In Situ Stabilization and Solidification for PFAS Remediation in Soils

A Sustainable Solution for Mass Flux Reduction

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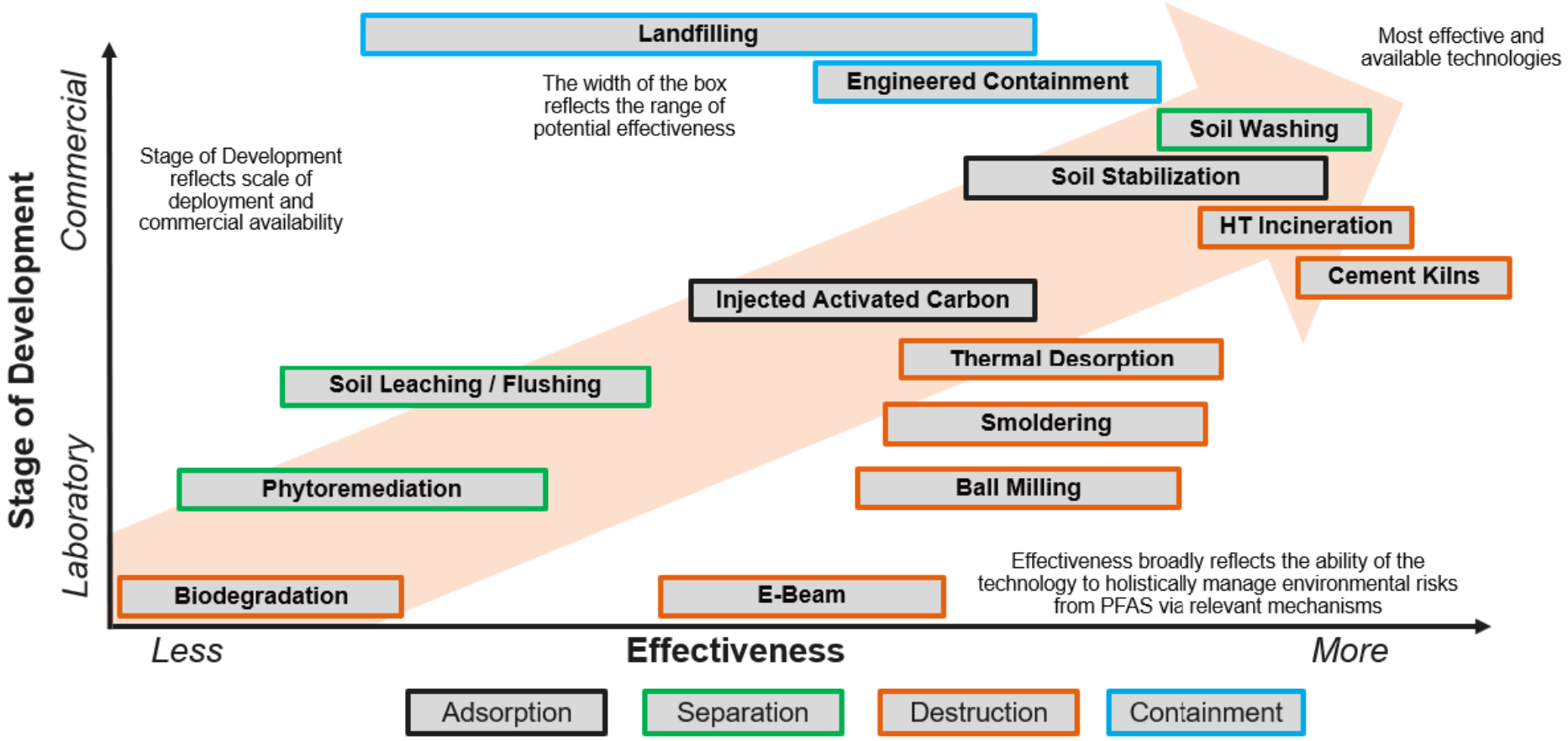
Battelle Chlorinated Conference 2024

Soil Treatment Options

PFAS Treatment Technologies for Solids



PFAS Soil Treatment Processes – A Review of Operating Ranges and Constraints - Concawe

Soil Treatment Takeaways

Landfilling is more expensive for PFAS-impacted soils

- Specialized options are safest:
  - Zero net leachate in arid environs
  - RCRA sub-title C with leachate treatment
  - Pre-treatment and stabilization is an option –many national landfills are exploring

Pending hazardous substance listing could favor on-site treatment

Thermal/incineration options are expensive and energy intensive

Soil washing is a waste minimization process

- Fines are harder to wash, can use thermal, stabilization and/or landfilling

Soil stabilization

- Reduce leachability of soils, manage long-term

Soil treatment options depend on your risk tolerance and business objectives

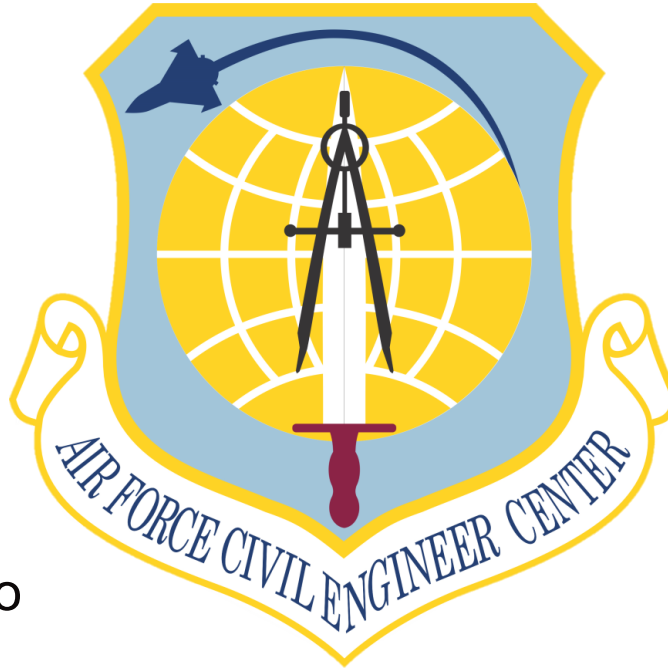
BAA Project Purpose and Technical Objectives

Typical PFAS source zone management practice:

- Soil excavation/groundwater extraction followed by *ex situ* treatment

Three Primary Objectives of this Broad Agency Announcement (BAA):

1. Evaluate ISS as a remedy to reduce or eliminate leaching of PFAS to groundwater from source areas via chemical fixation
2. Evaluate commercially available reagents (i.e., “fixants”) with Portland Cement (PC) to stabilize PFAS in ISS test pits (field scale)
3. Use of a sequential leaching procedure to understand how ISS test pit leachate will vary with time in PFAS concentrations

