Removing Short- and Long-Chain Per- and Polyfluoroalkyl Substances from Landfill Leachate: Comparing Two Pilot Studies

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SAINT LOUIS COUNTY ENVIRONMENTAL SERVICES
BETTER WASTE SOLUTIONS
Meeting Your Waste Material Needs

NTS Environmental Science & Engineering

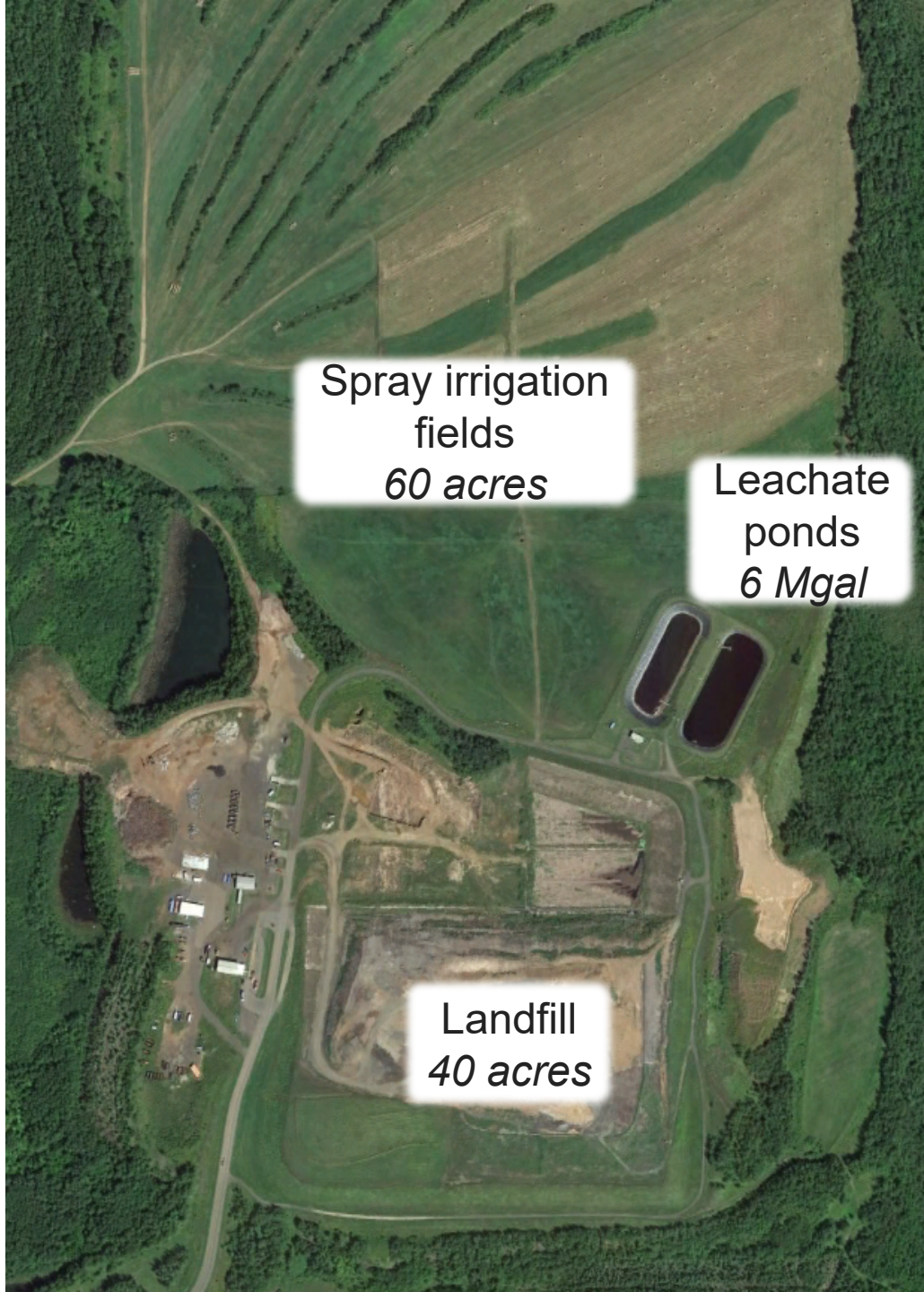
Stantec

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Acknowledgments

Background

- Publicly-owned Municipal Solid Waste Landfill
  - RCRA Subtitle D
  - Lined with leachate collection system
- Rural Northern Minnesota Location
  - 60 miles to POTW
- Current leachate treatment
  - Aerated lagoons
  - Spray irrigation
  - No surface water discharge
  - Groundwater monitoring network
- Regulatory drivers changing treatment requirements for continued land application



Goal

1. Develop an advanced PFAS treatment system for the landfill to continue to spray irrigate
2. Improve secondary contaminant removals

