Application of High Recovery Membrane Systems for the Separation of PFAS

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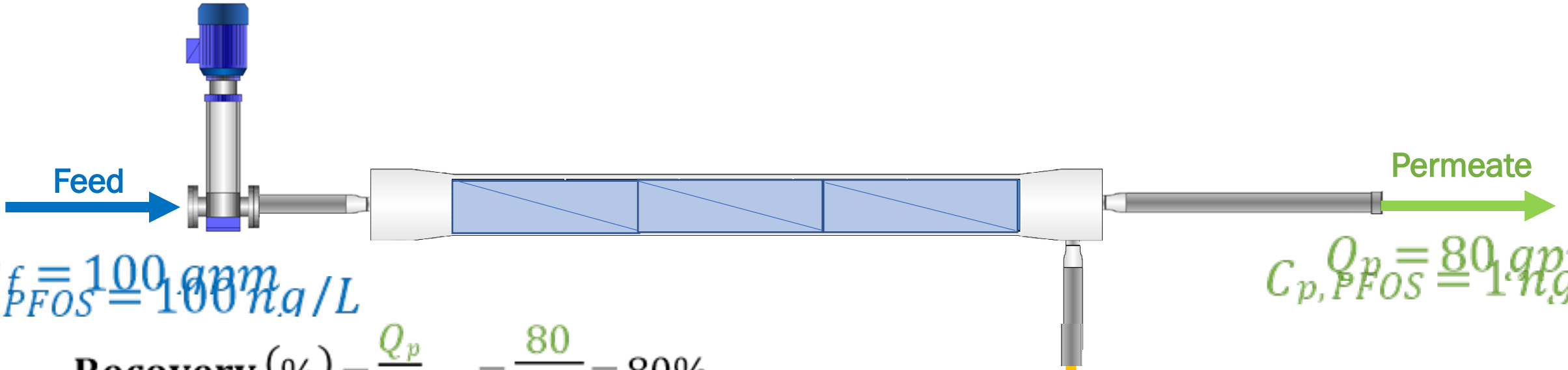
Brown AND Caldwell

Intro to High-Pressure Membranes



$$\textbf{Recovery}\ (\%) = \frac{Q_p}{Q_f} = \frac{80}{100} = 80\%$$

Recovery limited by water quality

$$\textbf{Rejection}\ (\%) = 1 - \left(\frac{C_{p,i}}{C_{f,i}}\right) = 1 - \left(\frac{1}{100}\right) = 99\%$$

Rejection a function of membrane and solute properties

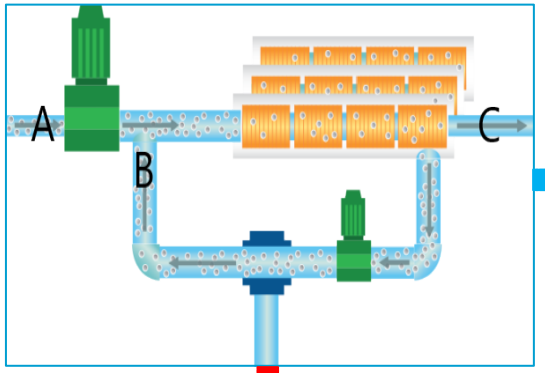
Closed-Circuit Desalination

- Nonconventional high-pressure membrane treatment
- Continuous flow, semi-batch process
- Increased operating flexibility & smaller footprint vs. conventional applications
- Capable of recoveries >97%

