PFAS Immobilisation in Soil – A Design Guide

Dr Richard Stewart, Managing Director, RemBind Pty Ltd

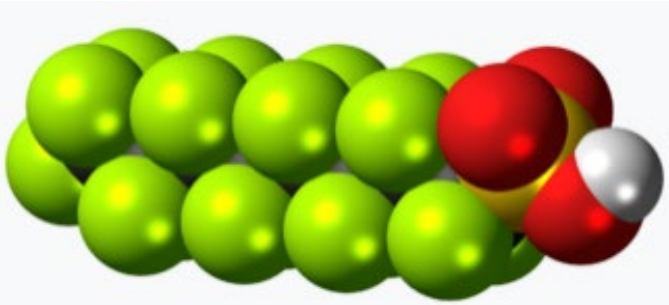
Demystifying Soil Treatment Alternatives, 26th October 2022

What is Immobilisation?

- Immobilisation is a remediation technique that uses additives/reagents to **lock up soil contaminants** to prevent them leaching into the environment.
- Also called ‘chemical fixation’ or ‘stabilisation’.
- ‘Solidification/Stabilisation’ (SS) also adds cement to form an extra physical barrier to leaching.

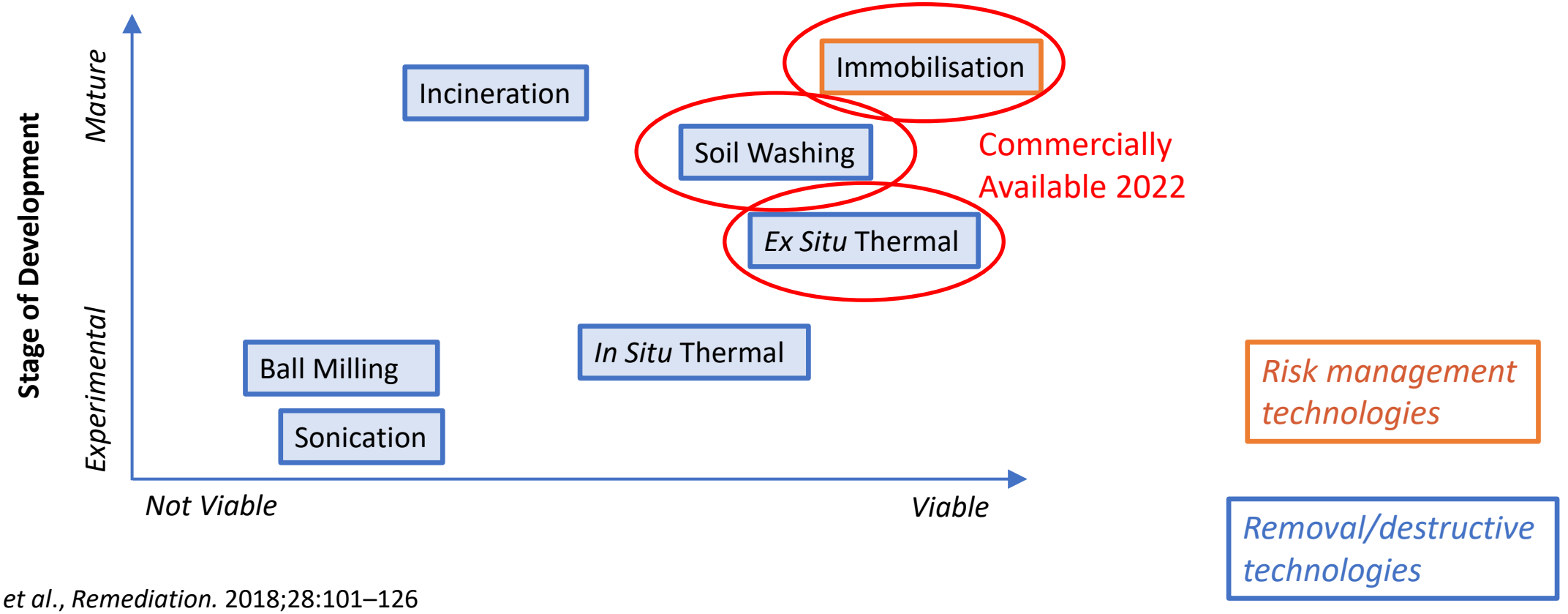
What is PFAS?