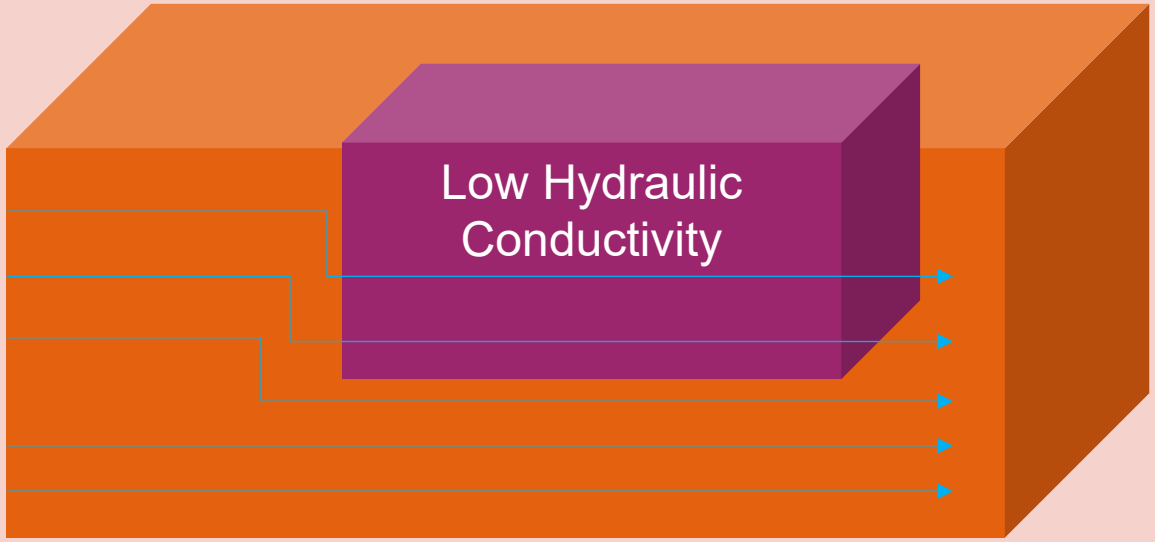


Broad Agency Announcement funding from AFCEC

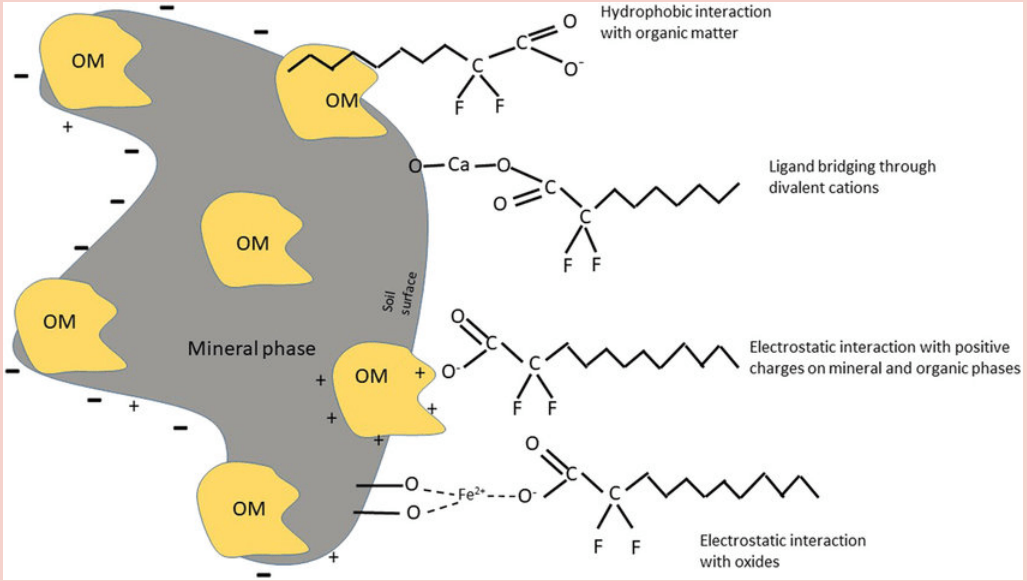
Provide an alternative for managing PFAS source zones

