National Alliance
for Water Innovation

NAWI Project 3.20: Mobile Demonstration DPR: Comparison of RO and non-RO DPR for aerobic and anaerobic effluents

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Your hosts today…

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NAWI 3.20: Project PIs

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Meagan Mauter, Prof.
CEE, Stanford

Michael Heeley, Prof., B&E,
University of Michigan

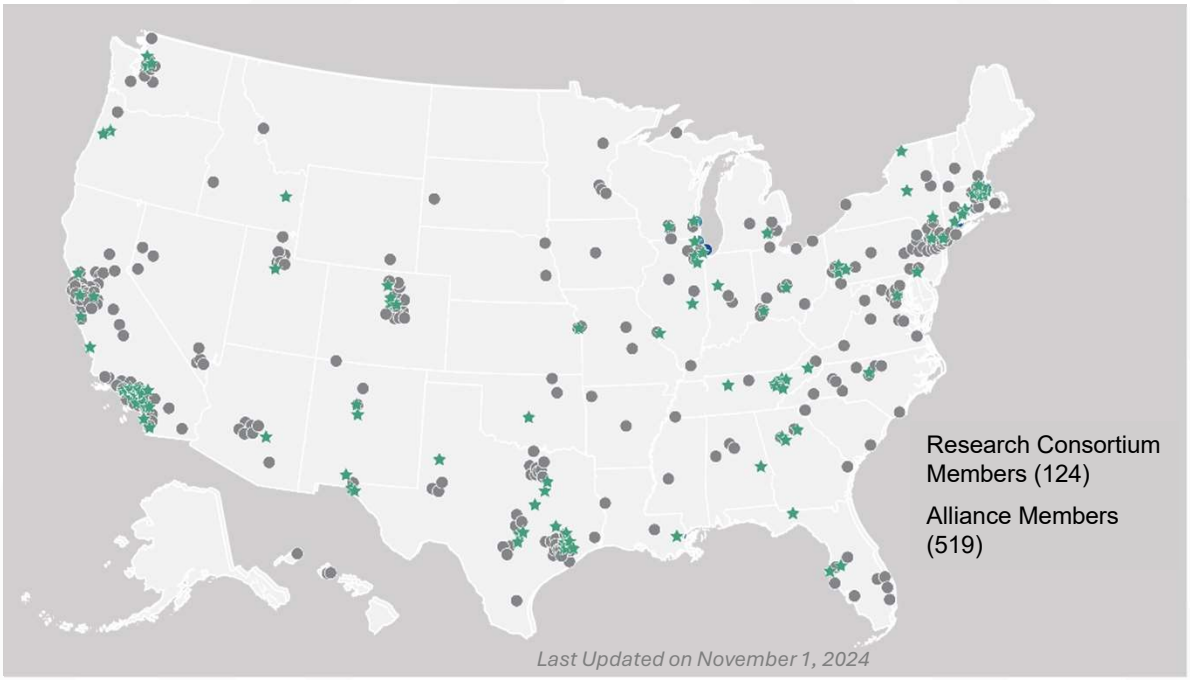
NAWI

NAWI Hub – At A Glance

- **Started in 2020 - 5-Year, $110M+ "early-stage applied research" program, sponsored by DOE, headquartered at LBNL**

- **$23 million in cost share support from CA State Agencies**
  - **DWR**
  - **SWRCB**
  - **CEC**

