Formulation and development of a novel dust-free carbon-based amendment for PFAS immobilisation in soil

Matthew James Richardson, Shervin Kabiri and Mike McLaughlin
The University of Adelaide

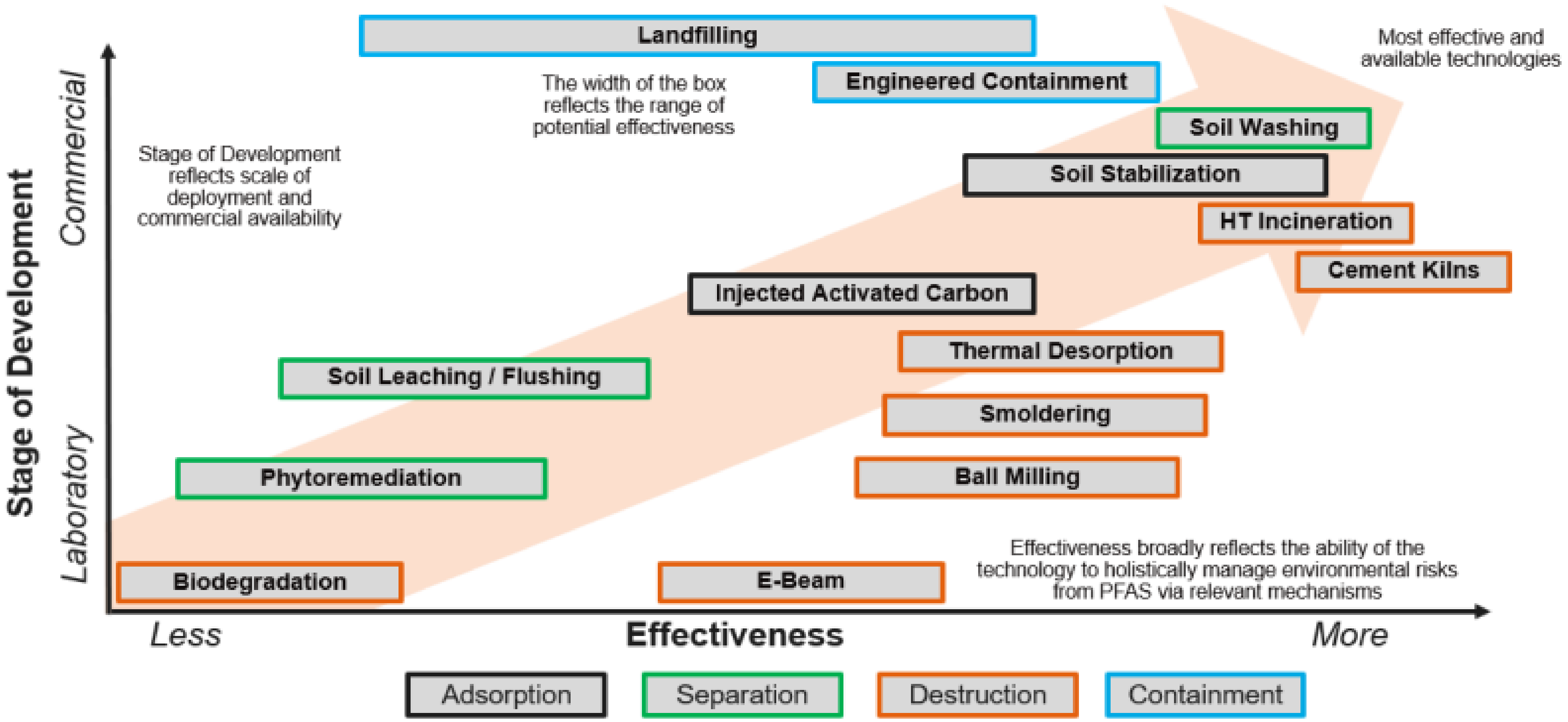
Poly- and perfluoroalkyl substances (PFAS) in soil

- The concentration of PFAS varies in soil, depending on whether it is a primary or secondary contaminated site.

Source zone	PFOA concentration (µg/kg)	Median PFOA (µg/kg)	PFOS concentration (µg/kg)	Median PFOS (µg/kg)
Primary	2- 50,000	83	0.4- 800,000	8,924
Secondary	7- 2,531	38	7- 5,500	680

Data are extracted from Brusseau et al. 2020, https://doi.org/10.1016/j.scitotenv.2020.140017