Benefits of CCD

2,000 gal of PFAS impacted feedwater

CCD System



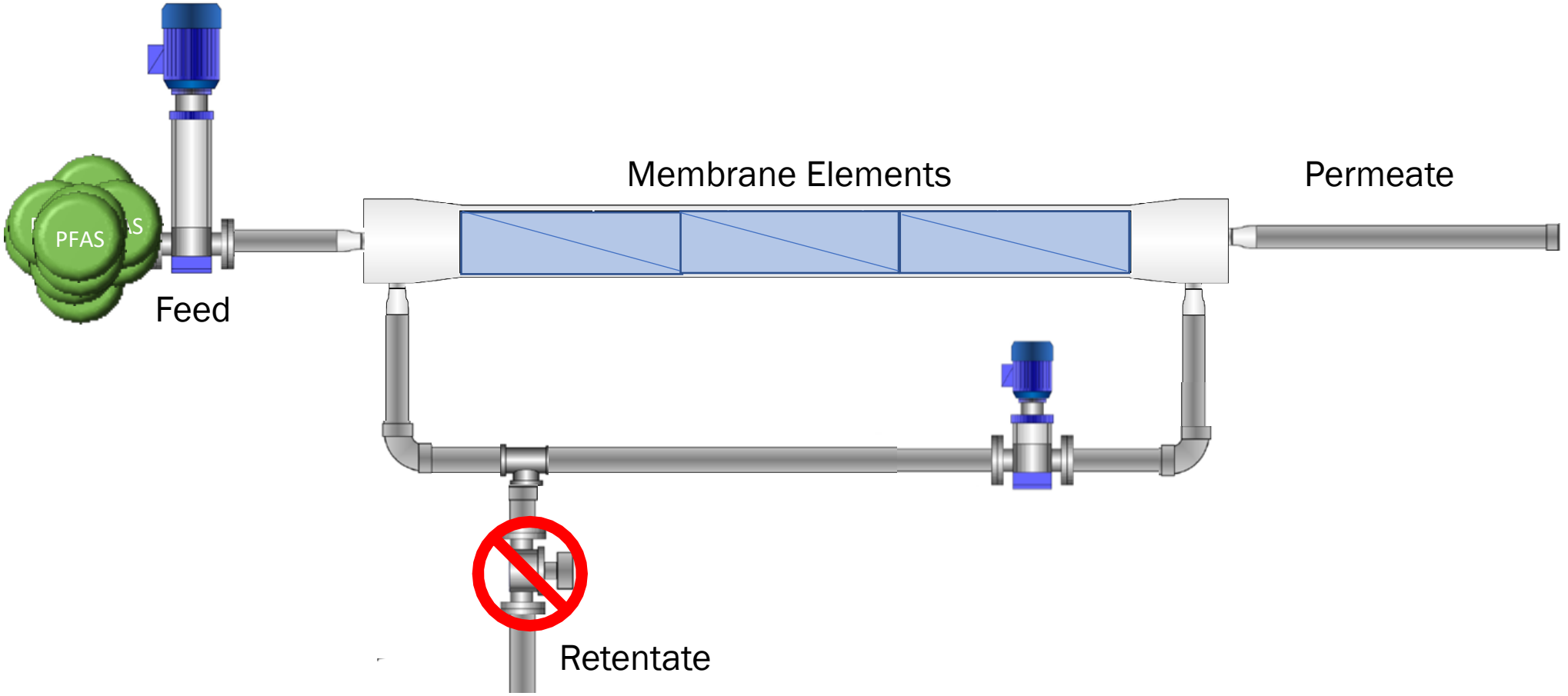
1,940 gal of permeate

<u>97% Recovery Experiments</u>