- **Renewed by the DOE for 5 more years and $75M**

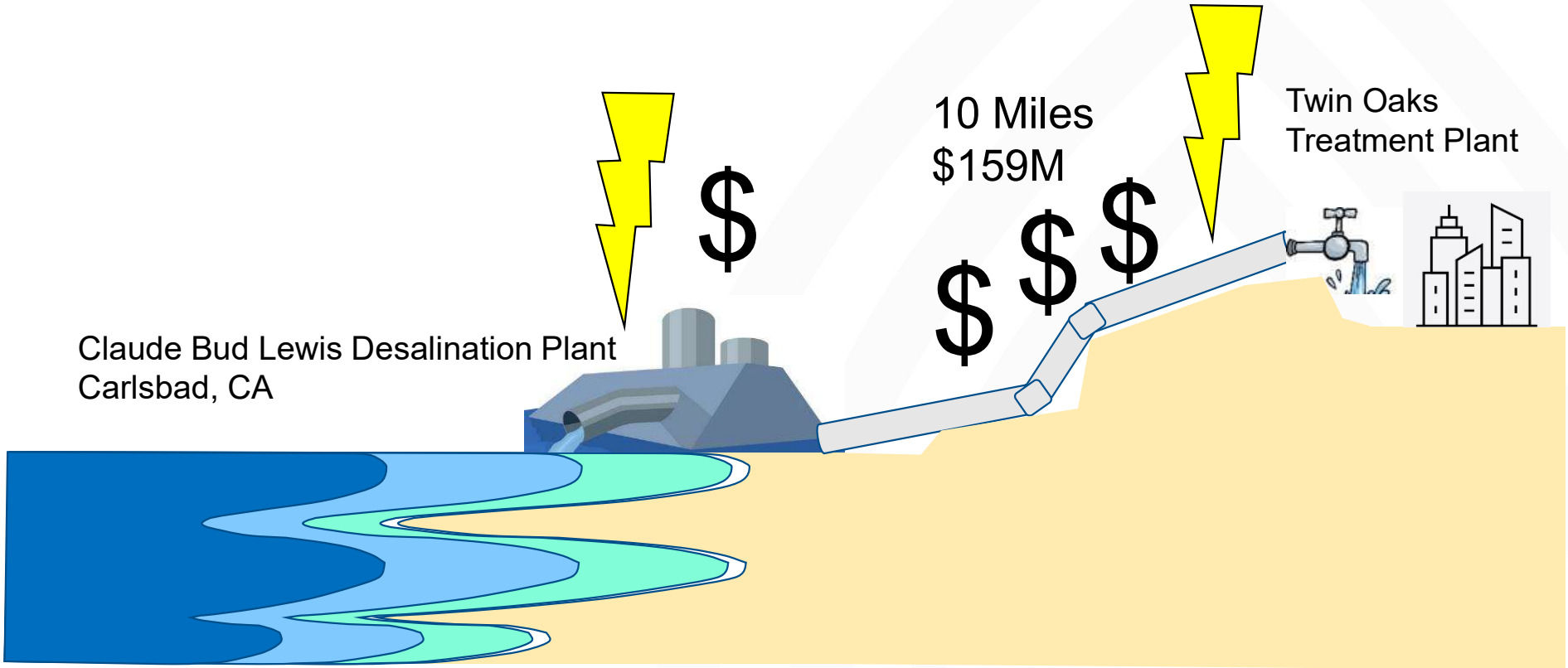


NAWI 2.0 will be launching new collaborative research projects – we are now seeking project partners and regions

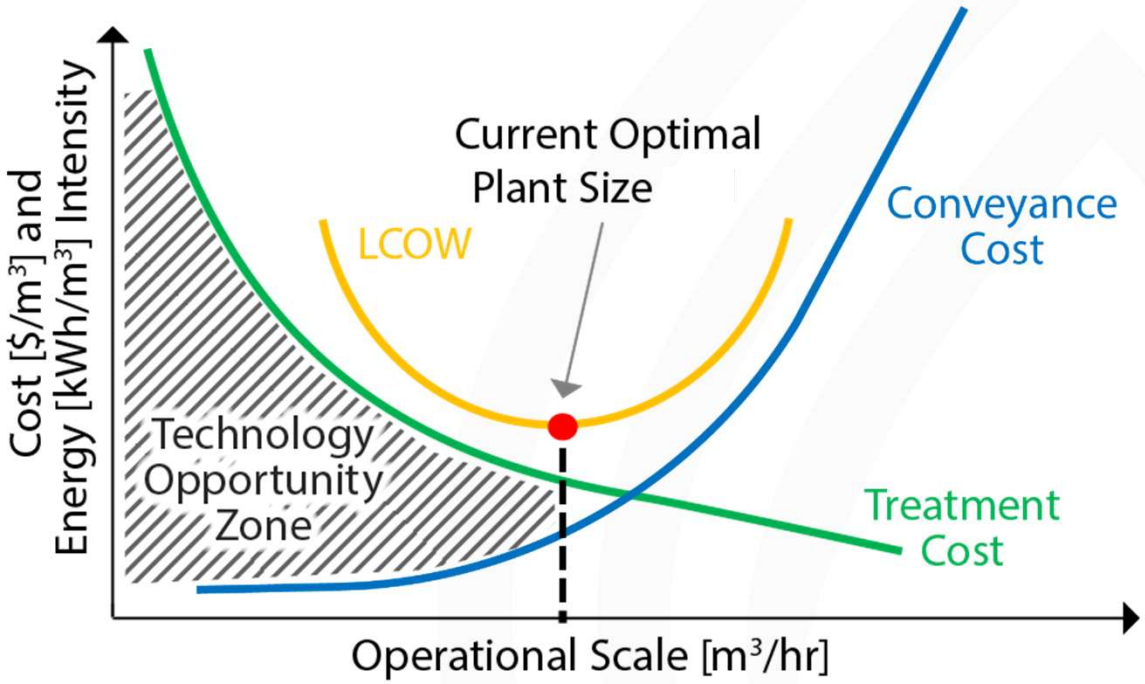
Our 20th Century Water Systems are Linear…

This served our nation well for decades…


50 MGD
Our Region's Trusted Water Leader
San Diego County Water Authority
POSEIDON WATER
Claude "Bud" Lewis
Carlsbad Desalination Plant


Claude Bud Lewis Desalination Plant
Carlsbad, CA
$
10 Miles
$159M
$ $ $
Twin Oaks
Treatment Plant

Where's the biggest opportunity in desalination? Go SMALL Go LOCAL Go REUSE



NAWI's Goal: Enable cost-effective (small-scale) distributed water treatment and reuse

The transition to decentralized water treatment reuse vision would mirror a transformation that has already happened in the energy sector…

Centralized
Custom-designed
Long lead time
$B
1 per city

Distributed
Manufactured
Short lead time
$K
1 per building

Flexible, Modular, and Reliable Potable Reuse Solutions

Ongoing Projects

Advanced control systems (model predictive control)

- Simultaneous optimization of multiple processes
- Challenges: small scale, integrated treatment train (sync)
- Early detection of failures of processes (focus on drift faults)
- Funded by DOE/NAWI (ORNL, Mines, Baylor)

Unlocking the Nationwide Potential for Water Reuse (WRF 5197)

- Safeguarding public health/risk assessment, treatment models and risk mitigation, community engagement, adoption pathways
- Funded by EPA (WRF, CU Boulder, Mines, SNWA)

DPR of challenging streams

- Comparison between RO-based and carbon-based DPR
- Funded by DOE/NAWI (Mines, Stanford, CU Boulder, Silicon Valley Clean Water)

Deployments

Colorado Springs, JD Phillips
(Jun. 2021 – Jun. 2022)

Aurora Water, Sand Creek
(Jun. 2022 – Aug. 2023)