Raw Leachate

Advanced Treatment

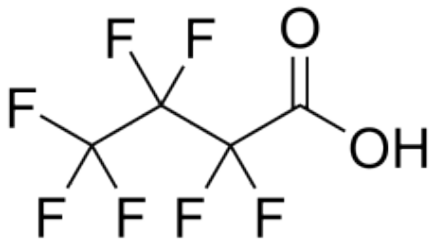
Spray Irrigation

Treated Leachate

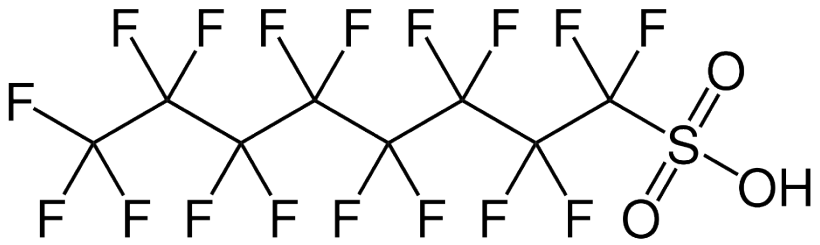
PFAS Primer

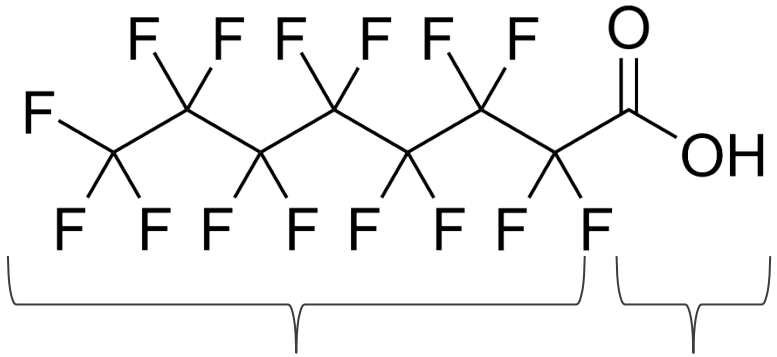
- Per- and polyfluoroalkyl substances (PFAS)
- Large chemical family - thousands of compounds
- Unique Properties
  - Thermal stability
  - Chemical stability
  - Stain repellency
  - Surfactant behavior
- Challenges
  - Toxic at ppt concentrations
  - Bioaccumulating
  - Difficult to destroy

Short-chain <6 C (PFBA)



Long-chain >6 C (PFOS)





PFAS in Landfill Leachate

MINNESOTA POLLUTION CONTROL AGENCY

Contaminants of Concern

- Leachate is a complex waste stream
- PFAS is the primary driver, but it is not alone
- Target effluent concentrations derived from:
  - Drinking water health guidance
  - Land application guidance

Parameter	Target Effluent Concentration	Pilot Raw Leachate
Boron (mg / L)	0.5	11
Manganese	0.1	0.9
Nitrite	1.0	0.08
Nitrate	10	< 0.1
Total Nitrogen	150	208
PFBA (ng / L)	7,000	2300
PFBS	100	1200
PFHxA	200	4700
PFHxS	9	630
PFOA	4	2200
PFOS	4	160
PFNA	10	89
HFPO-DA (GenX)	10	< 1.6

Red above target
Green at or below target

Need for Multiple Treatment Methods

Treatment Method[1]	Total Organic Carbon	Nitrogen	Manganese	PFAS	Boron
Constructed Wetland					
Reverse Osmosis					
Advanced Oxidation Processes (AOP)					
Conventional Activated Sludge					
Granular Activated Carbon (GAC)					
Ion Exchange (IX) for PFAS					
Foam Fractionation					
IX for Boron					
Sand/Mixed Media Filtration					

Poor

Varied

Good

[1] Treatment list is non-exhaustive and subjective to wastewater stream

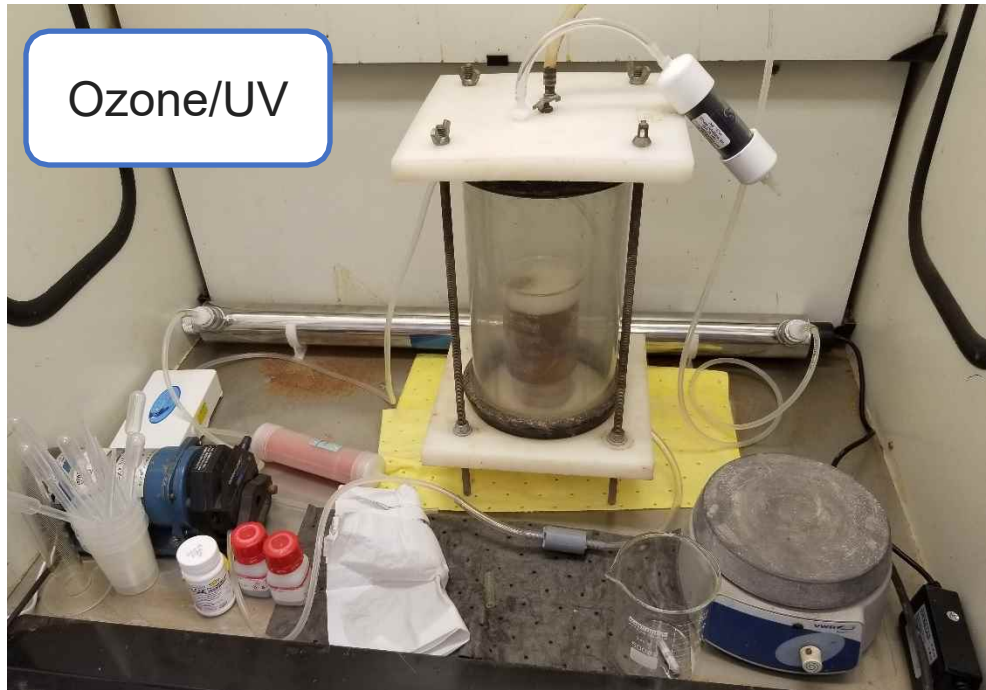
Project Timeline

- 2018 – literature review of alternative techniques for PFAS treatment
- 2019-2021 – bench scale testing
- **2022 – demonstration scale hybrid wetland (Pilot #1)**
- **2023 – demonstration scale reverse osmosis (Pilot #2)**
- 2024-2026 – design and build full scale system

