



## PFAS – Axes de traitement développés dans le groupe ORTEC

Recherches portées par ORTEC SOLEO et BIOGENIE

PFAS – Treatment developed by the group ORTEC  
Research carried on by ORTEC SOLEO and BIOGENIE



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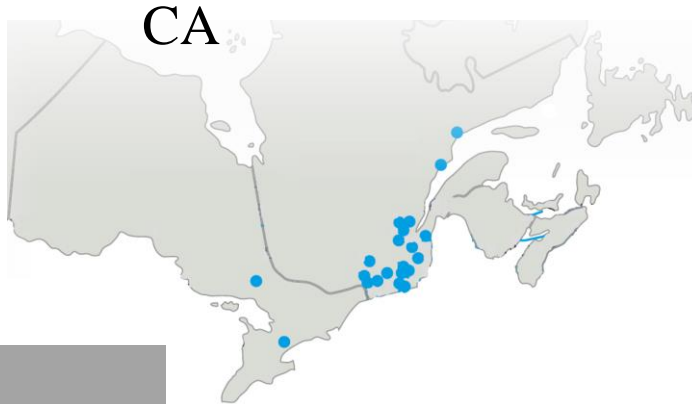


PFAS: poly- or perfluoro carboxylic/sulfonic/others acids : the “all-purpose” molecules which have generated ubiquitous pollution of soils, water, air and biosphere.

Over recent years there have been a significant increase in scientific research and projects dealing with these compounds.

Regulations are evolving in Europe and France, but still, the technically and economically viable treatment options are struggling to emerge.

➤ **Research on-going to provide a chain of treatment solutions from extraction to degradation**

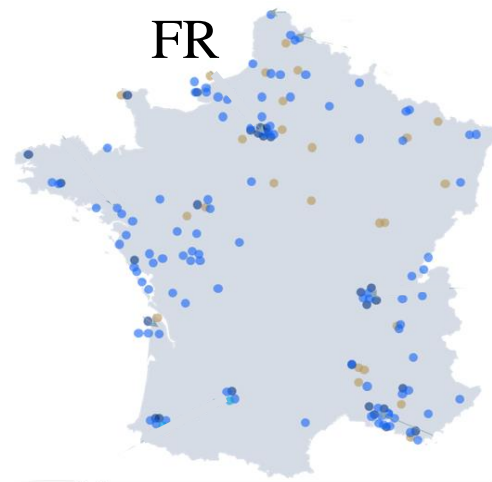
**ORTEC SOLEO and BIOGENIE – complementary research****Water treatment**

