

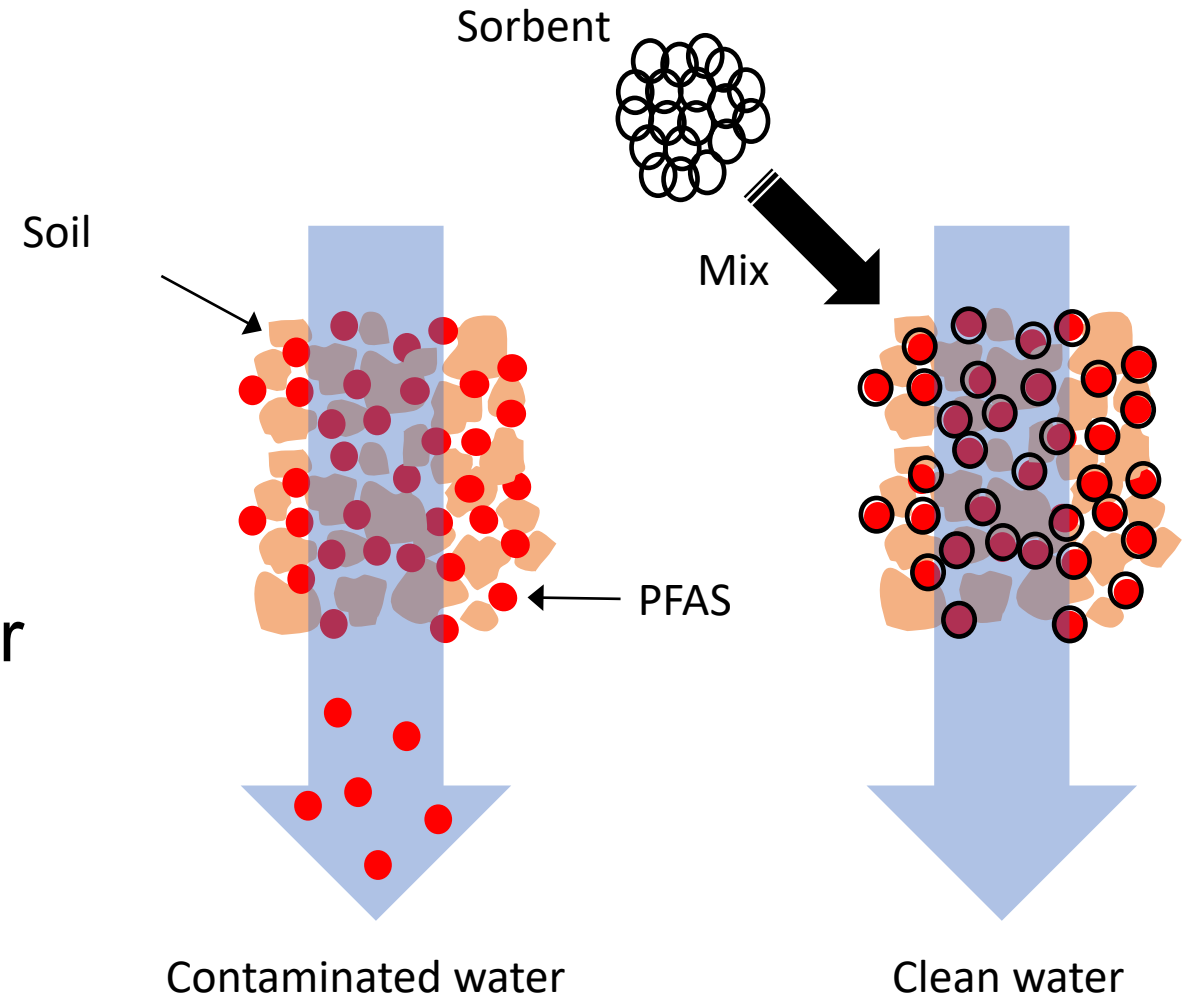
# PFAS Immobilisation in Soil: How Long is Long Enough?

Dr Richard Stewart, Managing Director, RemBind

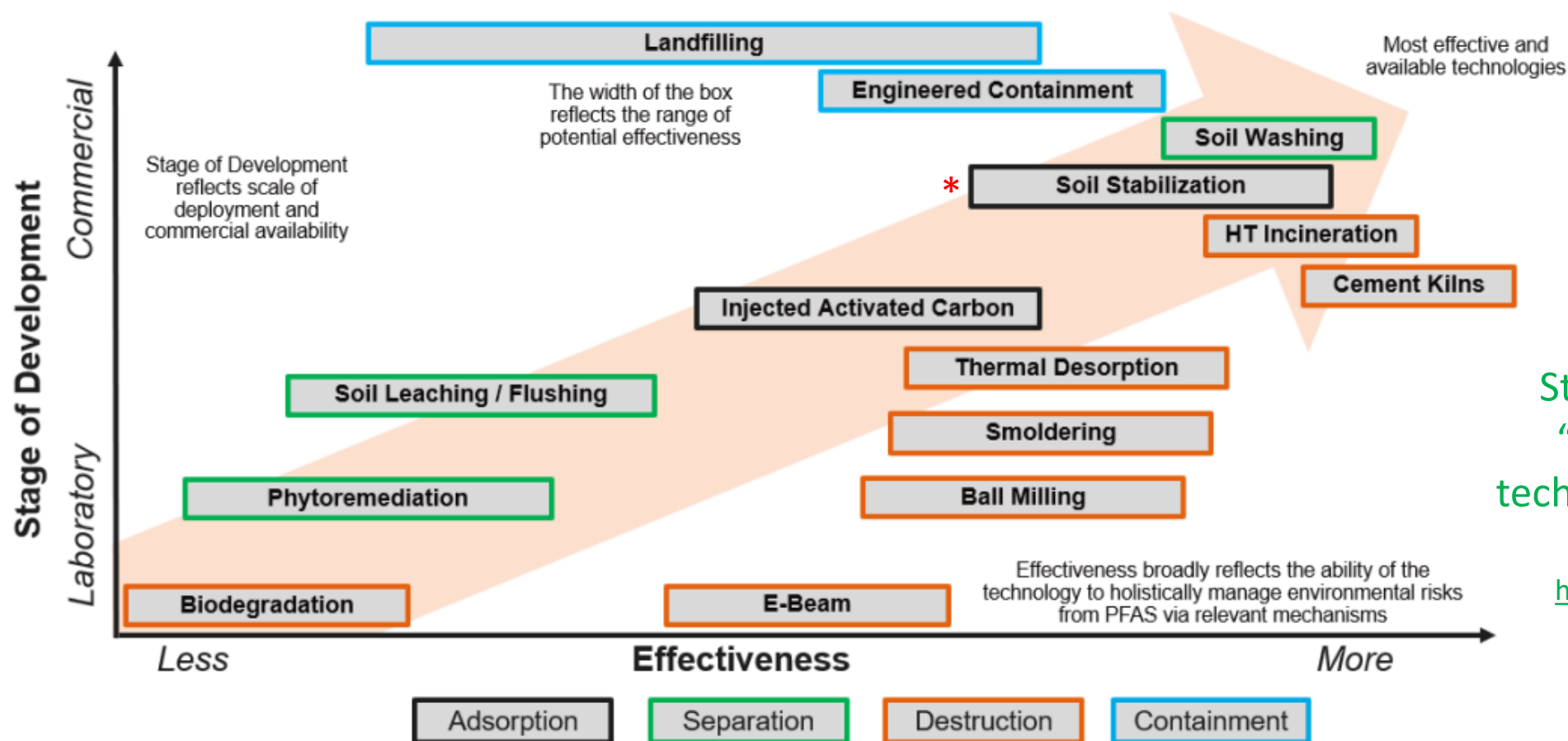


# What is Immobilisation?

- Immobilisation is a remediation technique that uses sorbents to **lock up PFAS** to prevent leaching into the environment.
- Also known as 'stabilisation'
- Can incorporate cement to further reduce leaching and to improve soil strength.
- Does not reduce *total* PFAS



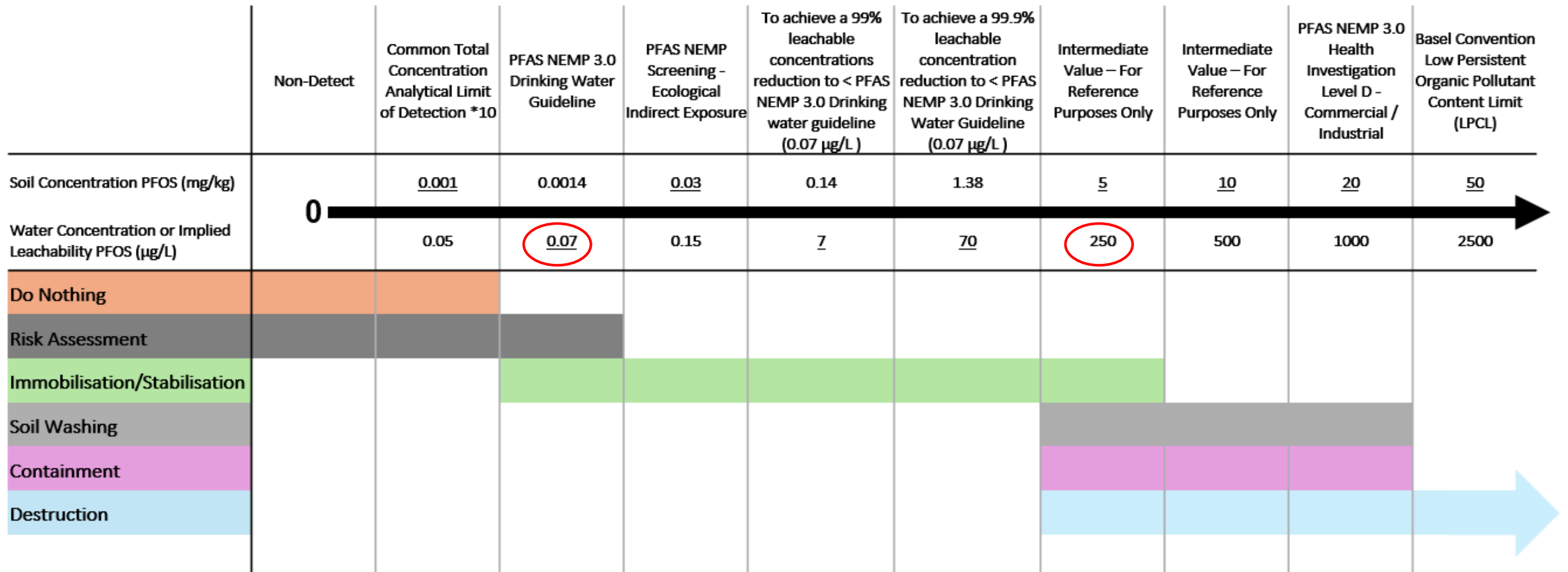
# Treatment/Disposal Options for PFAS in Soil