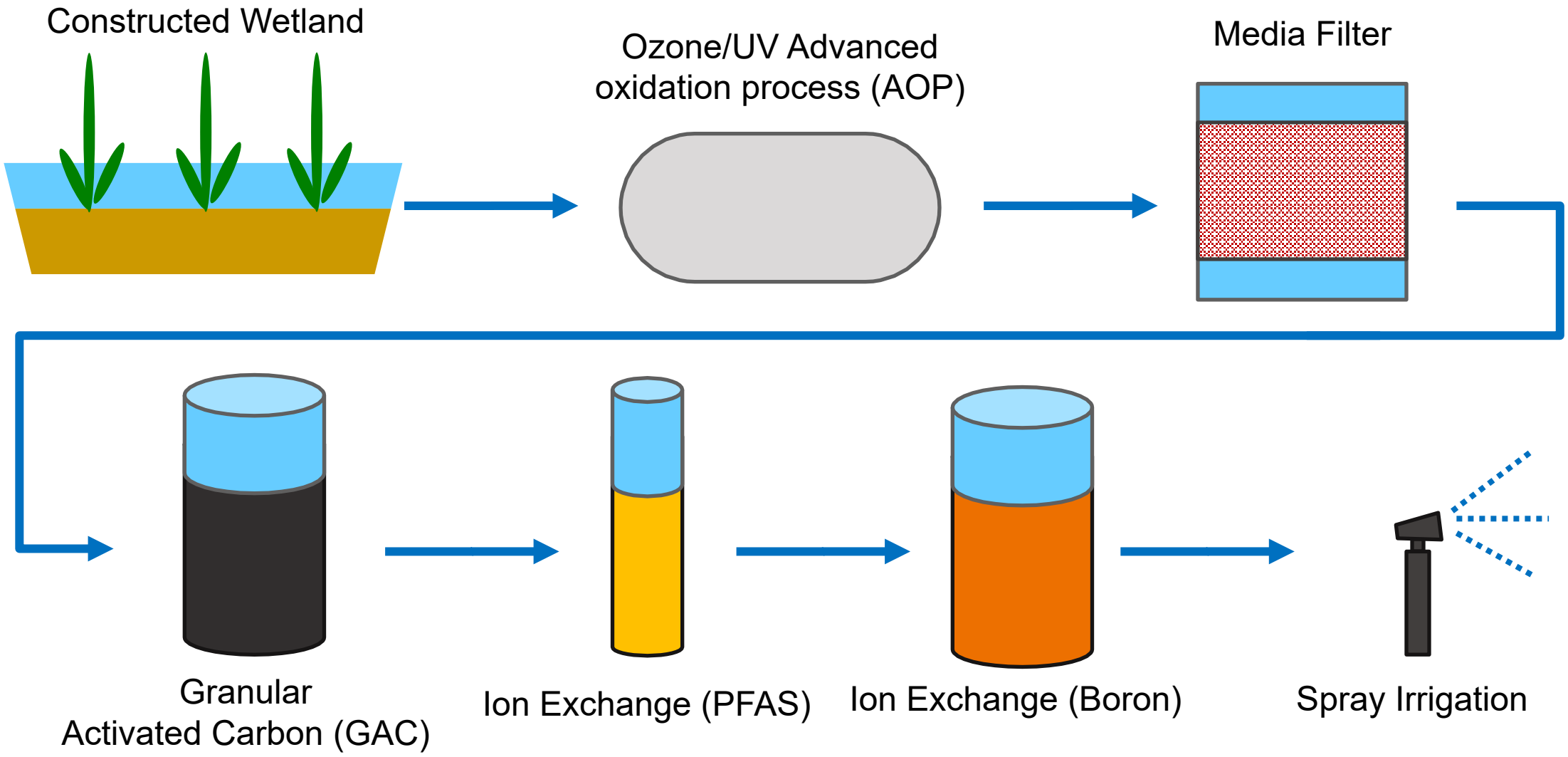
Bench Testing

- Constructed Wetland
- Advanced Oxidation
- Reverse Osmosis
- Media and Surface Filtration
- Granular activated carbon accelerated column test
- Chemical coagulation/flocculation
- Superoxide
- Organoclay
- Foam fractionation