- Extraction from water by foaming

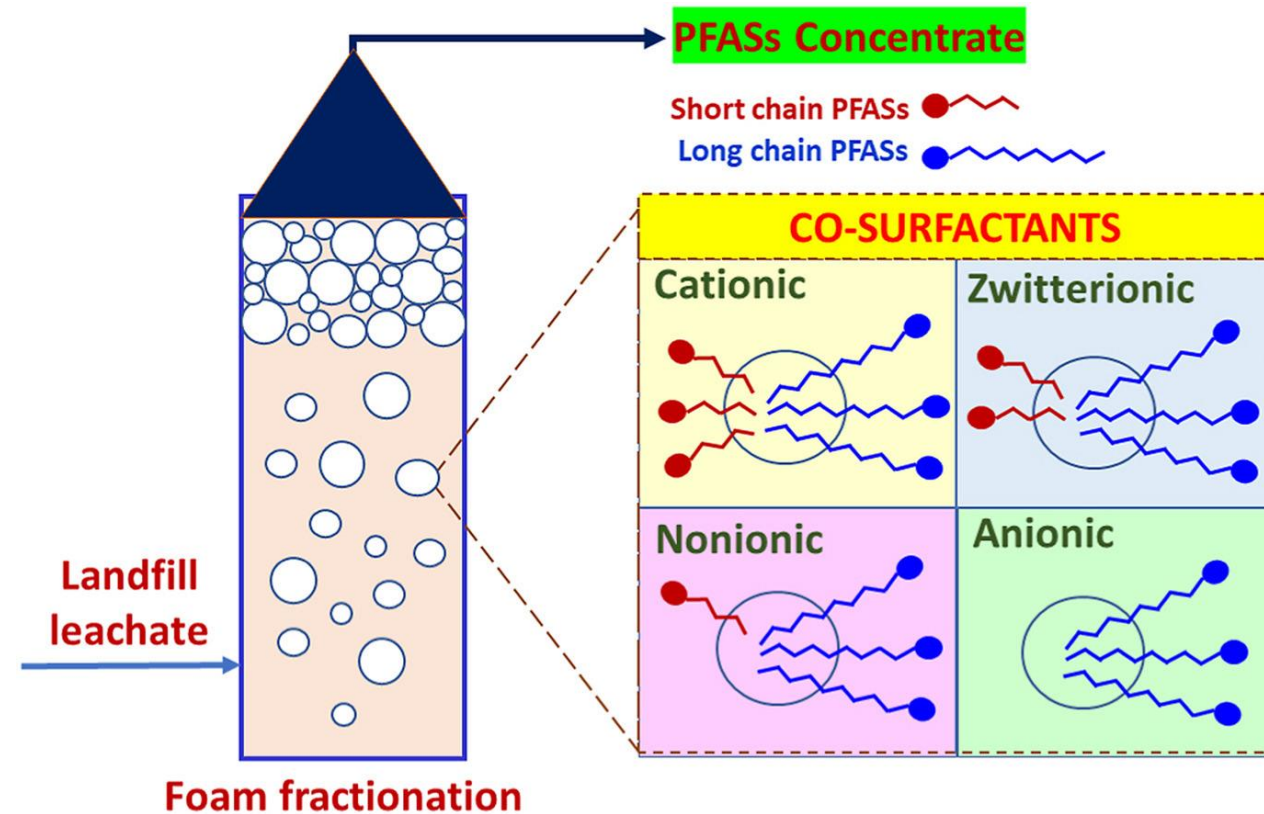
**Soil treatment**

- Stabilisation/Solidification in soils by hydraulic binders
- Granulometric sieving / washing : concentration or extraction
- Thermal desorption
- Thermal degradation

UK



## PFAS extraction by foam



## Foam fractionation

Foam fractionation removes PFAS from water by injecting air to create bubbles. PFAS attach to these bubbles due to their affinity for the air/water interface and their co-affinity for other surfactants

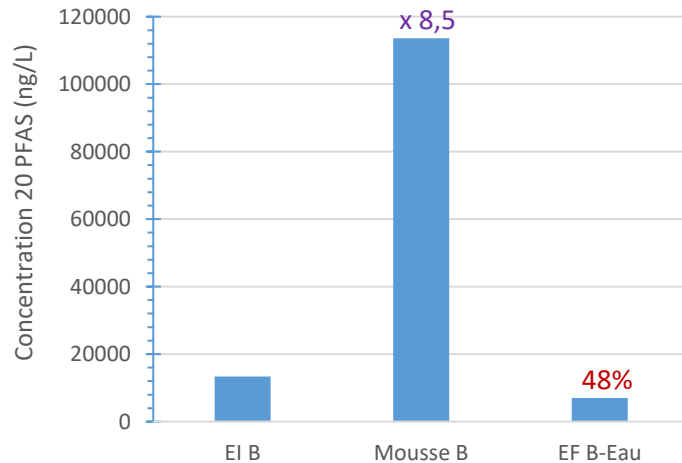
Vo, P. H., Buckley, T., Xu, X., Nguyen, T. M. H., Rudolph, V., & Shukla, P. (2023). Foam fractionation of per- and polyfluoroalkyl substances (PFASs) in landfill leachate using different cosurfactants. *Chemosphere*, 310, 136869.



