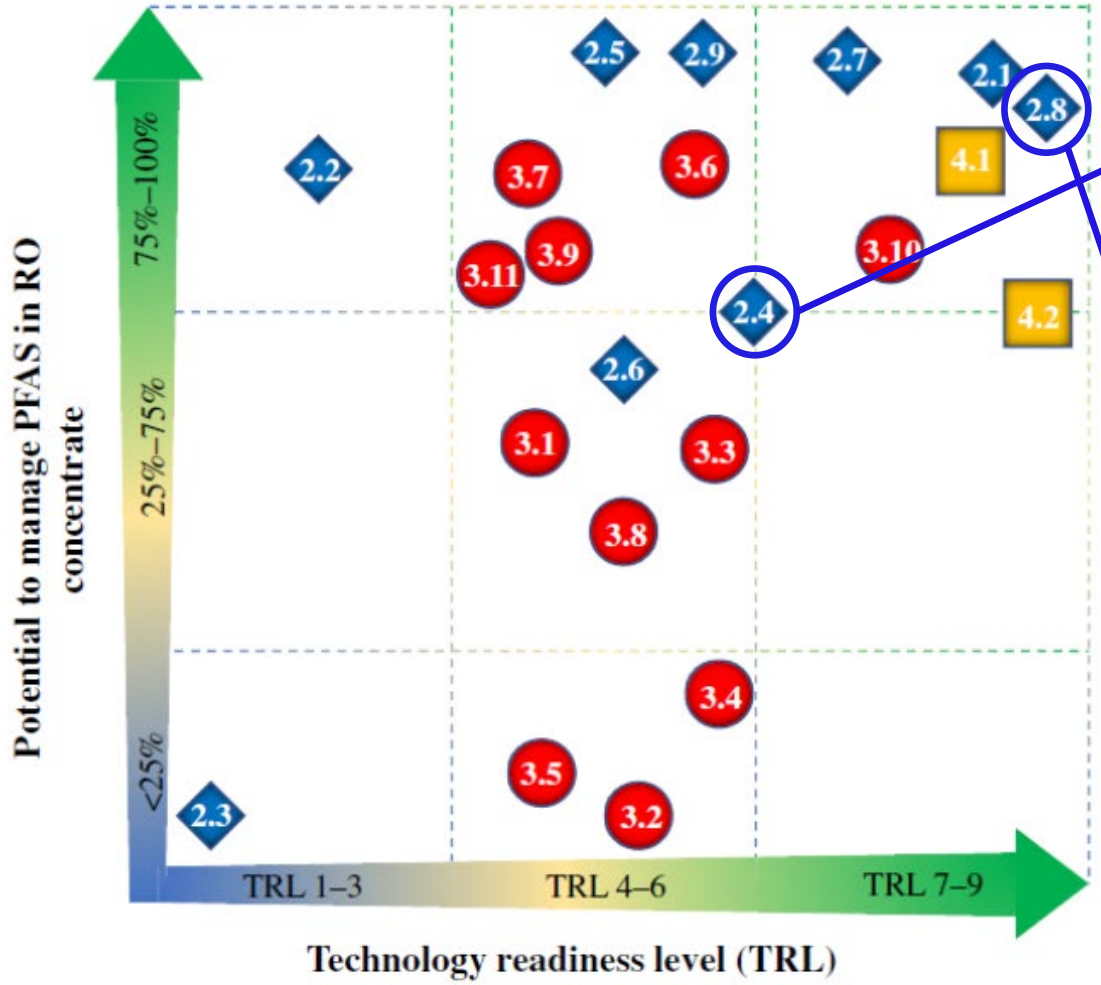
Source: Franke, V., et. al. (2019).
Maimaiti, A., et. al. (2018). Competitive adsorption of perfluoroalkyl substances on anion exchange resins in simulated AFFF impacted groundwater. Chem Eng J., 348, 494-502.