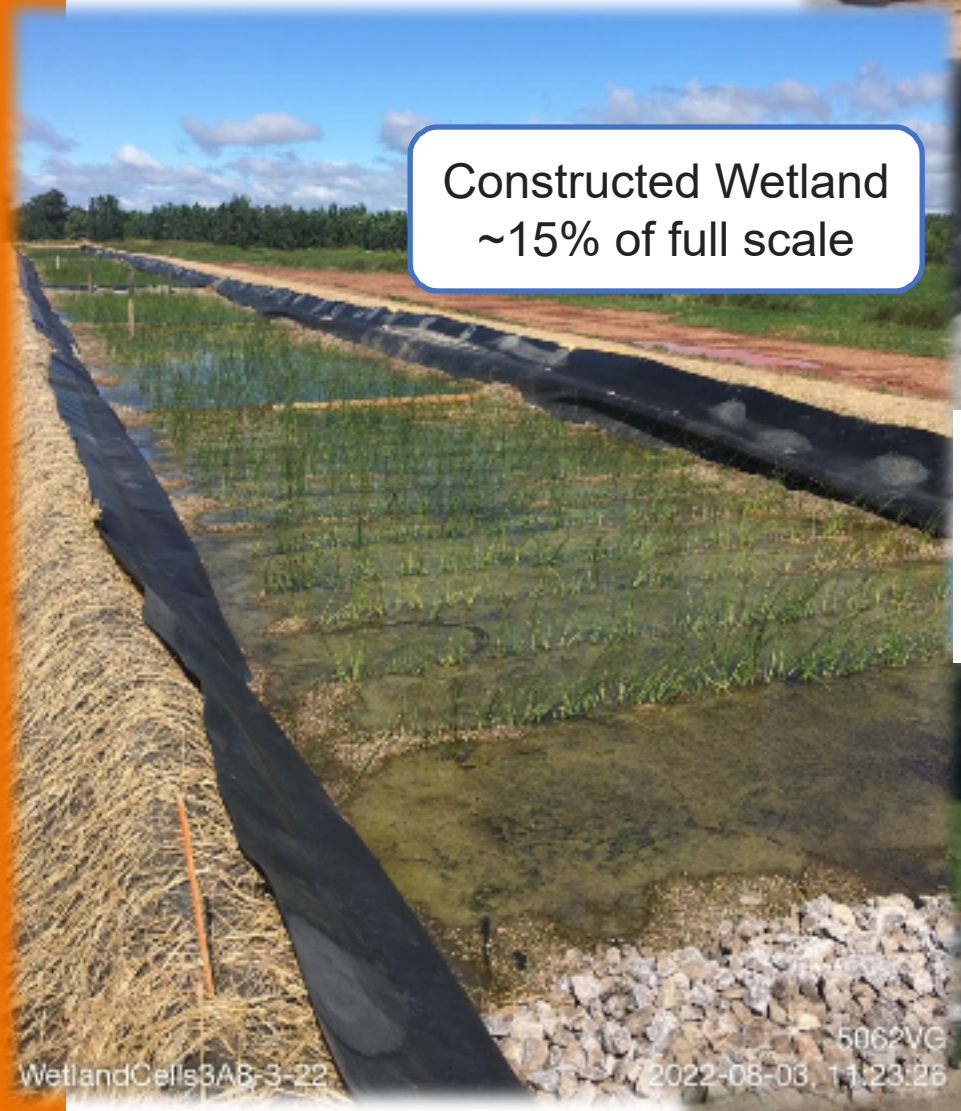
Continue to Demonstration Scale



Proposed Treatment Train No. 1



Pilot No. 1



Constructed Wetland
~15% of full scale

Average Removals

- Nitrogen ~30-60%
- Total Organic Carbon (TOC) ~25-40%
- PFAS ~0-20%

Pilot No. 1

Hybrid Equipment ~4% of full scale

Average Removals

- PFAS >98%
- TOC ~10-90%
- Boron >99%
- Manganese ~95%

Wetland Effluent

Final Effluent

Pilot No. 1

Ozone Venturi

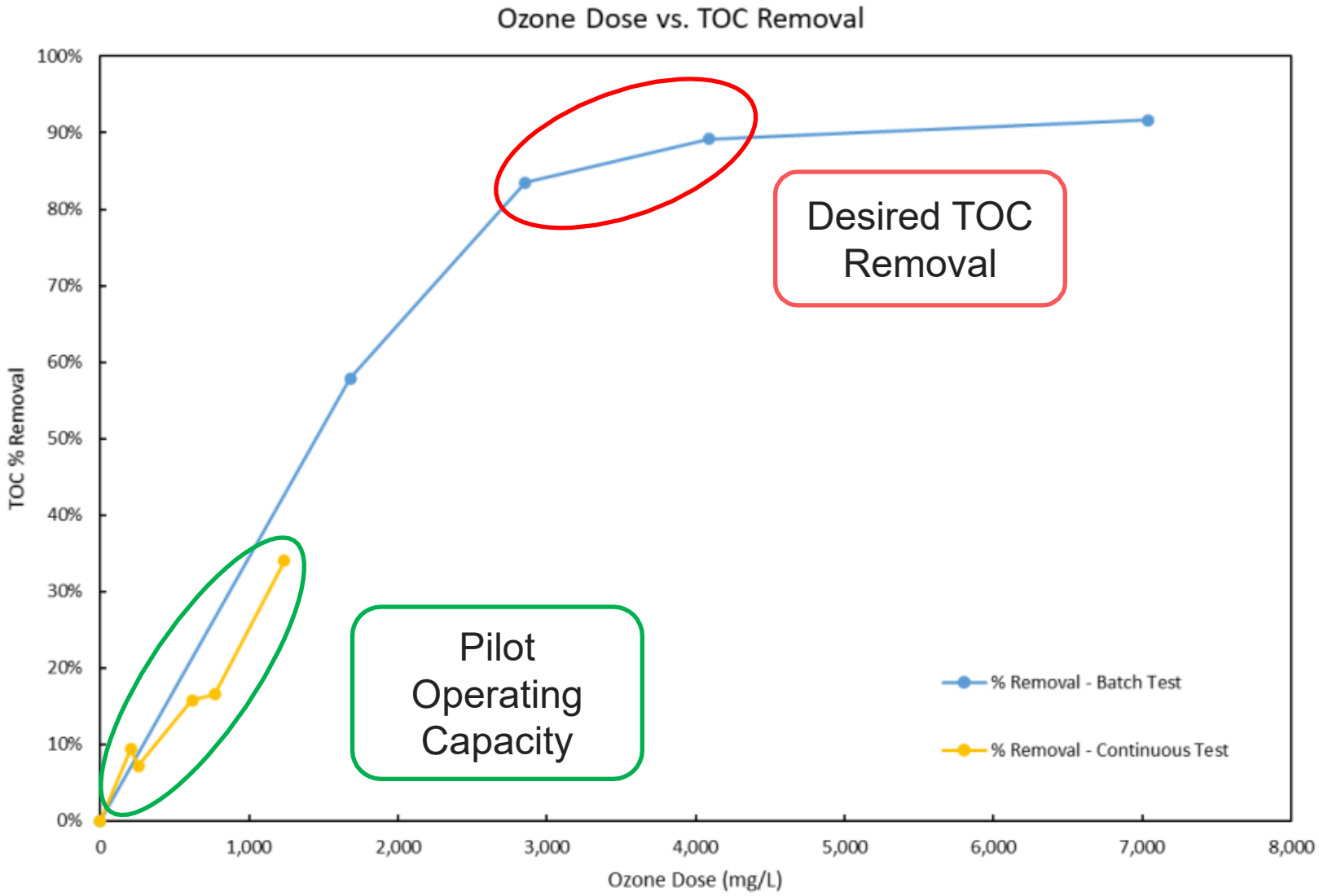
UV Lamp

Ozone Generator

Ozone Contact Tank

TOC Removal

- TOC removal important to avoid rapid fouling of GAC and IX
- TOC proved highly recalcitrant
- Required ozone dose greater than initially anticipated