## PFAS extraction by foam

Standard bubbling - macro-bubbles

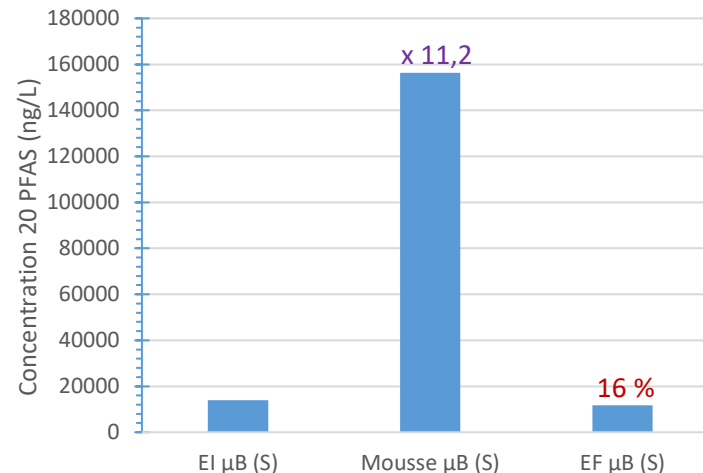
300  $\mu$ L Tween 80



High foam volume  
(> 3L coalesced water)

Micro-bubbles

50 mL Surfactant



High volume but lighter foam  
(0,1 L coalesced water)

## ORTEC SOLEO – France

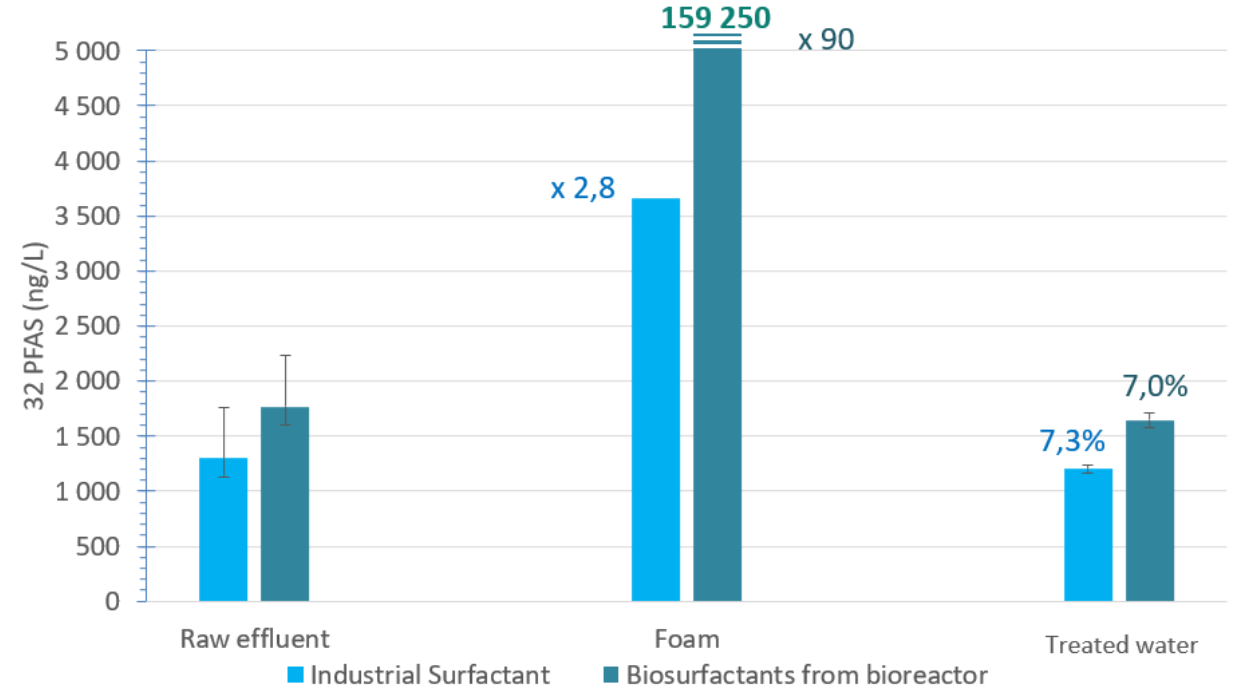
- Treatment of groundwater
- Difficult to Foam the groundwater with smaller air bubbles, but less concentrated effluent to process
- Extraction of 20 PFAS by the foam : concentration 8,5 to 11,2 times higher
- Almost no concentration of PFBA and PFPeA in the foam, better results with long-chain PFAS up to x20 for PFOS and PFNA, PFDA