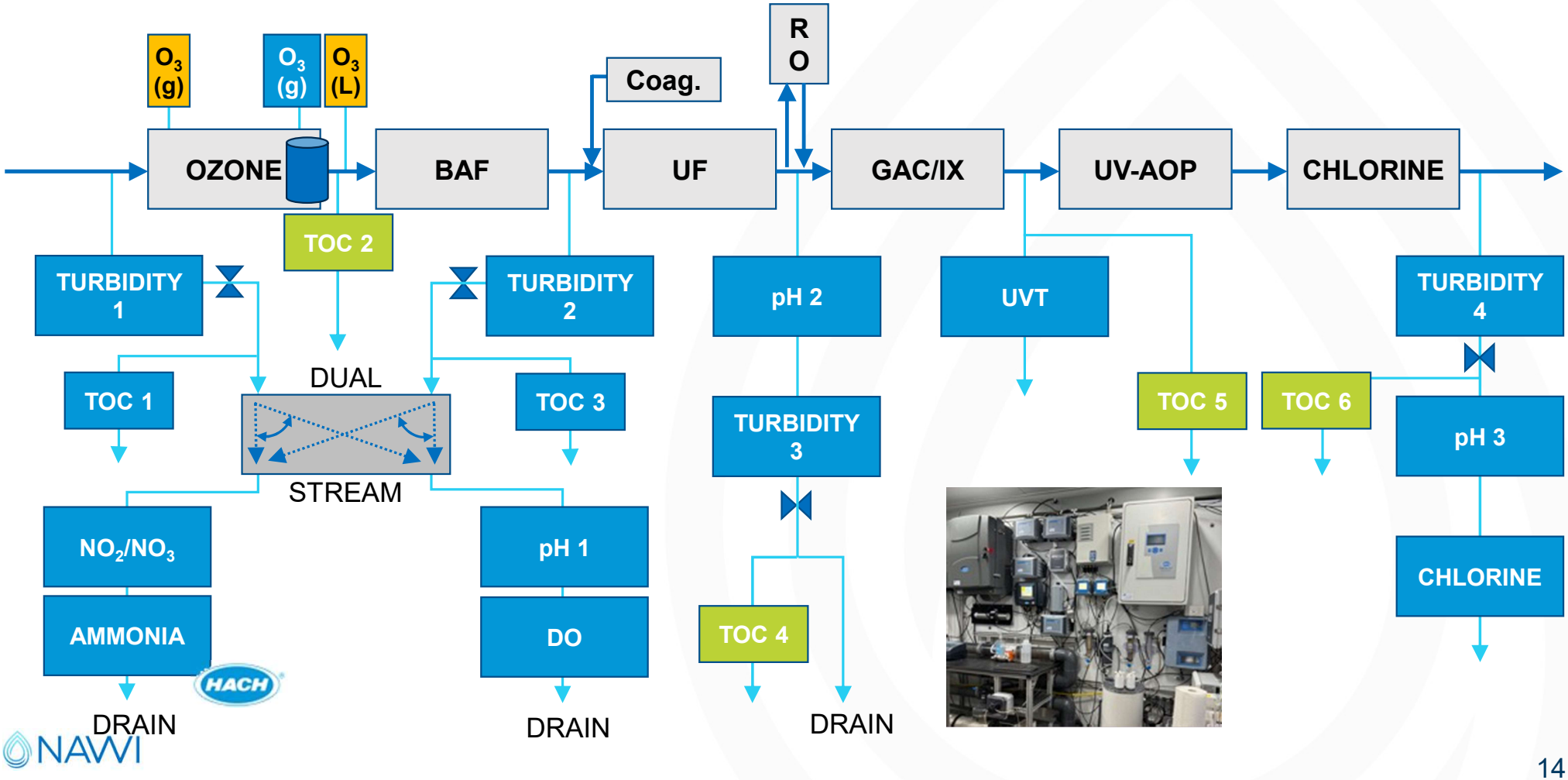
Littleton/Englewood, SPR
(Aug. 2023 – May 2024)

Redwood City, SVCW
(May 2025 – Present)

Littleton/Englewood, SPR
(Sep. 2024 – May 2025)

Denver, Metro Water Recovery
(May 2024 – Sep. 2024)

DPR Demonstration: Water Quality Sensors



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Flexibility and Adaptability…

Colorado Springs Utilities (CO)

- Tertiary effluent: *cloth media filtration → UV disinfection*

Aurora Water (CO)

- Tertiary effluent: *sand filtration → UV disinfection*

South Platte Renew (CO)

- Tertiary effluent: *sand filtration → Cl_2 disinfection*

Metro Water Recovery (CO)

- Secondary effluent: *densified activated sludge → secondary clarifiers*

Silicon Valley Clean Water (CA)

- Tertiary effluent (no NdN): *filtration → disinfection*

Past Research in the DPR Mobile Demonstration Lab

Advanced Control Systems (Model Predictive Control)

Overarching goal

- Develop, deploy, and quantify benefits of advanced monitoring and control methods for autonomous, plant-wide operation and optimization