Stabilization vs Solidification

Solidification: Create a solid



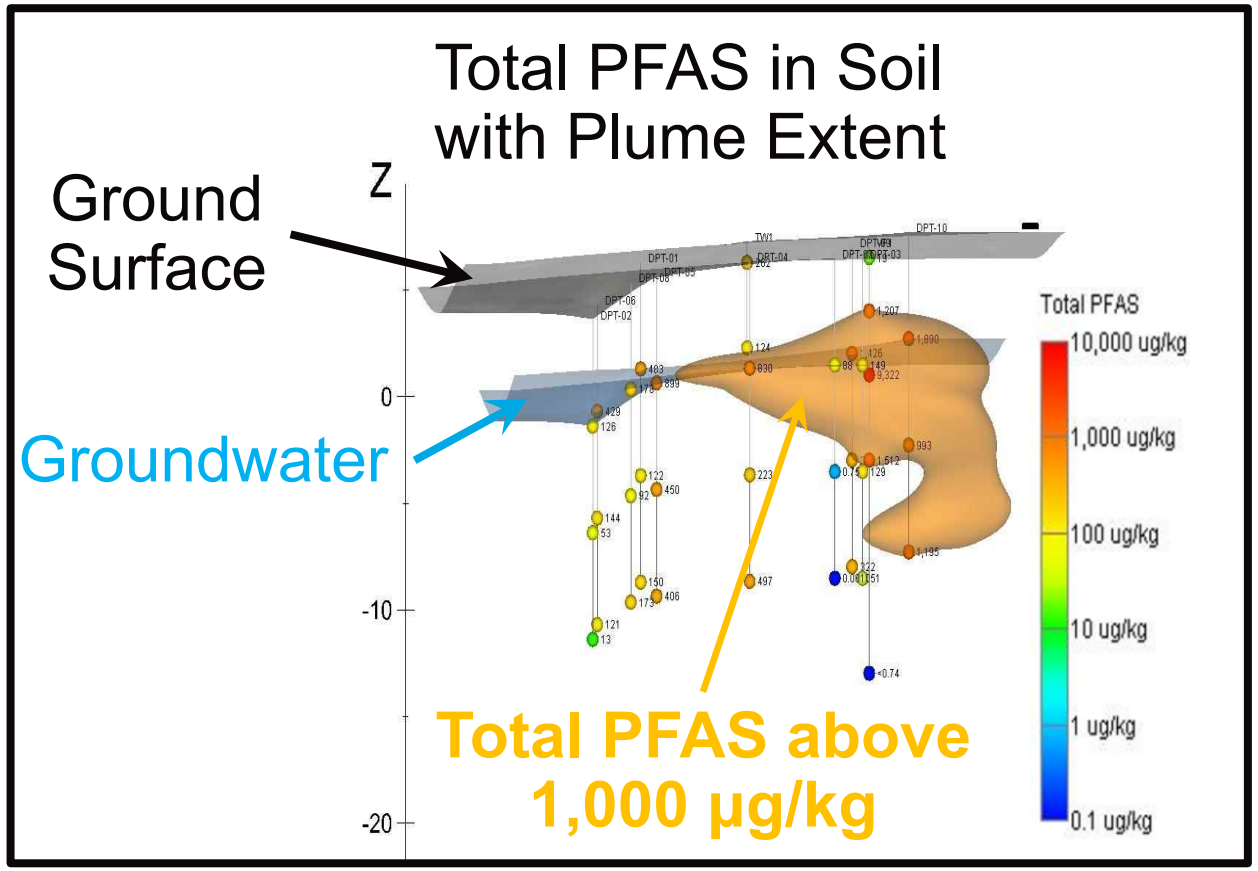
Stabilization: Stabilize the chemical



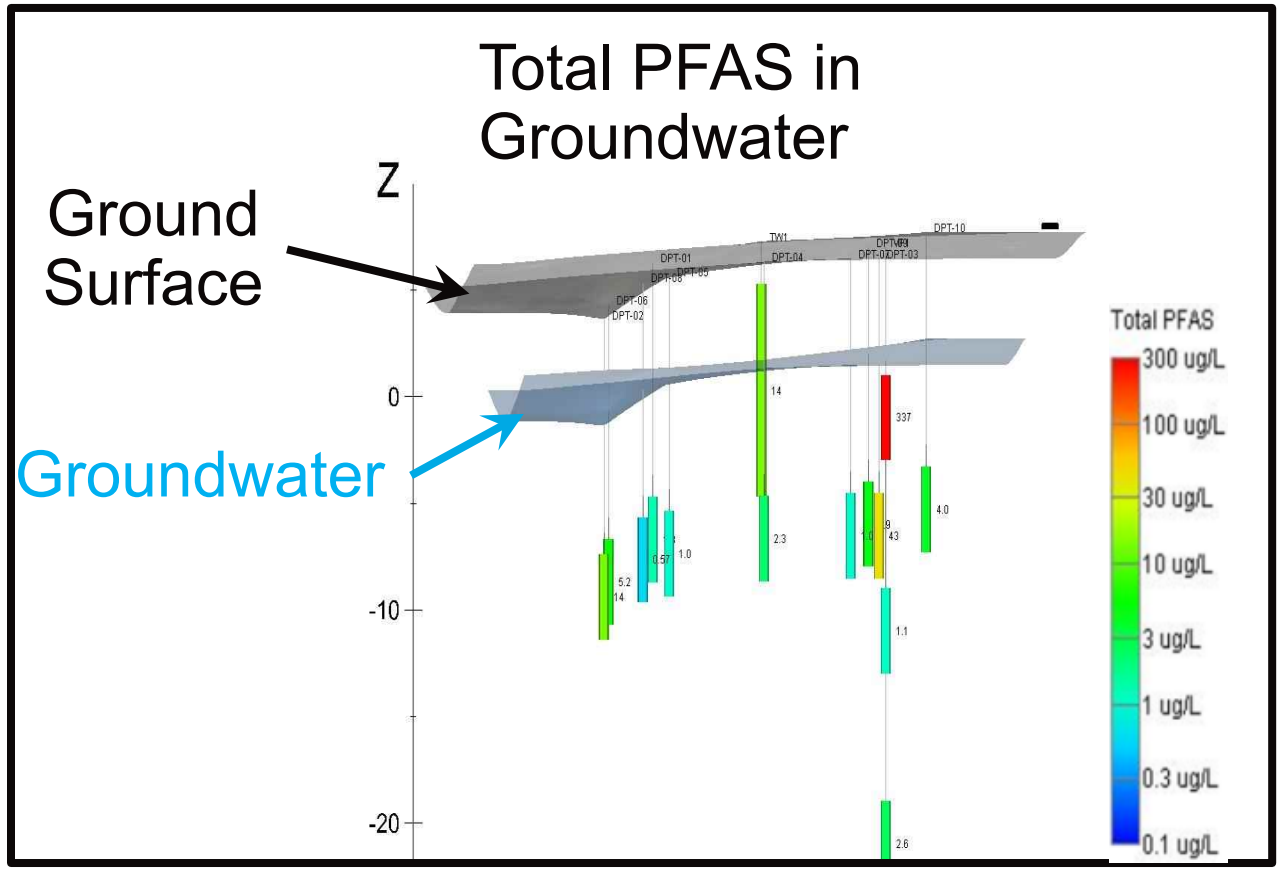
https://www.sciencedirect.com/science/article/abs/pii/S0304389420318811

Site Selection and Characterization

Soil



Groundwater



Site Selection and Characterization

- Ambient Depth to Groundwater = 5 feet
- TDS/salinity = <1.2 mS/cm and TOC = 4.3 to 9.3 µg/L
- Fine to coarse sand
- Max ∑PFAS (soil/groundwater) = 1,946 µg/kg / 43,262 µg/L
- Max PFOS/PFOA (soil/groundwater) = 1,739 µg/kg / 24,040 µg/L

Bench-Scale Treatability Test

Overall Stabilization Approach

Chemical fixation approach validated at FL DoD site – AFCEC BAA 120

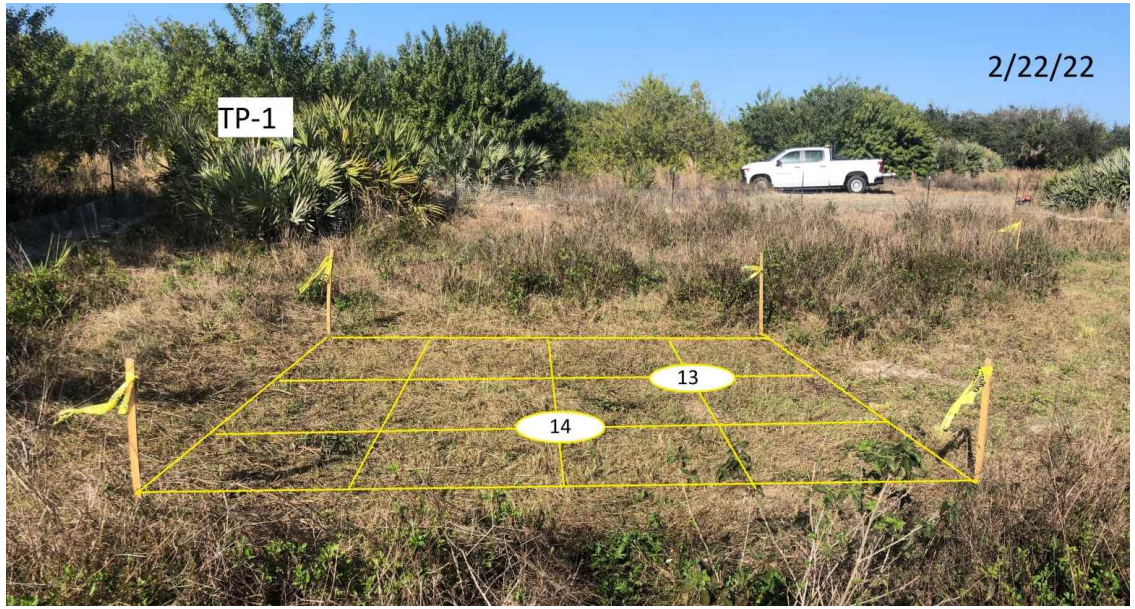
Consistent approach at three Space Force Bases:

