In Situ Treatment of PFAS using Sonolysis within a Horizontal Treatment Well

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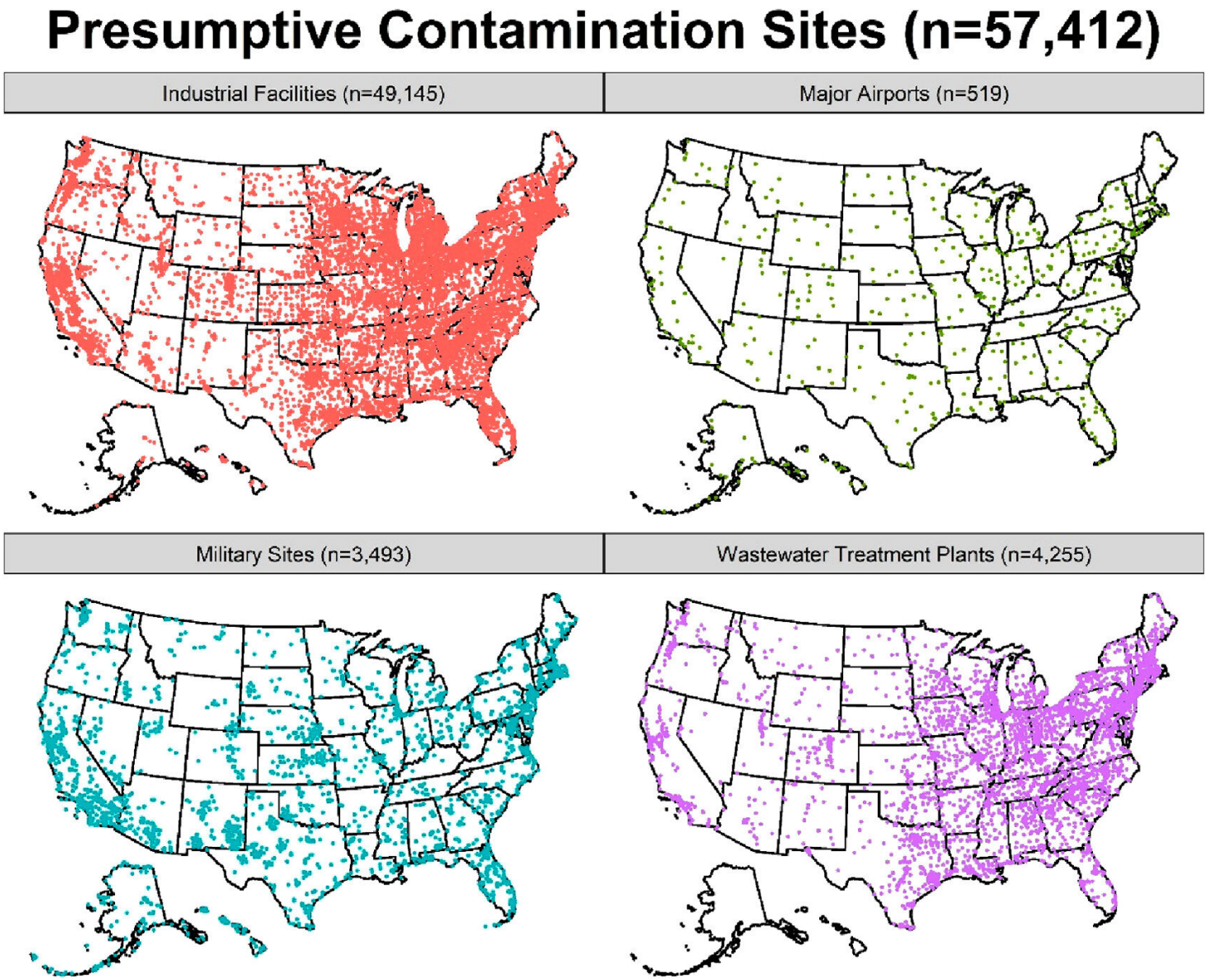
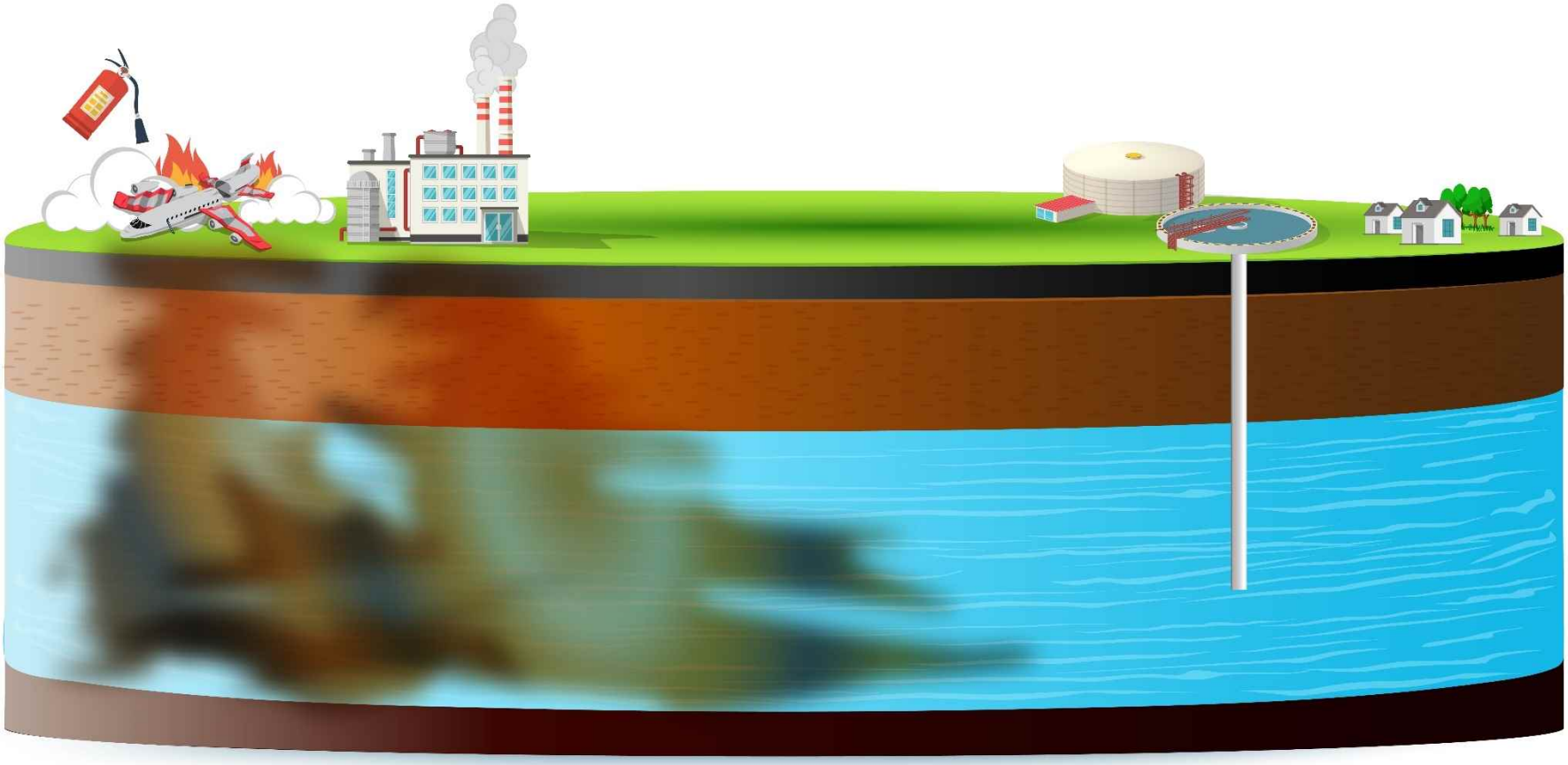
OCTOBER 12, 2022