Hampton Roads Sanitation District – NPR: Conventional Treatment



- Need to include significant pre-treatment to target PFAS
- Non-potable reuse program
  - 120 MGD of secondary effluent
- Project drivers
  - Nutrient reduction
  - TOC reduction
  - Emerging contaminants

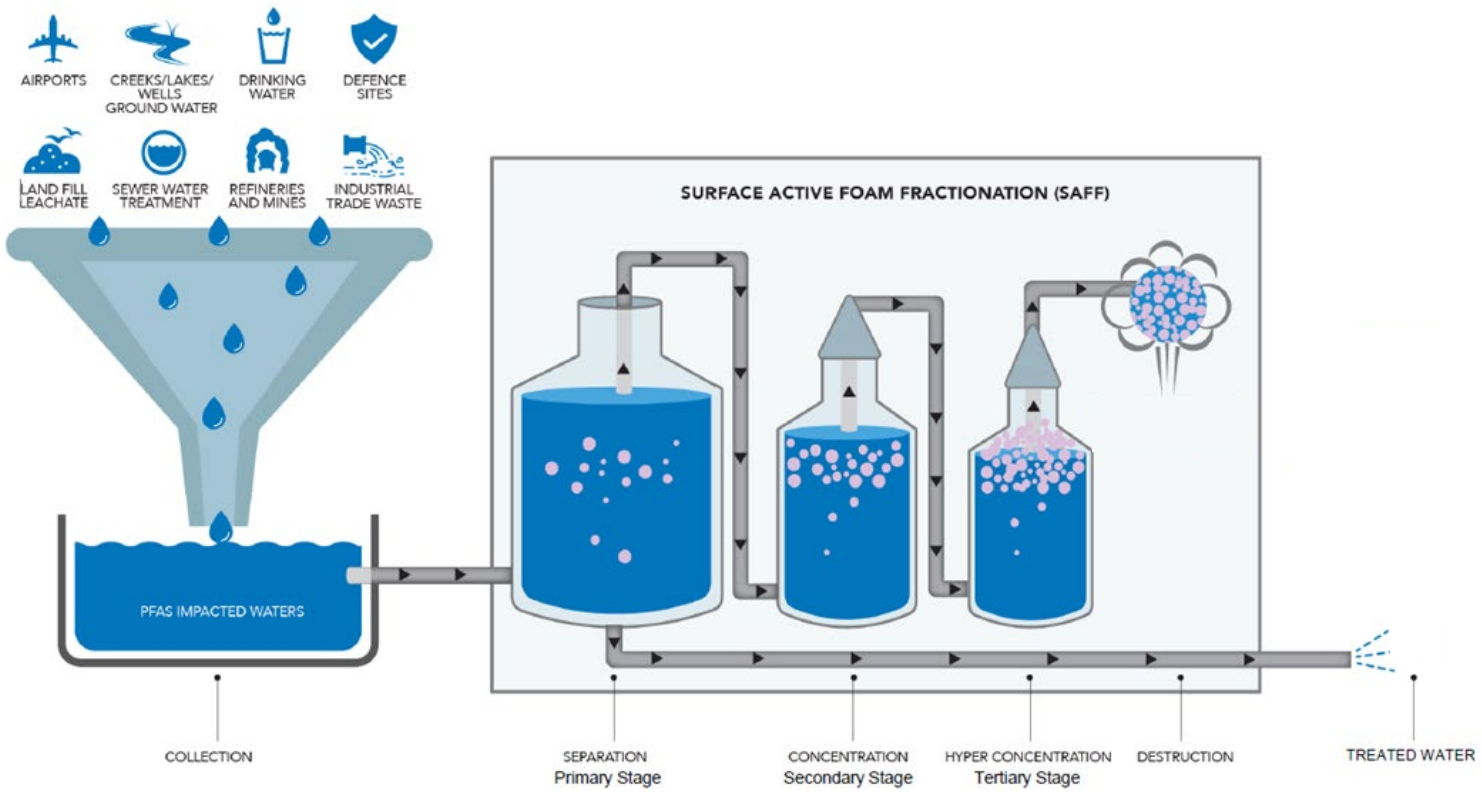
Technology Readiness as a function of RO Concentrate



Source: Managing and treating PFAS in membrane concentrates, Tow, E.W. et. al., Membrane Technology Conf 2022, Adapted from ITRC 2020.