## PFAS extraction by foam

Landfill Leachate raw  
effluent + Surfactant



Landfill Leachate +  
biosurfactants from bioreactor



## BIOGENIE – Canada

- Treatment of landfill leachate – effluent taken before or after biological reactor
- Industrial surfactant is not adapted for the PFAS with a concentration of only 2,8
- The foam from the Bioreactor gave extraction and concentration x 90 (average for the 32 PFAS), but foaming isn't the only factor : other organic materials are also enhancing the results
- Action on different PFAS were : PFBA, PFPeA, PFH<sub>x</sub>S < PFOA, PFOS, EtFOSAA << PFHpA, 6:2 FTS, PFBS

# Stabilisation/Solidification — PFAS - Treatment

## Diffusion tests : PFAS leaching from soil reduced by the addition of chemical binders

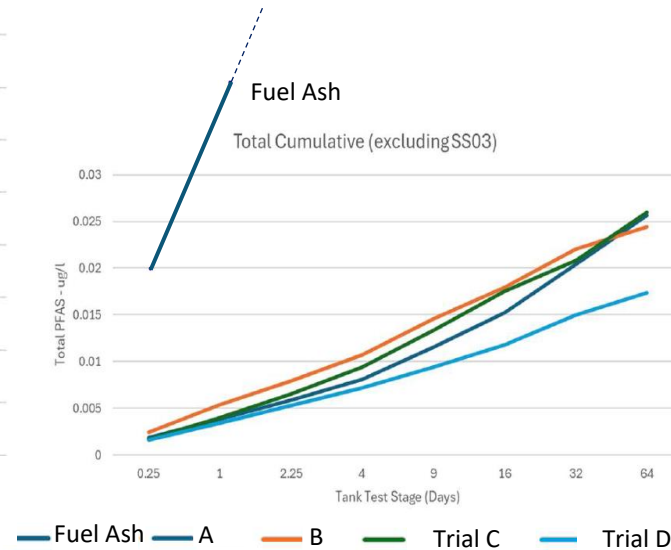
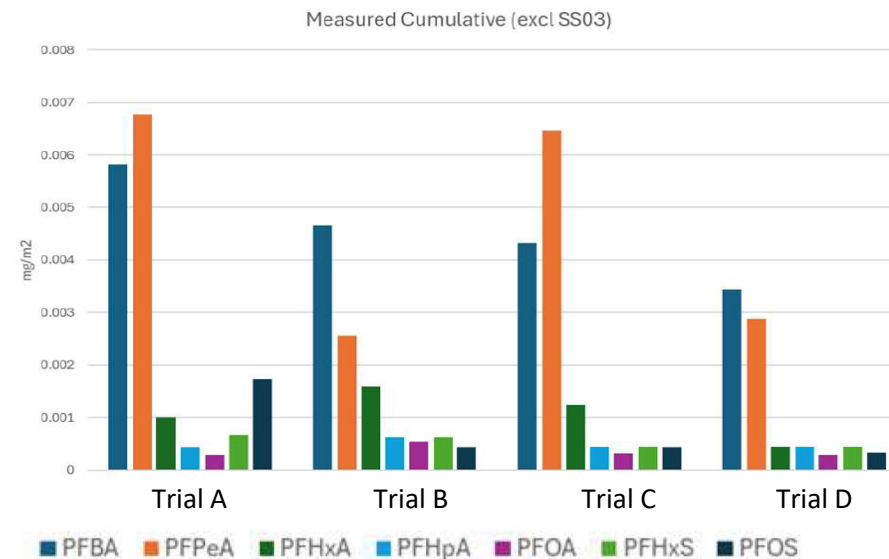
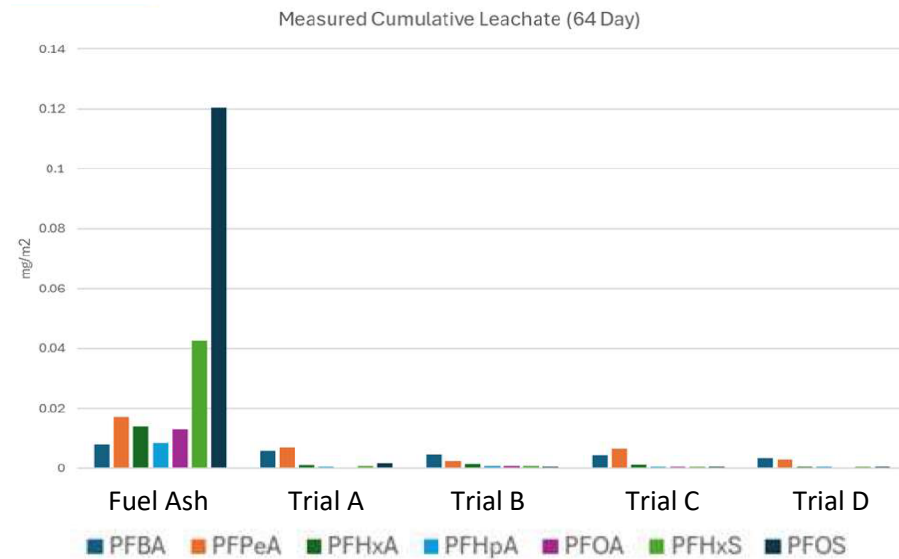