- Reduce volume by 97%
- Increase concentration by ~33 times

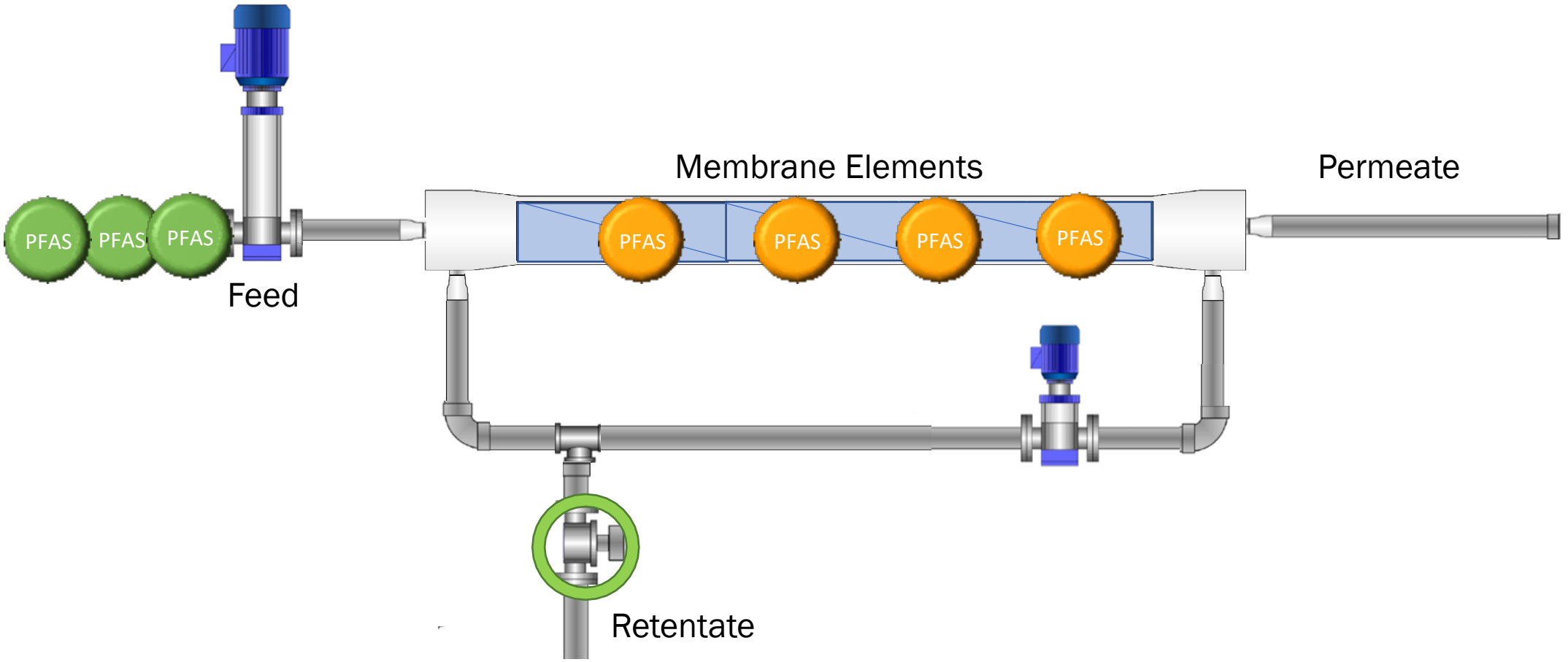
Super loading adsorbents, Increased destructive technology efficiency, …