Stabilization is rated as  
“field implemented”  
technology by the ITRC (US)

<https://pfas-1.itrcweb.org/12-treatment-technologies/>

# PFAS Data - The 'Sweet Spot' for Stabilisation



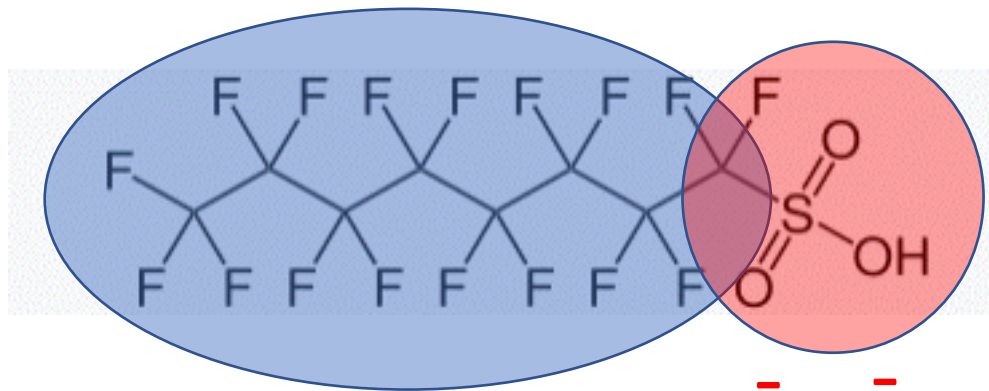
“Askeland, M. (2025). Reframing the efficiency spectrum of PFAS soil treatment technologies beyond conventional "source" and "diffuse" classifications (Unpublished short scientific communication manuscript). ADE Consulting Group.



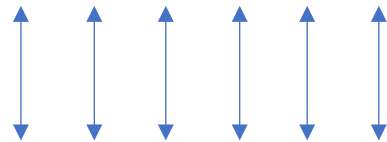
# How PFAS Sorbents Works

Hydrophobic Backbone    Charged Head

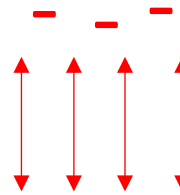
PFOS



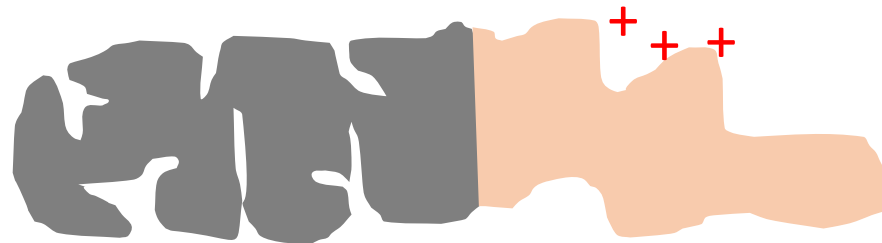
Hydrophobic



Electrostatic



RemBind  
'Mixed Mode'



Carbon

Clays



Carbon, Clays,  
Aluminum Oxyhydroxides

# Bench-Scale Feasibility Testing

- Compare different sorbents
- Determine the optimal dosage rate
- Identify matrix interferences.



1. Screen soil, dose reagents (0% to 5%)

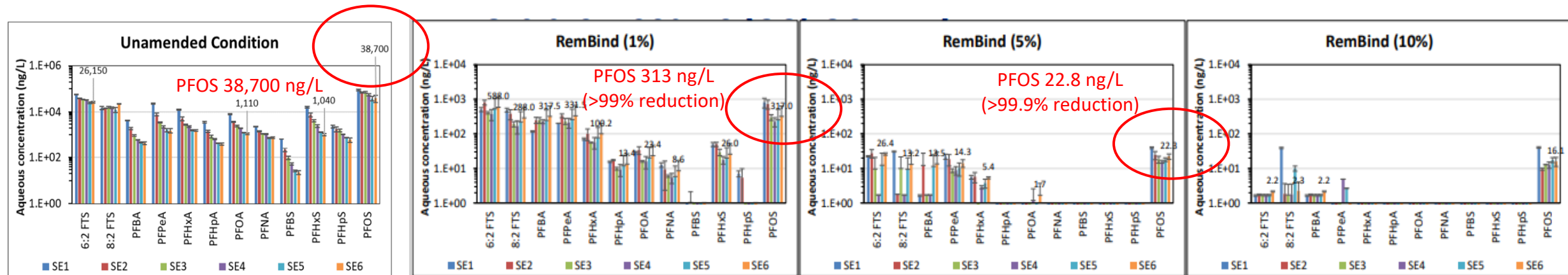


2. Add water, mix, fix for 24 hours



3. PFAS leachate analysis (e.g. TCLP, LEAF)

# Typical Lab Trial Results – Airport Site, USA



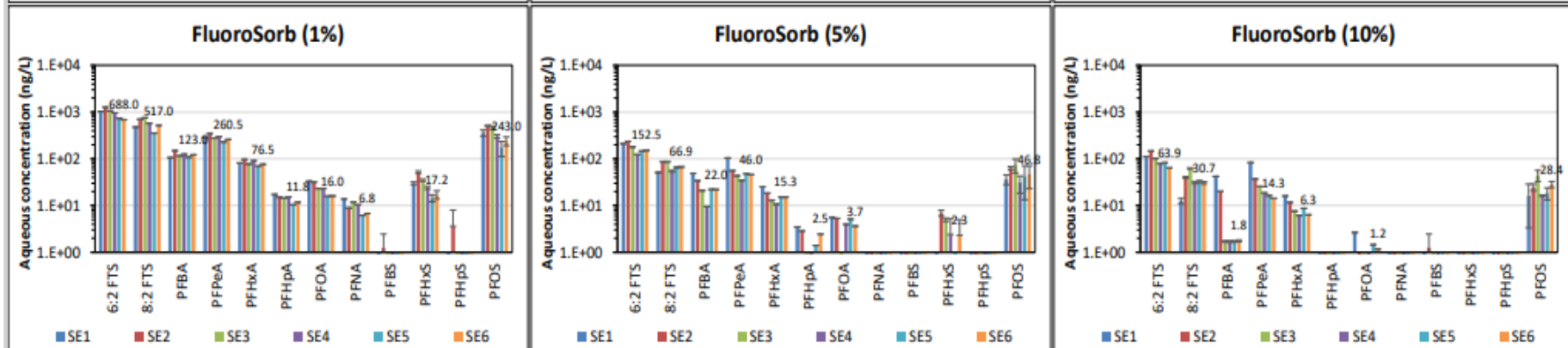
## Experimental Objectives & Design

### Objectives:

- Compare the effectiveness of soil amendments in sequestering PFAS:
- For different soil mixtures (100/0, 50/50, 0/100 topsoil/clay)
- For different amendments (RemBind vs. FluoroSorb 200)
- Under wetting and drying cycles
- As a function of amendment dosage used (1%, 5%, 10%)
- Evaluate adverse impacts on the surface water quality

### Experimental design:

- Simple batch experiments
- PFAS-"free" rainwater
- Serial dilution approach
- Simulated wetting & drying cycles (6 times)