PFAS treatment technologies

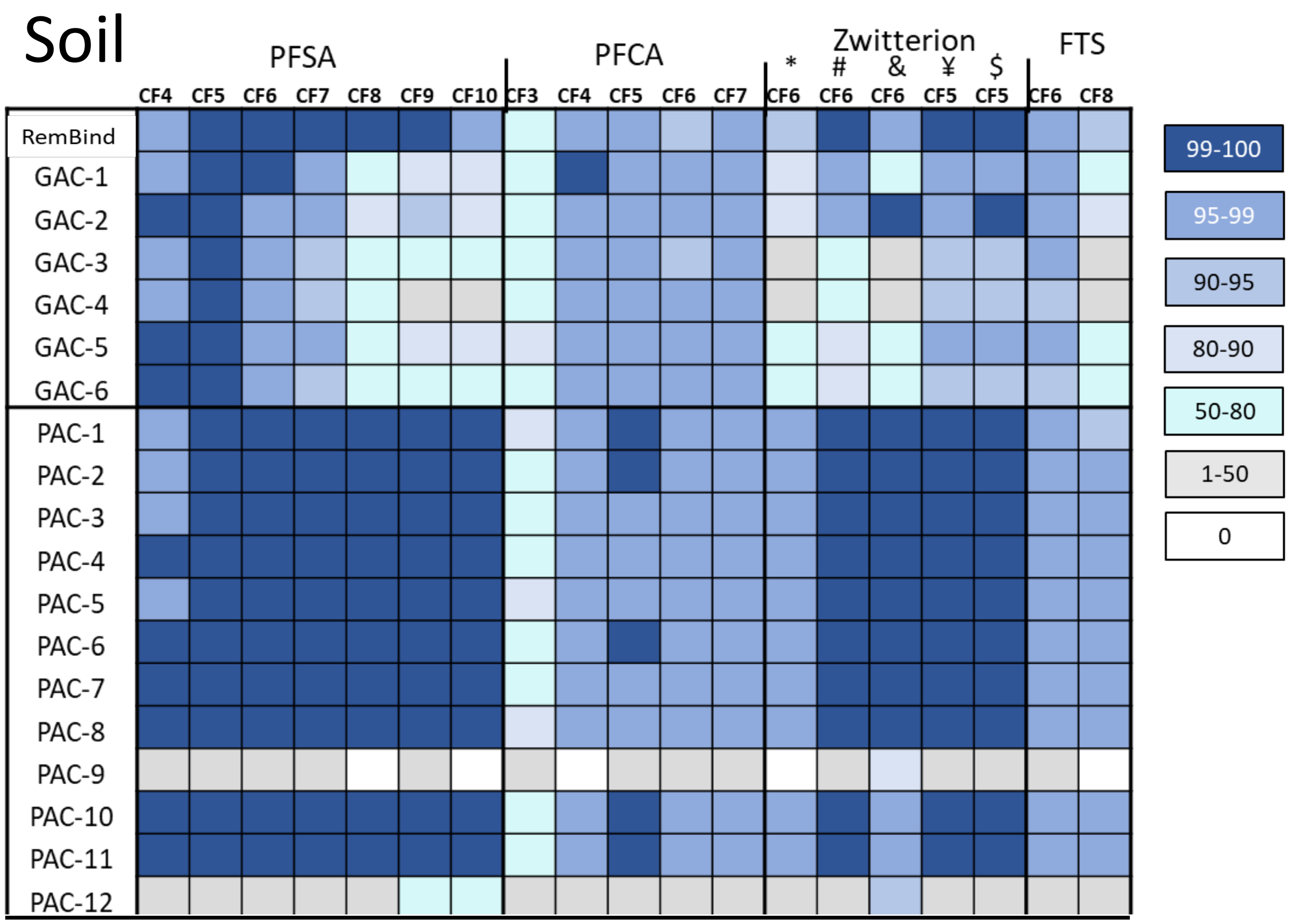


Concawe report no 8/24-PFAS Soil Treatment Processes – A Review of Operating Ranges and Constraints

Comparison of different soil removal technologies

	Soil Washing	Immobilisation	Thermal destruction
Mechanism	PFAS mobilised into solution	PFAS immobilise- sorbed to sorbent	PFAS desorption at 500 + vapour treatment
Treatment rate >1000 tons/day	Yes	Yes	No
Operating cost ($/kg)	$100-500/ton	$40-150/ton	$200 – 3500/ton
Efficient for long-chain removal	Less effective- depending on soil type	Yes	Yes
Efficient for short-chain removal	Yes	Yes – not complete removal	Yes
Resilient to variable soil condition	Less effective on clayey soils	Effective across different soil types	Effective
Effective for highly contaminated sites	Yes- require immobilisation	Yes- more dosage of sorbent is required	yes
Process Challenges/difficulties	Difficult to implement in remote regions; should be combined with immobilisation	Initial footprint may be large with excavation and ex situ treatment of soils	Soil require to be excavated and carried