Scientists say PFAS contamination should be presumed at over 57,000 US sites

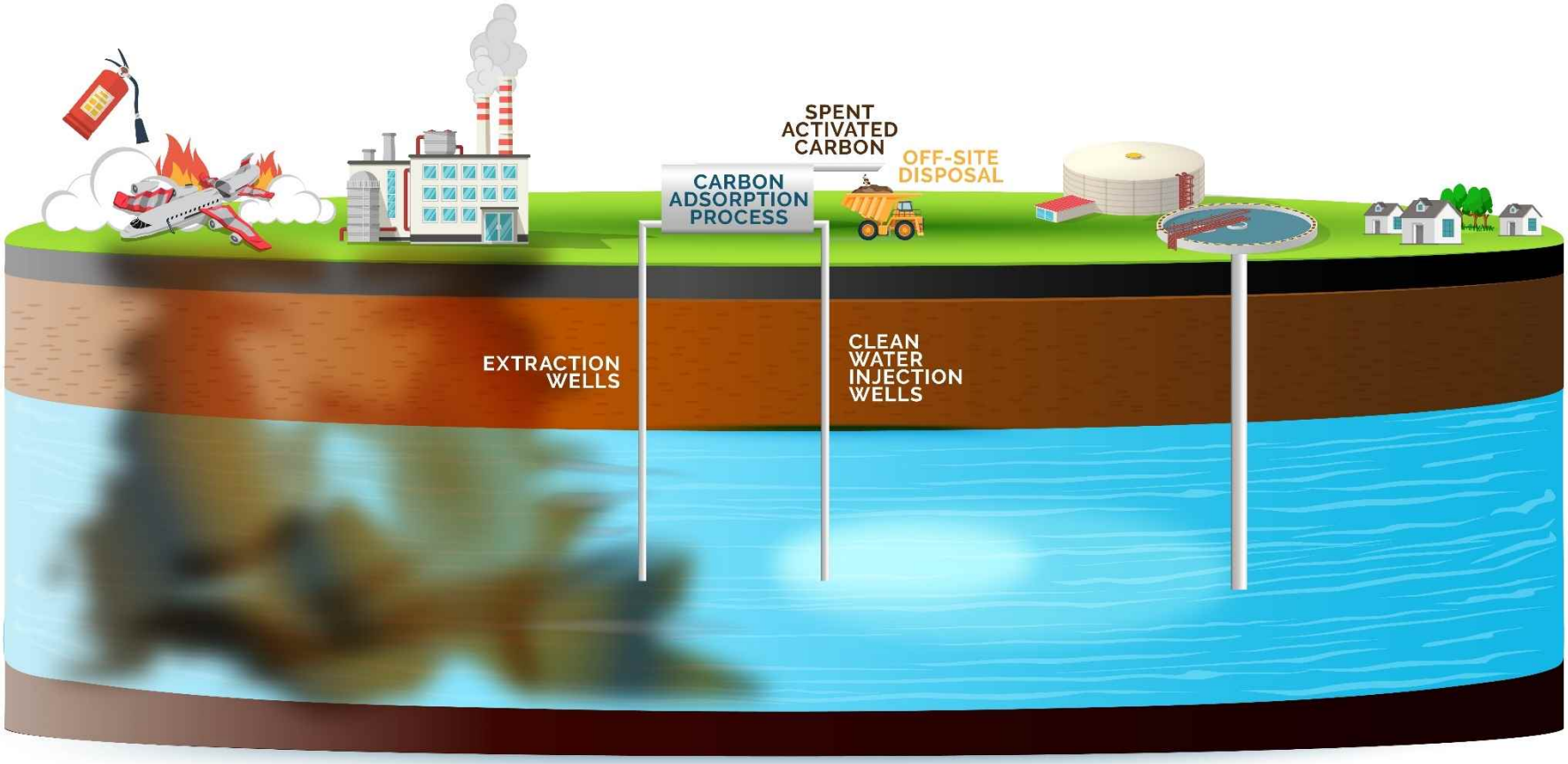
by Green Science Policy Institute



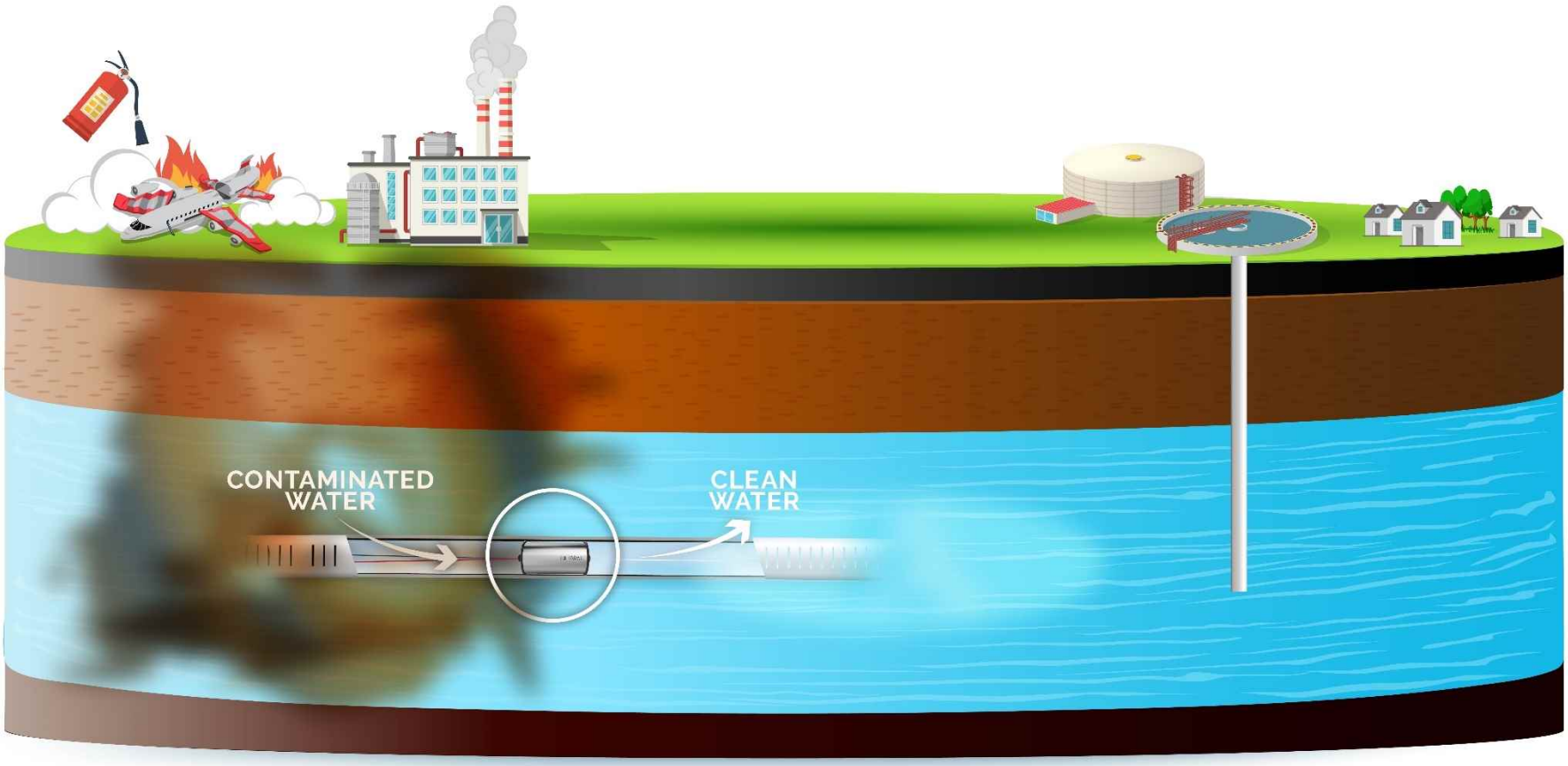
Groundwater Contamination



Pump-and-Treat with Granular Activated Carbon (GAC)

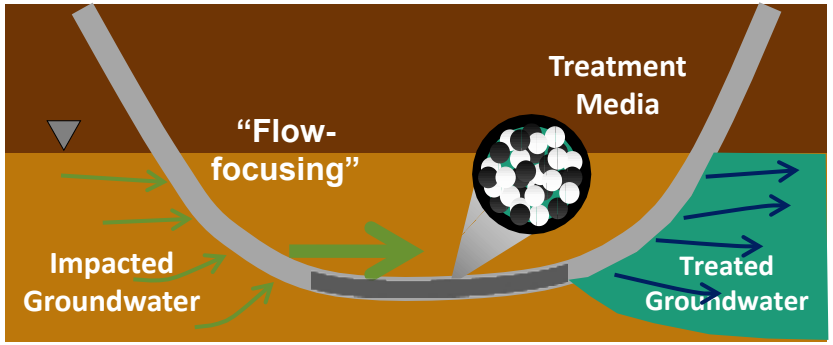


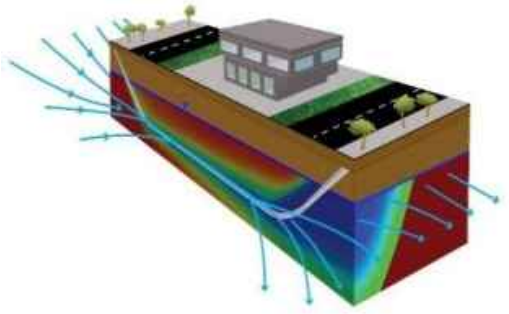
In Situ Treatment



HRX Well® Description

The HRX Well* is a large-diameter horizontal well installed along the groundwater flowpath that is filled with reactive or other treatment media