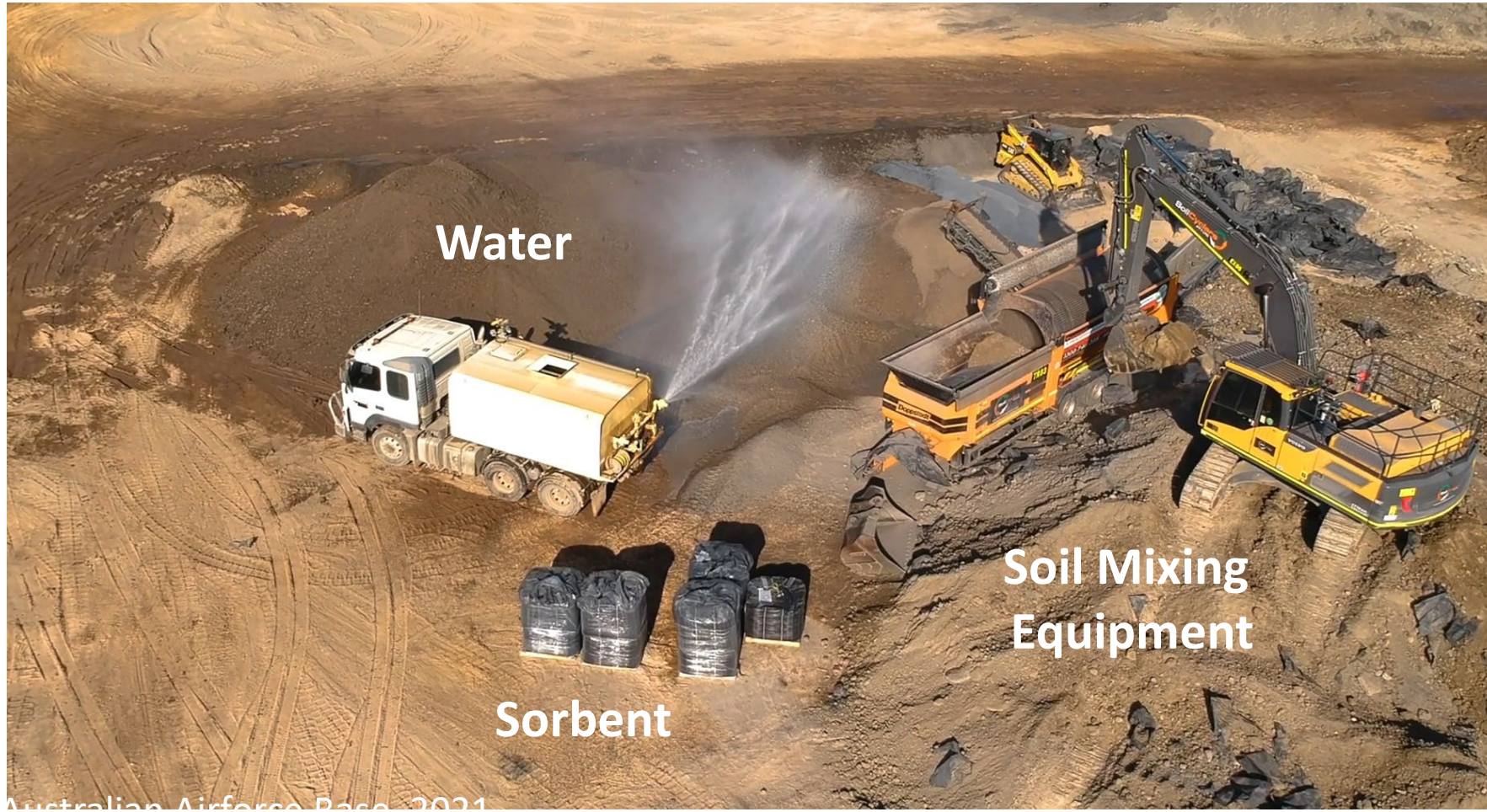
Increased PFAS sequestration with amendment dosages

No unintended consequences because of treatment

Jeff Bamer, Dung Nguyen, Chris Gurr, Jill Greene. In-situ soil stabilization to mitigate PFAS transport via stormwater at an AFFF source area. CDM Smith, 2024 Battelle Chlorinated Conference.

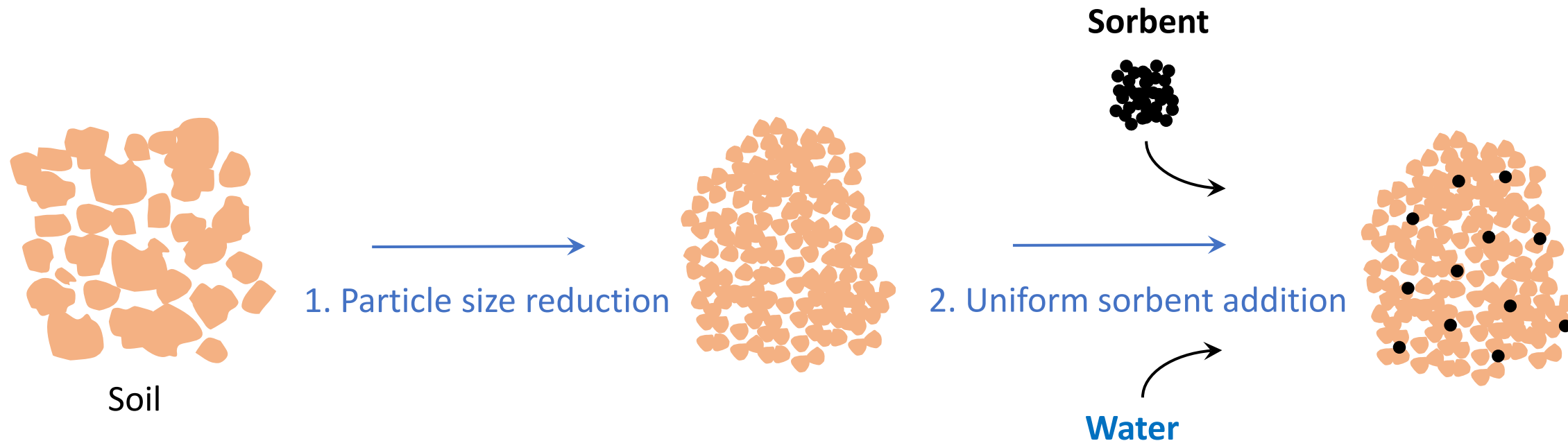


# Field Scale Implementation





# Soil Mixing – Key Success Factors



Avoid the 'lamington effect' where large soil particles are coated on the surface only!





# Soil Mixing Examples



Rotary Hoe



Road Stabiliser



Pug Mill



Allu Bucket



Soil Stabiliser

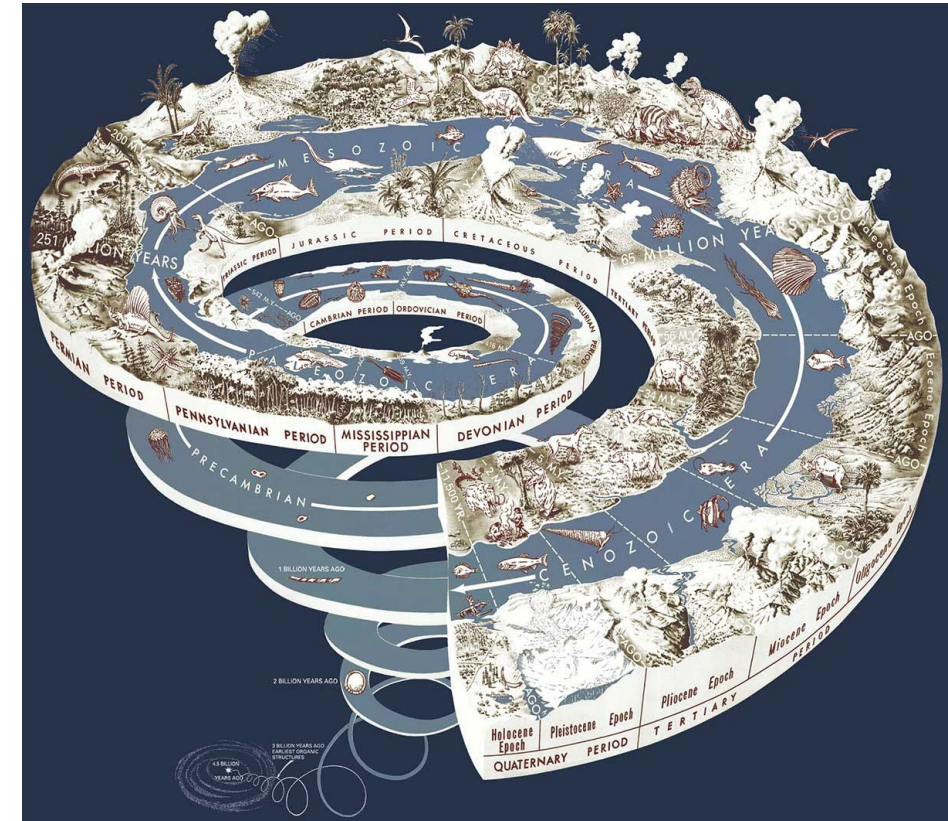


Trommel Screen



# Long Term Stability of PFAS Immobilisation

- Inherently difficult to prove. What does *perpetual* actually mean?
- We can only simulate in the lab (decades) or monitor in the field (few years)
- Metals & PAHs have been stabilised in soil for decades, why is PFAS any different?
- We need practical solutions built on quality independent data
- **PFAS is leaching as we speak!**





# Lab Simulations – Long Term Stability



ELSEVIER

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: [www.elsevier.com/locate/scitotenv](http://www.elsevier.com/locate/scitotenv)



Durability of sorption of per- and polyfluorinated alkyl substances in soils immobilised using common adsorbents: 1. Effects of perturbations in pH

Shervin Kabiri<sup>a,\*</sup>, Marc Centner<sup>b</sup>, Michael J. McLaughlin<sup>a,\*</sup>

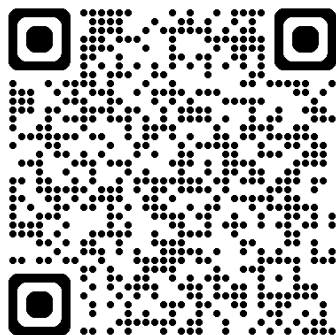
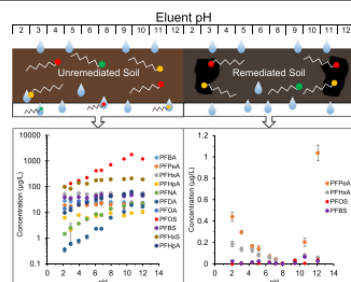
<sup>a</sup> School of Agriculture, Food and Wine, The University of Adelaide, PMB 1, Waite Campus, Glen Osmond, SA 5064, Australia

<sup>b</sup> ALS, Life Sciences Division, 277 Woodpark Road Smithfield, NSW 2164, Australia

## HIGHLIGHTS

- Systematic study on leaching of PFASs from remediated and unremediated soil
- PFASs desorption from soil depended to their C-chain length and chemical structure
- Short-chain PFASs desorption from soil was not pH dependent
- In-situ stabilisation of PFASs in soil remarkably decreased their desorption.