Reference	Cement	Pulverised Fuel Ash	Sorbent Trial A	Sorbent Trial B	Sorbent Trial C	Sorbent Trial D	Total additive
SS03	5%	10%	0%	0%	0%	0%	15%
SS04	5%	0%	1%	0%	0%	0%	6%
SS06	5%	0%	0%	1%	0%	0%	6%
SS08	5%	0%	0%	0%	1%	0%	6%
SS09	5%	0%	0%	0%	0%	3%	8%

Following curing (28 days), the monolith is submerged in water for a period of 64 days. With eluate changed and sampled at 8 stages. Water/Soil ratio L/S = 5.



## Percolation tests : contaminated soil mixed with hydraulic binders

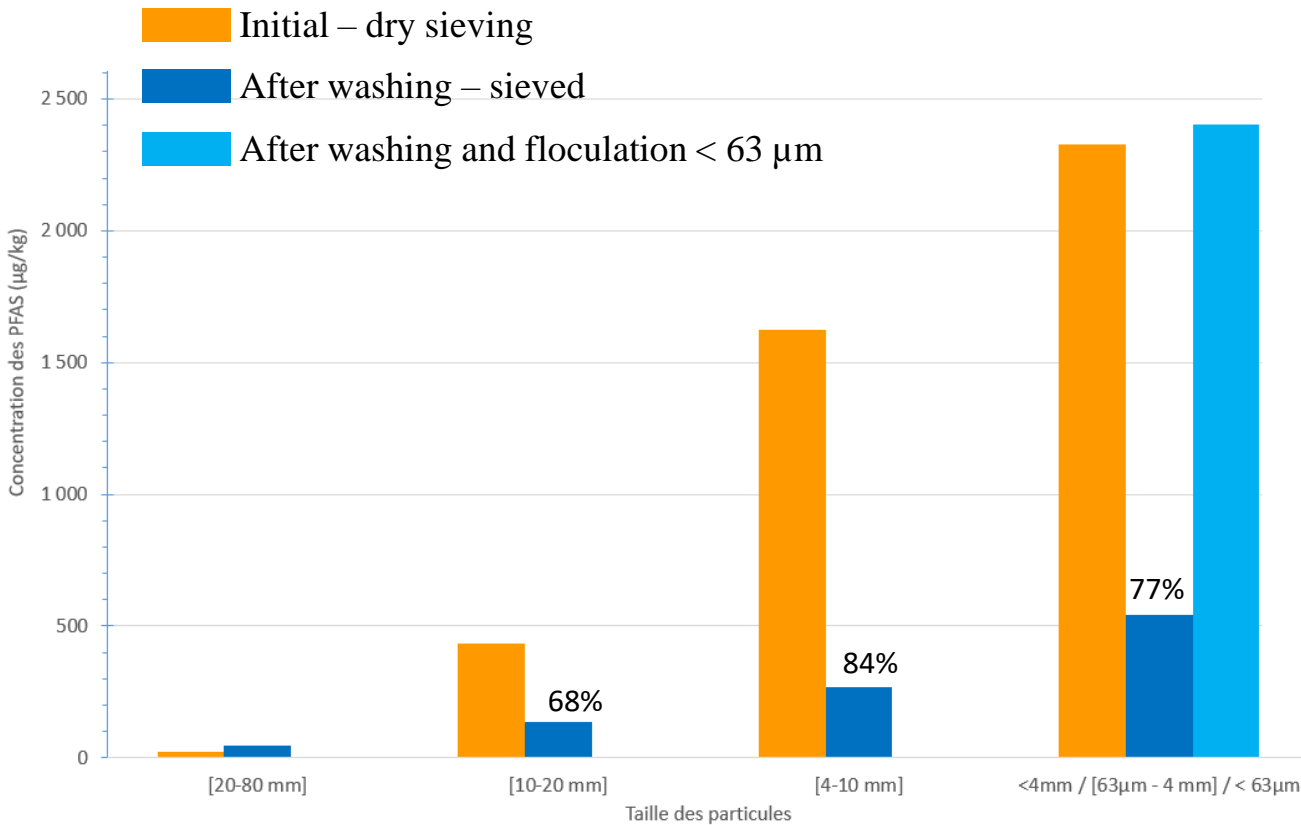


## BIOGENIE – UK

- Treatment of soil with different hydraulic binders and PFAS-sorbents
- Only Fuel Ash did not achieve the same reduction in PFAS leaching compared to other additives (especially for PFOS and PFHxS)
- Specific PFAS sorbents work well in symbiosis with the cement, even at low concentrations,
- Better results were obtained for longer chain PFAS
- Higher contact times give higher leaching of PFAS, but a maximum/an equilibrium seem to be reached after 30d



## Sieving and washing soil



23% fine particles (<63µm) are still present in the sand-fraction [63µm – 4mm]: the remaining PFAS are supposed to come from them.

water/soil ratio 2,25/1



➤ 20,8% PFAS in the water : 113 µg/L

## ORTEC SOLEO – France

- PFAS are sorbed on the fine particles
- After sieving/washing, PFAS behave mostly like organic compounds and adsorb to the finest particles (<63µm): the flocculated mud is enriched with PFAS readily removed from larger particles.
- Smaller chain PFAS are dissolved in the water phase (approximately 30 to 50% removed from the soil)

## Sieving and washing soil

Water treatment:

	pH 1,89 - HCl	anionic	Cationic A	Cationic B
Reduction of the 20 PFAS in water	<b>59%</b>	<b>11%</b>	<b>24%</b>	<b>41%</b>