Closed Circuit Desalination

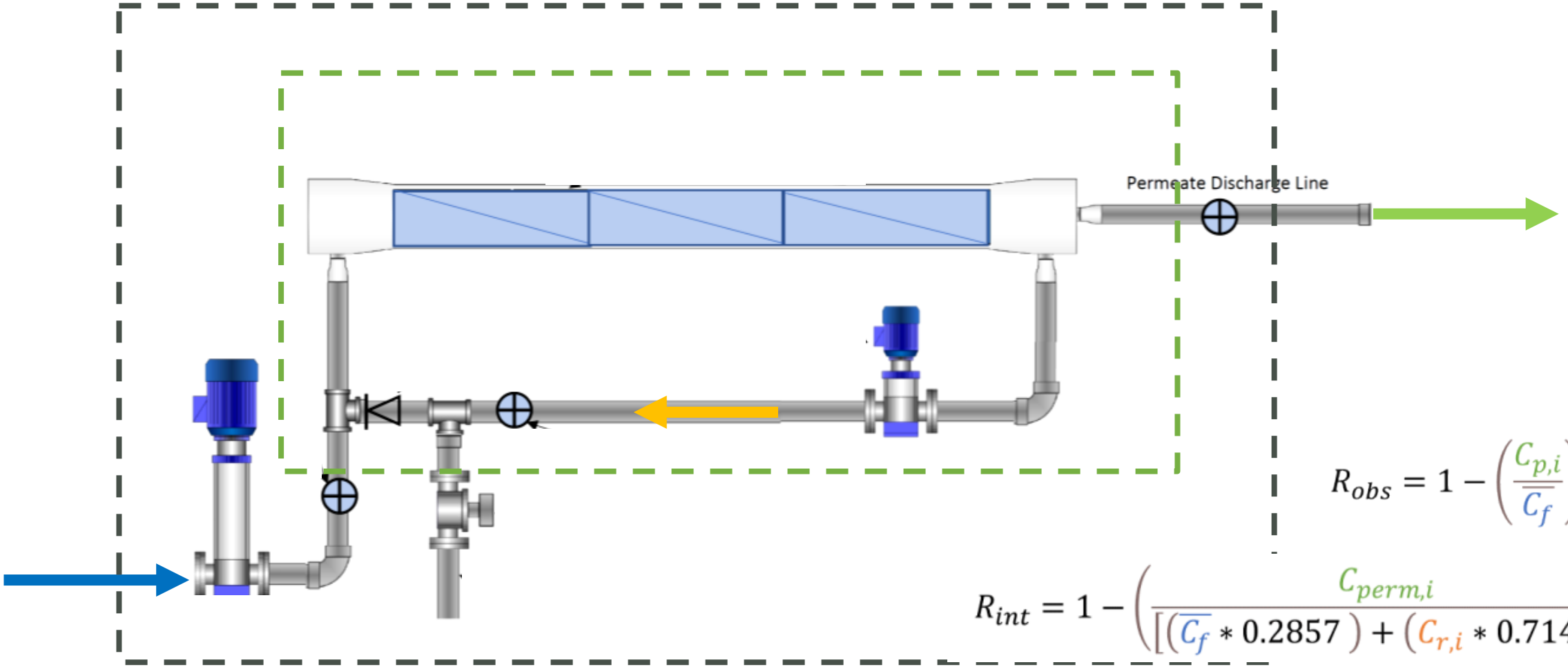


$$Sequence\ Recovery = 1 - \left(\frac{Retentate\ Volun}{Permeate\ Volun} \right.$$

Plug Flow Flush



CCD Rejection Calculations



$$R_{obs} = 1 - \left(\frac{C_{p,i}}{\overline{C_f}}\right)$$

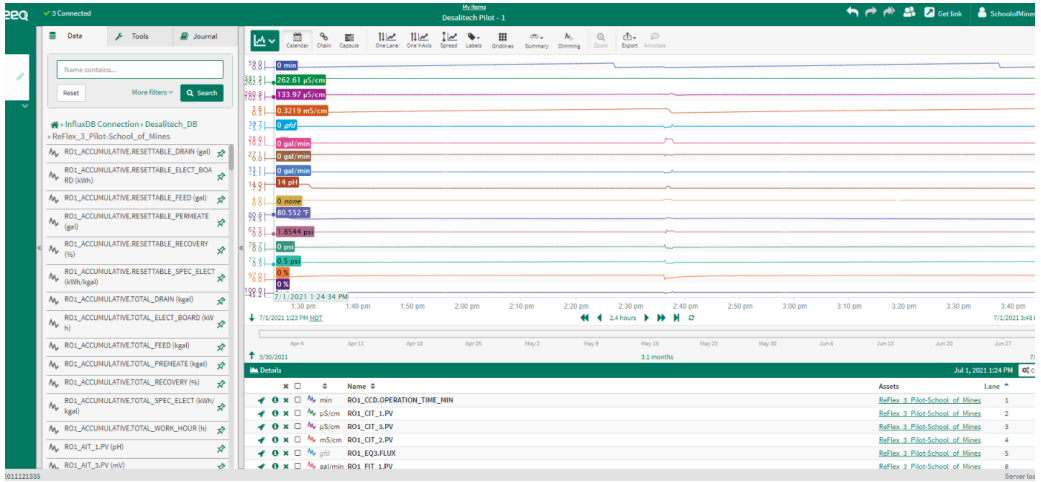
$$R_{int} = 1 - \left(\frac{C_{perm,i}}{\left[\left(\overline{C_f} * 0.2857\right) + \left(C_{r,i} * 0.7143\right)\right]}\right)$$

Study Objectives

- **Objective 1:** PFAS separation evaluation of four commercially available high-pressure membranes in CCD configuration.
  1. NF270
  2. NF90
  3. CR100
  4. SW30
- **Objective 2:** Mechanistic investigation of PFAS rejection by the NF270 membrane in CCD configuration.