## GRAPHICAL ABSTRACT



ELSEVIER

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: [www.elsevier.com/locate/scitotenv](http://www.elsevier.com/locate/scitotenv)



Durability of sorption of per- and polyfluorinated alkyl substances in soils immobilized using common adsorbents: 2. Effects of repeated leaching, temperature extremes, ionic strength and competing ions

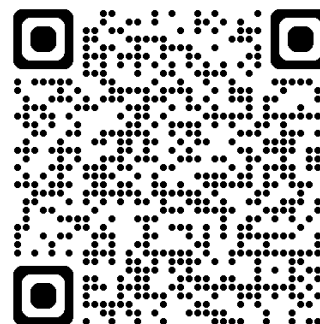
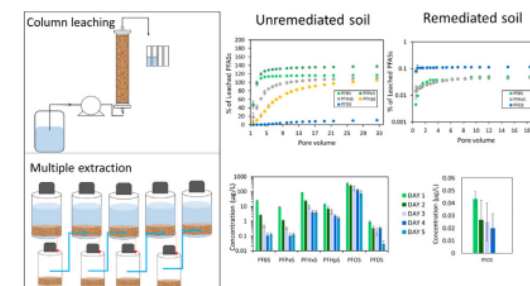
Shervin Kabiri<sup>\*</sup>, Michael J. McLaughlin<sup>\*</sup>

School of Agriculture, Food and Wine, The University of Adelaide, PMB 1, Waite Campus, Glen Osmond, SA 5064, Australia

## HIGHLIGHTS

- Short-chain PFASs desorbed completely and quicker than long-chain compounds during column leaching.
- Long-chain PFASs did not desorb completely using repeated or column leaching.
- No effect of temperature and ionic strength on PFASs leaching from remediated soils.
- No effect of HA and competing ions on PFASs leaching from remediated soils.

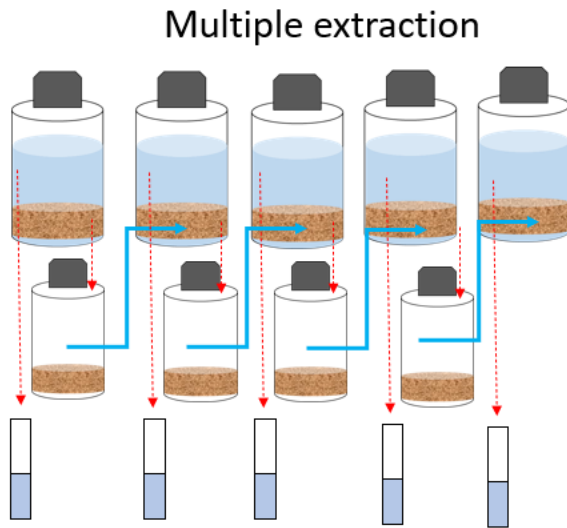
## GRAPHICAL ABSTRACT



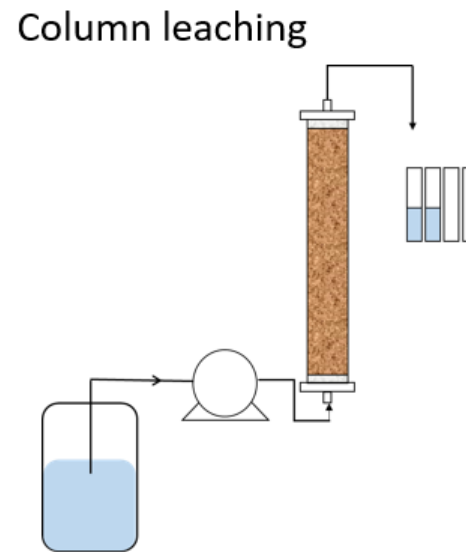
# Lab Simulations – Long Term Stability

Soil 1 (clay, 35 mg/kg, ~600 ug/L PFAS)

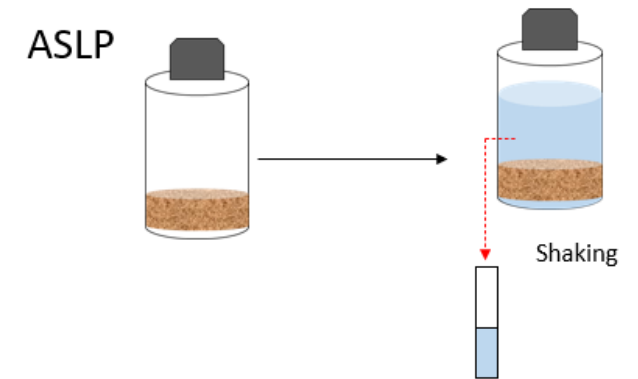
Soil 2 (sand, 0.7 mg/kg, ~60 ug/L PFAS)



Modified US EPA Method 1320, simulates **1,000 years** of stability using worst case scenario repetitive leaching using DI water as the leaching fluid



Simulates **field conditions** over ~17 years of precipitation in the region where Soil 1 was sourced

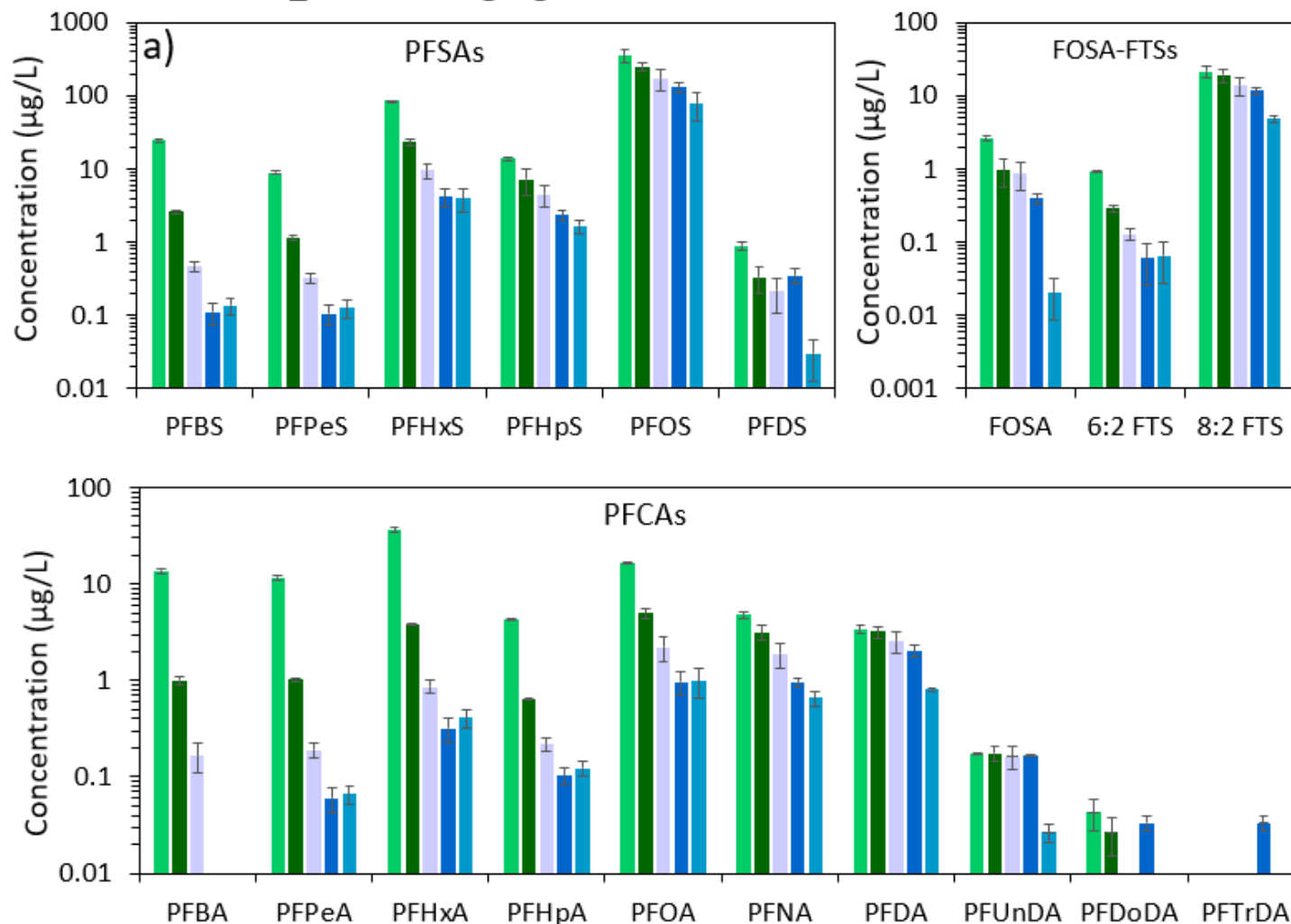


Simulates durability over a wide range of environmental conditions:

- pH 2-12
- Temperature -15°C to 45°C
- Salinity EC 0 to 17 dS/m
- Phosphate  $3 \times 10^{-4}$  to  $3 \times 10^{-2}$  P
- SOM 50-200 mg organic C per L