## ORTEC SOLEO – France

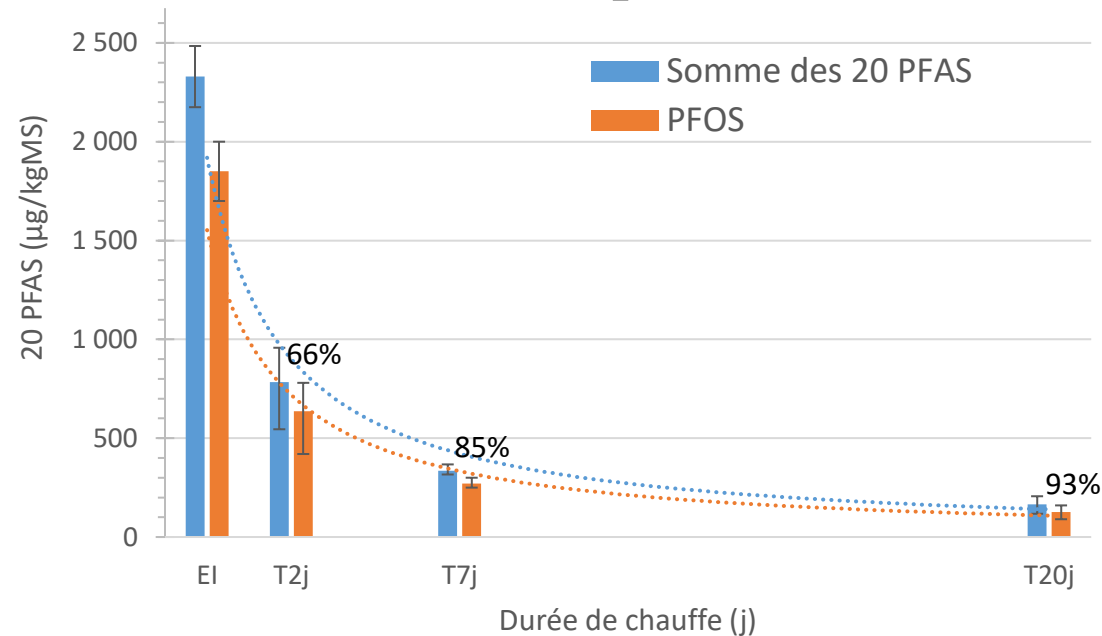
- Acidic pH help protonating the PFAS and force their adsorption/precipitation
- The tested flocculants, especially the cationic ones, have an impact on adsorption of long chain PFAS : PFOS and PFHpS. Anionic flocculants probably induce electrostatic repulsions towards the PFAS.
- Smaller chain PFAS, and particularly carboxylic PFAS, don't seem to adsorb with help of tested flocculants.

## Thermal desorption

### Soil treatment:

Oven heating 300°C, Air extraction – condensation and air filtration on activated carbon