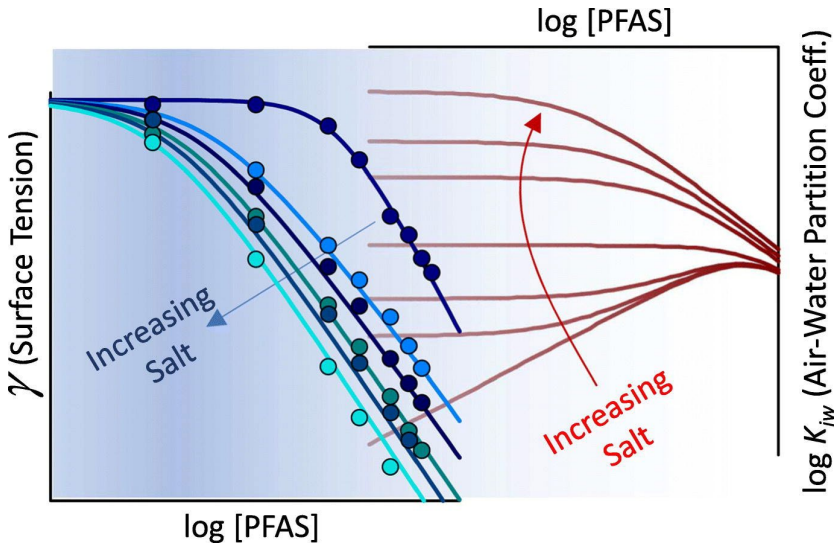
Surface Active Foam Fractionation - SAFF®

- Strips PFAS using air only
- Concentrates PFAS using vacuum
- Removes Criteria PFAS down to trace levels
- Can manage most short and long chain PFAS compounds
- Field-demonstrated for GW/Leachate
- Up to 1 : 3,000,000 concentration factor

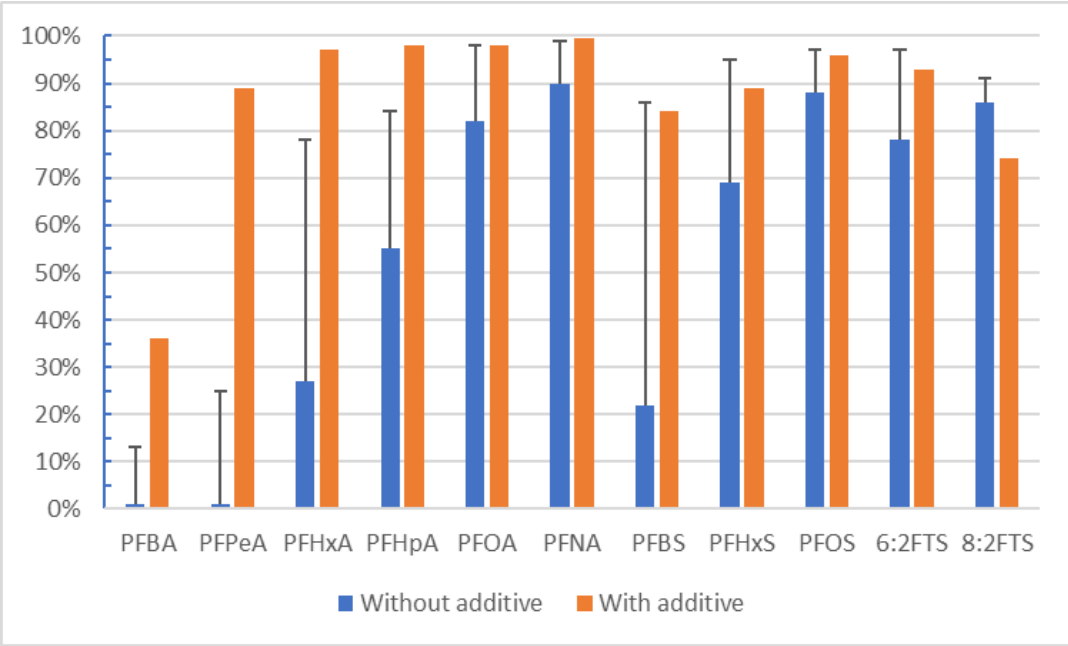


SAFF® Performance

- The more conductive the water the more effectively SAFF will strip surface active PFAS compounds from solution.