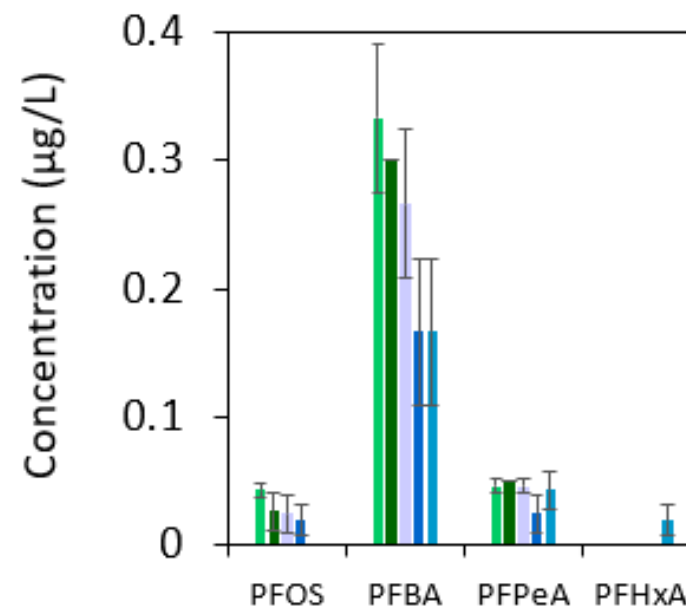
# MEP – Simulating 1,000 Years of Stability

Concentration of leached PFAS from untreated soil  
1  $\Sigma$  PFAS=35mg/kg



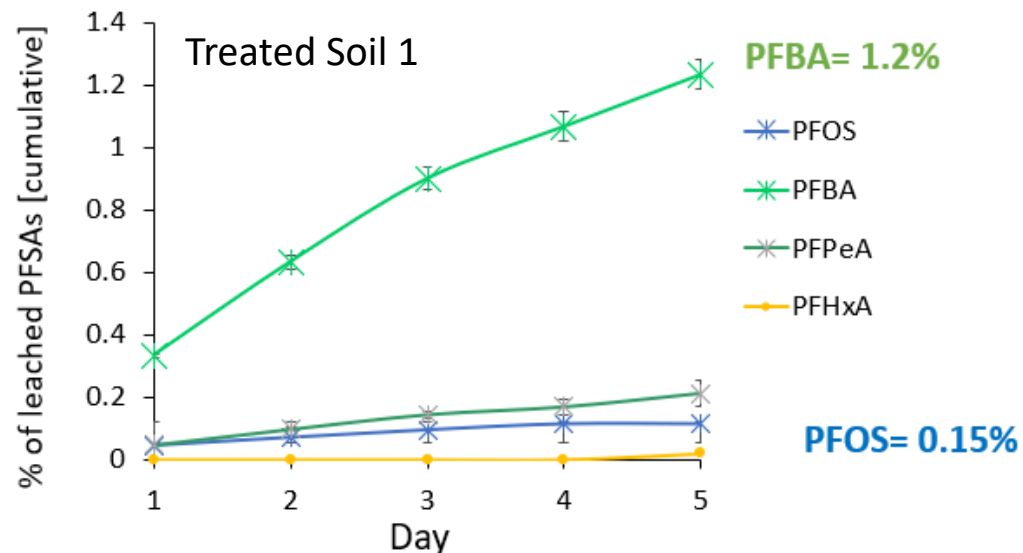
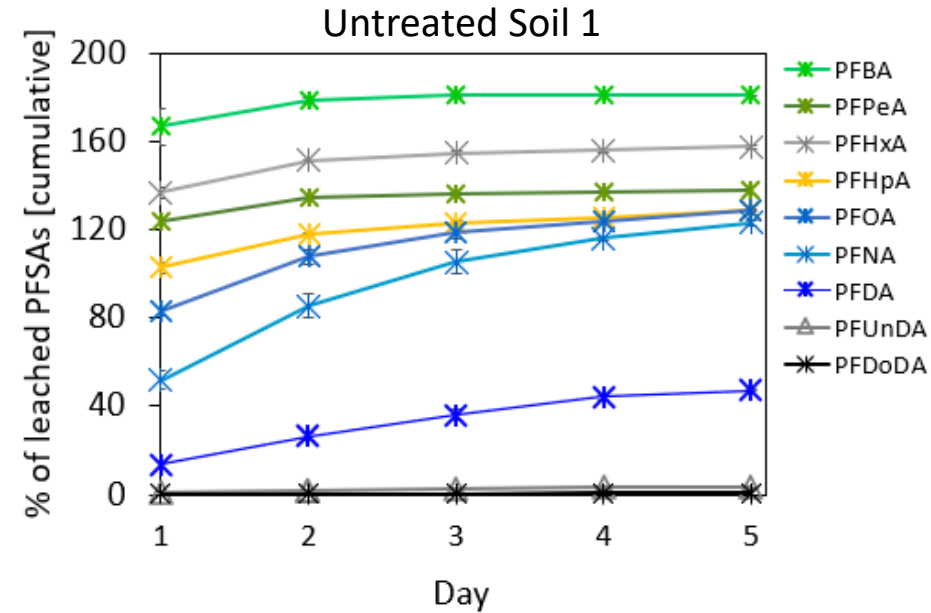
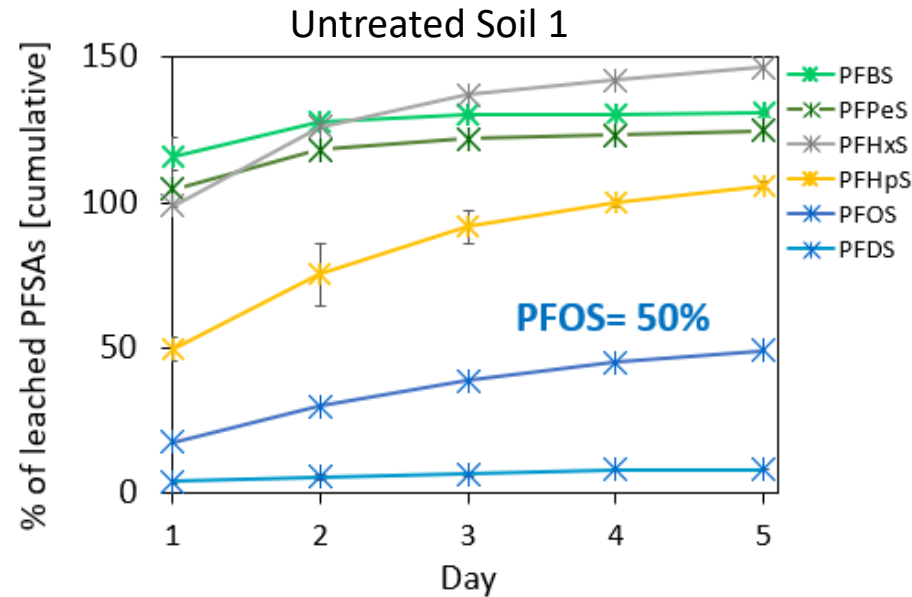
DAY 1 DAY 2 DAY 3 DAY 4 DAY 5

Concentration of leached PFAS from treated soil 1  $\Sigma$  PFAS=35mg/kg





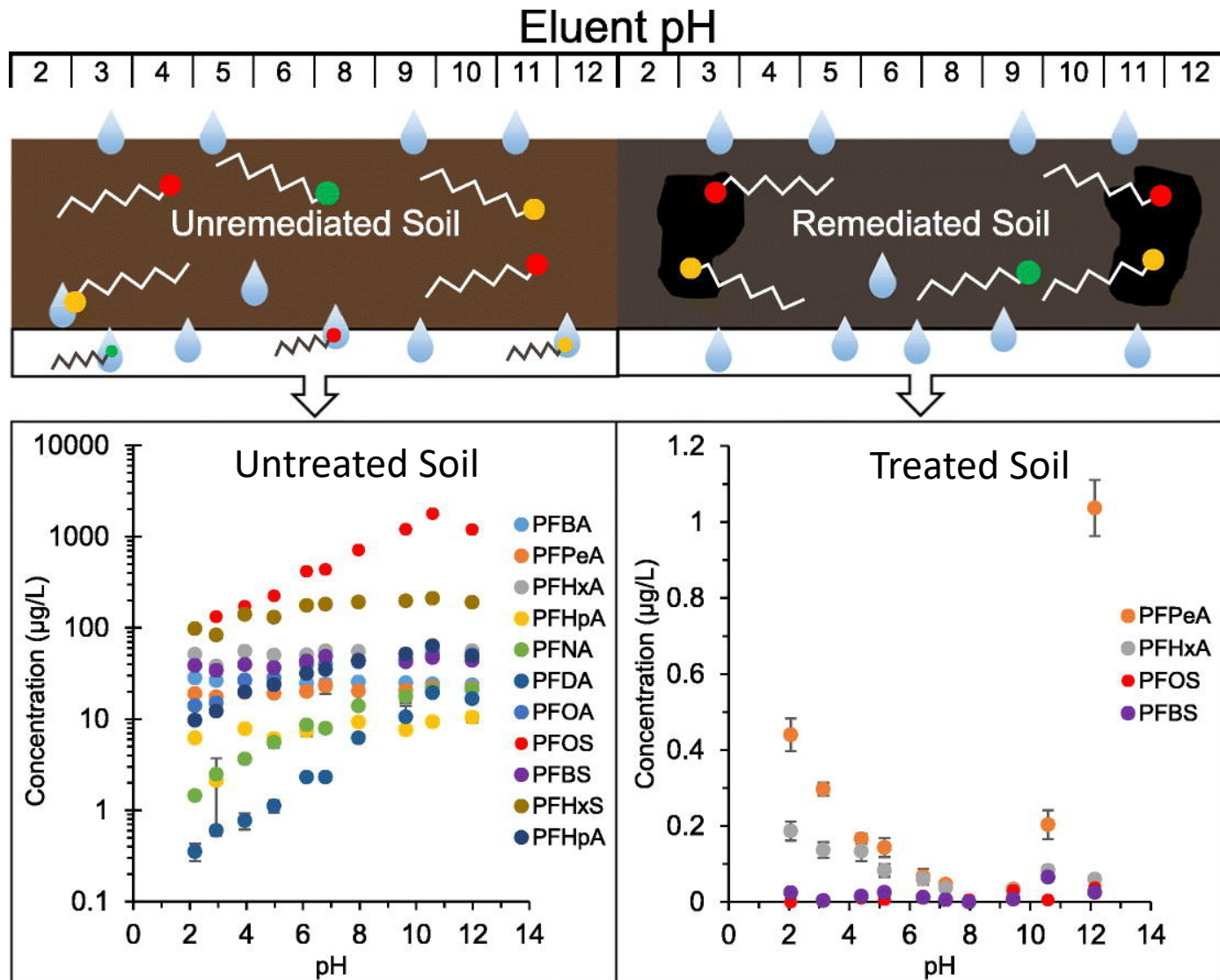
# MEP – Simulating 1,000 Years of Stability