PFAS immobilisation using different PAC, GAC and RemBind

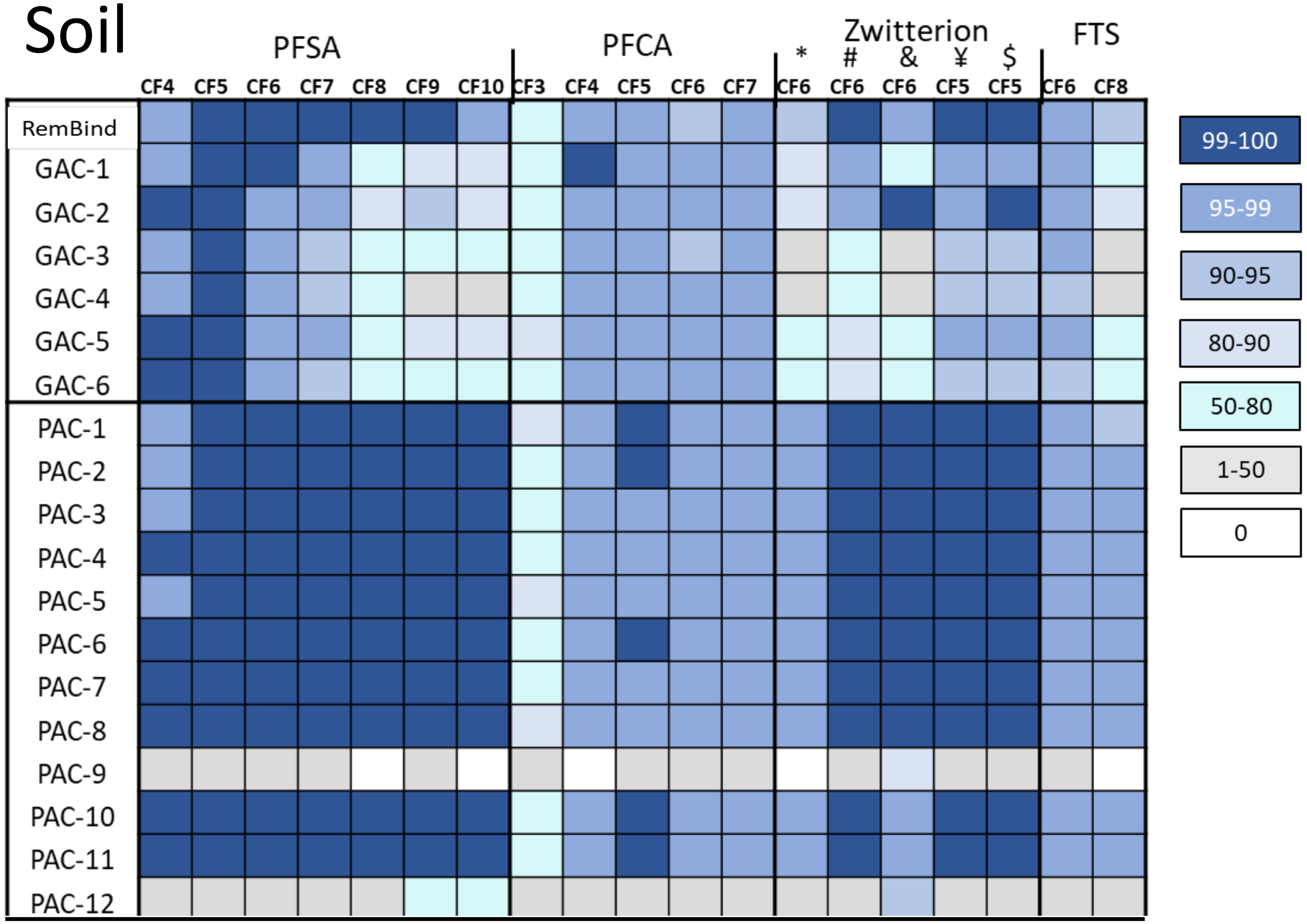


- Short- and long-chain PFAS were immobilised more than 95% in soil for most of PACs, GACs and RemBind.
- Overall the performance of the sorbents is PAC≈RemBind>>GAC

Kabiri et al. STOTEN, 2023,
https://doi.org/10.1016/j.scitotenv.2023.162653

PFAS immobilisation using different PAC, GAC and RemBind

Soil



- Short- and long-chain PFAS were immobilised more than 95% in soil for most of PACs, GACs and RemBind.
- Overall the performance of the sorbents is PAC≈RemBind>>GAC

The handling and application of any sorbents with small particles can pose health risk to workers

Kabiri et al. STOTEN, 2023,
https://doi.org/10.1016/j.scitotenv.2023.162653

Dust-Free PFAS sorbents

RemBind powdered sorbents

Granulation → Dispensable granules ✓

- Dust free
- High physical strength
- Degradable
- Disintegrate in soil
- Easy to apply in field