### Thermal desorption 300 °C



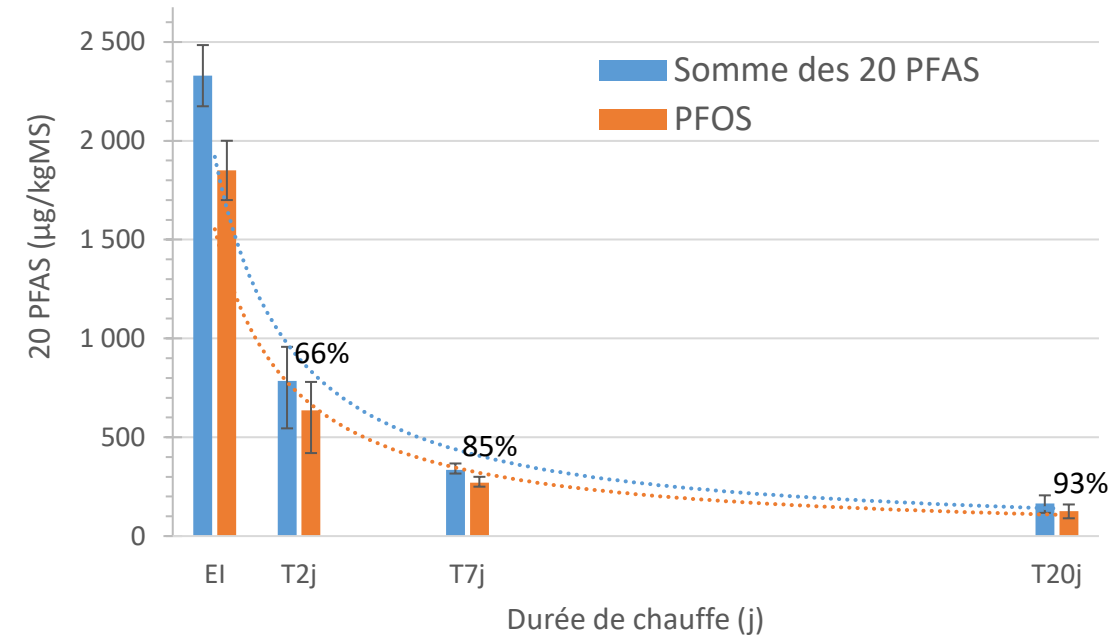
ORTEC SOLEO – France



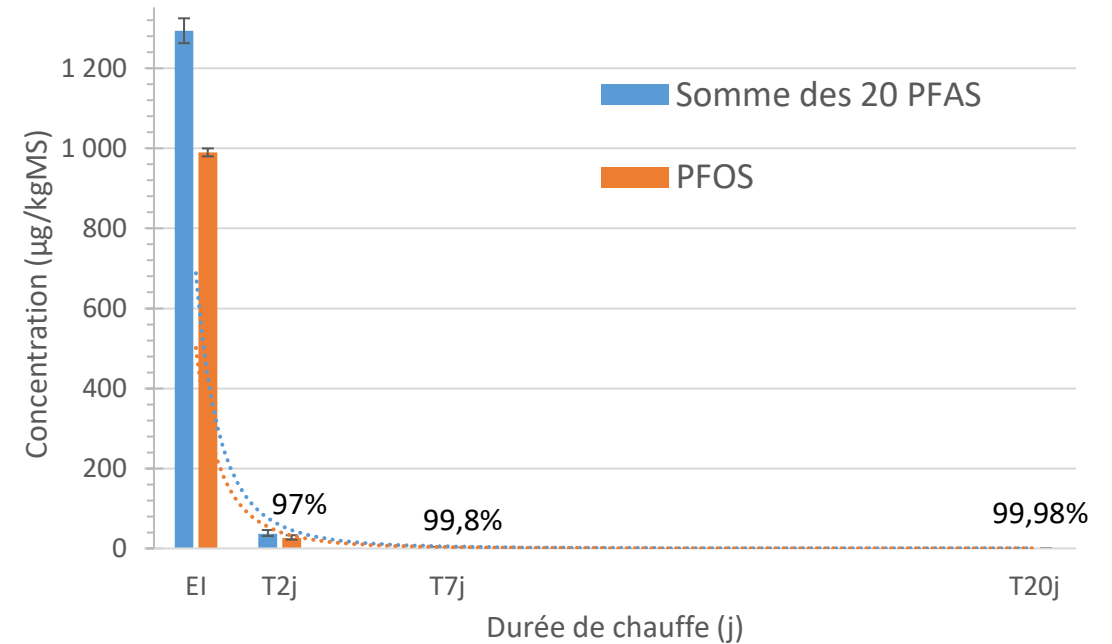
- Thermal desorption of PFAS in soils is possible at 300°C, with 93% removal in soil after 20 days heating.

## Thermal degradation of the PFAS

### Thermal desorption 300 °C



### Catalyzed thermolysis at 300 °C



ORTEC SOLEO – France

- Thermal degradation of the PFAS with 97% destruction/removal in 2 days.
- Leachable fluorine augmentation : 0,2 mg/L in leachate at t0 and in the soil under thermal desorption, enhanced to 2,1 mg/L in the soil treated with thermolysis : PFAS compounds seem to be broken down to F-

➡ **Patented in 2024**

## Complementarity in the research axes

### Water treatment:

- CA+FR ➤ Extraction from landfill leachate or groundwater by foam fractionation

### Soil treatment:

- UK ➤ Stabilisation/Solidification with hydraulic binders and sorbents
- FR ➤ Sieving and washing to concentrate the PFAS in the fines (<63µm), work to limit the solubilisation
- Thermal desorption
- Thermal catalytic degradation at 300°C

**To be continued... in lab and also on sites !**





**ORTEC**  **SOLEO**

 **BIOGENIE**  
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# Thank you for your attention

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