## Conclusions:

- Only 4/15 PFAS species found in treated soil leachate
- After 1,000 yr simulation, 0.15% of PFOS has leached
- PFOS leaching has plateaued, PFBA predicted to plateau at <2%

# Lab Simulations – pH Stability



- Total PFAS ~35 mg/kg
- Soil treated with 5% RemBind
- 24-hour ASLP bottle leach across pH range 2 - 12

## Conclusions:

“Remediation ... with these sorbents could be considered **robust and durable** in terms of changes in soil pH, with little risk of subsequent PFASs desorption under normal environmental pH conditions”

# Conclusions from Kabiri Lab Studies

“...these results provide site owners and regulatory authorities with a high level of confidence that PFASs binding by **RemBind** is **predicted to be persistent in the long term**”.

“However, to give the greatest level of confidence, these simulations should be validated under field conditions for at least several years”





# Long Term Stability Study 2023 Germany

Jurgen Buhl, Cornelsen. Sorbed PFAS under Weather Conditions: Resilient Enough?

Battelle Chlorinated Conference 2024



## Stress test at Eurofins/D

- Durability of sorption process
- Idea: Weathering / Landfill / Chemical
- Eluate 2:1 & 10:1

eurofins

Freeze - Thaw

Wet - Dry

?

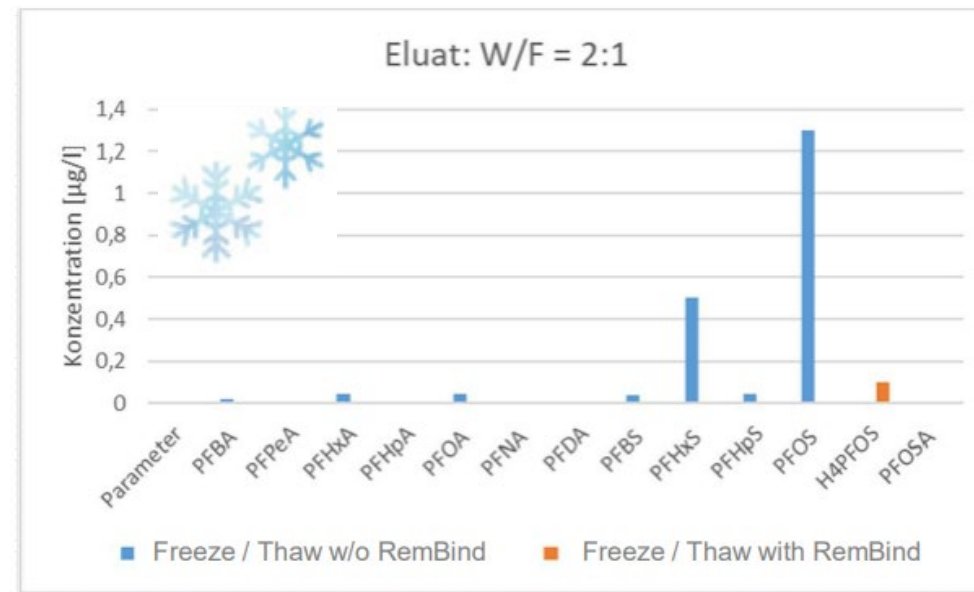
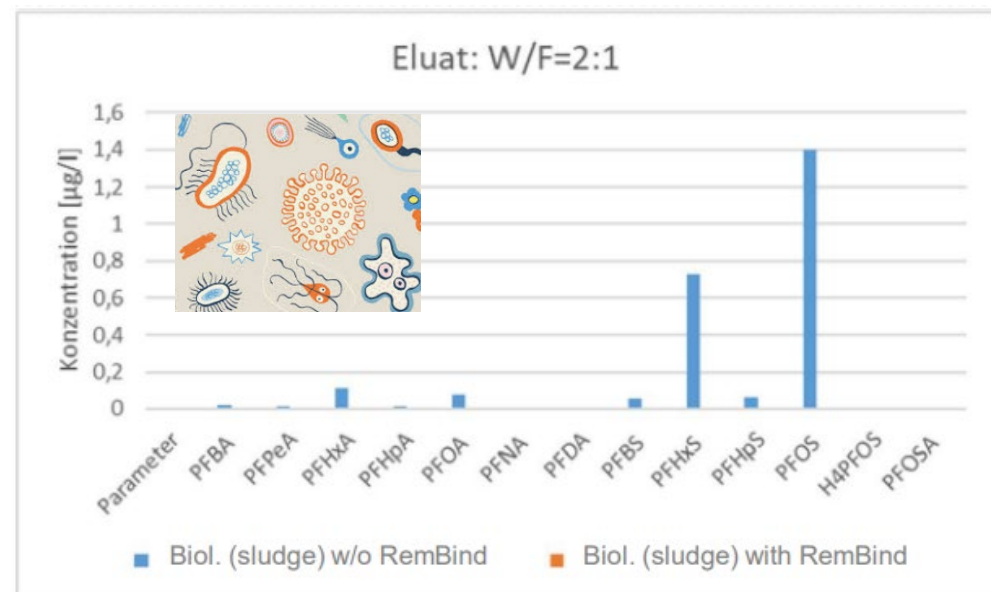
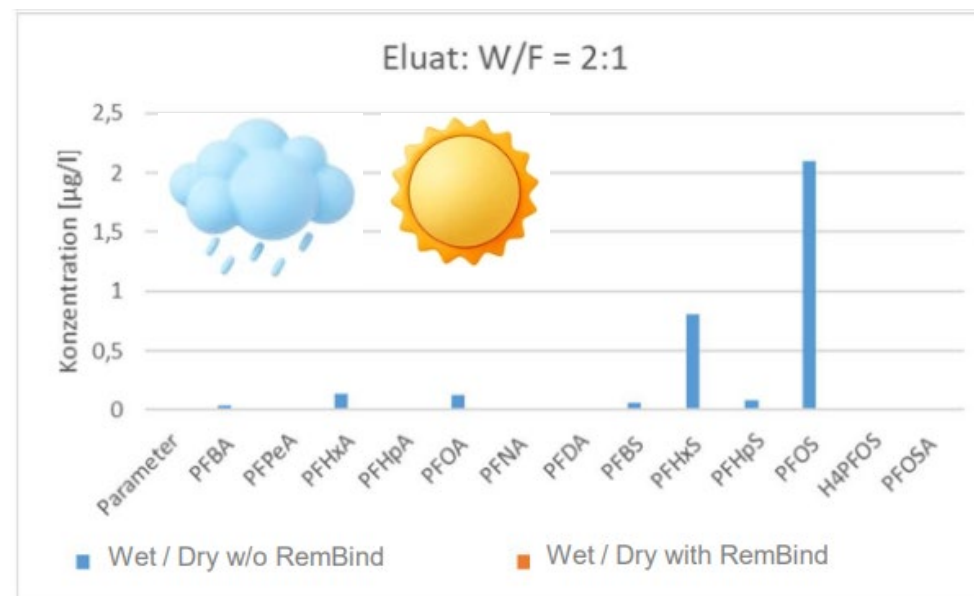
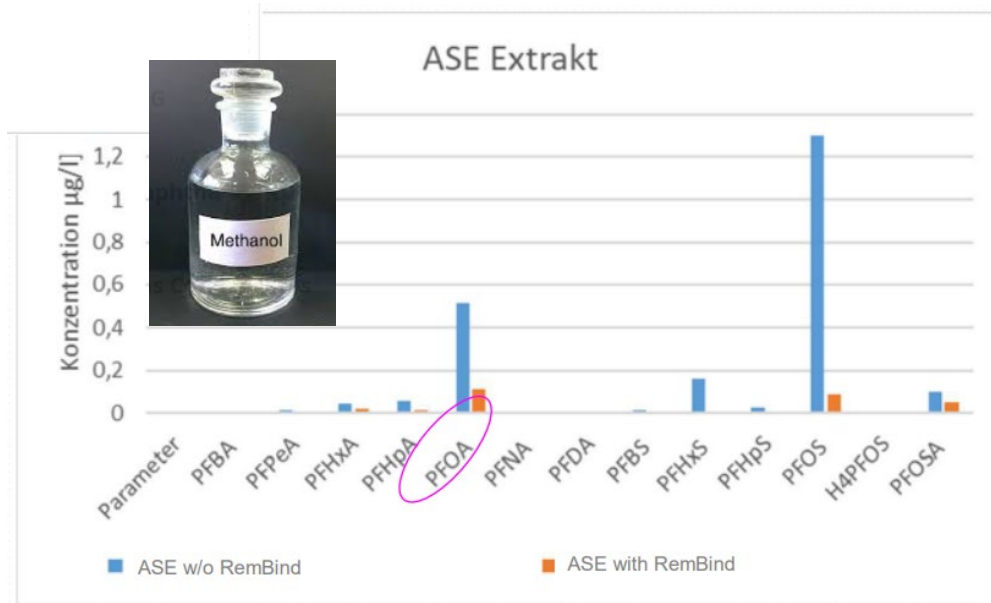
Activated  
Sludge