Membrane Evaluation

- Experimental Conditions
  - Constant flux: 12 gfd (20 LMH)
  - 2 Sequences
  - Dechlorinated tap water
- Membranes operating performance:
  - Monitoring feed pressure
  - Temperature corrected specific flux (TCSF)
  - TOC & conductivity rejection

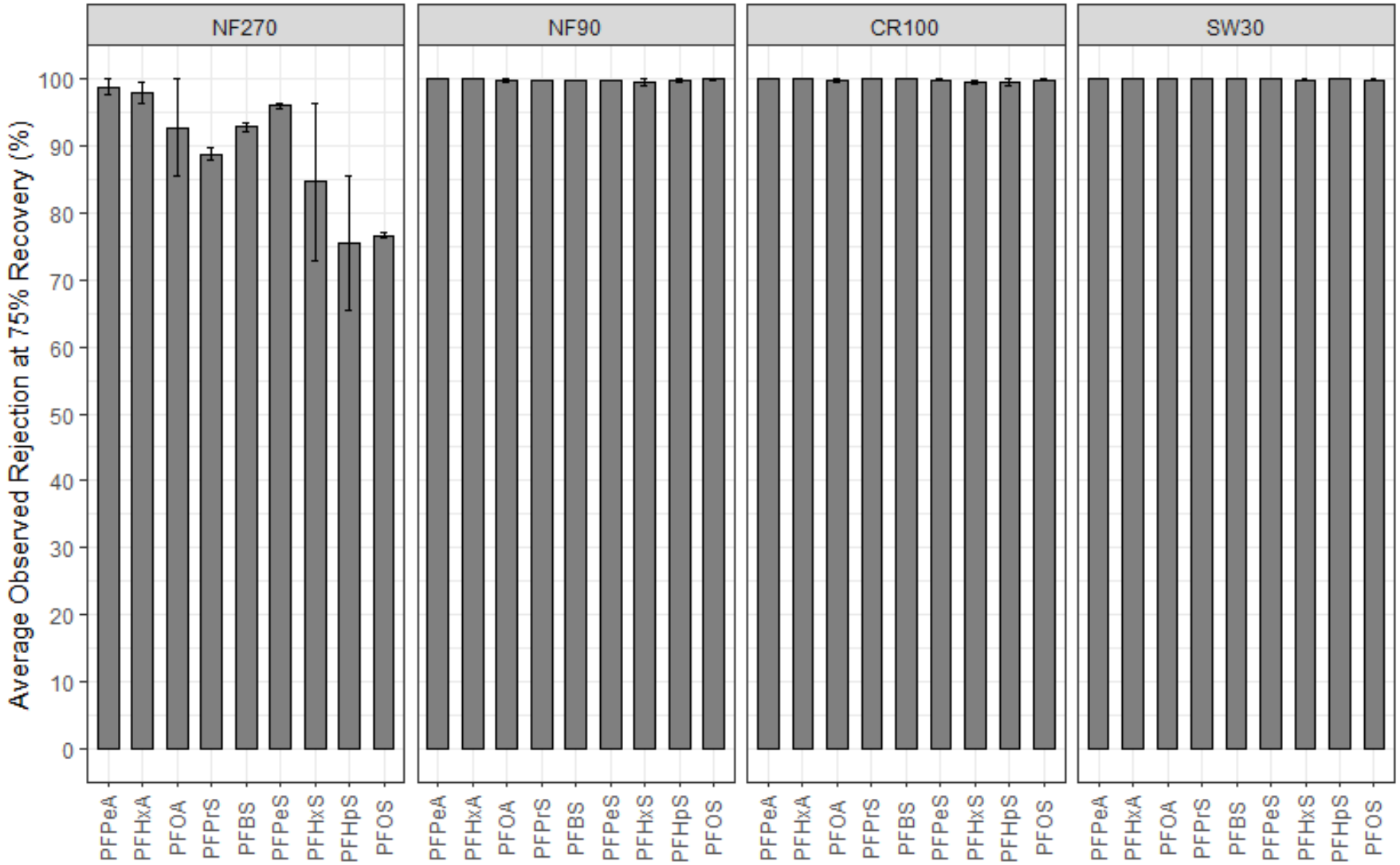