- Passive in-situ treatment
- Many solid-phase reactive media options
- Efficient use of reactive media
- Treatment train approach possible
- Not limited to high-permeability aquifers
- Can be applied in relatively deep settings
- Limited above-ground footprint
- Minimal O&M
- No ongoing energy requirements
- Pumping can enhance treatment zone size

**Patent US20120261125A1*

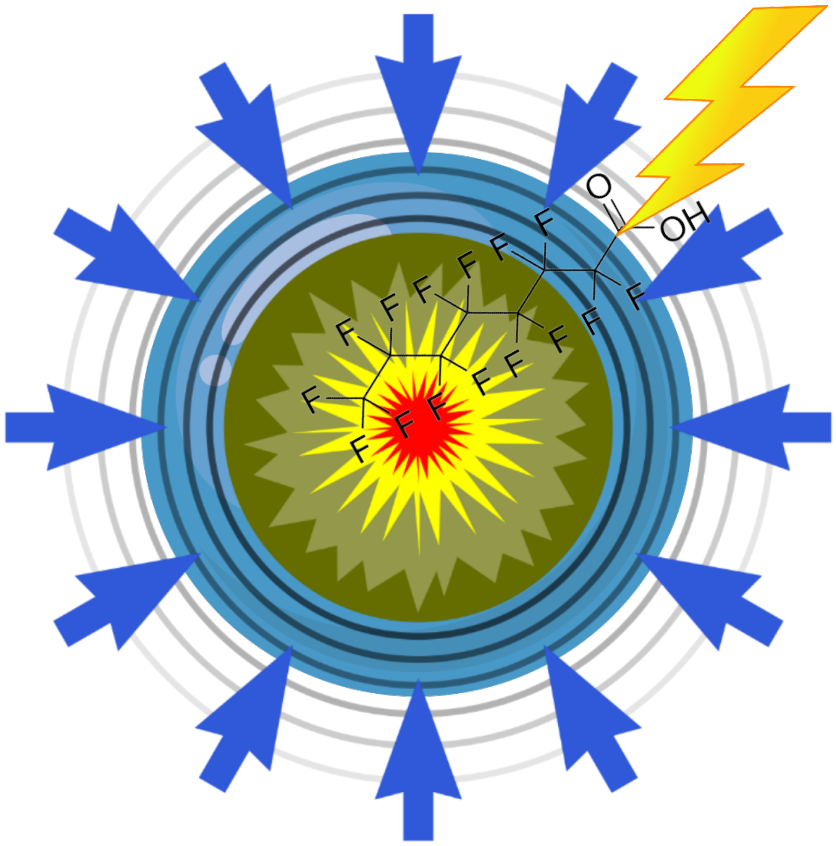
Sonolysis

Sound waves >19 kHz create cavities in liquids

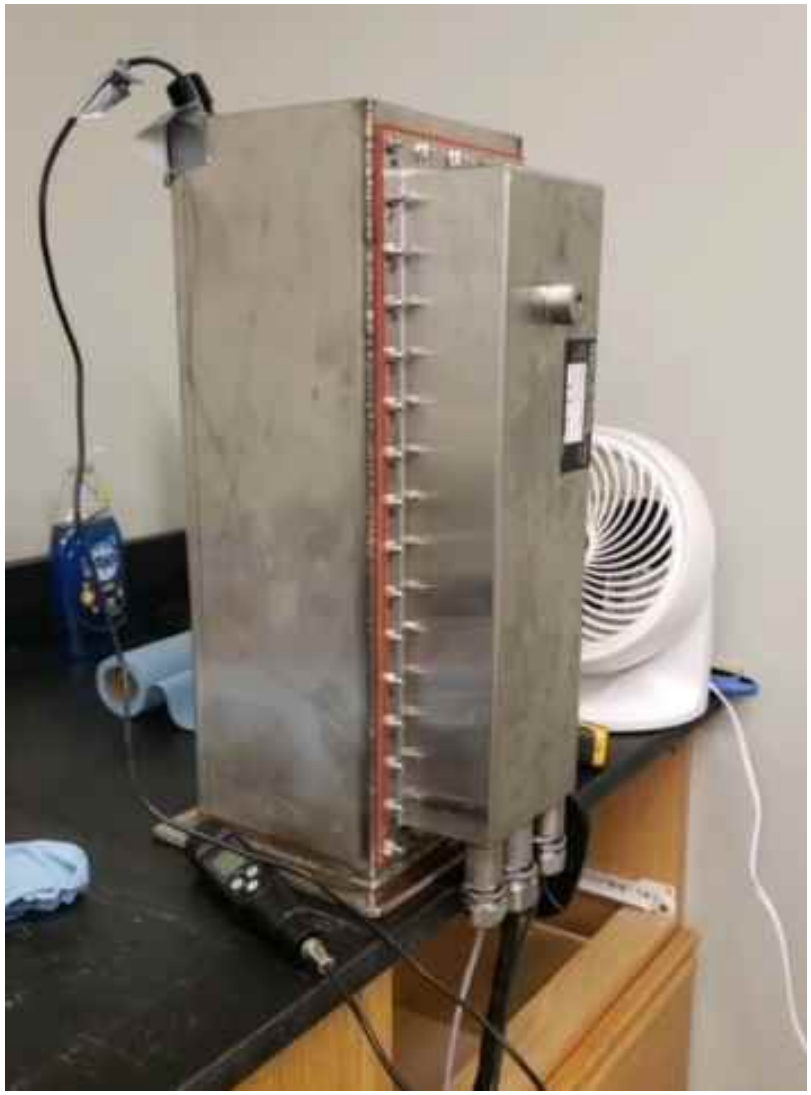
PFAS sorb to the cavity interface

Cavities collapse at maximum radius creating extreme localized conditions

- High heat (5000 °K)
- High pressure (1000 bar)

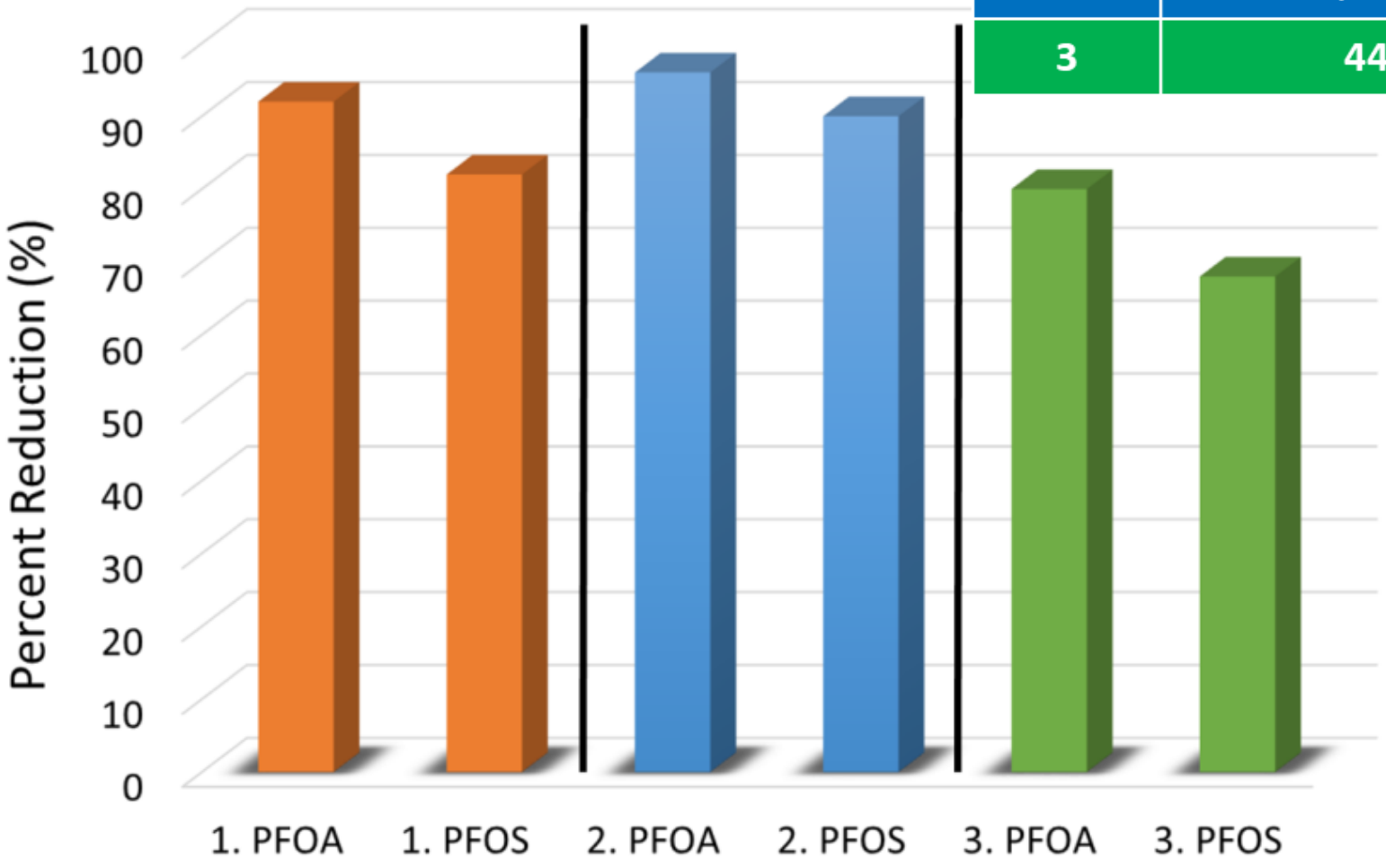


In situ reactor technology (InSRT)