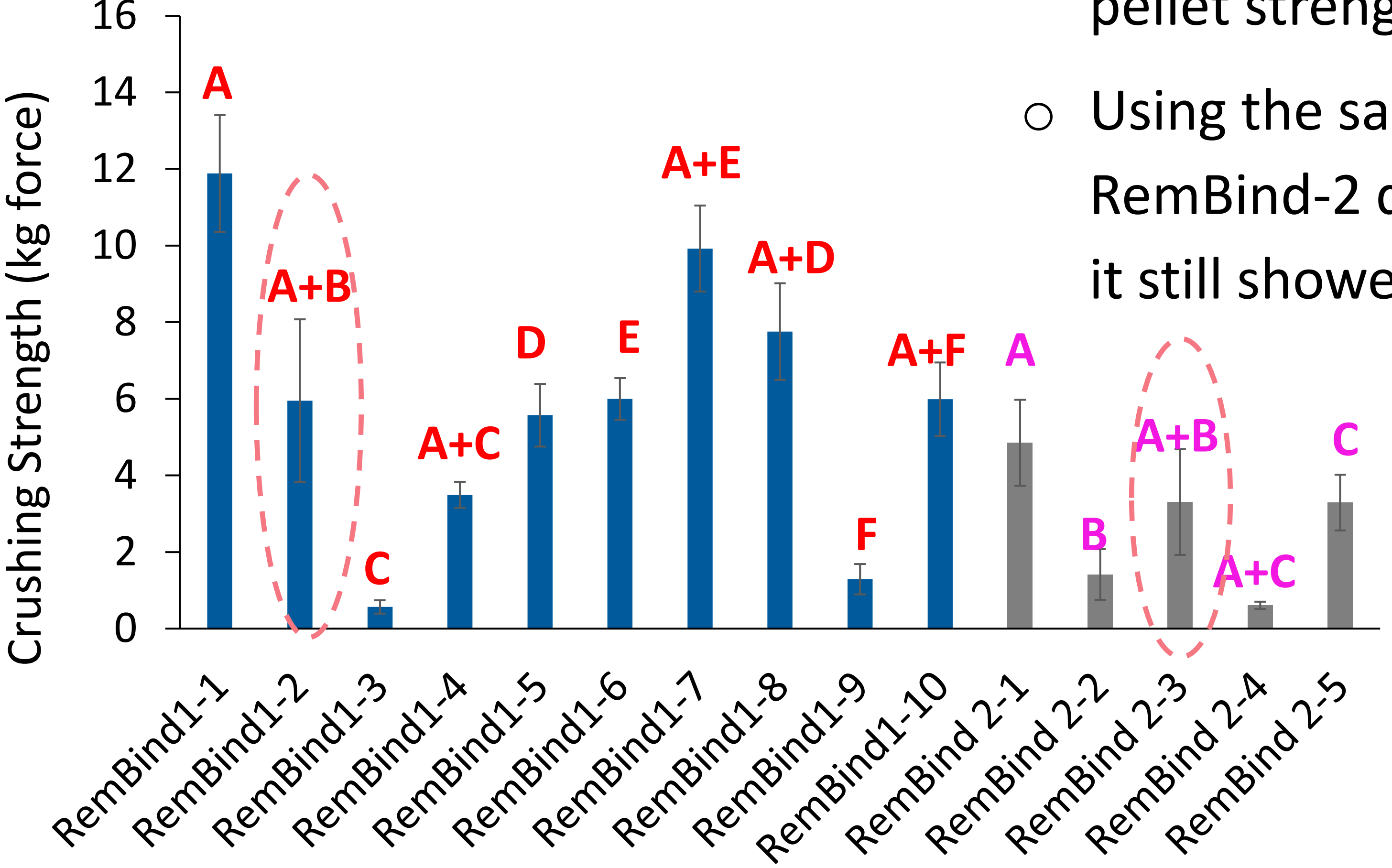
Granulation → Decrease the surface area ✗

Experiments

- Materials
  - RemBind 1- (small particles less than 100 µm)
  - RemBind 2- (mixture of particles with µm and mm size)

- Different rates of single binder or mixture of them (6 different binders tested)
- Granulated using a bench top granulator
- Pelletised
- Effect of drying condition and moisture are tested- results are not presented
- Crushing strength of the granules/pellets were tested
- Disintegration of granules in water and soil tested
- PFAS immobilisation is tested using LEAF 1314 (column leaching experiment)