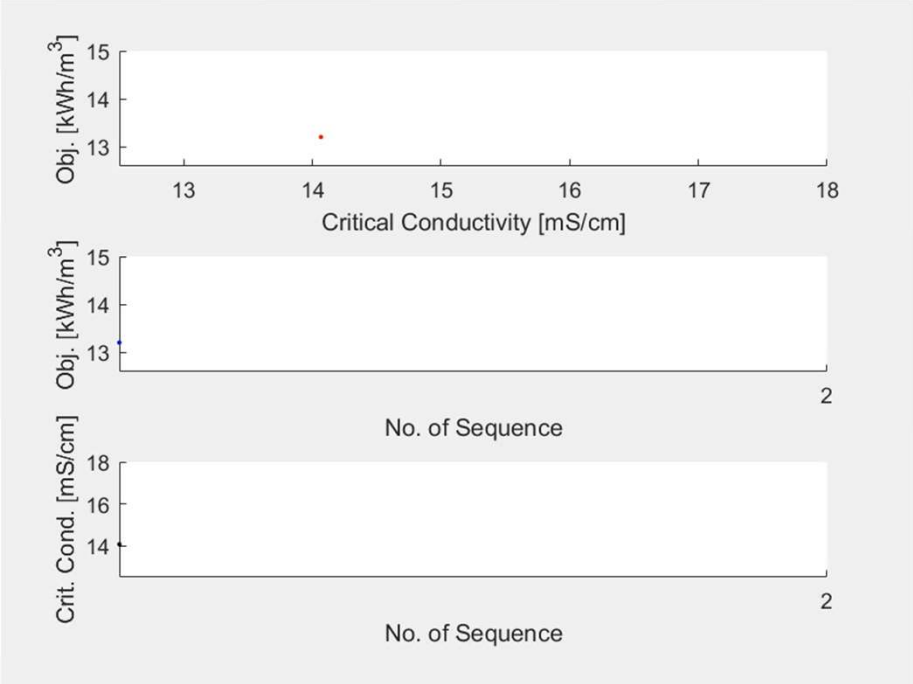
Objectives

- Develop methods for control and optimization that minimize resource utilization
- Demonstrate that modern machine learning tools enable autonomy and optimization at the process and plant-wide scales

Process and Impact Identification: Closed Circuit RO (CCRO)

Optimization of one process (RO) with a digital twin

- Minimizing energy and brine disposal



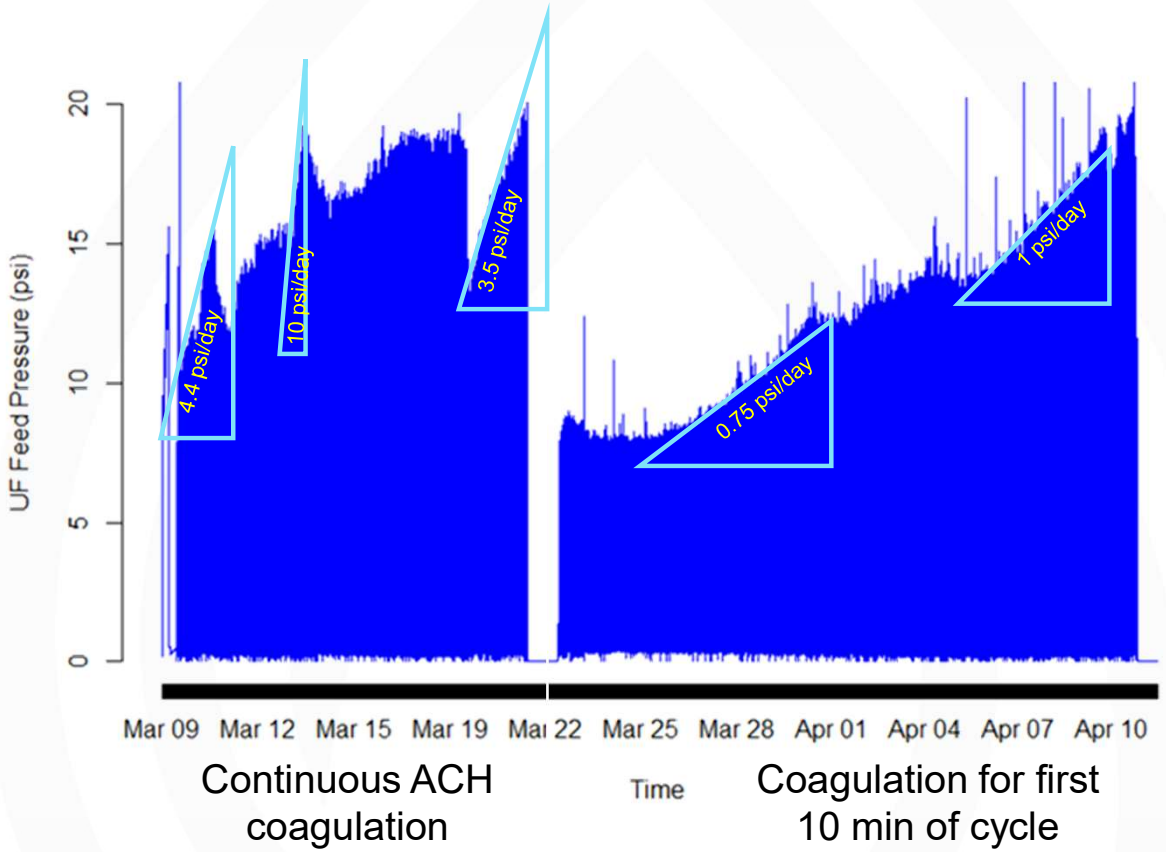
Chowdhury, D., Kuras, A., Weix, D., Cath, T., Melin, A., Polsky, Y., Hering, A., Cath, T.Y., Villez, K. (2022). Black-box optimization of a closed-circuit reverse osmosis system for desalination through extremum seeking control. Proceedings of the 13th IWA Specialized Conference on Instrumentation, Control and Automation (ICA2022), 64-66.

Chowdhury, D, Melin, A, Villez, K (2022). Method for automatic correction of offset drift in online sensors. Celebrating passion for Water, Science and Technology: Festschrift in Honour of Gustaf Olsson, 17-41.