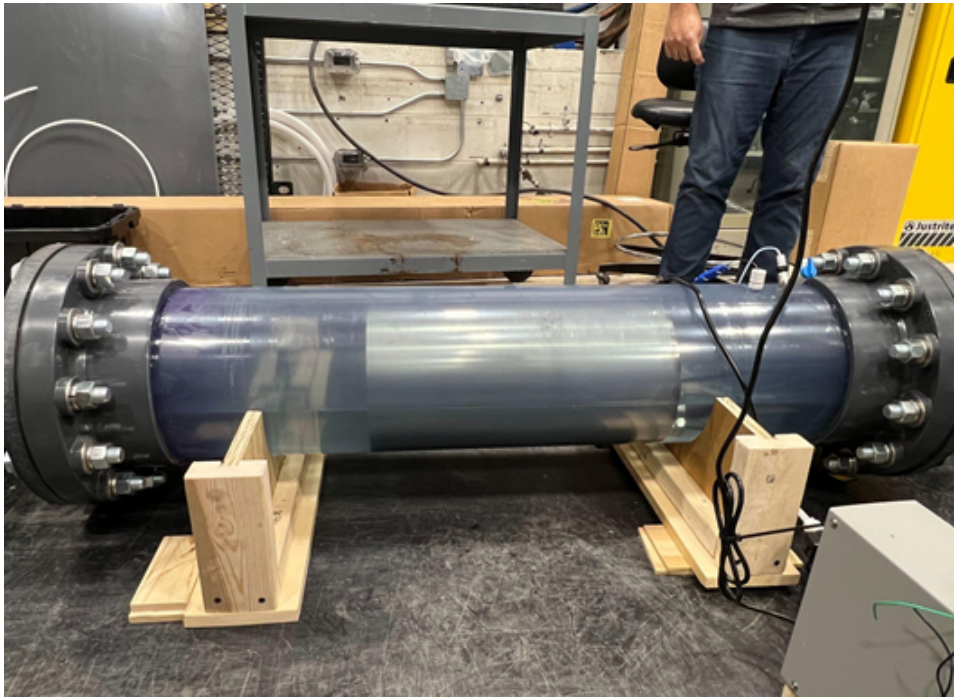


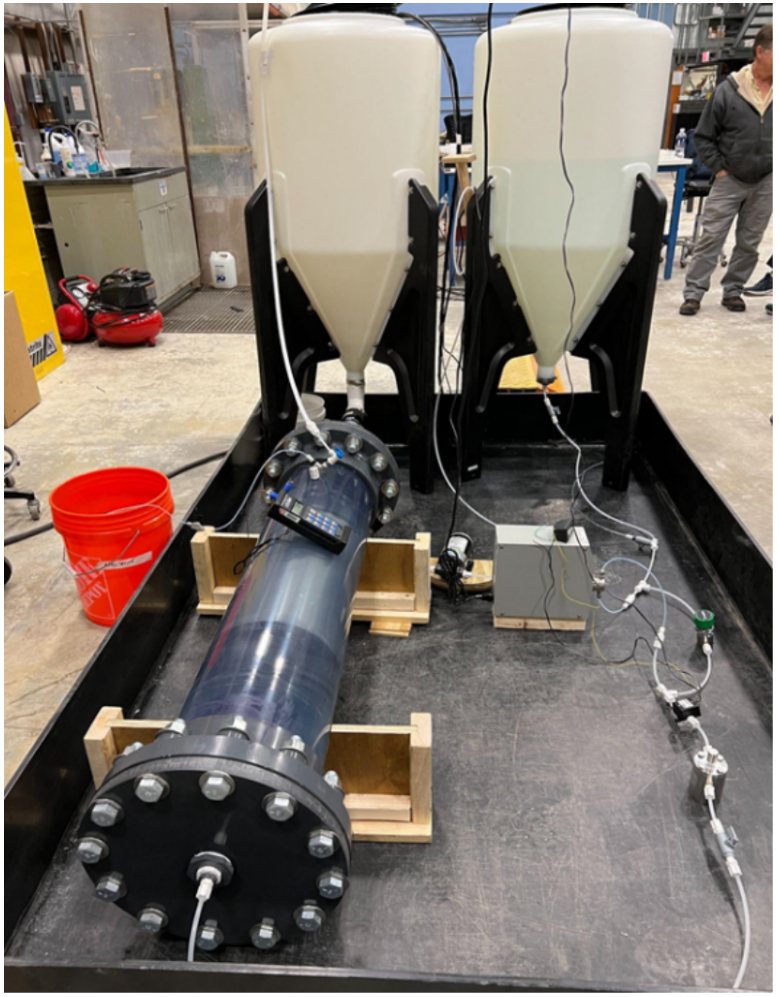
Laboratory Testing

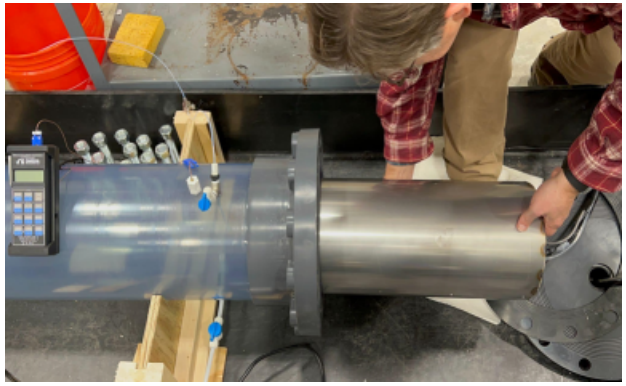
Site	PFOS Concentration (µg/L)
1	402
2	4,000
3	44