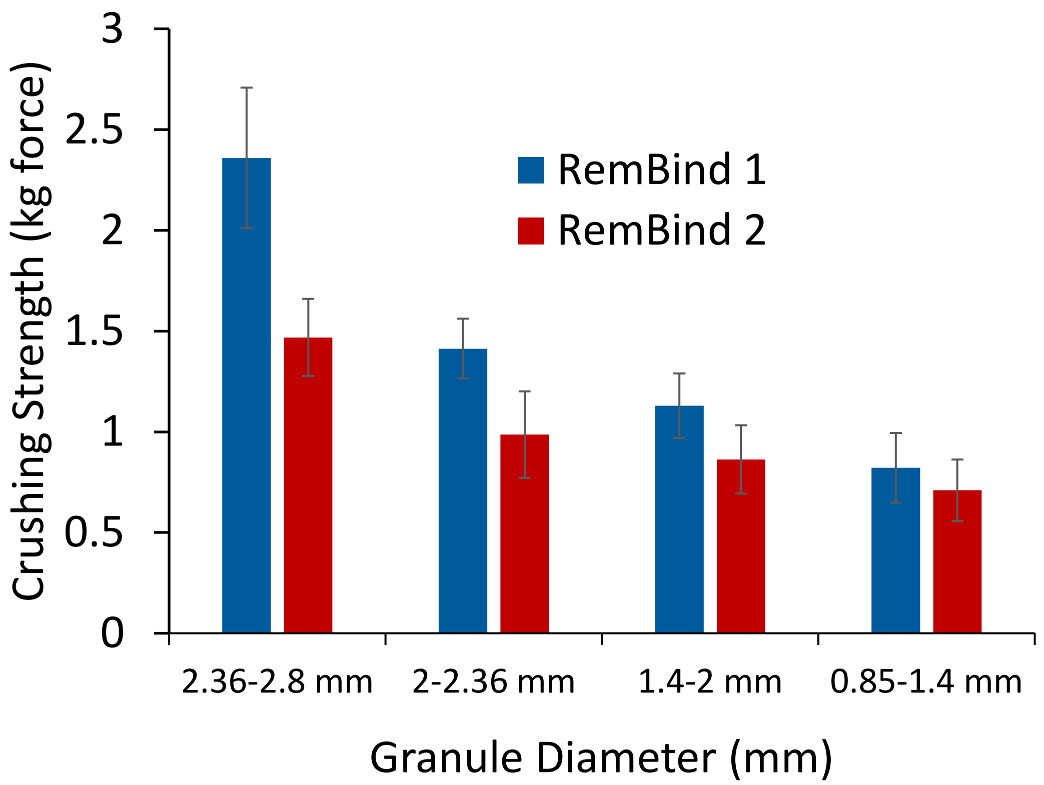
Pelletised formulations



- Binder type and rate had an important effect on pellet strength.
- Using the same binder the crushing strength of RemBind-2 decreased compared to RemBind-1 but it still showed very high crushing strength

Minerals in RemBind formulation played an important role on strength of pellets /granules