Experiment Conditions

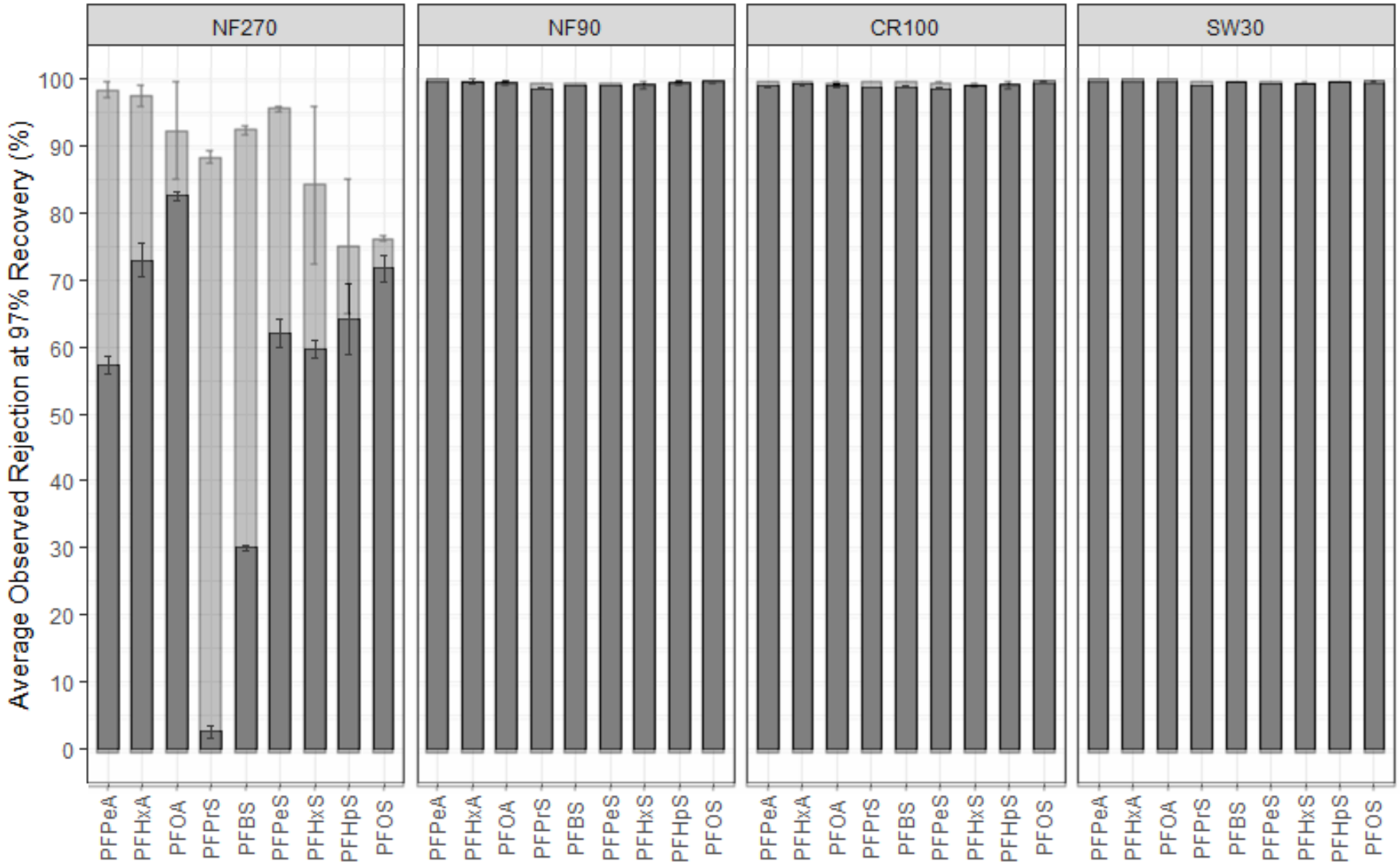
Membrane	NF270	
Feed pH	6.4	←
Feed Temperature (°F)	58.3	
Flux (gfd)	12	←
Target Recovery (%)	97	
Anti-Scalant Dose (ppm)	1.6	←

	PFAS Analtye (n=6)								
	PFPeA	PFHxA	PFOA	PFPrS	PFBS	PFPeS	PFHxS	PFHpS	PFOS
Avg Feed (ng/L)	191	579	373	326	696	1,056	3,393	123	15,311