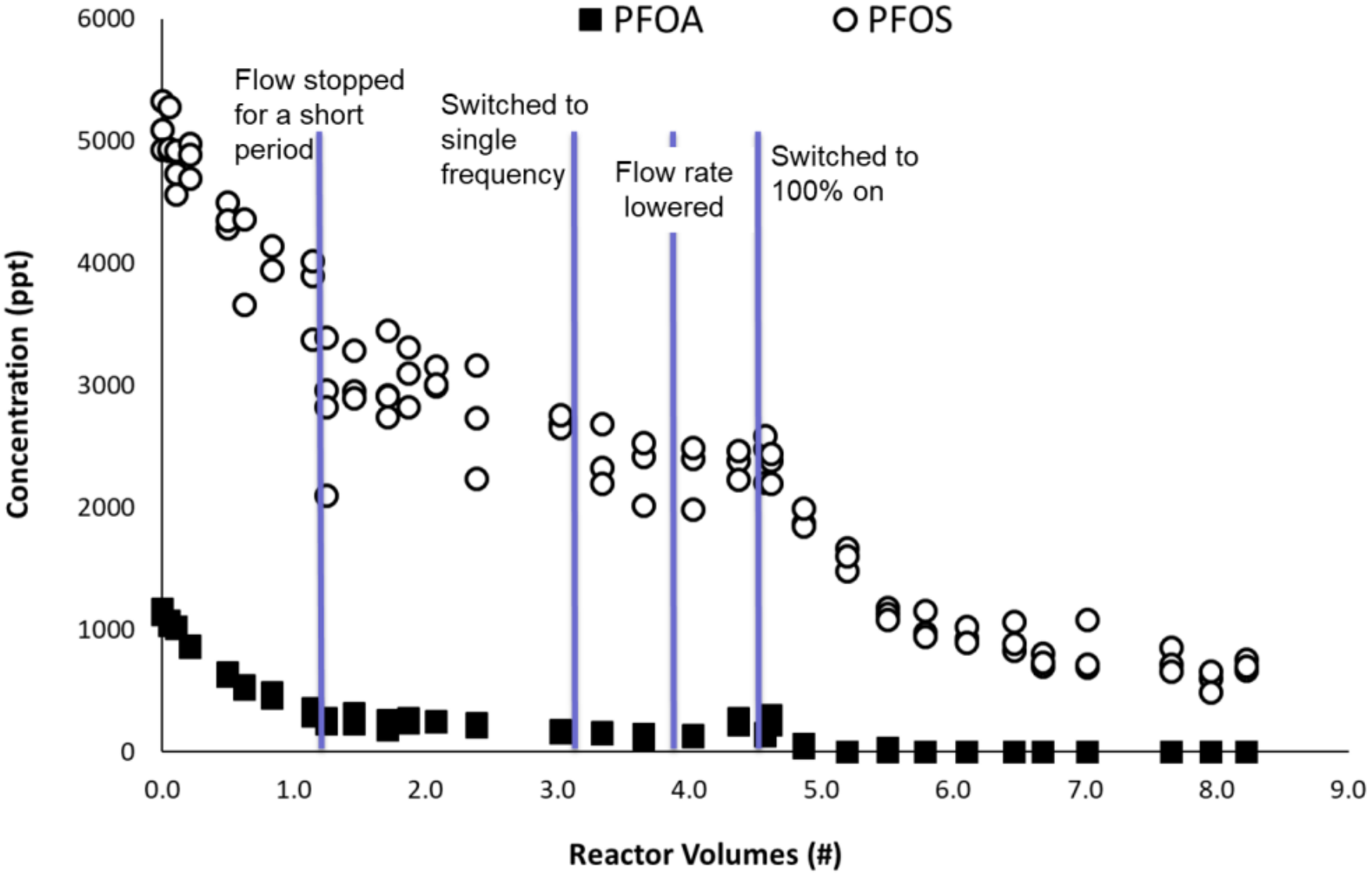


Pilot Testing







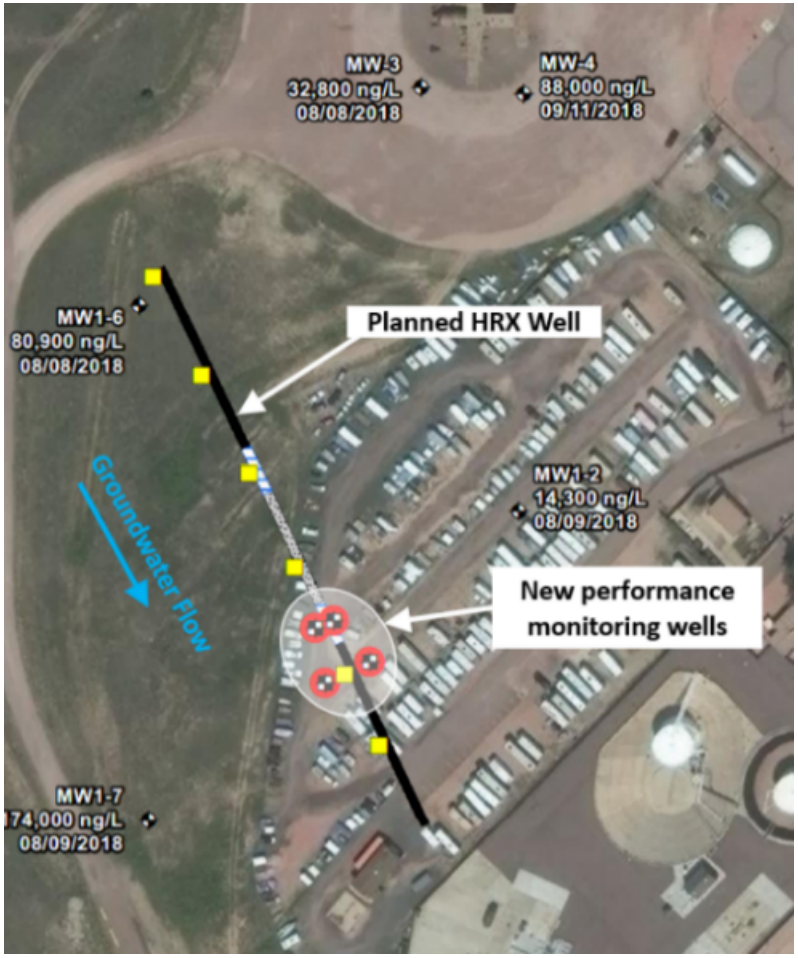


> 99% decrease in PFOA

86% decrease in PFOS

Field Demonstration

- Uses a horizontal well installed under separate contract
  - PFAS removal via GAC cartridges
- Test design allows both passive and active (i.e., pumping-enhanced) operation
- Well was installed in April 2021
  - Spring 2021: Well installation
  - Fall 2021- Spring 2023: Well passive operation using GAC
  - Fall 2023: InSRT demonstration



HRX Well at Peterson SFB

Treatability Test

Compound destruction rate and extent

Compound	Initial Conc (ng/L)	Final Conc (ng/L)	% Removal in 48-hr
6:2 FTS	1,239	Below detection	>99%
8:2 FTS	117	Below detection	>99%
PFBA	1,454	Below detection	>99%
PFBS	3.457	12	99.4%
PFHpA	657	Below detection	>99%
PFHpS	601	Below detection	>99%
PFHxA	5,646	Below detection	>99%
PFHxS-B	2,233	Below detection	>99%
PFHxS-L	9.399	Below detection	>99%
PFNA	123	Below detection	>99%
PFOA	1,142	38	96.7%
PFOS-B	10,559	60	99.4%
PFOS-L	35,345	195	99.4%
PFPeA	2,556	Below detection	>99%
PFPeS	2,625	Below detection	>99%

A: InSRT with plate removed being prepared for testing

B: GAC cartridge being removed

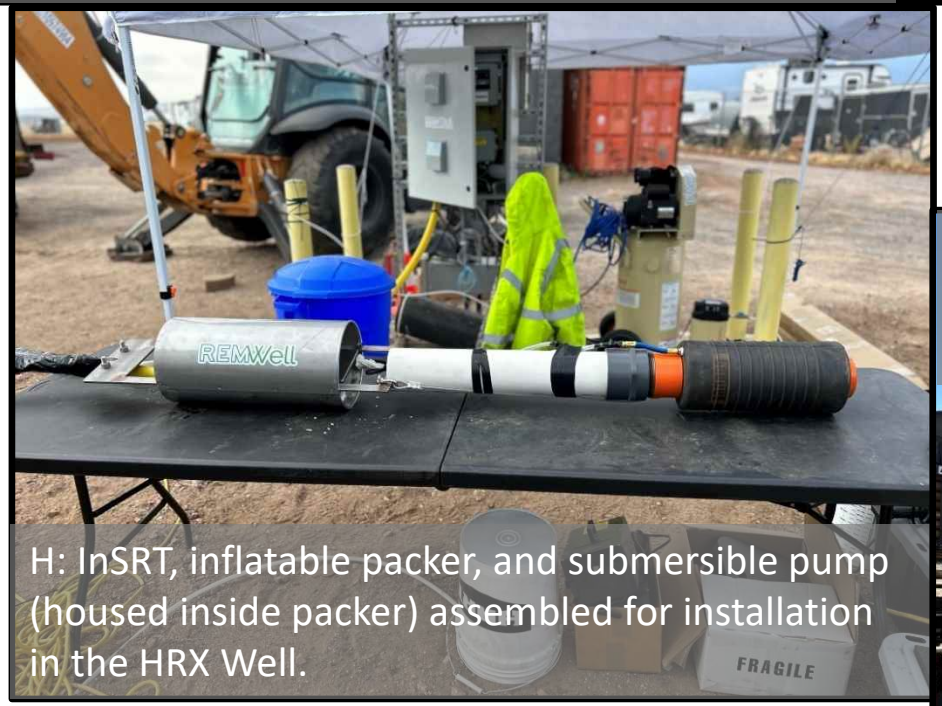
C: GAC cartridges temporarily removed

D: Air compressor and air dryer for supplying cooling air to the InSRT

E: GAC cartridge being re-installed

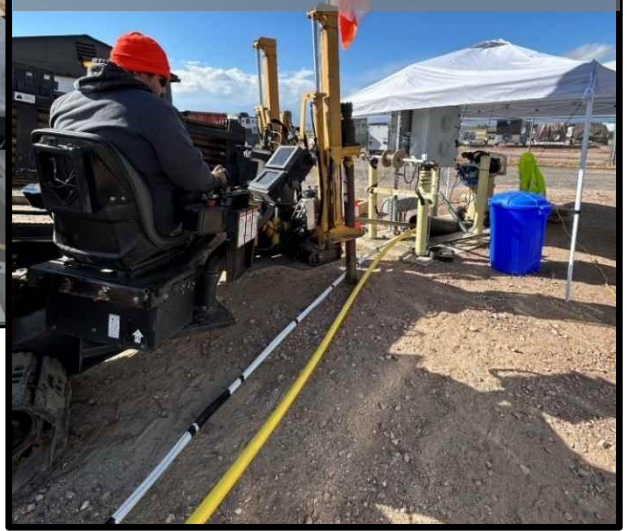
F: Custom-built pushing tool used to install InSRT