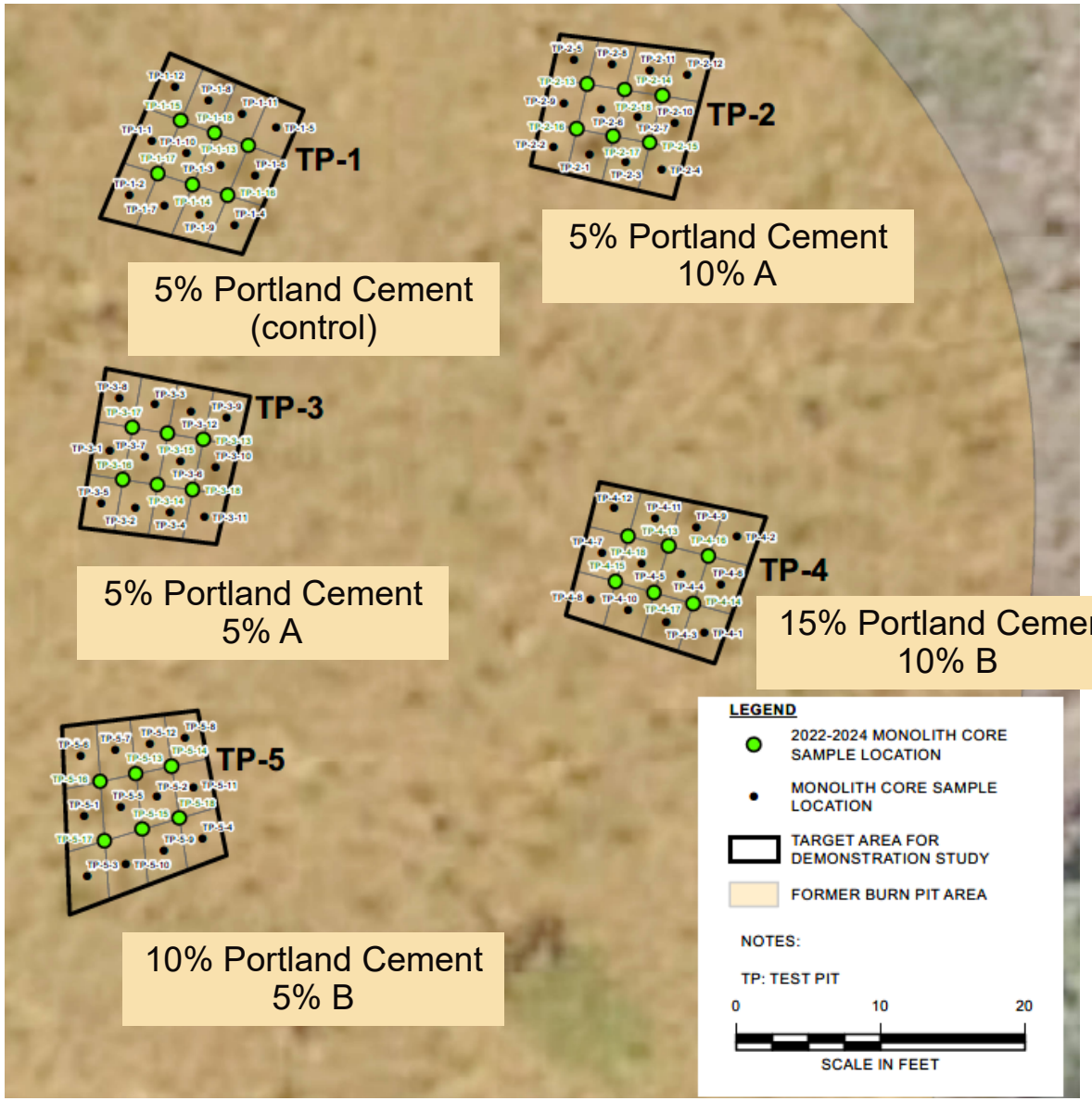
- Cavalier, SD
- Buckley, CO
- Peterson, CO

Deployments implemented with Rembind ® and Portland cement for bearing capacity

Field Demonstration and Validation

- Demonstration Sampling
- Laboratory Analysis and Reporting
- Data Validation
- Data Review and Analysis





Field Implementation of Soil Mixing

Soil Mixing with FluoroSorb® (Test Pit 2)

FluoroSorb® Core (Test Pit 3)

FluoroSorb® Core (Test Pit 3)

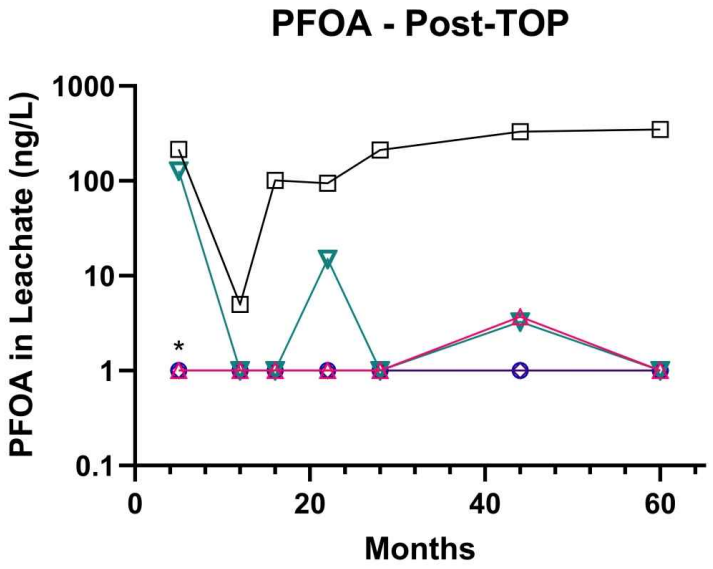
Soil Mixing with RemBind® (Test Pit 4)

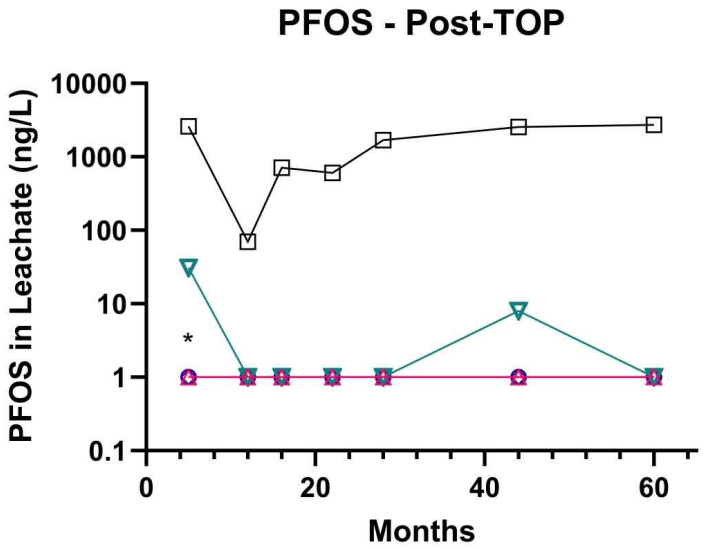
RemBind® Core (Test Pit 5)

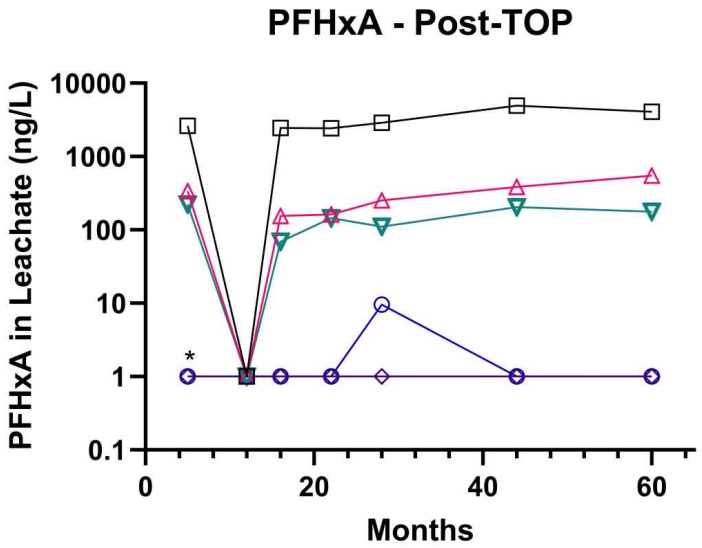
RemBind® Core (Test Pit 5)