- Per- and Polyfluoroalkyl Substances (PFAS) are a group of man-made chemicals that have toxicity characteristics.
- Found in a variety of products like fire fighting foams, non-stick pans and even lipstick!
- Due to their highly stable C-F backbone, they are very persistent in the environment.
- Have made their way into soil, groundwater, drinking water and even biosolids & compost.



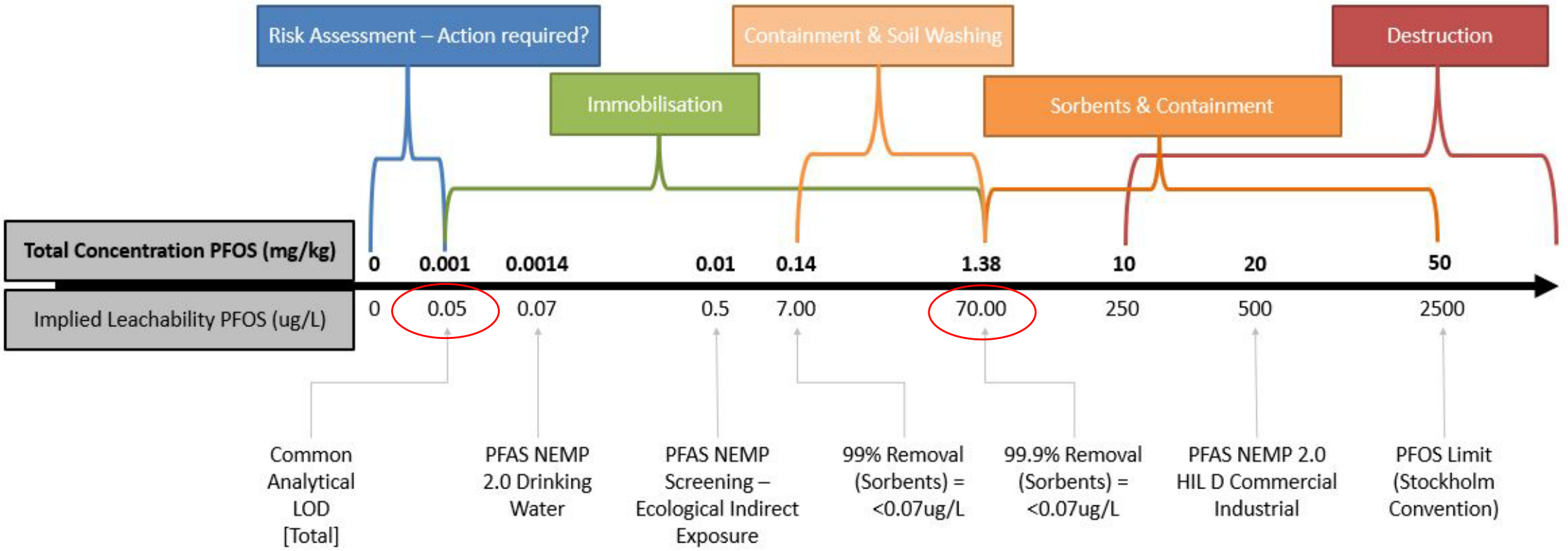
Perfluorooctanesulfonic acid (PFOS)