G: Control panel

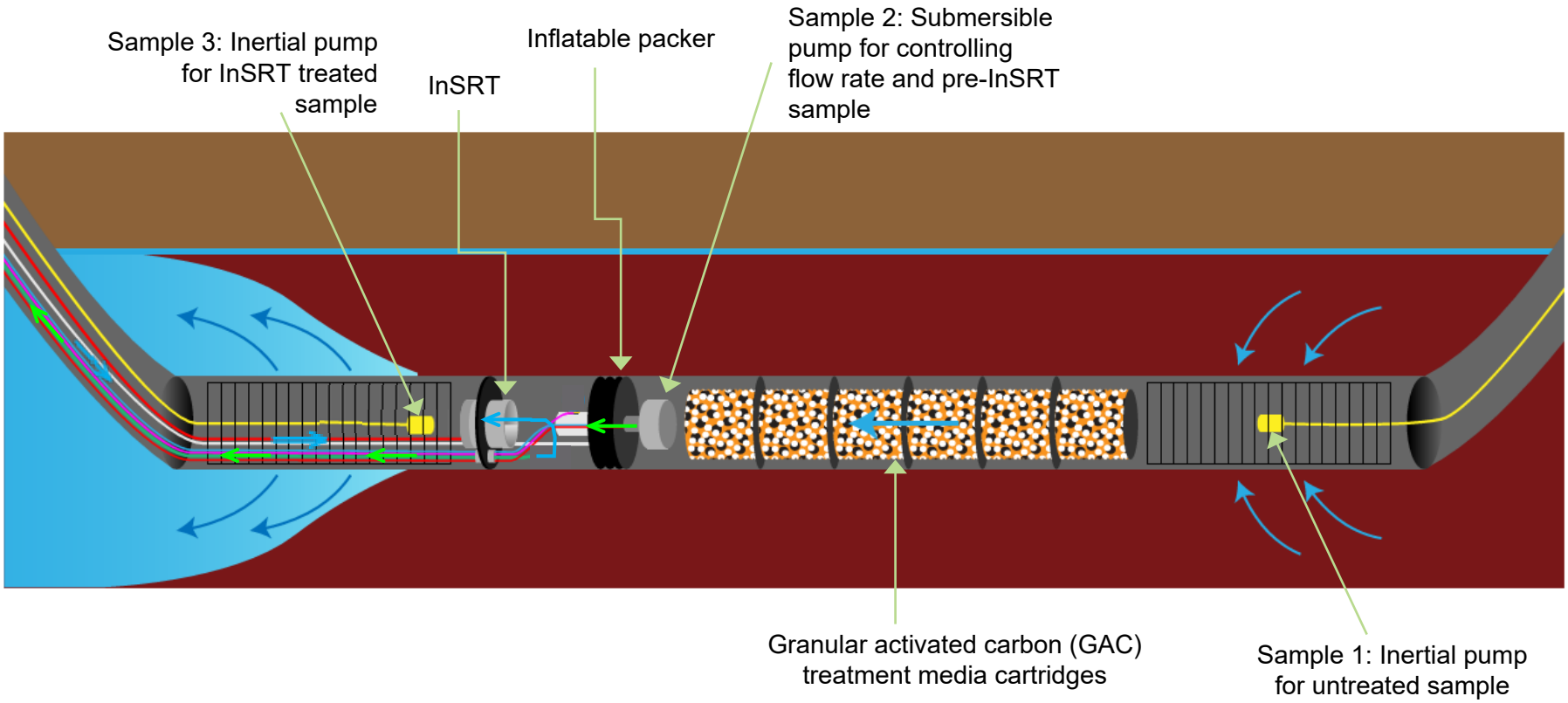


H: InSRT, inflatable packer, and submersible pump (housed inside packer) assembled for installation in the HRX Well.

I: Installation of InSRT and pumping system using directional drilling rig



View of Components



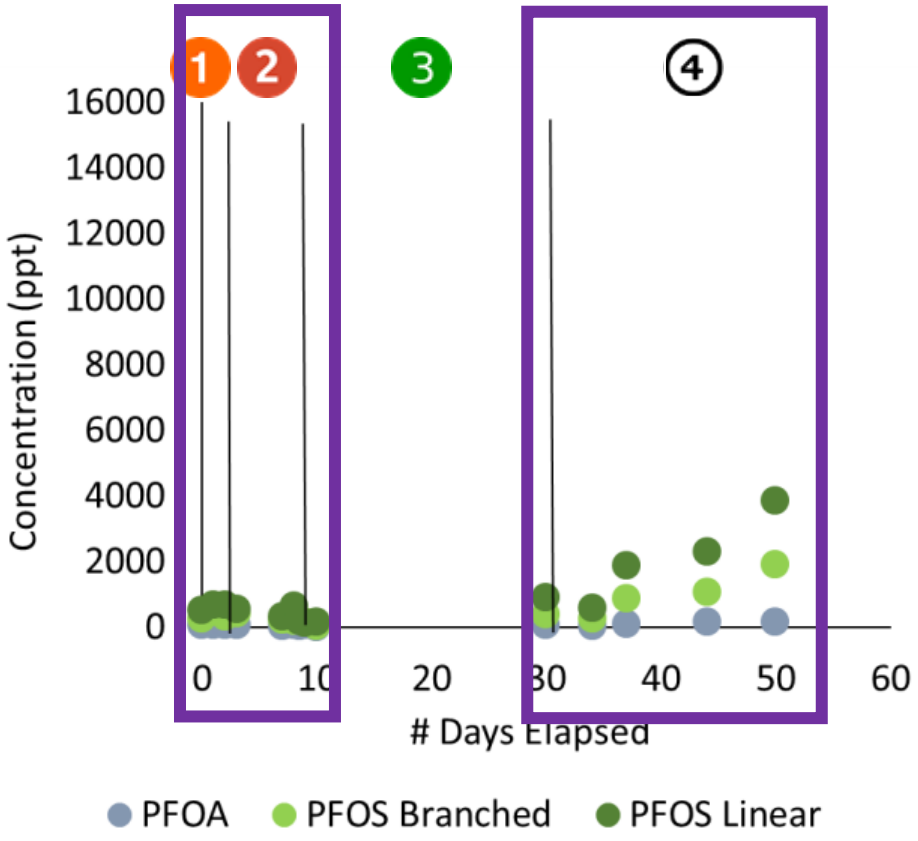
Pump discharge routed to surface through flow meter and sample port sample. Sample is post-GAC / pre-InSRT.

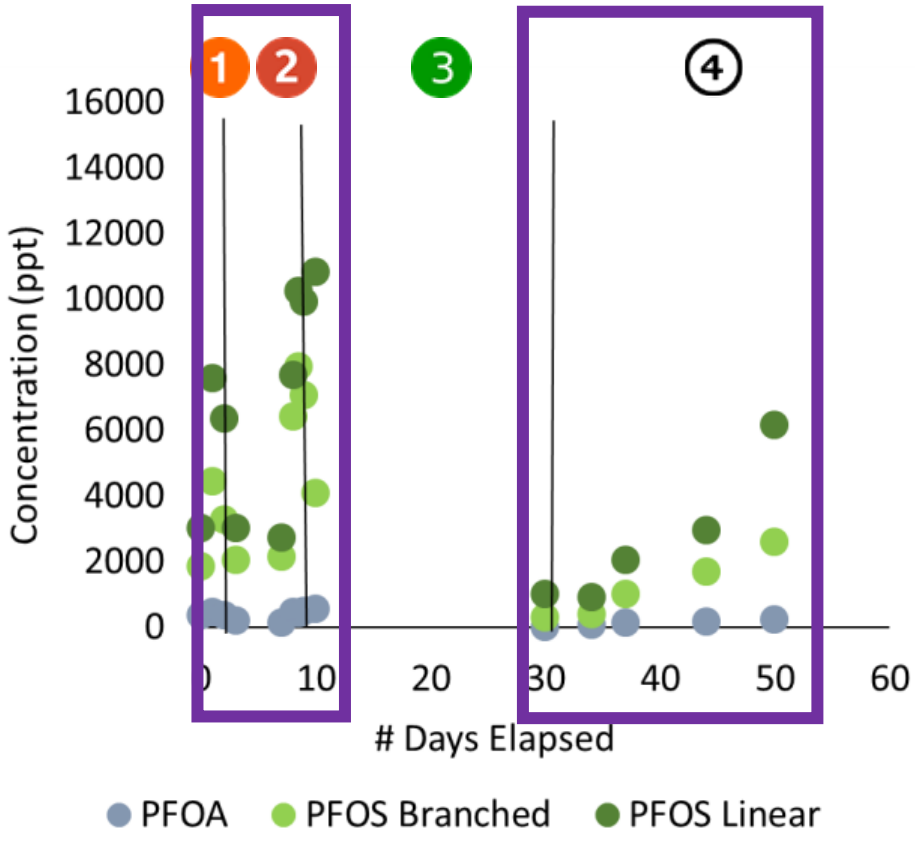
Flow from pump returns down the well to upstream side of InSRT