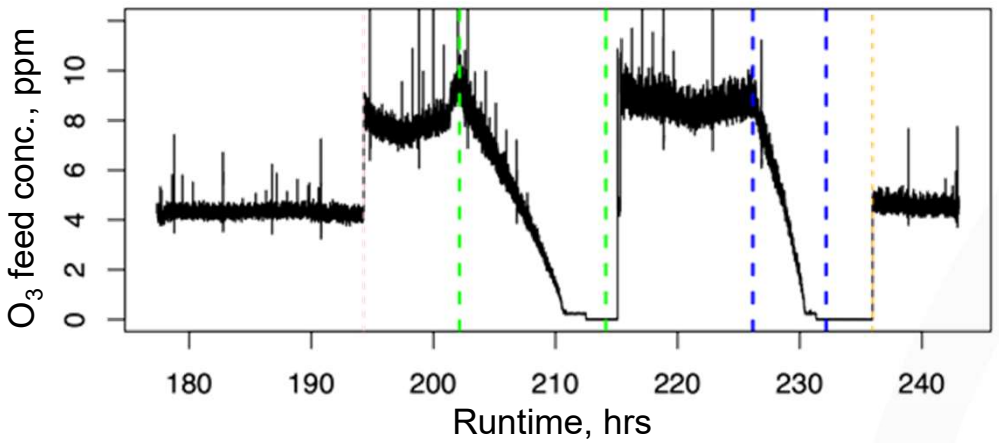
Process and Impact Identification:
UF Membrane Performance

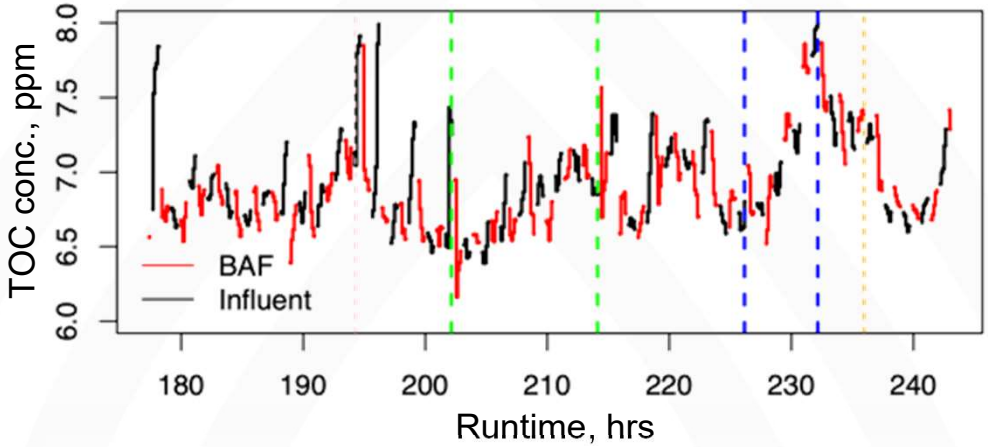
The UF membrane is a critical, active process in the middle of the train

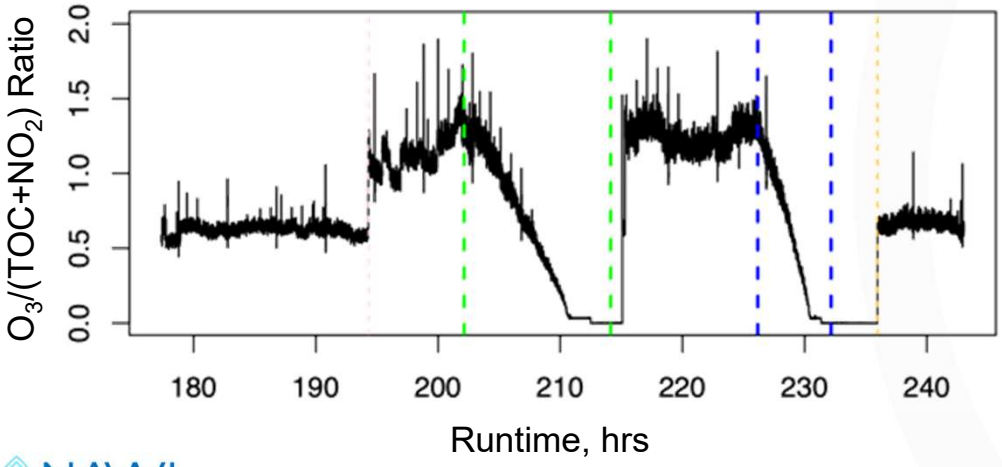
- Backwash for ~4 min every 30 min
- Coagulant addition in the feed prevents pore clogging
- Coagulant reaction with particle from the BAC results in severe fouling