- Performance is a function of chain length.
- Can be enhanced with additive to reduce surface tension (may not be needed for concentrate)

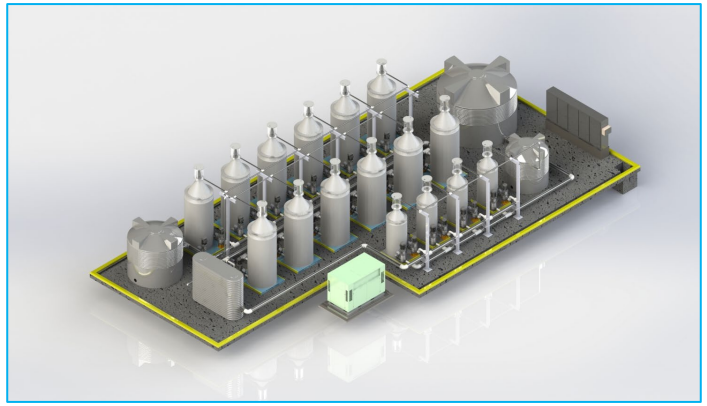


Scalable Technology

- Operates in semi-batch mode (like SBR)
- Can sit indefinitely in low/no flow scenarios
- Removes PFAS in heavily and lightly contaminated waters
- Low unit cost and per gram of PFAS removed
- Can be combined with Fluoro-Sorb (or other adsorbent for polishing)

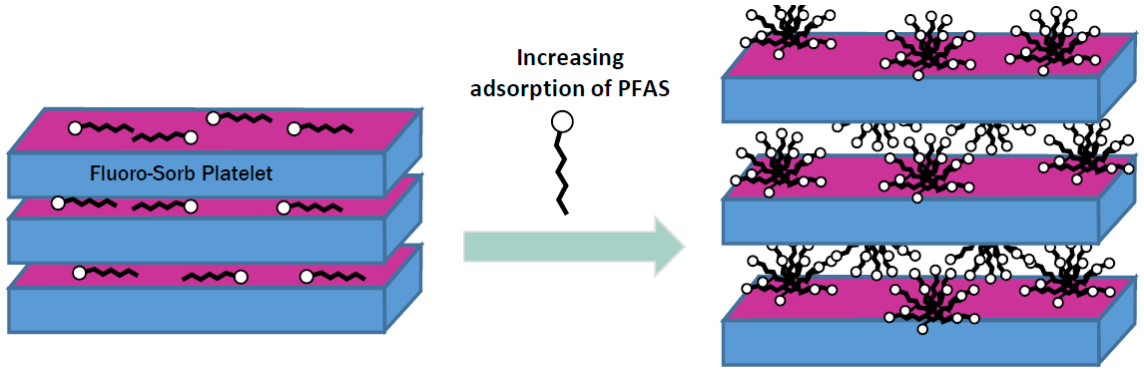
SAFF40 – Containerized and Portable 150 gpm PFAS Water Treatment Plant