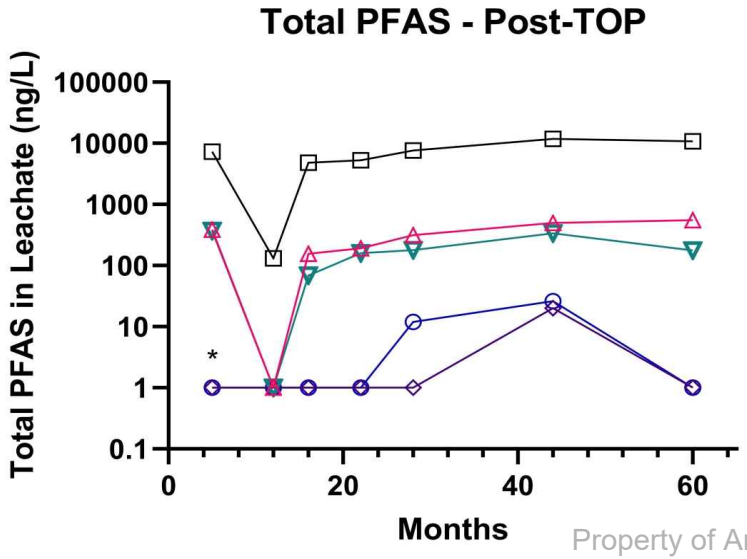
Summary of Results (Log Scale)

Leaching Concentration of PFOS, PFOA, PFHxA and Total PFAS
(5 years = 60 months)







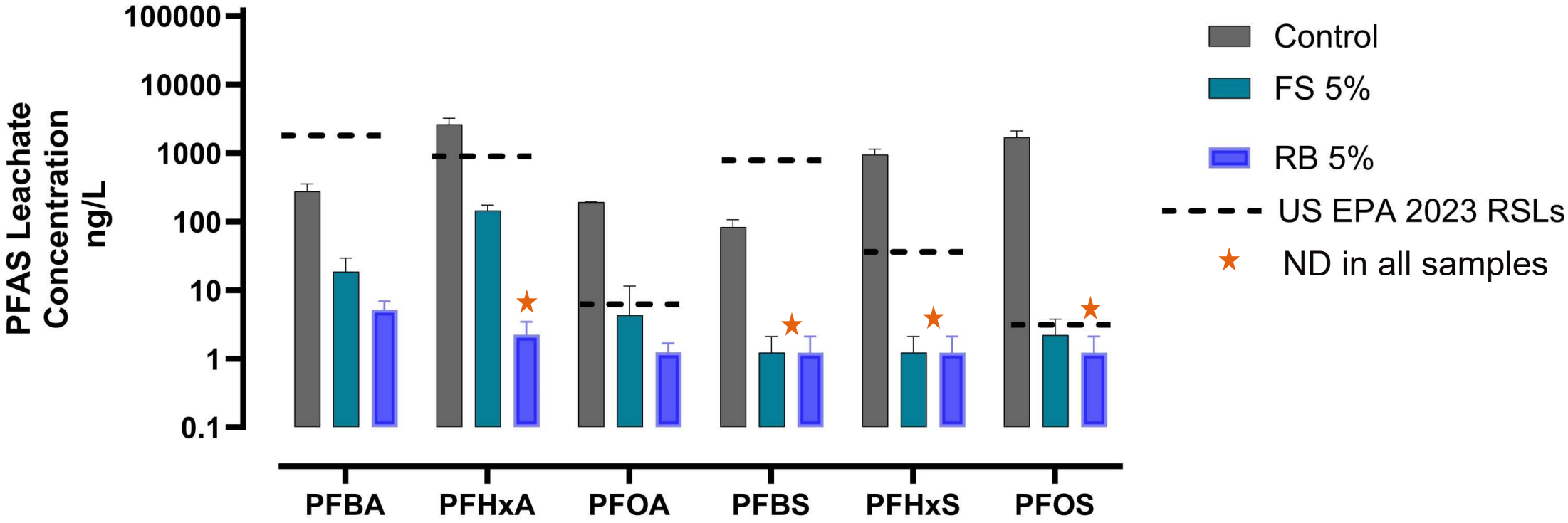


- 5% Portland Cement (PC)
- 5% PC/ 10% FluoroSorb
- 5% PC/ 5% FluoroSorb
- 15% PC/ 10% Rembind
- 10% PC/ 5% Rembind

Mention of RemBind® and FluoroSorb® is not an endorsement

*Non-detected levels

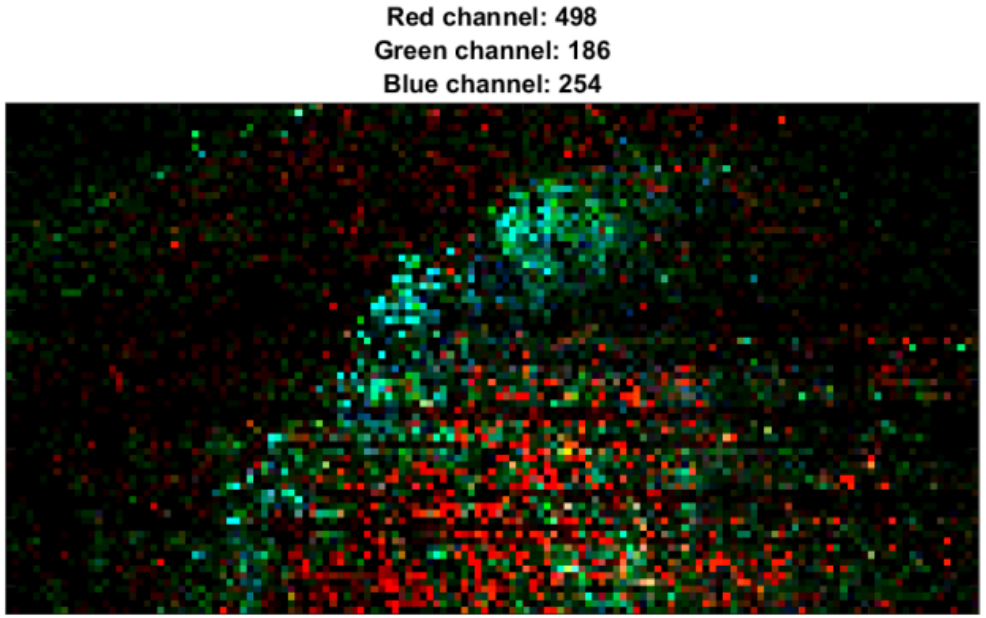
Leaching results compared to EPA 2023 RSLs



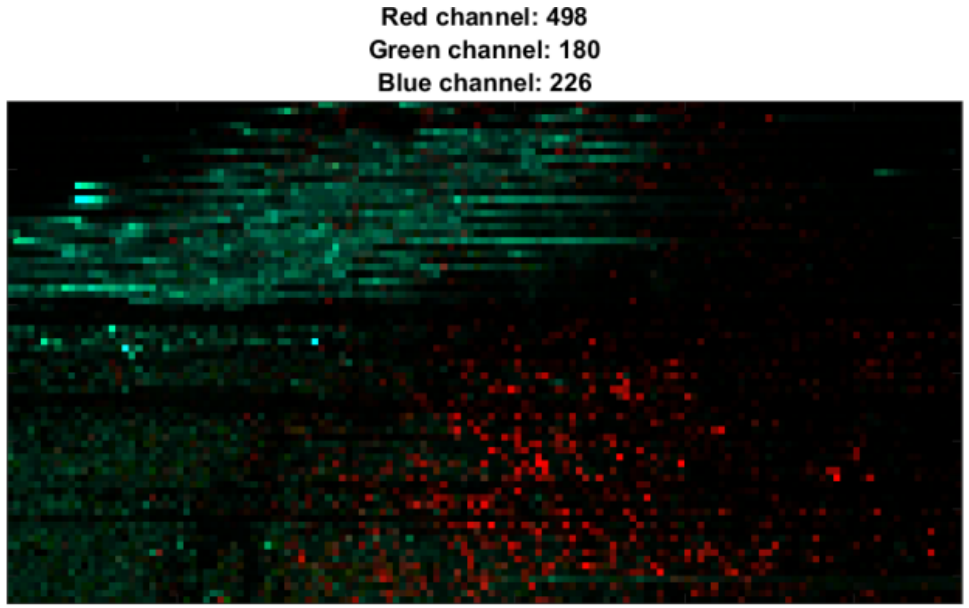
Geometric mean with SD of all LEAF 1314 samples collected