Treatment Alternatives for PFAS in Soil



Adapted from Ross *et al.*, *Remediation.* 2018;28:101–126

The ‘Sweet Spot’ for Immobilisation



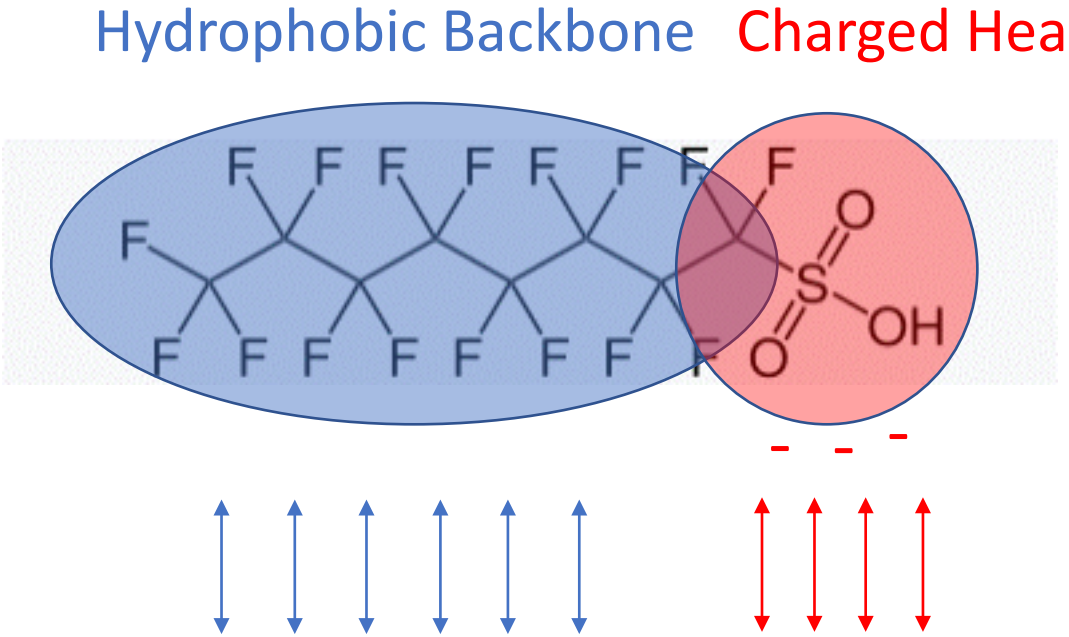
Matthew Askeland, ADE, Federal Contaminated Sites National Workshop, 16th November 2021 RPIC.

Selection of Reagents ('Sorbents')

Type	Examples	Benefits	Limitations
Mixed Mode - Carbon & Clay Mixture	RemBind	• Binds short and long chain PFAS • Designed specifically for soil • Binds some co-contaminants	• Availability restricted in some regions due to high demand.
Modified Organoclays	FluoroSorb	• Binds short and long chain PFAS • Can require lower dosage rates	• Relatively expensive for soil • Restricted availability in some regions for high volumes.
Activated Carbon	FiltraSorb	• Good availability • Familiarity with consultants	• Weaker bonding to short chain PFAS – risk of long term leaching. • Variable quality & performance.

How RemBind Works – Mixed Mode

PFOS



RemBind

Binds to activated carbon through adsorption

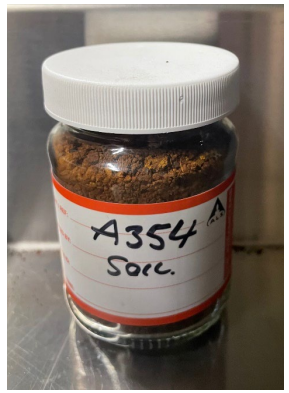
Binds to positively charged clays through ionic bonding

Lab-Scale Feasibility Testing

- Compare different reagents
- Determine the optimal dosage rate
- Identify soil-specific factors that may impact on the process.