Summary of Field Operations

- InSRT was successfully installed and is still running
    1. Well purge and preliminary operational test
    2. Controlled flow test @20 mL/min
    3. System turned off
    4. Passive flow operation

Performance Data: PFOA & PFOS





1. ~100mL/min
2. 20 mL/min
3. ~10 mL/min
4. ~120+ mL/min

Flow rate
Power
Cavitation

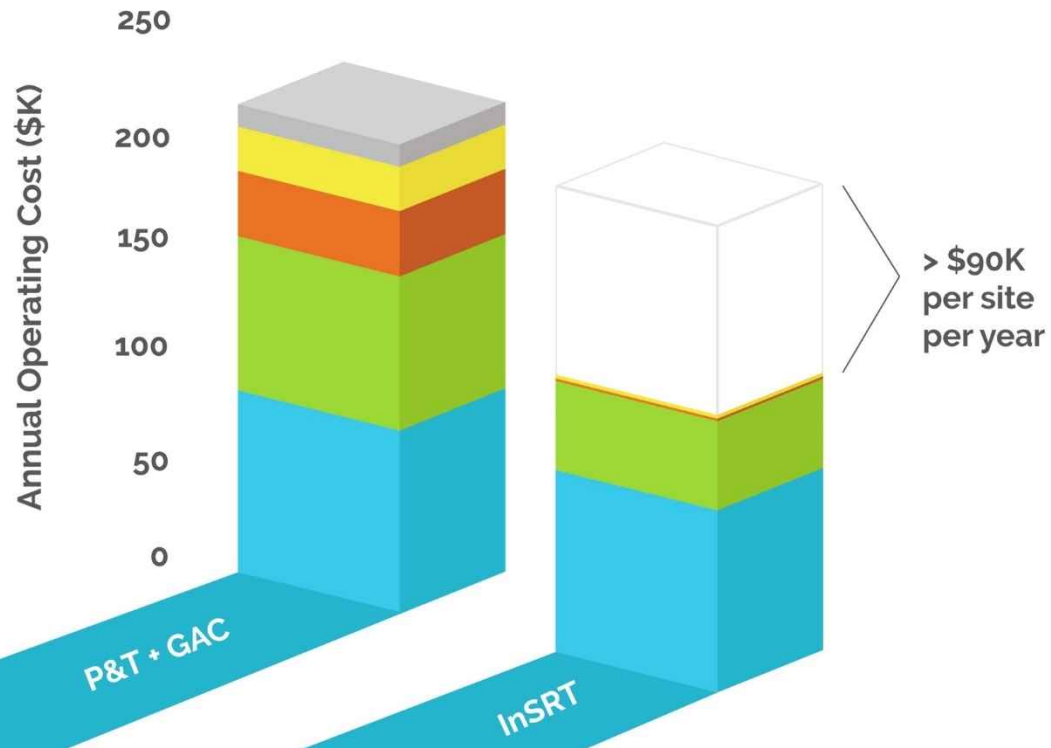
Next Steps

- Regain control of flow
- Optimize power to reactor
- Assess site power supply
- Evaluate cavitation *in situ*

Summary

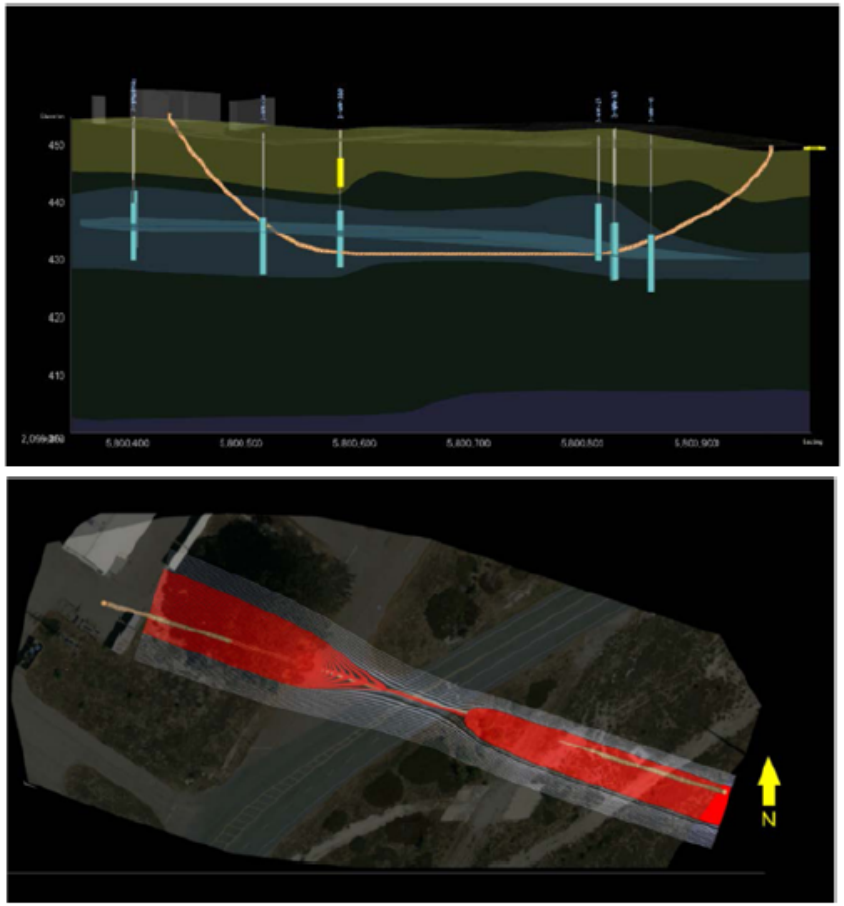
- Initial laboratory and pilot testing
  - Final design for field operation flow rate, run time, on/off cycling, management of heat generation
  - Observed treatment efficiencies of >99% PFOA and 86% PFOS
- InSRT installed in existing HRX Well in November 2023
- All system components operated briefly; however, the *in situ* pump is not currently functioning
- Performance data collected to-date do not show treatment - testable explanations are possible
- Additional diagnostic effort and field servicing is in progress

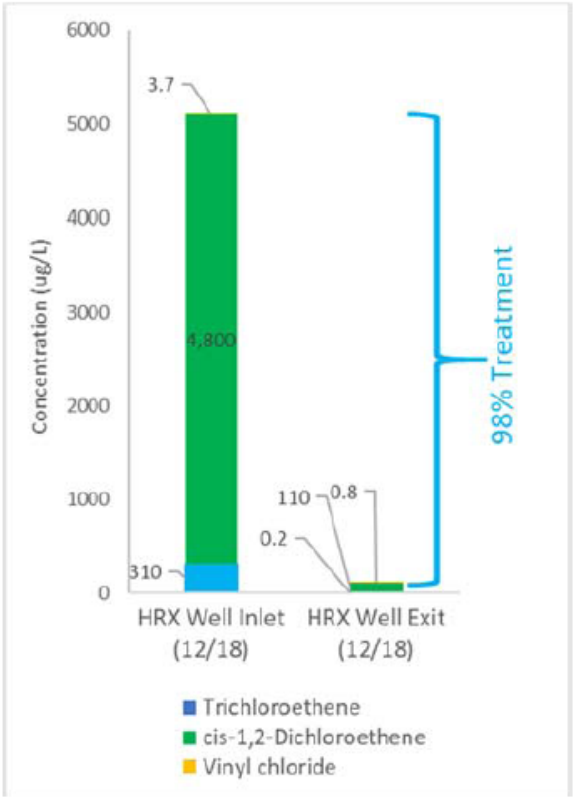
40% savings
in annual operating costs
compared to carbon treatment