RB 5% shows slightly better performance

PFOS and stabilizer (RemBind) are associated on core surface



PFOS and RemBind



PFOS and PC

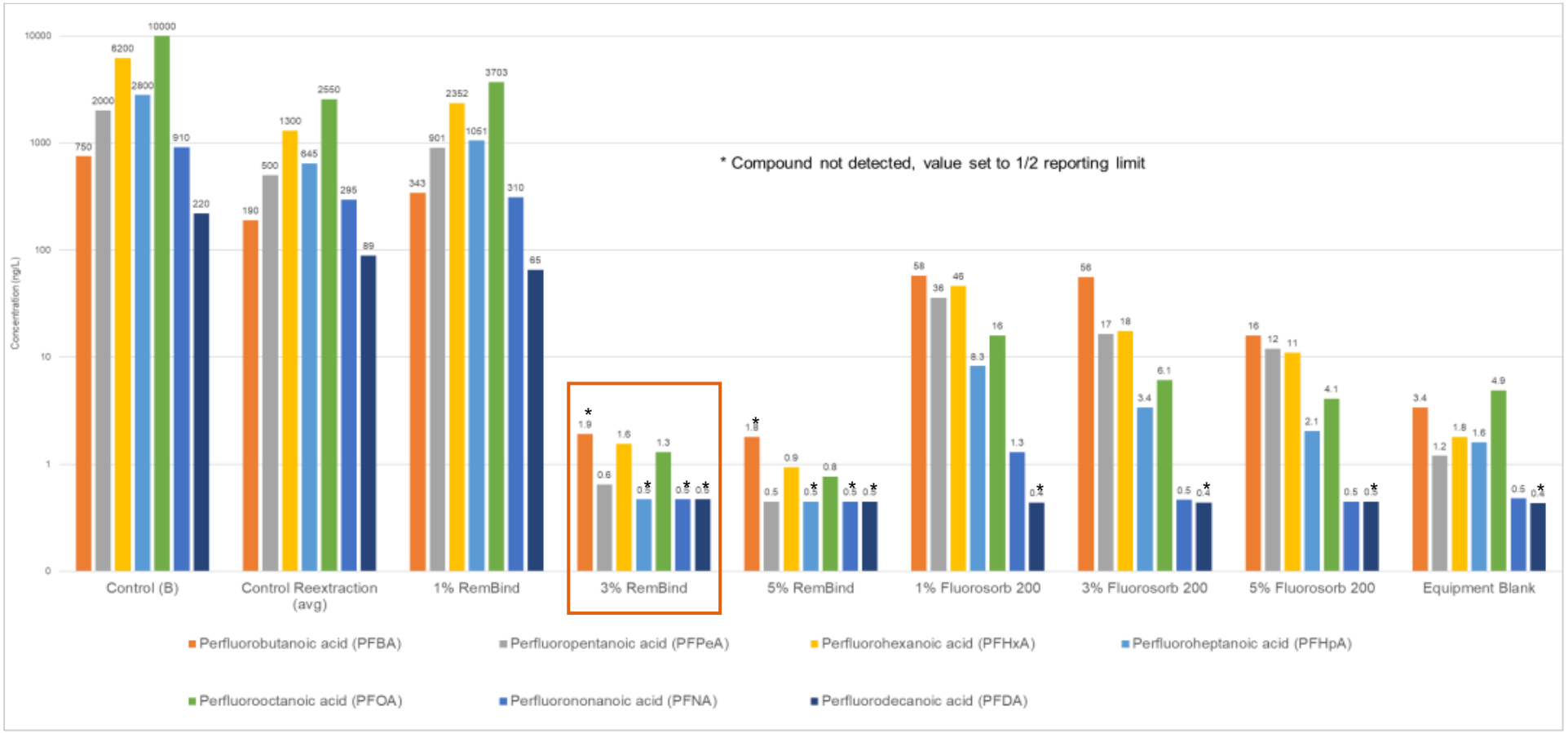
Stabilization chemically “fixes” PFAS, reducing leachability. Can be managed on-site, or used as pretreatment for landfilling

- Portland cement added for structural integrity, not needed otherwise
  - **Portland alone is not better than no treatment control**
- Long term stability evaluated between two commercial agents – develop site-specific recommendations

Additional Demonstrations

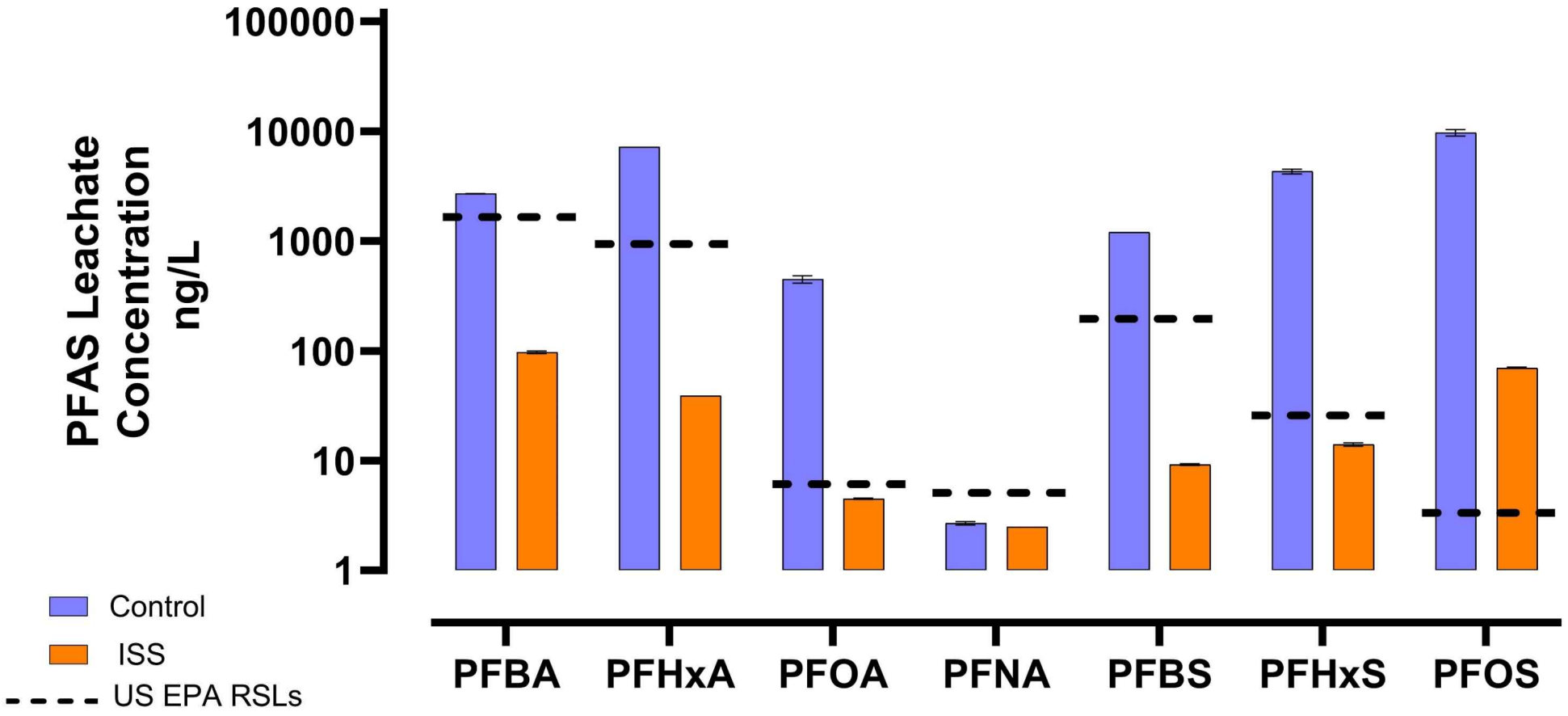
- Subsequent ISS demonstrations in 2022 following BAA 120 framework
  - Cavalier SFS (North Dakota)
    - 100’ W x 100’ L x 3’ D ISS treatment area divided into 18 mixing cells
  - Buckley SFB and Peterson SFB (Colorado)
    - 16’ W x 16’ L x 4’ D ISS treatment and control cells – one of each
    - Portland cement added for solidification – 4,000 – 4,500 lbs per cell
- Bench testing compared RemBind 100X with Fluorosorb 200. RemBind 100X chosen for all sites based on bench testing performance.
- Fixant dosing based on bench test performance
  - Cavalier – 3%
  - Buckley and Peterson – 2%
- Mixing with standard excavator bucket at all sites
- Water requirement highly dependent on site-specific geology