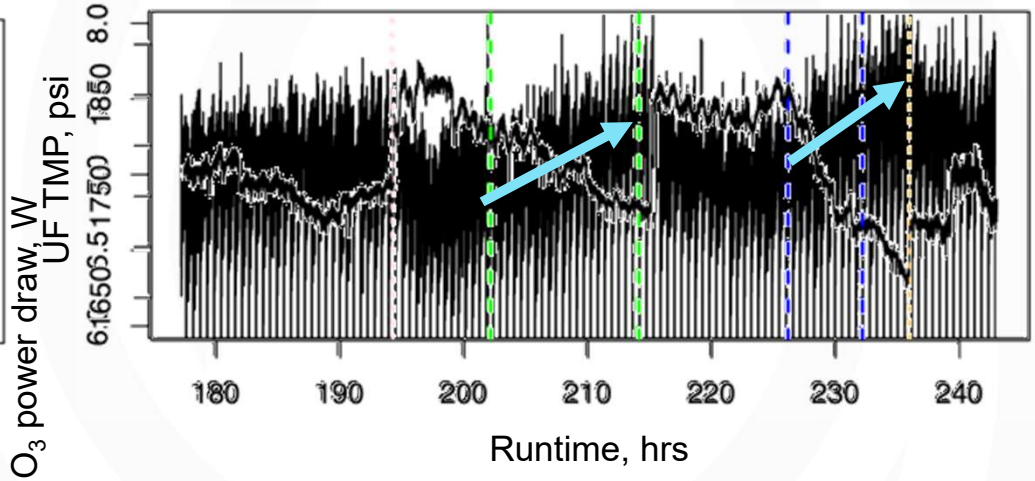


Process and Impact Identification: Ozone Decay Tests









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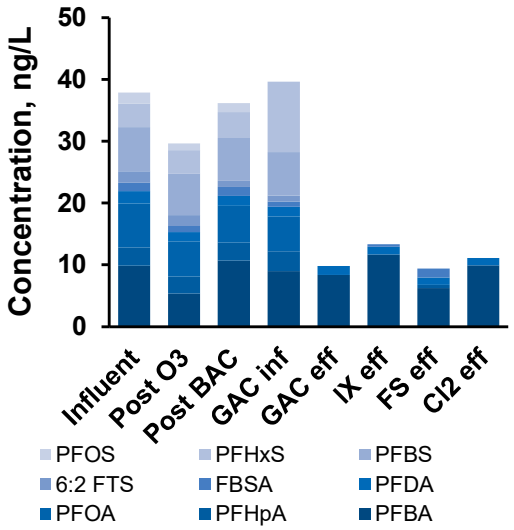
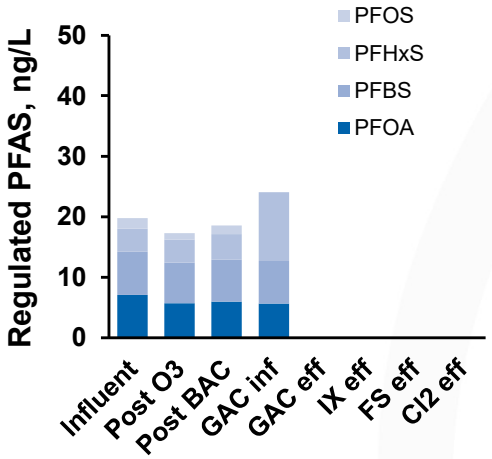
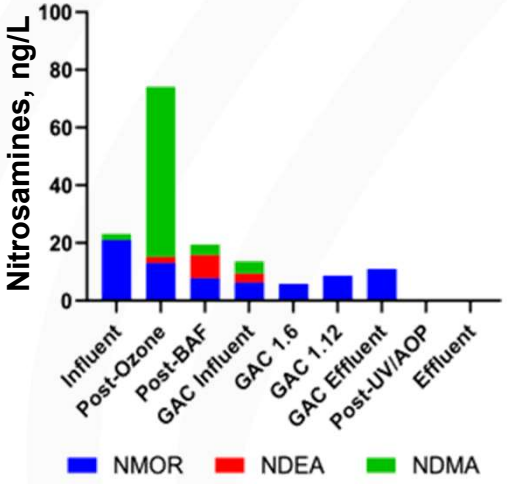
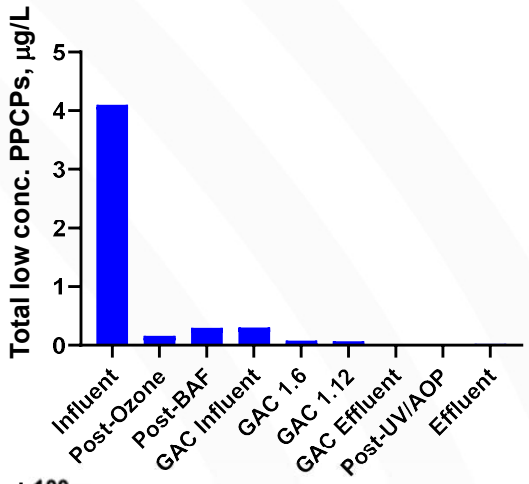
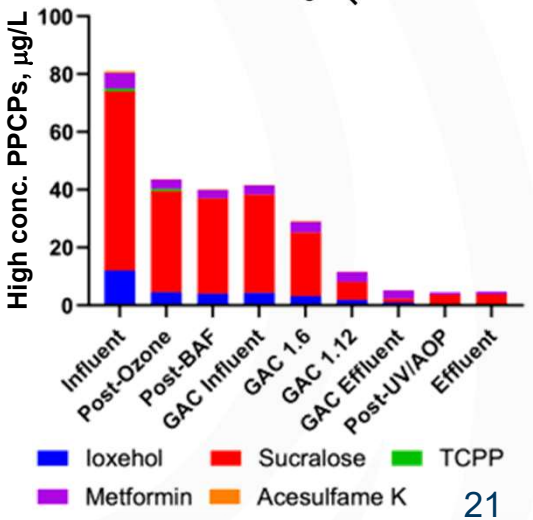
Monitoring of Indicator Compounds and CECs











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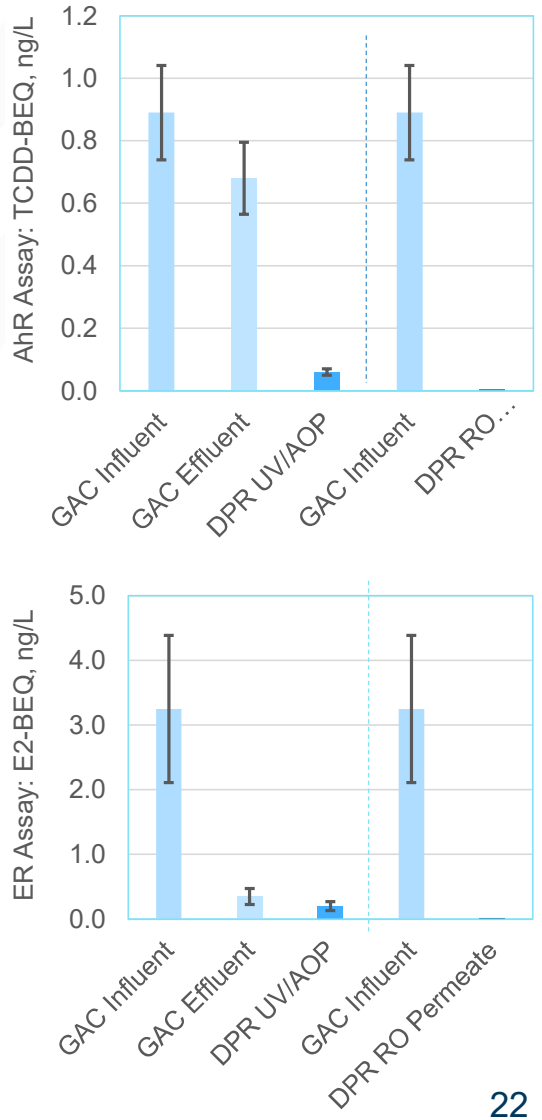
Environmental Toxicity: Carbon-Based vs. RO-Based DPR