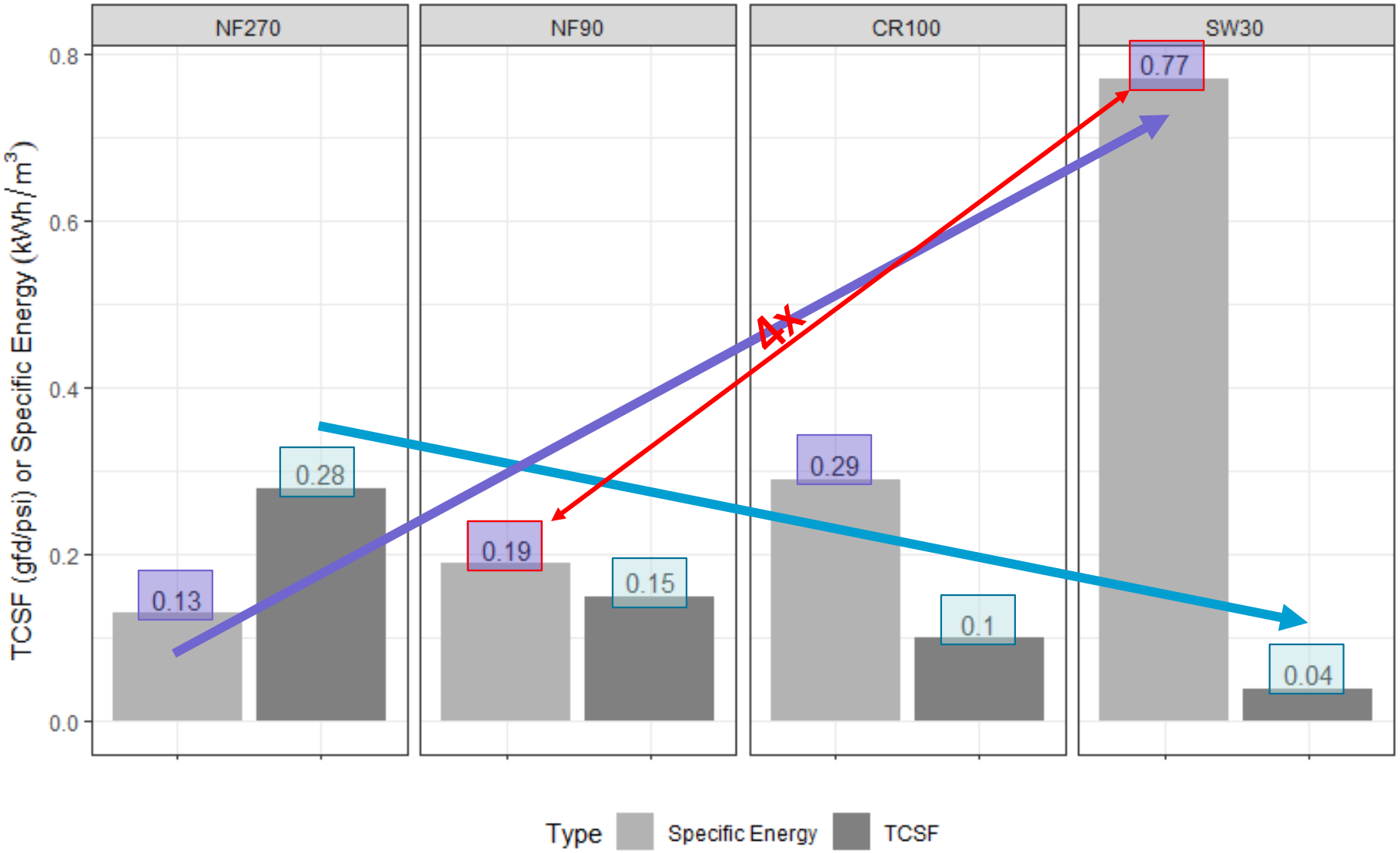
PFAS Rejection at 75% Recovery



PFAS Rejection at 97% Recovery



Specific Energy & TCSF



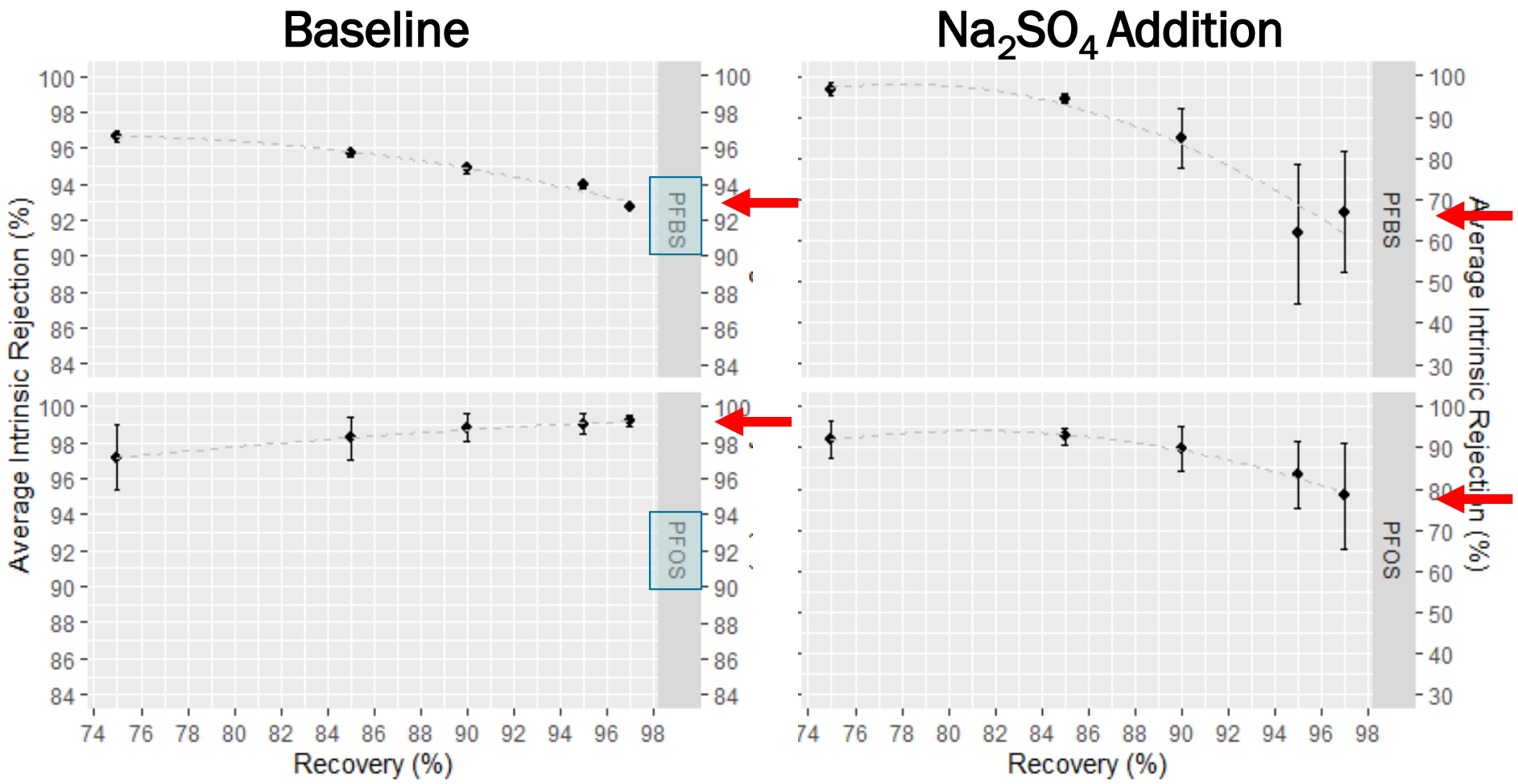
NF270 PFAS Rejection Mechanism

- NF270 underperformed in CCD
- Electrostatic repulsion diminished w/ recovery?
- Effect of increasing ionic strength

Add 500g of Na_2SO_4

~0.85 mM sulfate ion addition

Impact of Ionic Strength on PFAS Rejection



Conclusions

- Membranes operated within spec during CCD experiments
- NF90, CR100, SW30 maintained PFAS rejection >98%
- NF90 best membrane for PFOS rejection & cost
  - Long term performance?
- NF270 performance severely impacted by addition of sulfate co-ion
- CCD has promising future in PFAS treatment

Safulko, A., Cath, T. Y., Li, F., Tajdini, B., Boyd, M., Huehmer, R. P., & Bellona, C. (2023). Rejection of perfluoroalkyl acids by nanofiltration and reverse osmosis in a high-recovery closed-circuit membrane filtration system. *Separation and Purification Technology*, *326*, 124867. https://doi.org/10.1016/j.seppur.2023.124867

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COLORADO SCHOOL OF MINES

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ESTCP

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Desalitech
a DuPont brand

Thank you.

Questions?

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