Cavalier: Bench Treatability Leaching Results – PFCAs



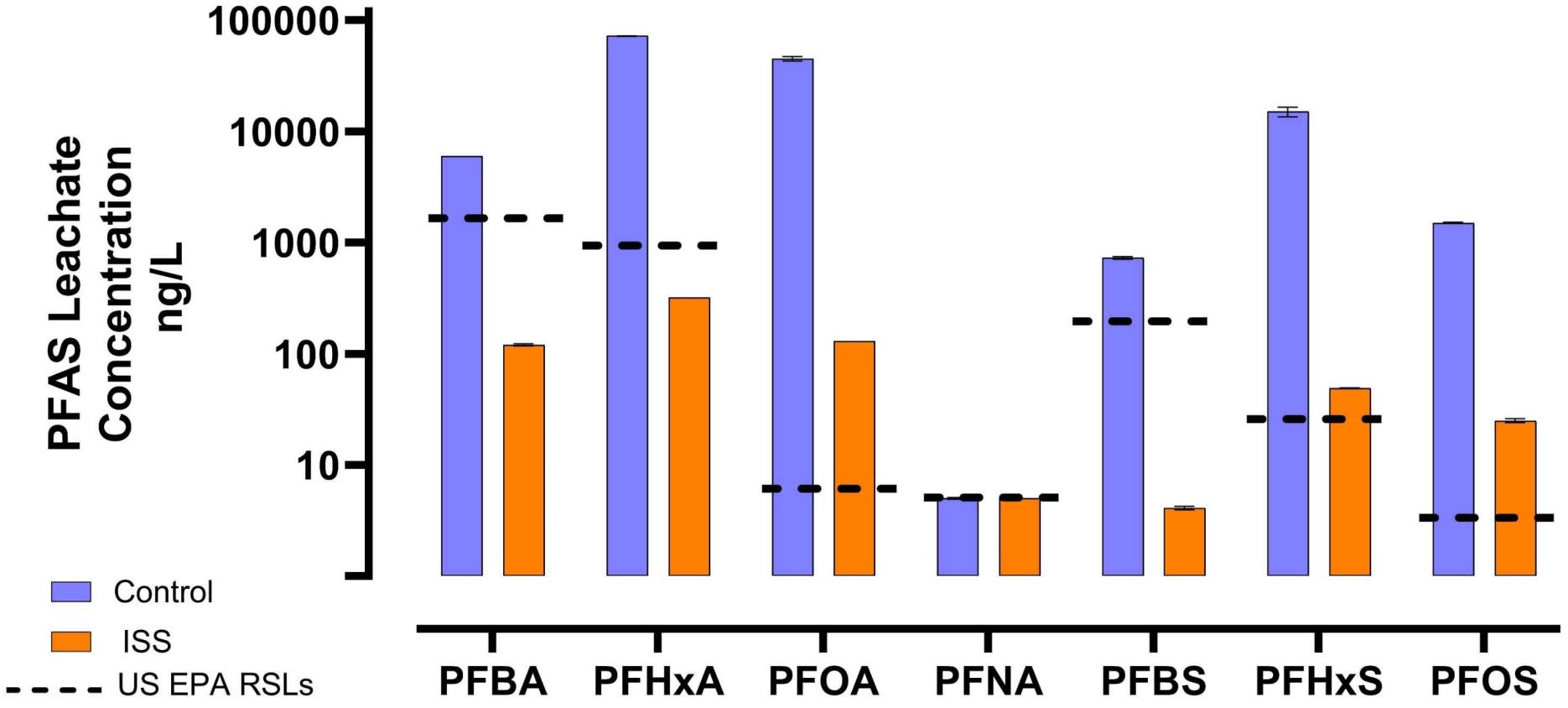
- 3 and 5% RemBind had highest levels of reduction for all PFCAs
- 3 and 5% Fluorosorb also reduced PFCAs, but performed worse for all PFCAs
- Fluorosorb had low reduction for shorter chain PFCAs compared to RemBind

Peterson SFB: AFFF source zone soil treatment with ISS



- LEAF 1315 for Control and ISS treated soils
- Total Oxidizable Precursor (TOP) assay on leachate
- For treated soils, PFOS only exceedance at 70 ng/L

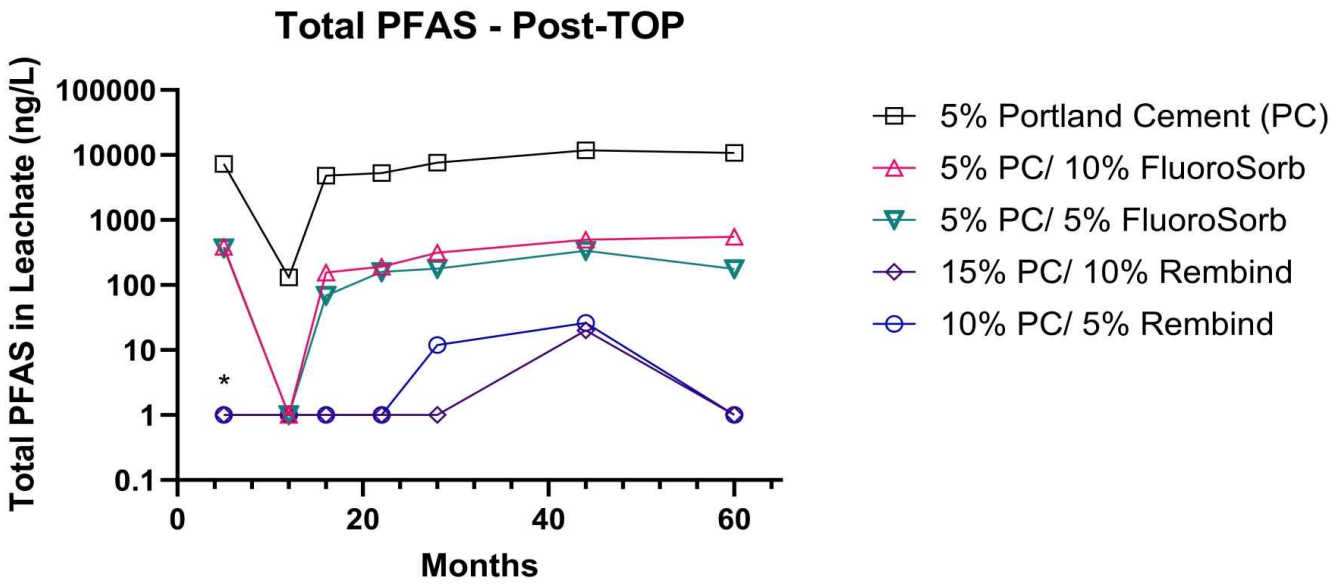
Buckley SFB: AFFF source zone soil treatment with ISS