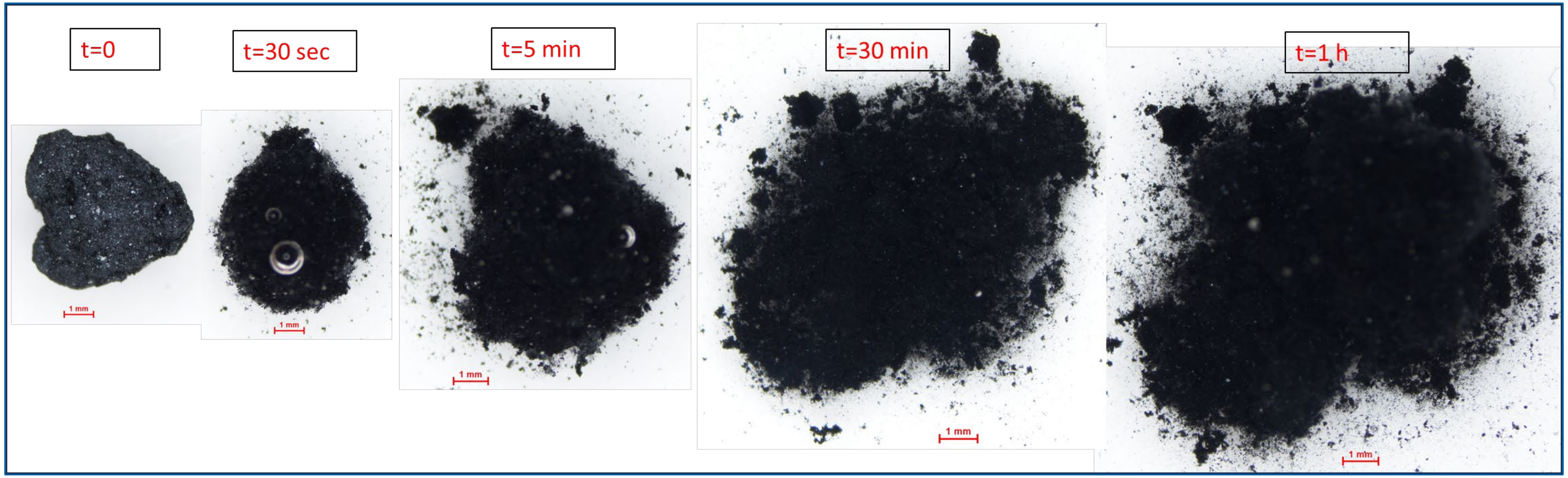
Granulated products



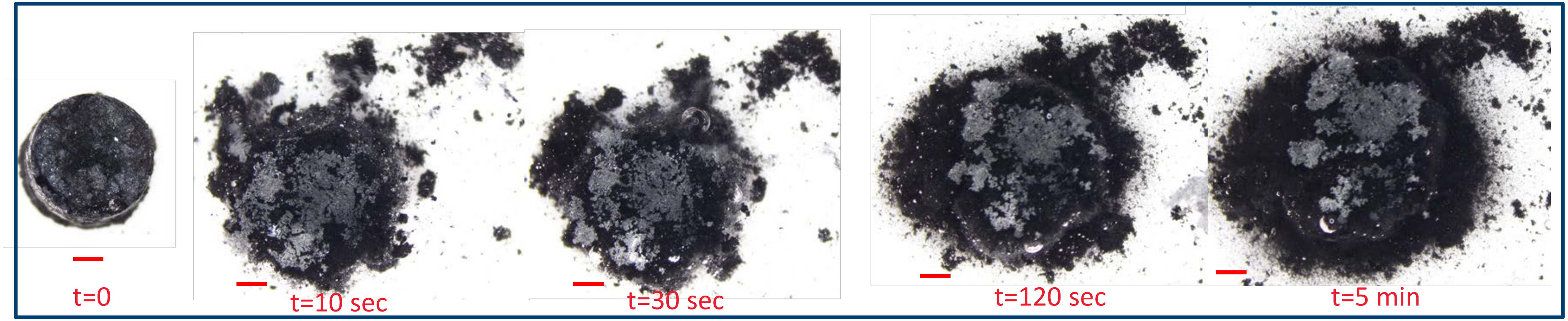
- Like pellets, binder type and rate had an important effect on granules crushing strength and swelling
- RemBind 1 had greater crushing strength than Remind 2 granules at the same conditions and with the same binders.

Granules/pellets disintegration in contact with water (RemBind 1)