Example 900 gpm PFAS Water Treatment Plant

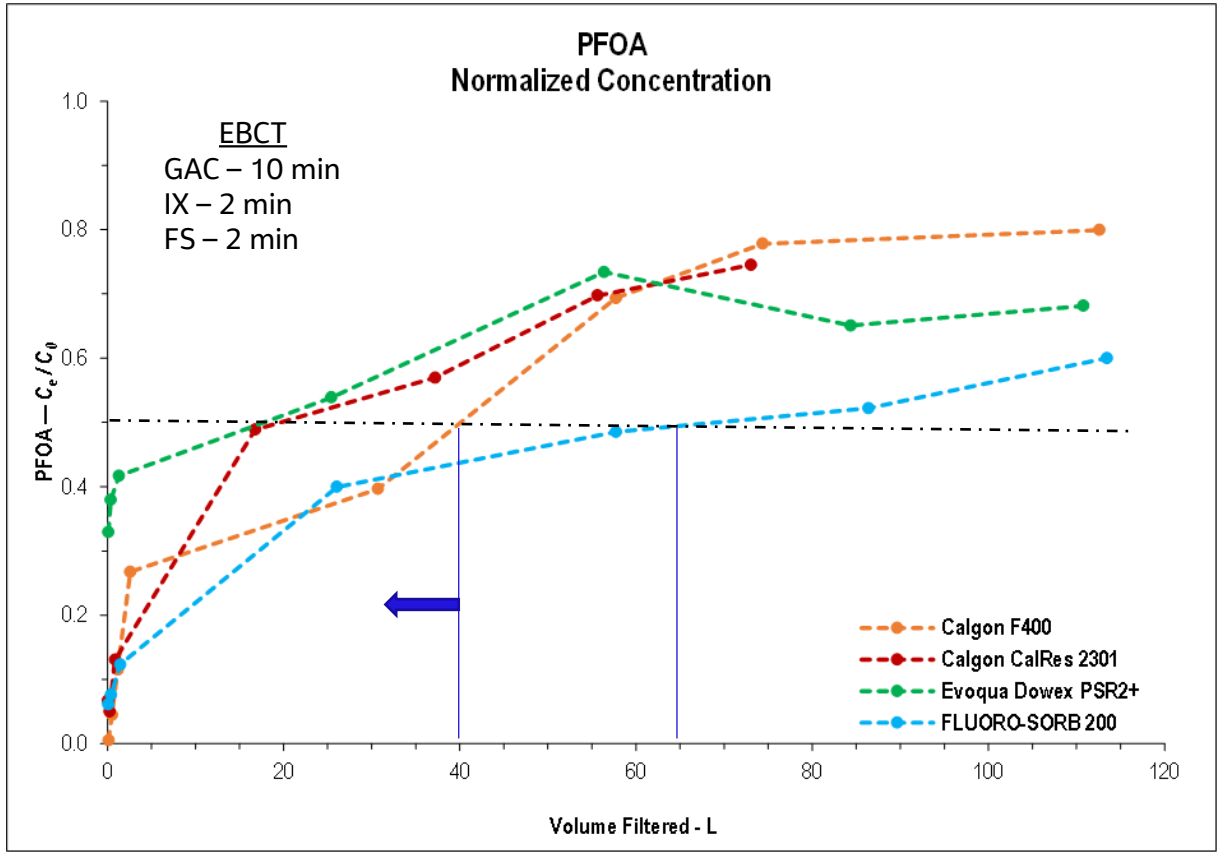


Fluoro-Sorb®

- Granular Material
  - Modified clay-based material
- Rapid kinetics
  - Design 2 min EBCT
- More selective towards PFAS
  - avoids TOC interferences
- ANSI/NSF 61 Certified
- Manufactured in USA (ISO9001:2015 Facility)



Adsorption performance on MF-treated wastewater



>50% capacity reduction compared to high-TOC groundwater

Summary

- EPA Updates to HA, AWQC, and NPDES
- PFOA/PFOS MCLs and CERCLA designations are forthcoming
- RO (and NF) provide excellent PFAS rejections
- RO Reject is more challenging matrix to apply DW technologies
- Newly commercialized technologies hold promise for lower cost and scalable treatment of Wastewater & RO reject
  - Surface Activated Foam Fractionation (SAFF)
  - Alternative adsorbents such as Fluoro-Sorb

Thank You

Scott Grieco Scott.Grieco@jacobs.com

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Reinventing tomorrow.