Bioassays

- A snapshot of what is in the water in terms of specific biological activity
- Account for mixture effects
- Can be cheaper than testing for a suite of analytes

ER and AhR environmental bioassays were used to measure environmental toxicity (17β-Estradiol ER standard and TCDD AhR standard)

A non-RO treatment train with GAC and UV/AOP can reduce activity levels to the same levels as RO treatment…



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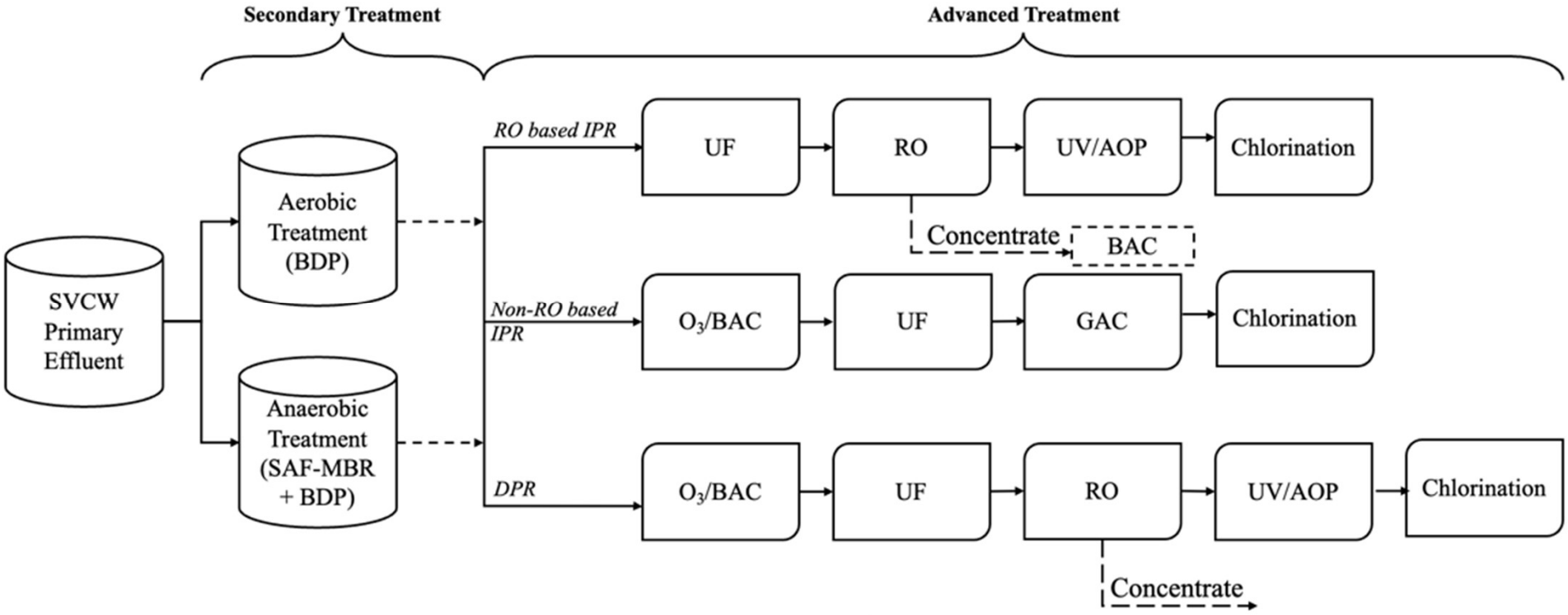
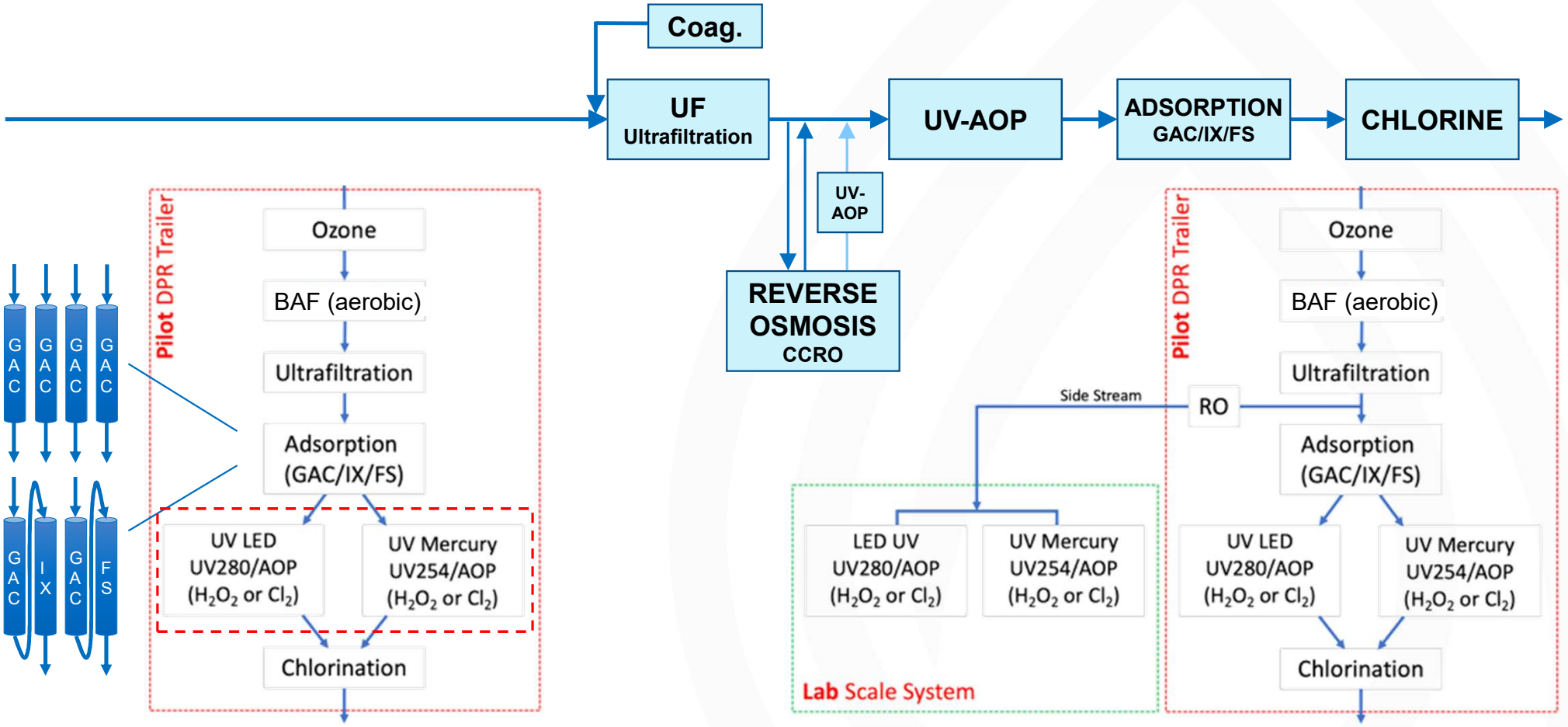
At SVCW…