Granule



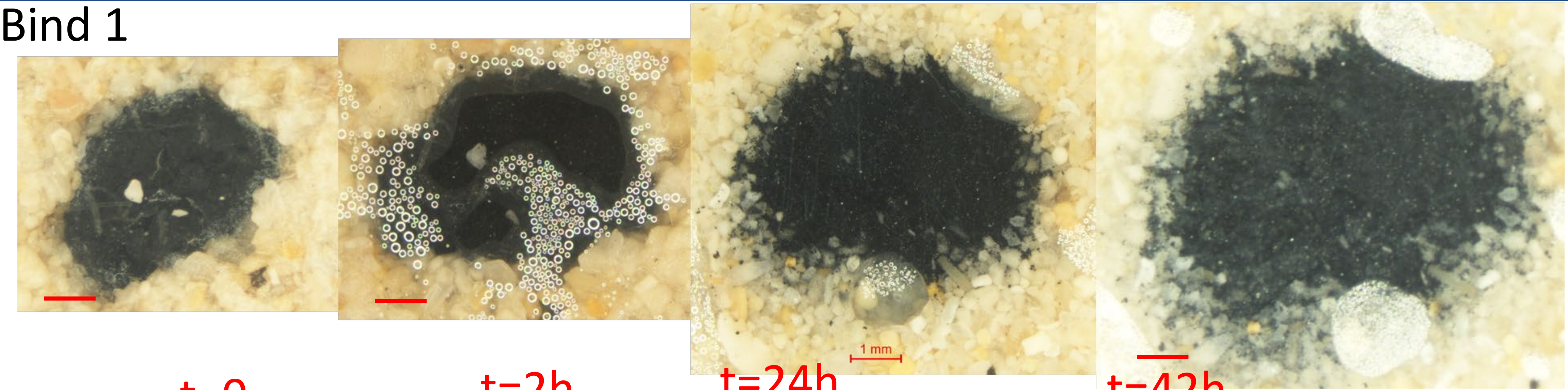
Pellet



Despite having greater crushing strength pellets swelled quicker than granules

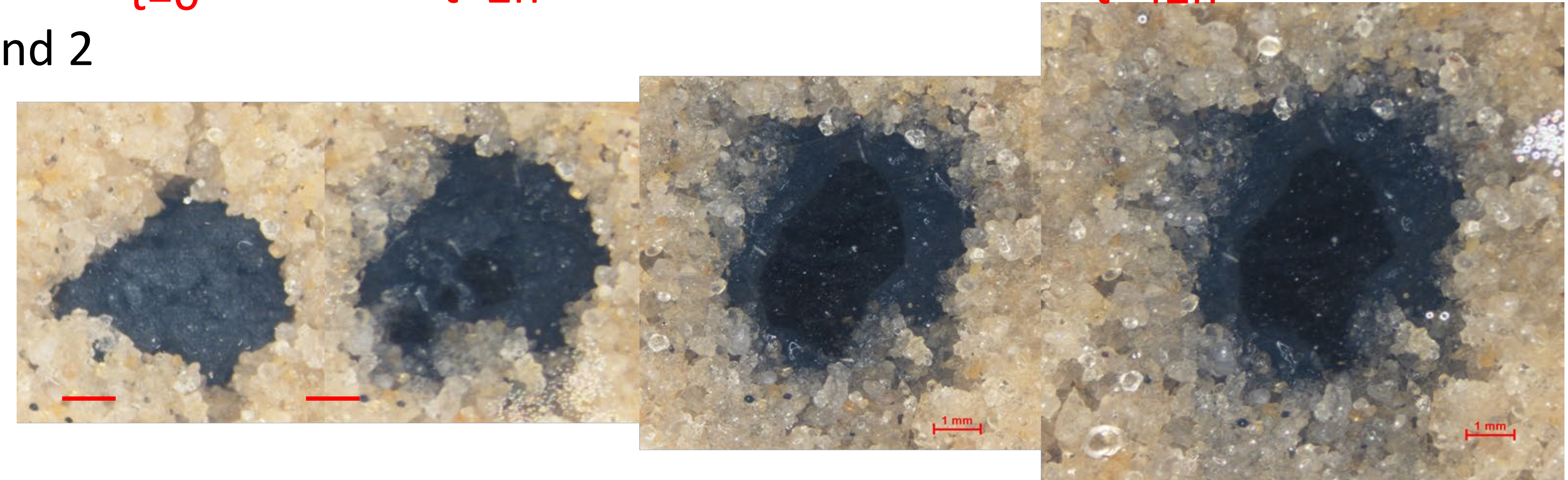
Granule disintegration in soil

RemBind 1



t=0 t=2h t=24h t=42h

RemBind 2



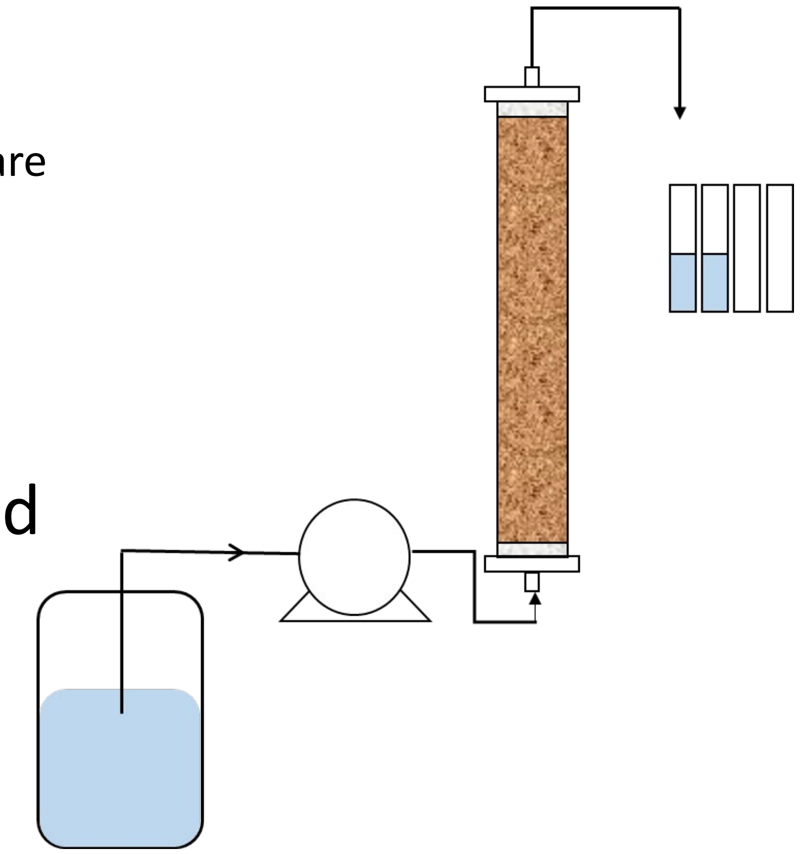
Column leaching experiment

AFFF- contaminated soil- PFAS concentration (µg/kg) – sandy soil

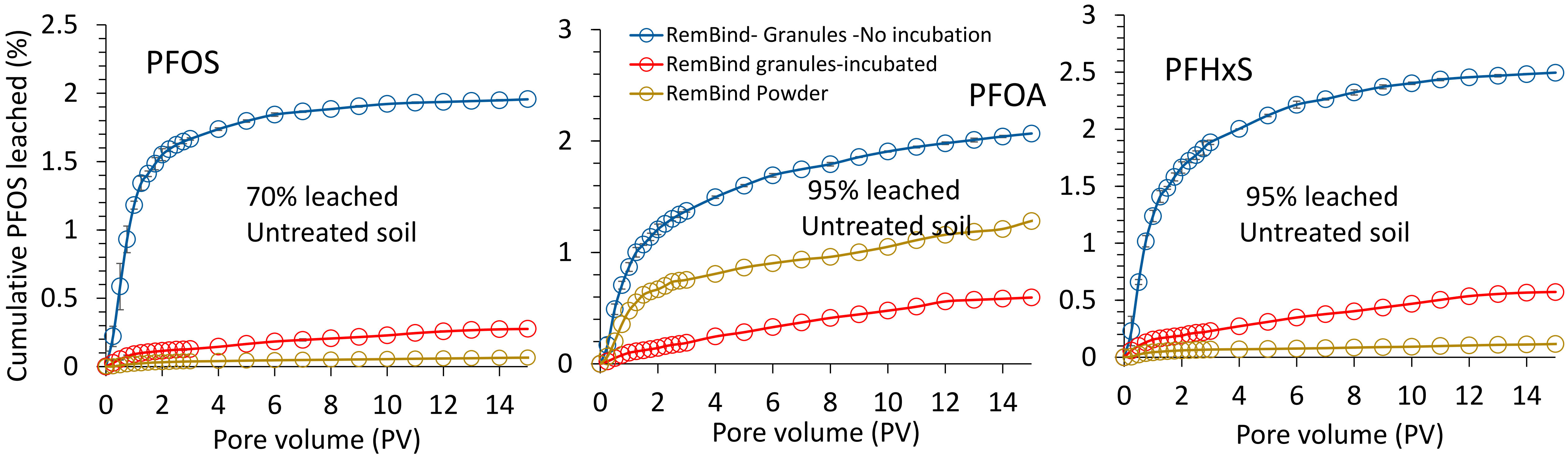
PFBA	PFBS	PFHpA	PFHpS	PFHxA	PFHxS	PFOA	PFOS	PFPeA	PFPeS
3.0	3.7	6.0	13.9	27.8	88.6	17	2855	7.25	7.55

Leaching experiment

- RemBind 1 & 2 were tested (RemBind 2 results only are presented)
  1. RemBind 2 mixed with soil as a powder
  2. Granular RemBind 2 mixed with soil
  3. Granular RemBind 2 mixed and incubated for 2 weeks
- Leachates were analysed for PFAS



PFAS leaching Results



- All formulations immobilised PFAS in soil, with granular formulations showing comparable efficiency to powder

- Incubation of granules and mixing them before performing the leaching tests improved their efficiency compared to the unincubated samples

Leaching results for other PFAS

PFAS	Cumulative Leached (%)		
	RemBind 2 Powder-no incubation	RemBind 2 Granule- incubated	RemBind 2 Granule- no incubation