chemical  
with ASE

**Boiling Methanol!**

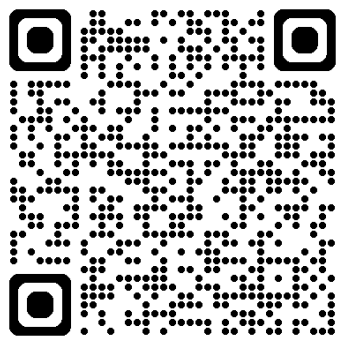
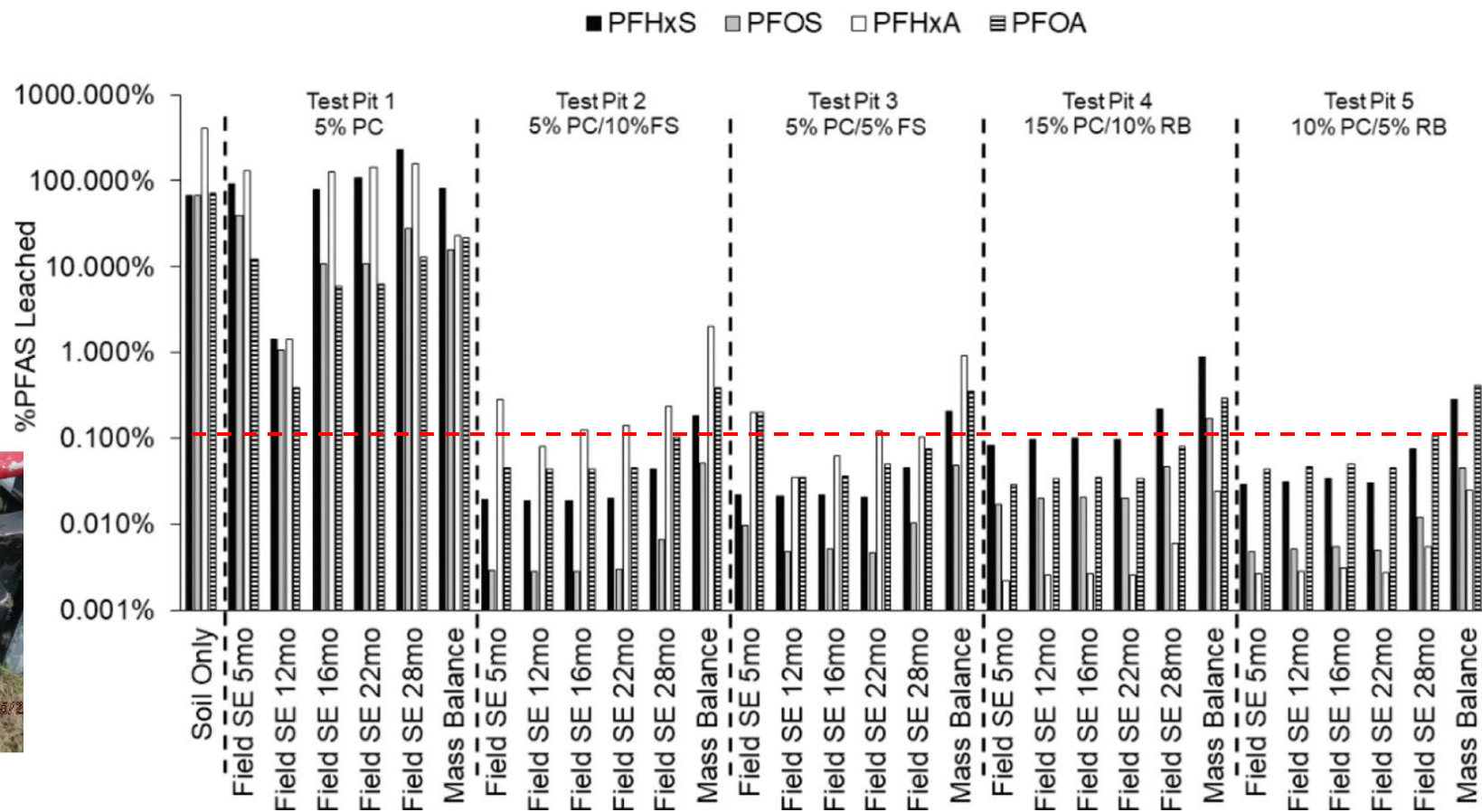
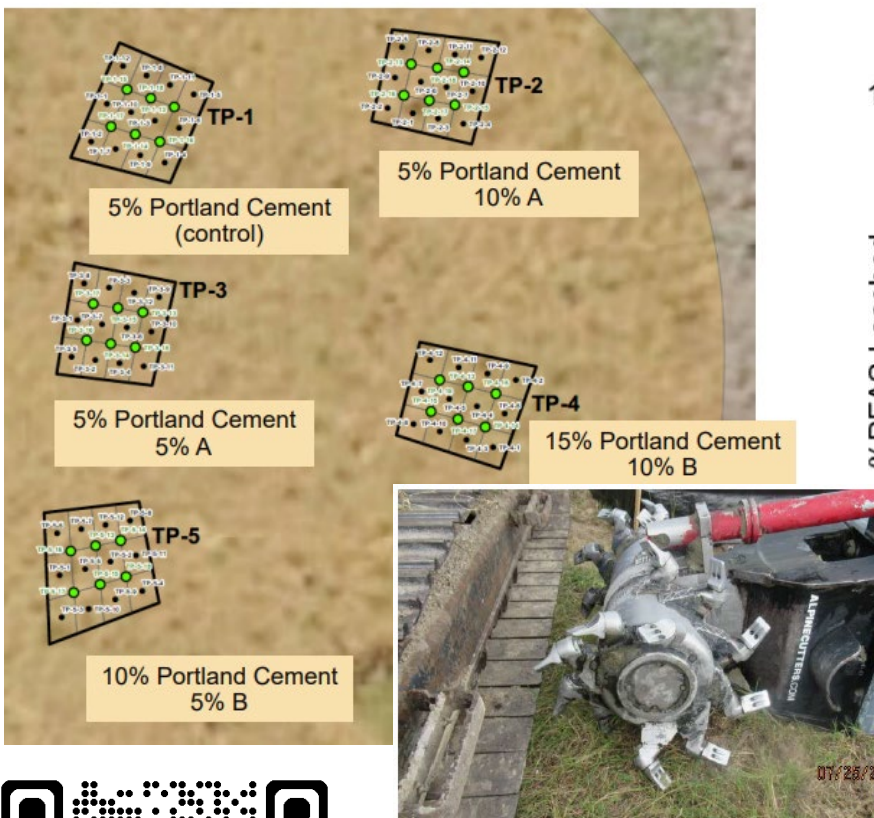
cornelsen