Pilot No. 1


Media Filters


GAC & Ion Exchange Columns

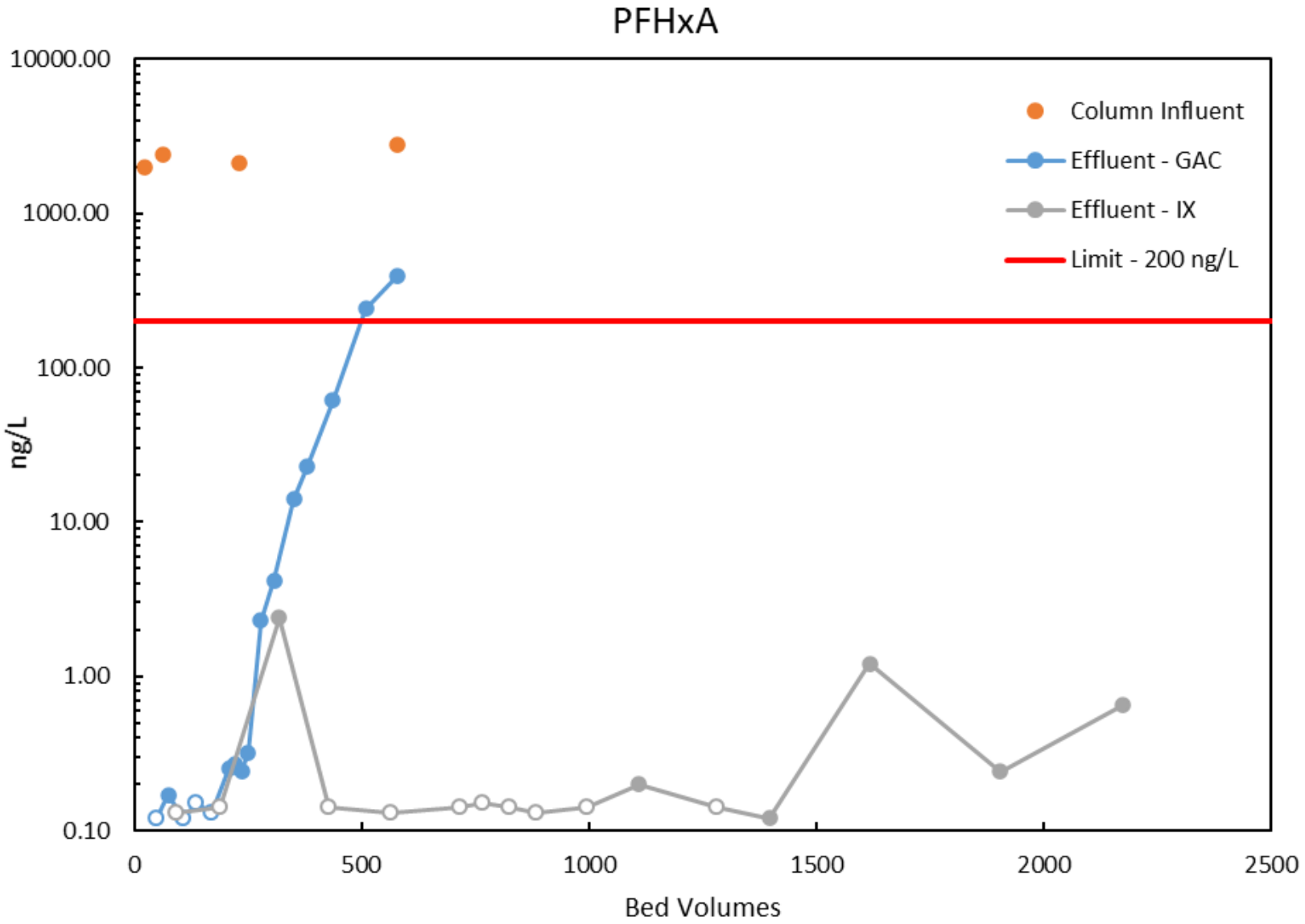

GAC: Calgon F400


PFAS Resin: ResinTech SIR-110-HP

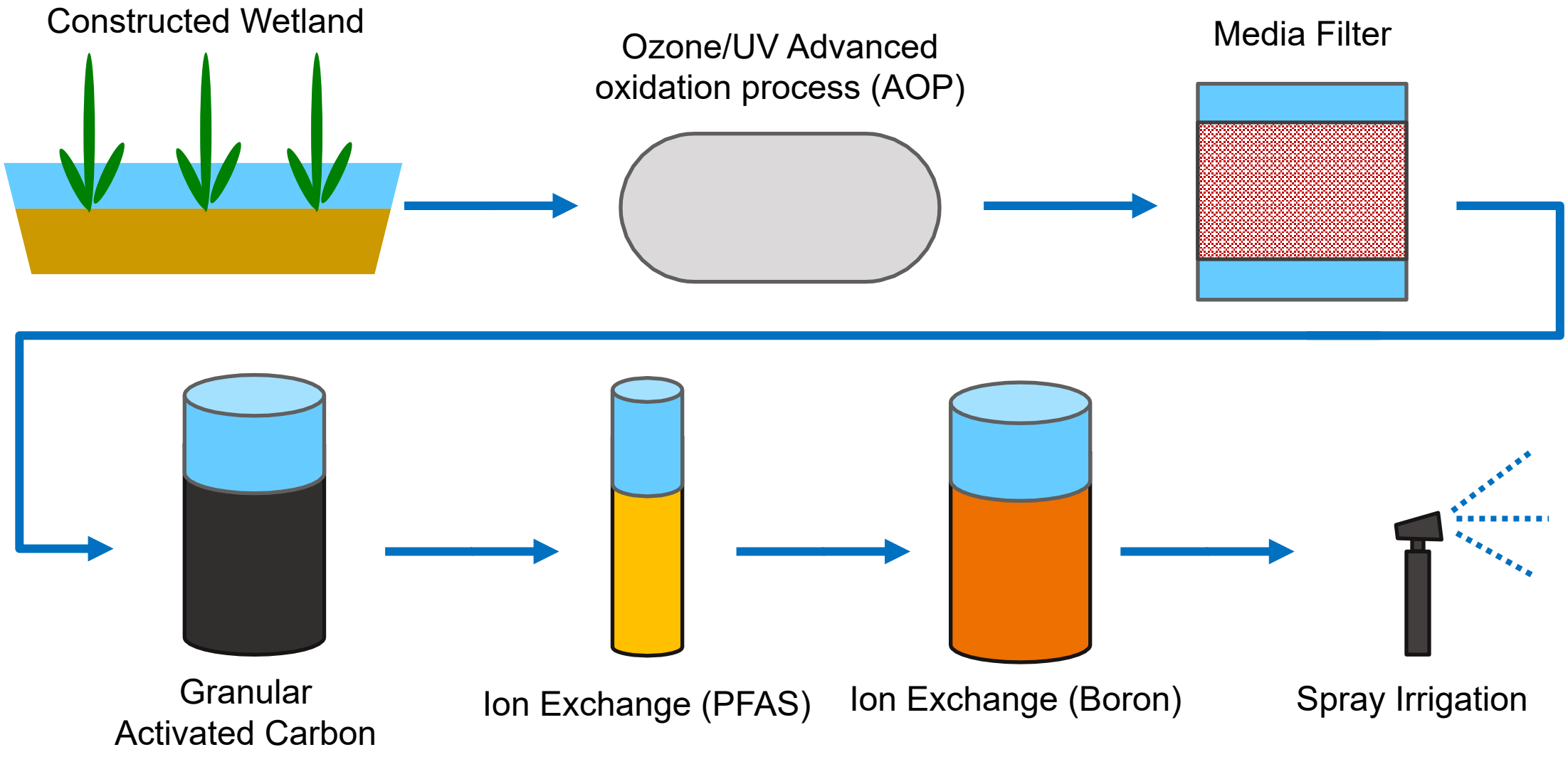

Boron Resin: ResinTech SIR-150

PFAS Breakthrough

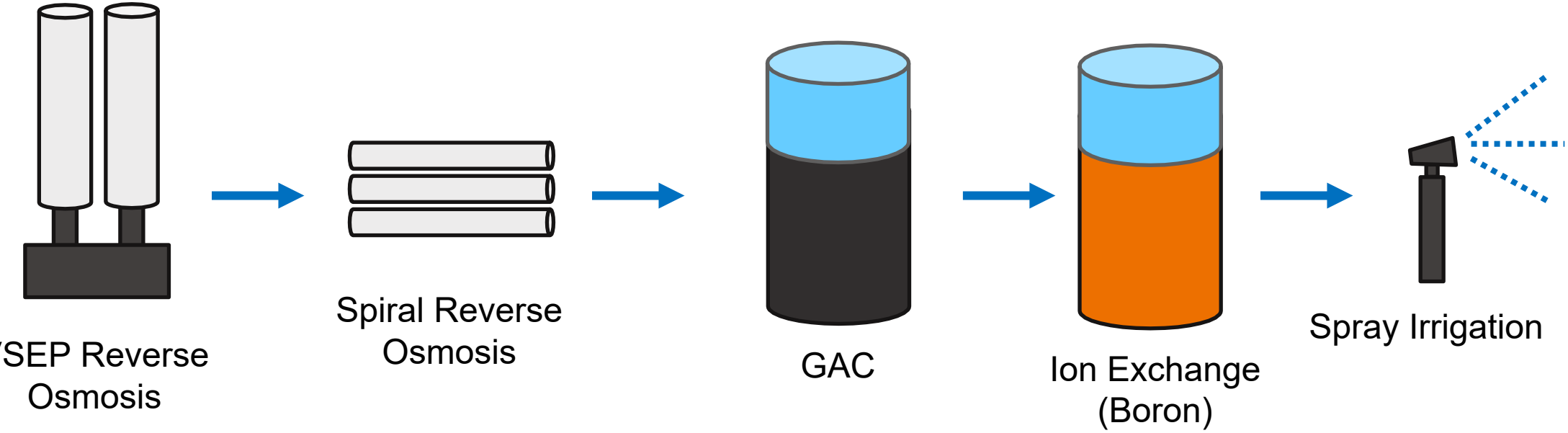