PFBS	ND	0.1	3.9
PFBA	ND	ND	0.4
PFPeS	0.02	0.03	2.7
PFPeA	0.3	0.7	5.2
PFHxS	0.1	0.6	0.1
PFHxA	0.3	0.1	1.5
PFHpA	0.4	0.9	3.2
PFHpS	ND	0.08	0.9
PFOS	0.06	0.3	1.9
PFOA	1.3	0.6	2.0

Conclusions

- The granulation or pelletising of RemBind with different particle size was successfully performed.
- The optimised formulation of pellets and granules had disintegrated when in contact with moisture.
- The binder type and rate had an important role in the strength and dispersion of the final products. The presence of minerals in RemBind formulations played an important role on granules/pellets strength.
- Granules are dust free for handling and disintegrate/disperse in soil on wetting.
- Dust-free granules disintegrate in soil upon contact with moisture, offering similar efficacy to powdered products.
- Granular/pelletised products incorporating various binders offer immobilisation efficacy close to that of powdered products mixed through soil.

Acknowledgements

THE UNIVERSITY of ADELAIDE

Australian Government

RemBind®

Prof. Michael McLaughlin
Mrs Suhair Ahmed Hamad

Australian Government Department of Industry, Innovation and Science and RemBind for funding this study

Thank you for your attention!