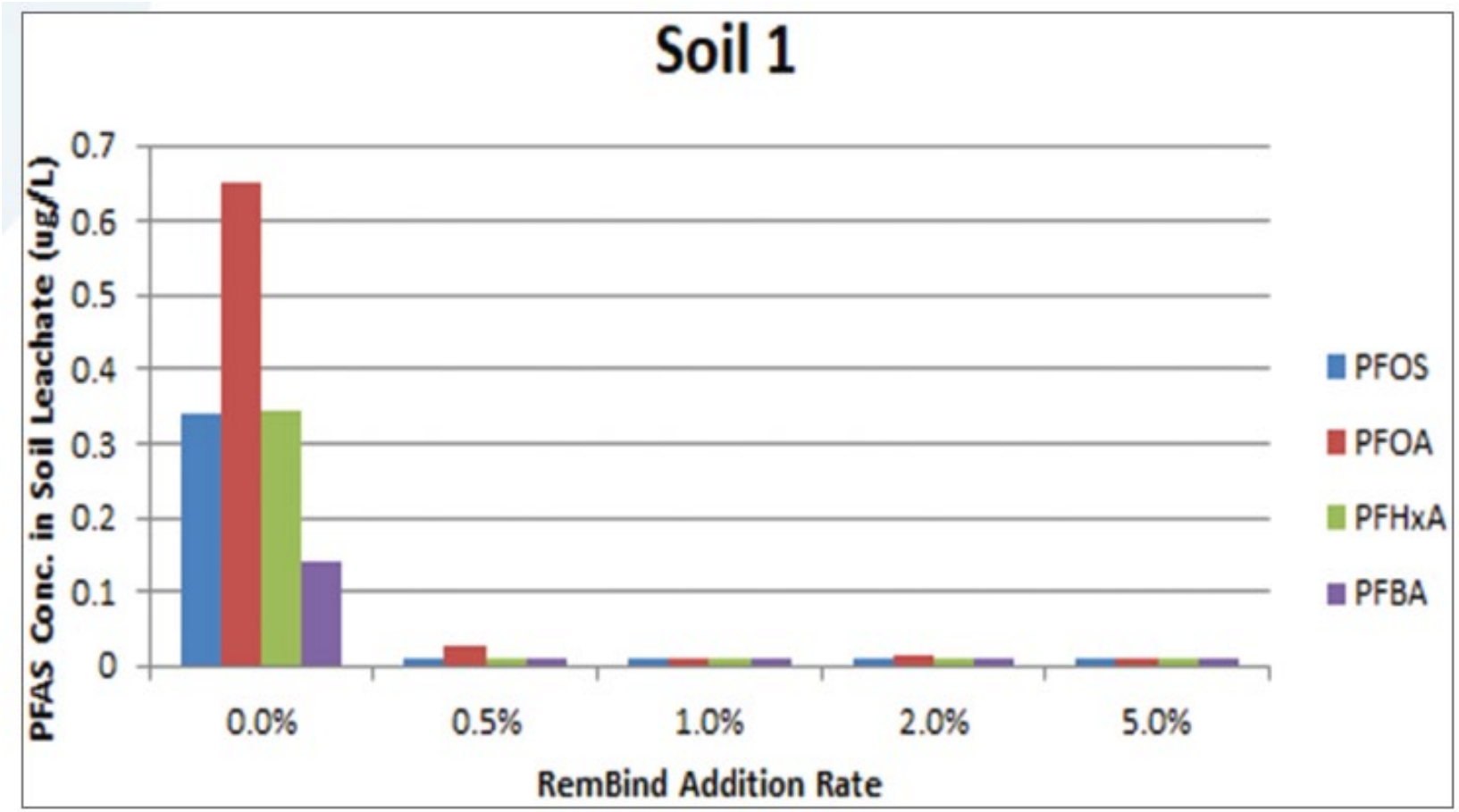
1. Screen soil, dose reagents (0% to 5%)