Treatment Trains



DPR Demonstration: A Flexible Testbed



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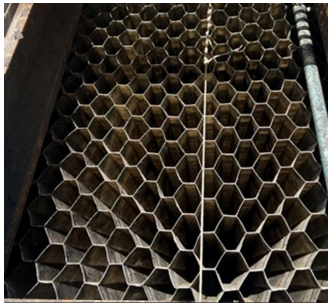

Pre-Treatment Approaches at SVCW

Biological Double-Efficiency Process (BDP) Pilot

- Suspended growth
- Nitrogen removal
- Solids removal

Goal: Optimization of simultaneous nitrification/denitrification (SND)

- Flow rates/retention time
- Dissolved oxygen
- Carbon source

Backup Option: Nitrification Trickling Filter (NTF) and Biological active filtration (BAF) denitrification

- Attached growth
- Confirmed complete nitrification and denitrification for small batches

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Pre-Treatment Approaches at SVCW

- Cloth Media Filter (CMF) Pilot
  - Solids removal from raw wastewater
  - Data snapshot of CMF performance:

	Min TSS (mg/L)	Max TSS (mg/L)	Avg TSS (mg/L)
Influent	96	399	182
Effluent	27	82	49

- Goal: Additional removal of solids from BDP effluent prior to feeding the DPR

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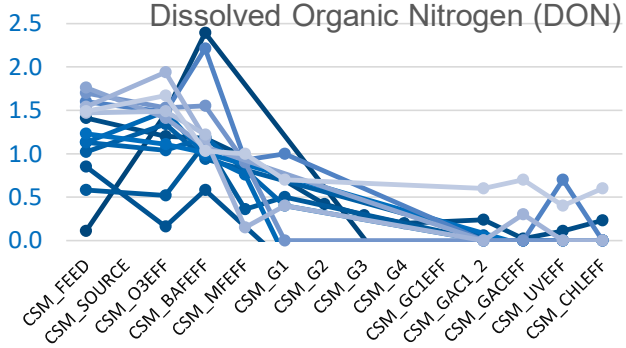
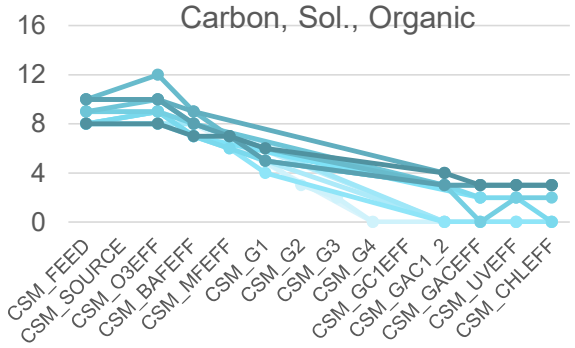
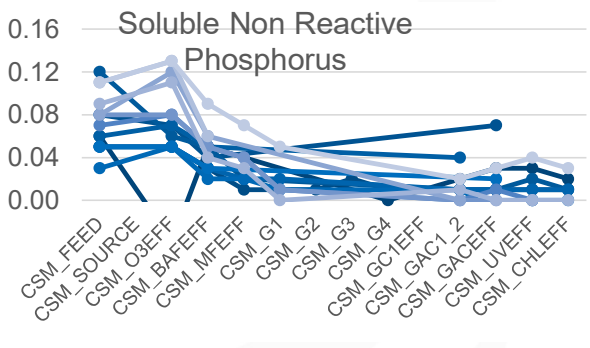
Upcoming and On-going Research

Organics Removal

- Tracking organics (TOC, DON, and DOP) along varying treatment trains:
  - Main pathway
  - Alternative pathway
- Organics Removal:
  - BAF optimization
    - Testing of residual adsorption on BAF media
  - Coagulation dose/type
  - Ozone to TOC ratio







Adsorption and UV/AOP

- New treatment pathway!
  - Adsorption to UVAOP v. UVAOP to adsorption
    - LP UV lamps (x3)
    - UV LED reactor
    - Breakthrough time
- Other variables:
  - Coagulation dose/type
  - Ozone to TOC ratio