Backup Slides

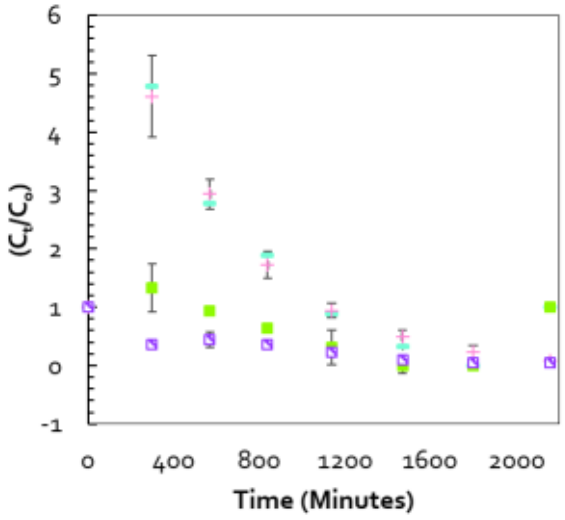
Horizontal Wells



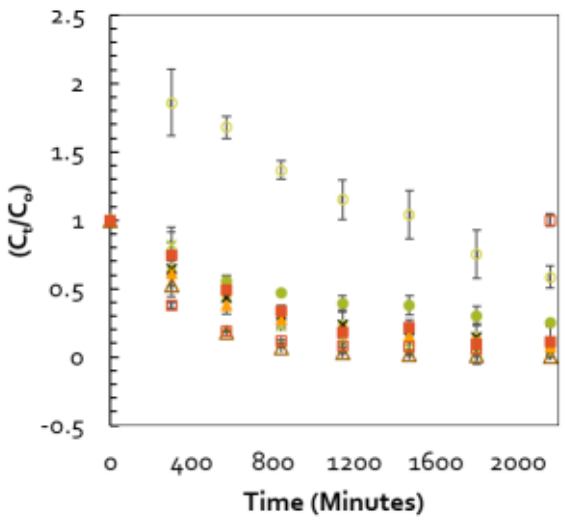


Courtesy of Arcadis

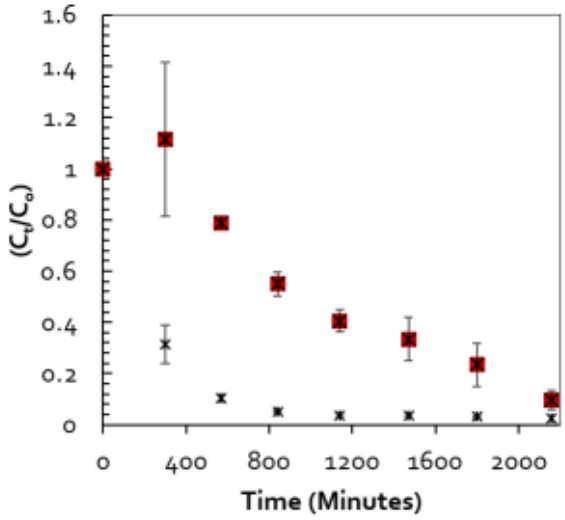
Treatability Tests



Example precursors

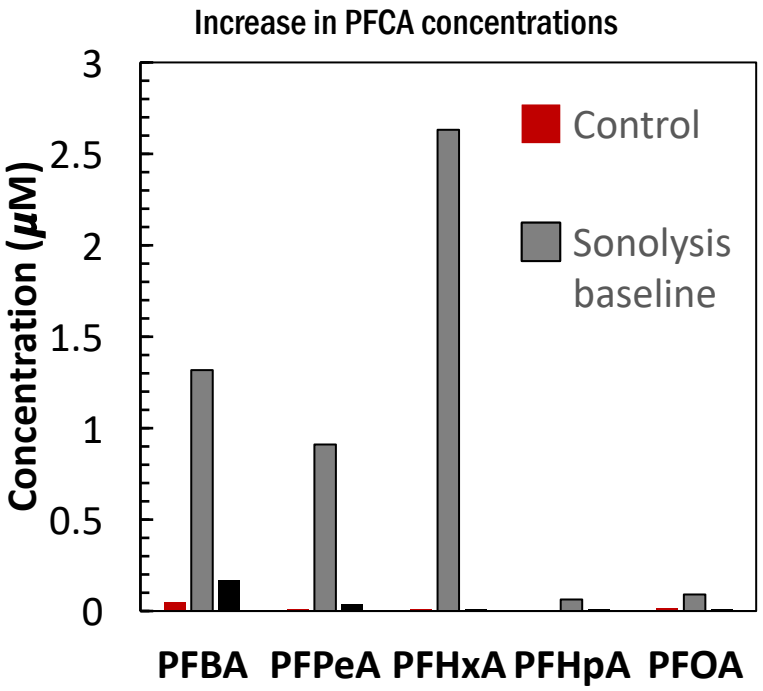


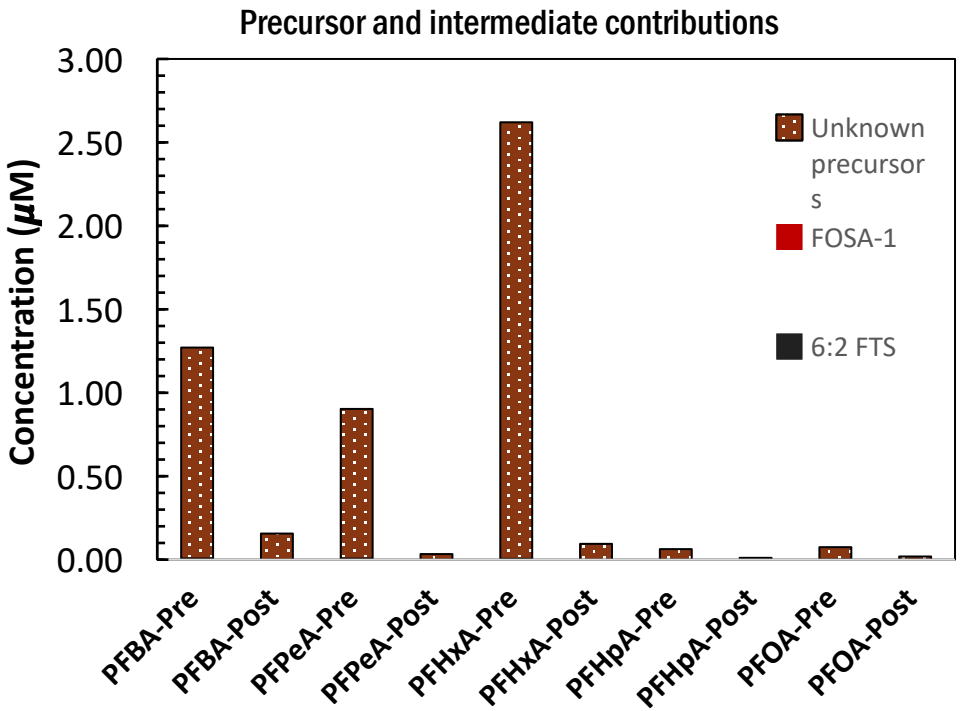
Example shorter-chain compounds



PFOA and PFOS

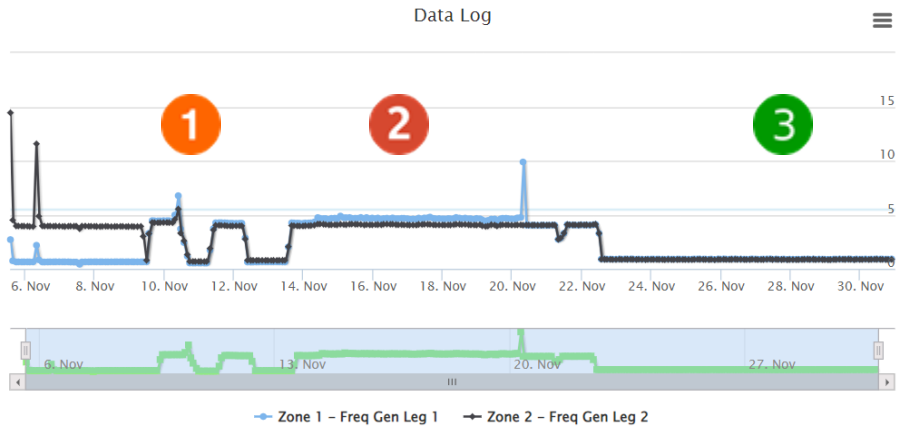
Treatability Tests: TOP Assay





Pre = Groundwater before sonolytic treatment
Post = Groundwater after sonolytic treatment

Operational Data: Reactor Signal



Key for graphs

1. Ambient conditions, pre-pumping and pre-reactor start
2. Pump and reactor started, pumping was continuous, reactor was off-and-on, but more on than off – optimizing
3. Pump stopped working, packer remained inflated – no pumping, reactor off
4. Packer deflated and ambient flow allowed, reactor turned back on