- Able to meet all targets after GAC at startup
- GAC life likely on order of weeks rather than months
- PFHxA breakthrough exceeded limit through GAC in ~1 week



Pilot No. 1 Challenges



Proposed Treatment Train No. 2



VSEP (Vibratory shear-enhanced process)

Pilot No. 2

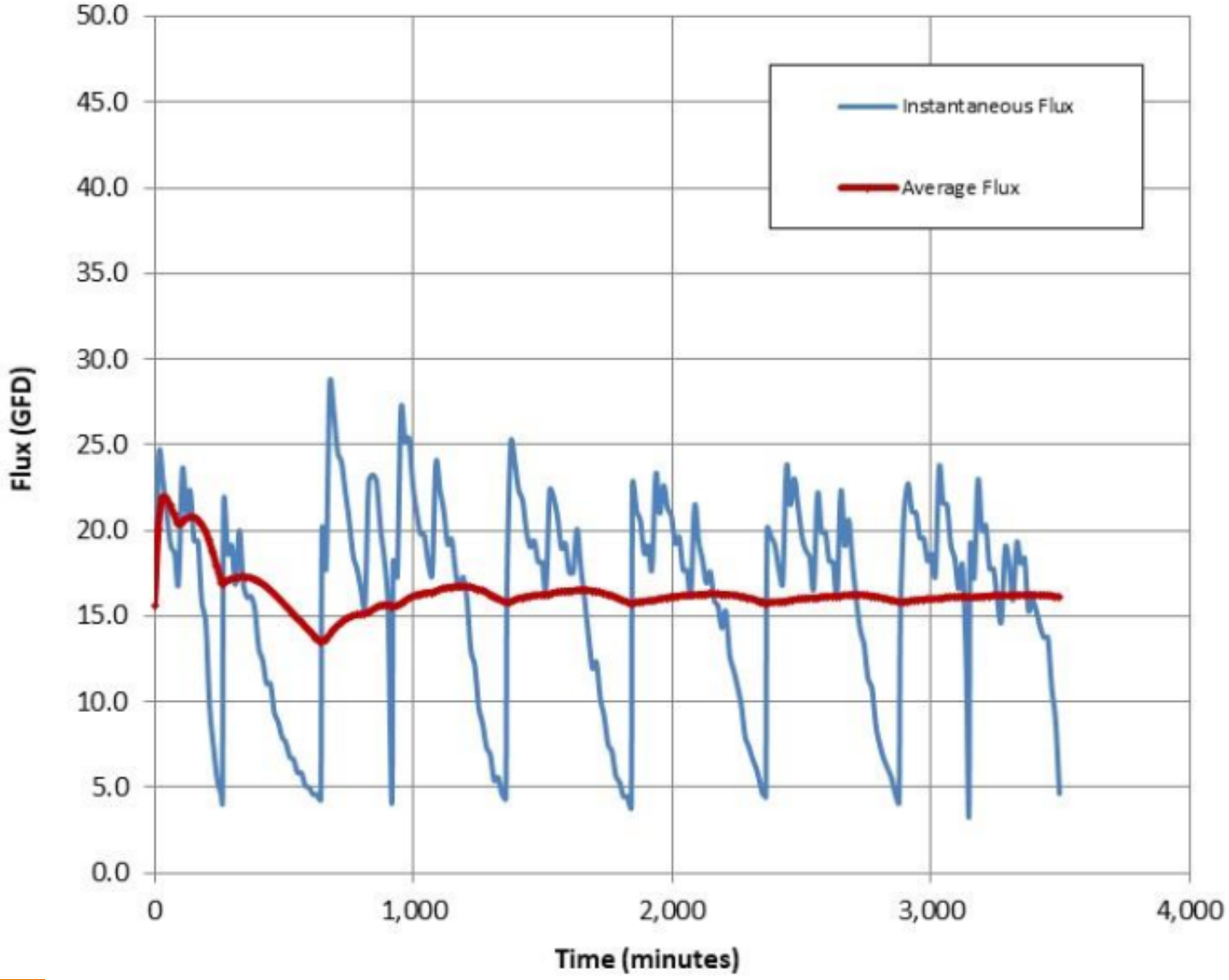
VSEP
membrane unit
~1% of full scale

Average Removals

- PFAS >99%
- TOC >99%
- Nitrogen ~97%
- Boron >99%
- Manganese >99%

Spiral
membrane unit
~5% of full scale

Pilot No. 2 Operation



VSEP membranes showed excellent average flux – 16 GFD (20°C)