2. Add water and fix for 24 hours

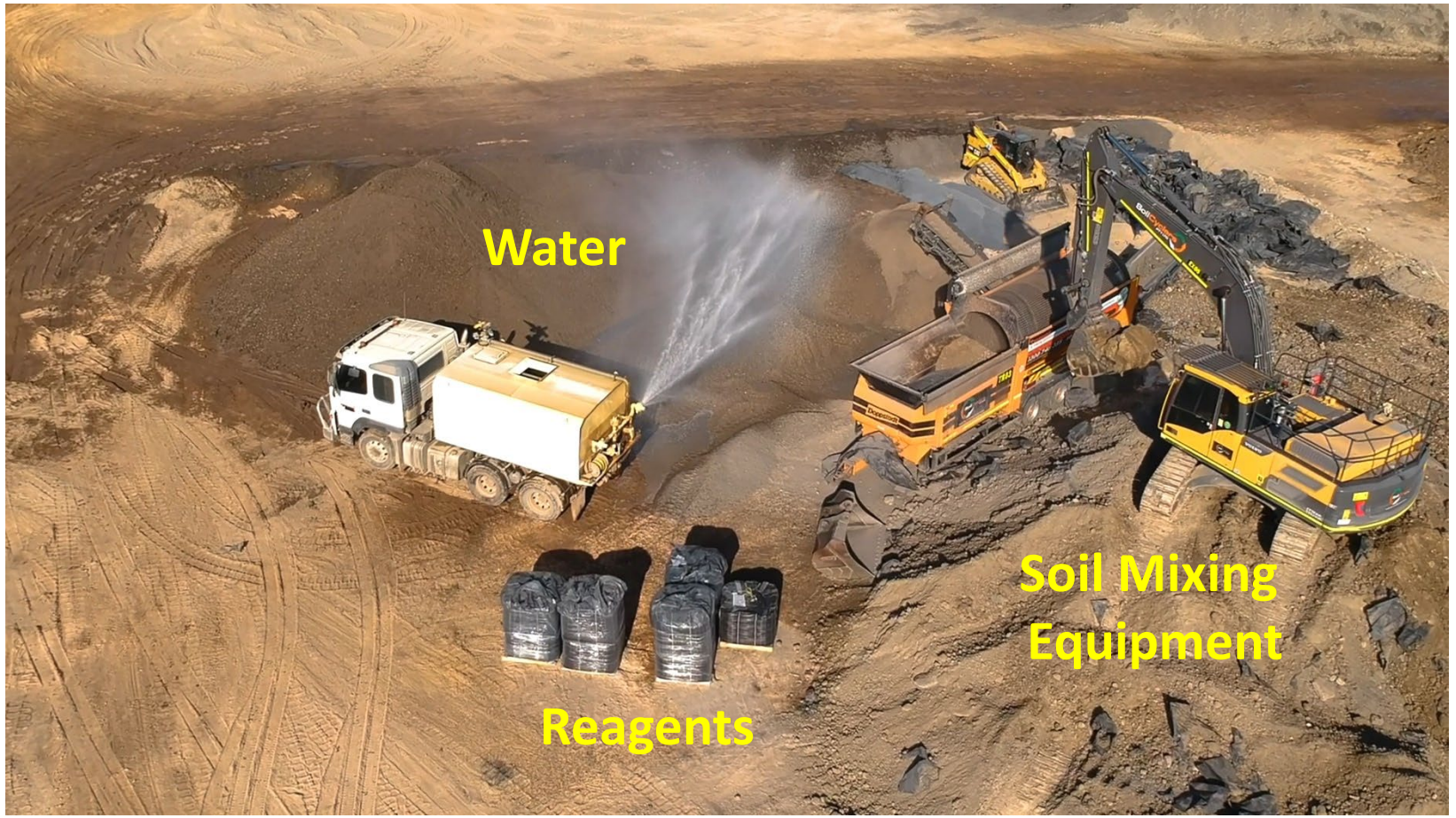


3. Analyse PFAS Leaching using ASLP

Example Lab Trial Outcome



Field Scale Implementation



Common Soil Mixing Options – Trommel Screen

Trommel Screens

- Pre-mix with excavator
- Mix through rotating screen
- ~500 m3 to 1,300 m3 per day
- Very cost-effective
- Portable, track mounted
- Suitable for most soils
- Heavy/wet clays may need extra processing step

Common Soil Mixing Options – Soil Recycler

Soil Recycler

- Purpose built soil blender
- Cutters in mixing chamber
- ~250 m3 to 500 m3 per day
- Designed to handle clay soils
- Automated dosing system
- Wet clays can slow production rate considerably.