- LEAF 1315 for Control and ISS treated soils
- Total Oxidizable Precursor (TOP) assay on leachate
- For treated soils, PFOA, PFOS, and PFHxS exceedance

Multi-site Analysis : Lessons Learned

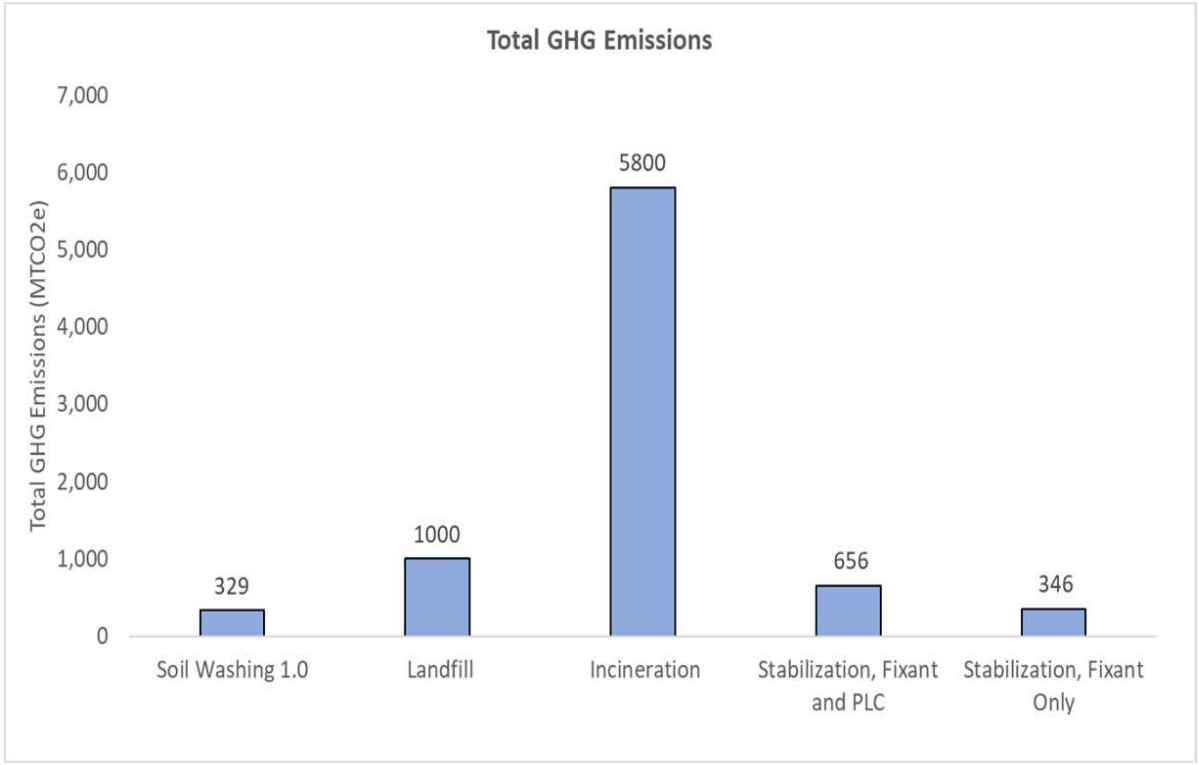
- **Site characterization and fixant optimization needed prior to field demonstration**
- **Develop site specific RSLs / cleanup objectives**
- **Determine PFAS composition and analysis needs prior to field demonstration (higher PFCAs /shorter chain compounds lower performance)**

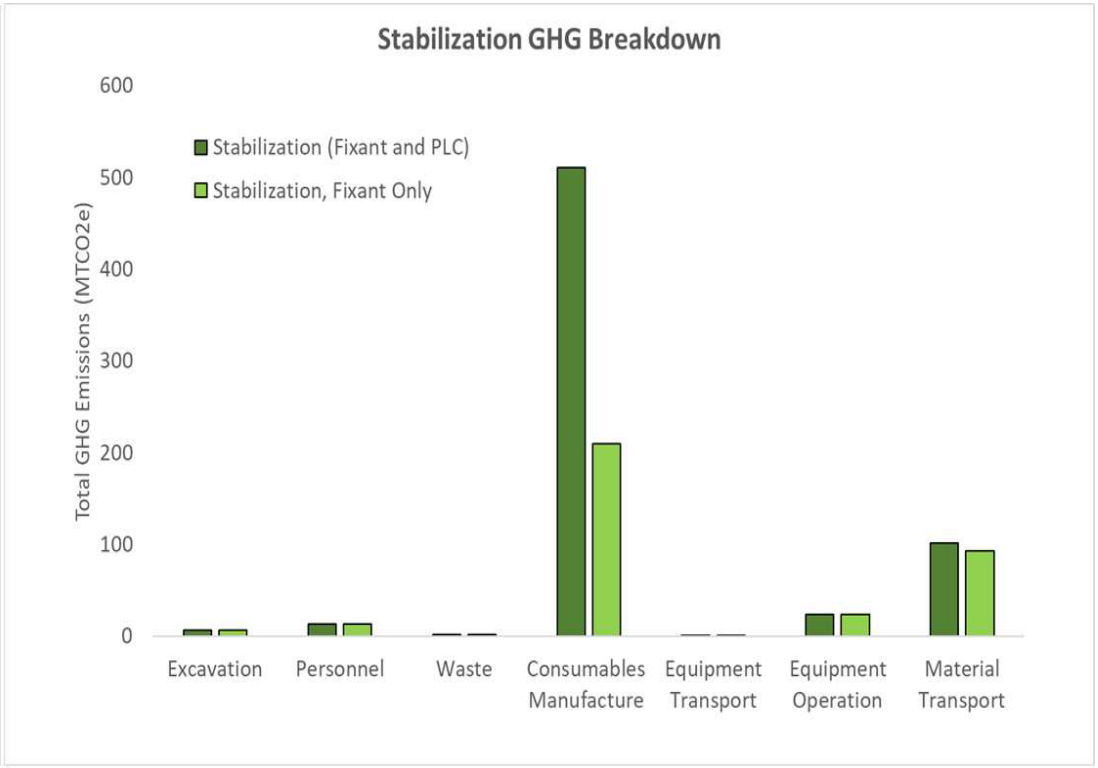


Sustainability Analysis

SiteWise Tool for Green and Sustainable Remediation – Developed by USACE, Battelle, US Army, US Navy

- Stabilization with Rembind (4%), with and without Portland Limestone Cement/Type 1L cement (PLC).
- Compared against landfill disposal, incineration, and soil washing
- 10,000 tons of soil for site in contiguous U.S.





Soil Stabilization Takeaways

Soil Stabilization (S/S)

- Reduce leaching by chemical fixation and permeability reduction
- Fixation reduces leachate through chemical reaction
- Solidification reduces infiltration through monolith by permeability reduction
- Pre-treatment via stabilization is an option many landfills are exploring
- Sustainability/GHG footprint of stabilization compared to landfilling or incineration is lower
- GHG dominated by reagent manufacture and cement for bearing capacity/strength

Soil Stabilization is a sustainable, cost-effective solution

Thank you

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