Recovery 80-90%

Time between chemical cleaning:

- Raw: 0.25 days
- With antiscalant: 1-4 days
- pH Adjusted (6.5): ~3 days

PFAS Removal Comparison

Red above target
Green at or below target

- Both series removed PFAS of interest to below target concentrations
- Pilot No. 1 removal non-steady state
- Pilot No. 2 removal approximately steady-state

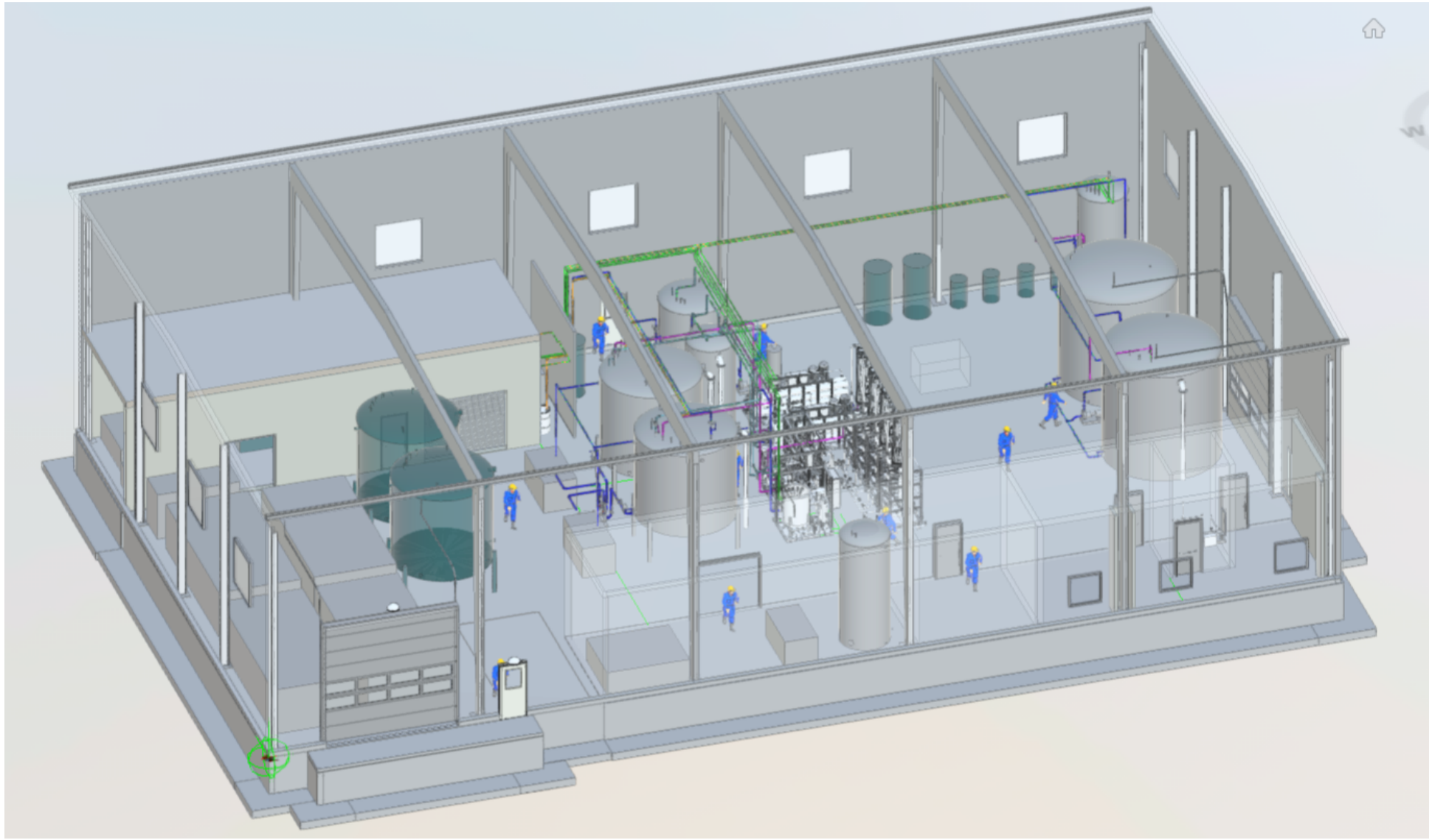
Parameter	Target Effluent Concentration	Pilot No. 1*	Pilot No. 2
PFBA (ng / L)	7,000	1	6
PFBS	100	< 0.15	< 0.3
PFHxA	200	< 0.49	< 0.1
PFHxS	9	< 0.09	< 0.2
PFOA	4	< 0.49	0.4
PFOS	4	< 0.19	< 0.2
PFNA	10	< 0.2	< 0.2
HFPO-DA	10	< 0.1	< 0.7

*Lowest final effluent; media life for absorptive processes untested

Pilot Comparison

	Pros	Cons
Pilot No. 1	• Met target limits for PFAS at times	• Peak performance difficult to maintain • Large ozone dose required • Complex operations • Seasonal aspect of pretreatment • Large footprint
Pilot No. 2	• Ability to continuously meet removal targets • Additional treatment can easily be added as needed • Operational flexibility	• High energy use • Concentrate stream management

Moving Forward: Full Scale Design




Questions?
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Thank You!