Other Soil Mixing Options


Rotary Hoe


Arcadis

In Situ Mixer


Allu Bucket


Loader


EDCORP Project Solutions

Pug Mill

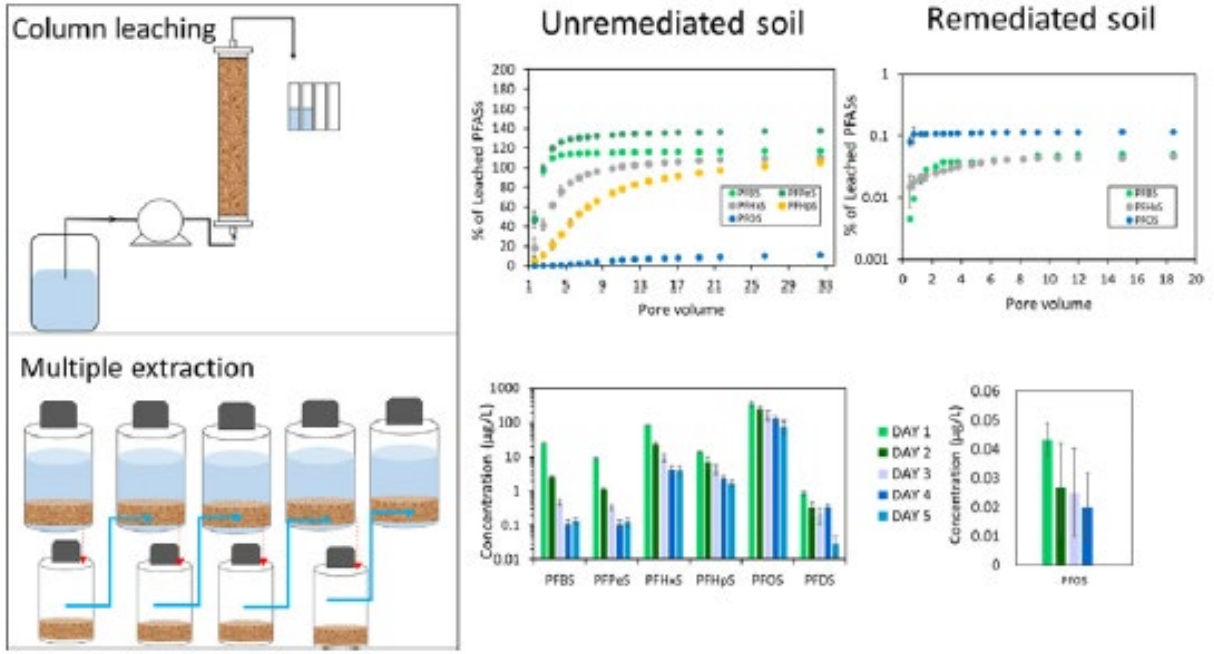
How to Measure Success in the Field

- Avoid the ‘lamington effect’ where large soil particles are coated on surface only!
- Volumetric mass balance – there should be no soil or reagent left over!
- Infield tests – dyes bind to reagent giving an indication of the spread of reagent.
- A sensible sampling and analysis plan showing reduced PFAS leachability.

Disposal Options after Treatment

	Benefits	Challenges
Landfill	• Can dispose as reduced hazard class • 'Quick/final' risk mitigation for project owner	• Costly • Unsustainable • Potential for leachate contamination
Onsite reuse or containment	• Sustainable, cost-effective • Circular economy approach • Unlock benefits of soil • Reduce need for clean fill	• Not always a viable use/space for soil onsite • Potential for long term leaching