 **RemBind®**





# Long Term Stability in the Field – 2018 USA



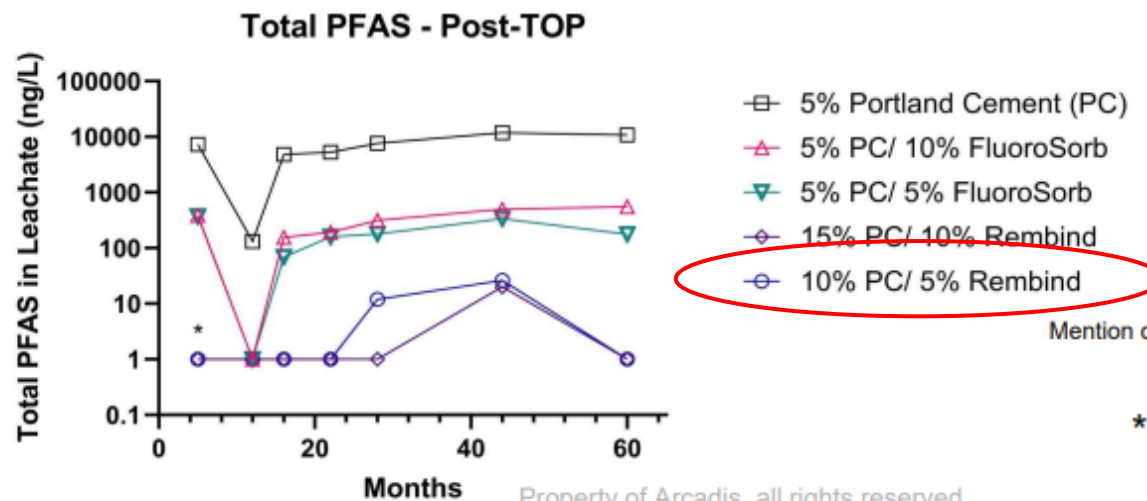
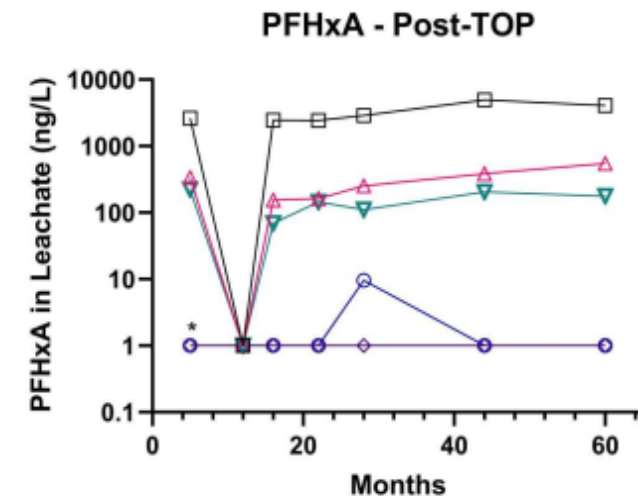
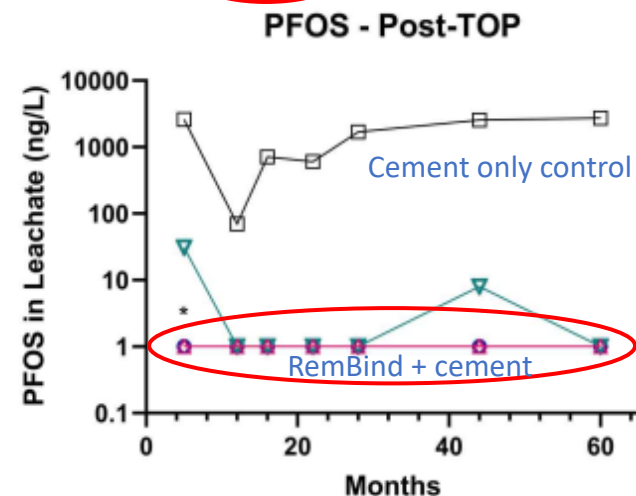
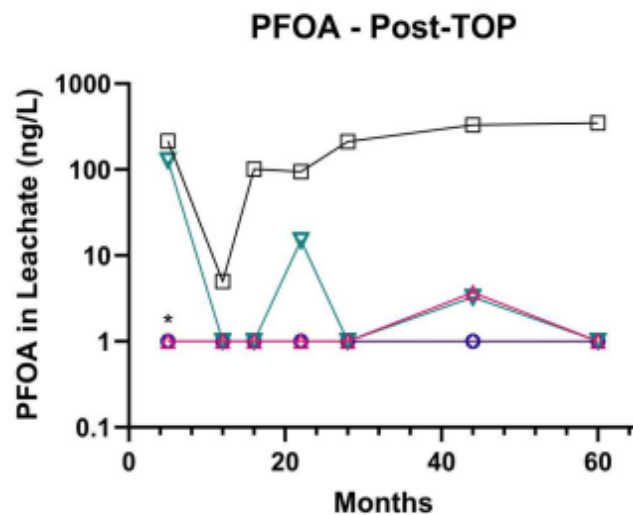
McDonough et al. ACS Omega 2022 7 (1), 419-429  
<https://doi.org/10.1021/acsomega.1c04789>





# Summary of Results (Log Scale)

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

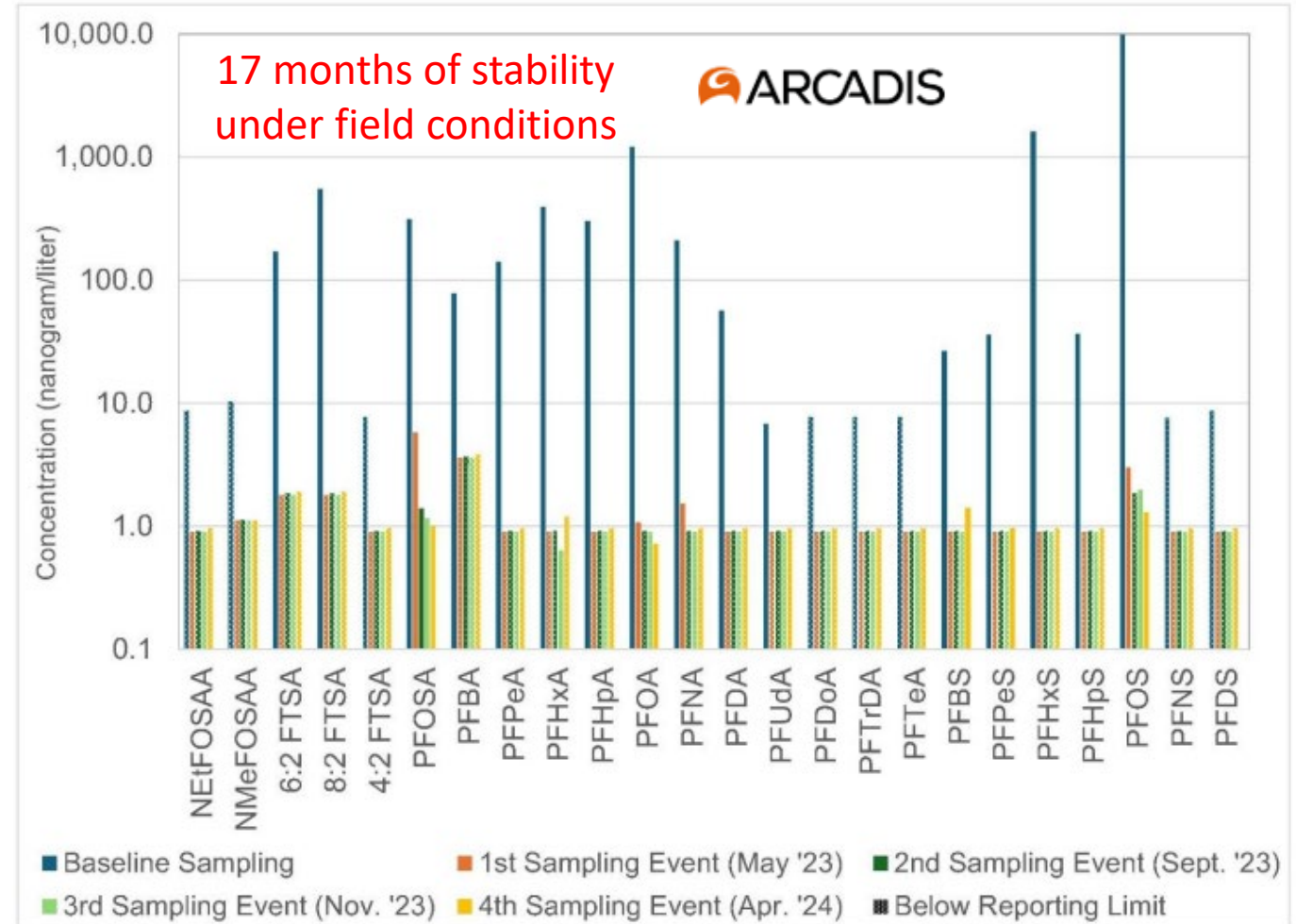
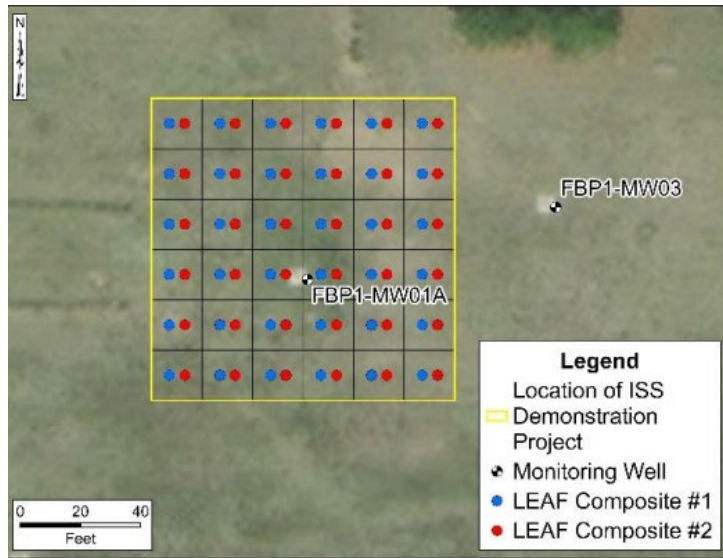


Mention of RemBind® and FluoroSorb® is not an endorsement

\*Non-detected levels

Theresa Guillet, Arcadis.  
In Situ Stabilization and Solidification for PFAS Remediation in Soils.  
2024 Battelle Chlorinated  
Conference, Denver, CO, USA

# Long Term Stability in the Field – 2023 USA



**Divine et al. 2025.** Field Demonstration of In Situ Stabilization (ISS) of PFAS in Soil with RemBind. *J. Haz Mat., in review.*



# Full-Scale Global Project Examples with Regulatory Signoff

- Commercial airport, [Canada](#) (full-scale, 2025)
- **Residential development**, [Australia](#) (full-scale 2024)
- Commercial airport, [USA](#) (pilot 2024)
- **Aged care home**, [New Zealand](#) (full-scale 2023)
- Military base, [Sweden](#) (full-scale 2023)
- 3 Airforce bases, [USA](#) (pilots 2022-24)
- Space base, [USA](#) (full-scale 2022)
- Metal plating site, [Sweden](#) (full-scale 2021)
- Airforce base, [Australia](#) (full-scale 2021)





# Take Home Messages

1. Immobilisation is an acceptable remediation method for PFAS contaminated soil
2. Peer reviewed studies using RemBind simulate:
  - 1,000 years of long-term stability
  - Durability across a wide range of conditions
3. Independent field data validates durability for >5 years
4. We don't need to reinvent the wheel!