Predicting Long Term Stability

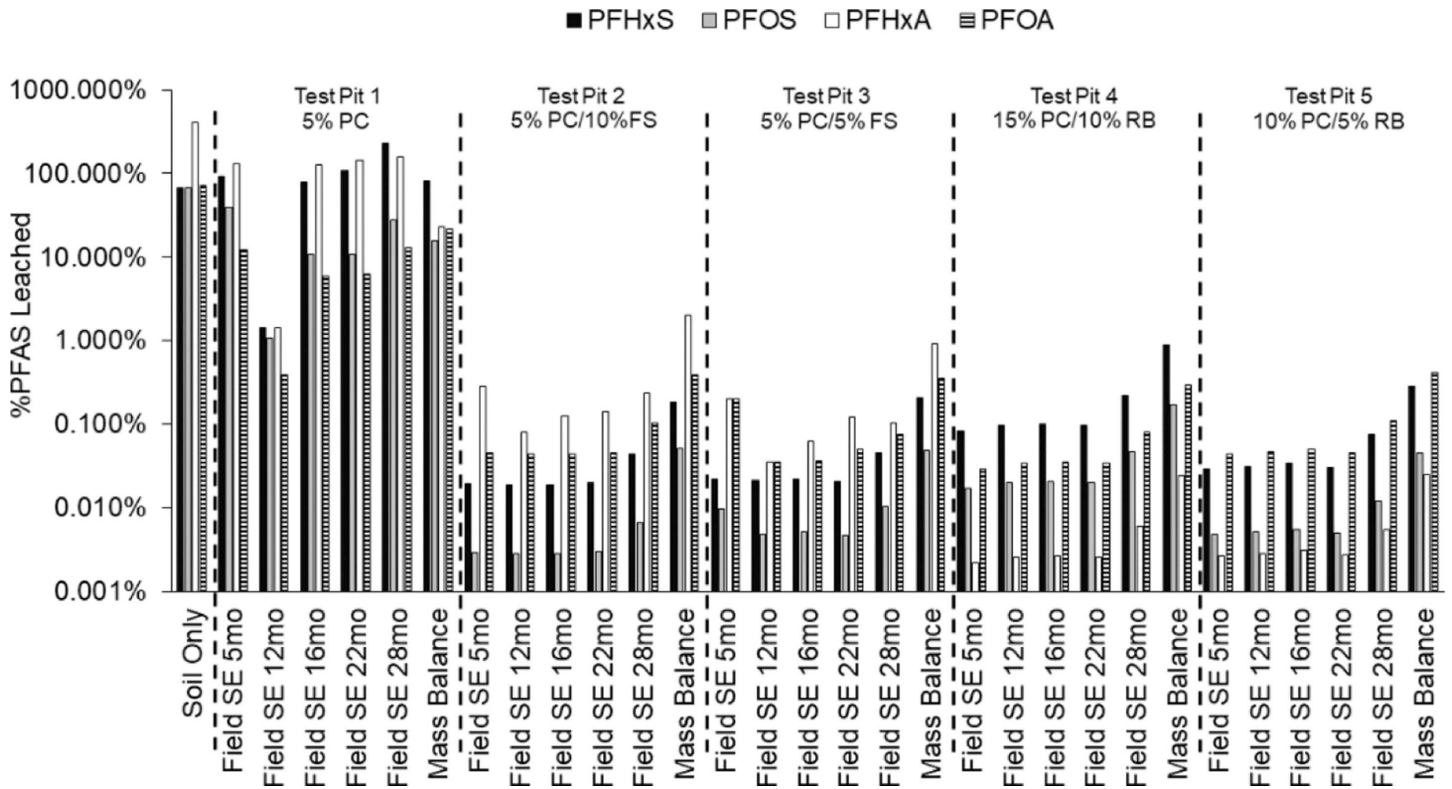


Little or no PFAS desorption from immobilised soil under a wide range of environmental conditions:

- pH 3 to 10
- Temperature -15°C to 45°C
- Salinity EC 0 to 17 dS/m
- Phosphate $3x10^{-4}$ to $3x10^{-2}$ P
- SOM 50-200 mg organic C per L

"While short-term laboratory…cannot exactly mimic long-term field conditions, 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." S. Kabiri and M. McLaughlin, 2021. https://doi.org/10.1016/j.scitotenv.2020.144718

Monitoring Long Term Stability in the Field



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

Regulatory Considerations

National PFAS NEMP 3.0 (draft)

- Contains a decision tree to allow soil reuse for certain PFAS levels
- Contains landfill disposal guidelines based on leachable PFAS
- https://haveyoursay.agriculture.gov.au/nemp-on-pfas

Defence PFAS Construction & Maintenance Framework

- Allows onsite reuse under different categories based on PFAS levels
- https://defence.gov.au/estatemanagement/governance/Policy/Environment/PFAS/docs/DefencePFASConstructionandMaintenanceFramework.pdf

EPA Victoria Interim Criteria for Reuse of PFAS-Impacted Soil

- Very conservative – work in progress
- https://www.epa.vic.gov.au/about-epa/publications/1669-4

https://wastemanagementreview.com.au/consultation-opens-on-nsw-epa-draft-regulatory-strategy/

Cost of PFAS Immobilisation

Typical Cost Breakdown

- Reagents ~$3,000/t
- Typical dosage rates 1% to 3% (w/w)
- Mixing costs = ~$5 to $10/t of soil

Example

- Reagents 2% dose x $3,000/t = $60/t of soil
- Mixing = $7/t of soil
- Total cost = $67 per tonne of soil

Take Home Messages

- Immobilisation is a proven and cost effective option for PFAS
- Not destructive – PFAS remains in the soil
- Effective carbon/clay reagents are commercially available
- Mixing machinery should be fit for purpose and validated
- Long term stability testing is important
- Onsite reuse of immobilised PFAS soils should be supported as a sustainable alternative to landfill.

Contact Information

Email: richard.stewart@rembind.com
Phone: +61 8 8470 1716
Website: www.rembind.com

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