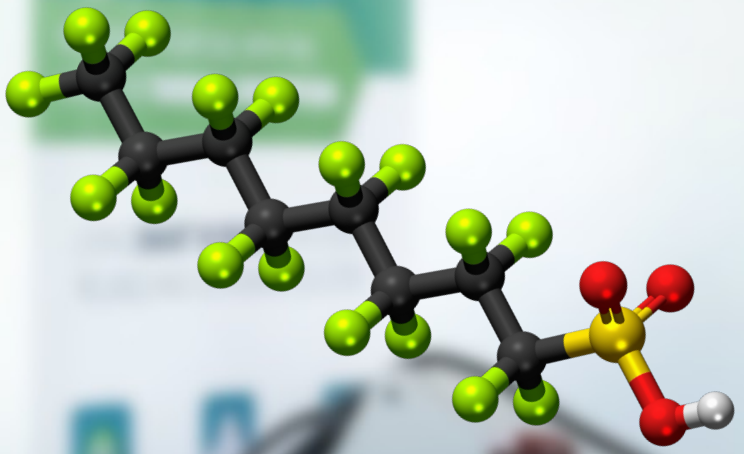
Haemers® technologies



Containerized Thermal Treatment for PFAS

Jean Rhoné

27-03-2025 Intersol

intersol 2025 24e Edition

Congrès-Exposition International sur les Sols, les Sédiments et l'Eau

International Conference-Exhibition on Soils, Sediments and Water

SOMMAIRE

01 EXPERIENCE & TEAM

Our campany

We invent and develop Thermal Desorption Technologies

Award-winning Technology

Based in Belgium

Own Smart Burners manufacturing facility

Own Lab and R&D facility

82 Completed Projects

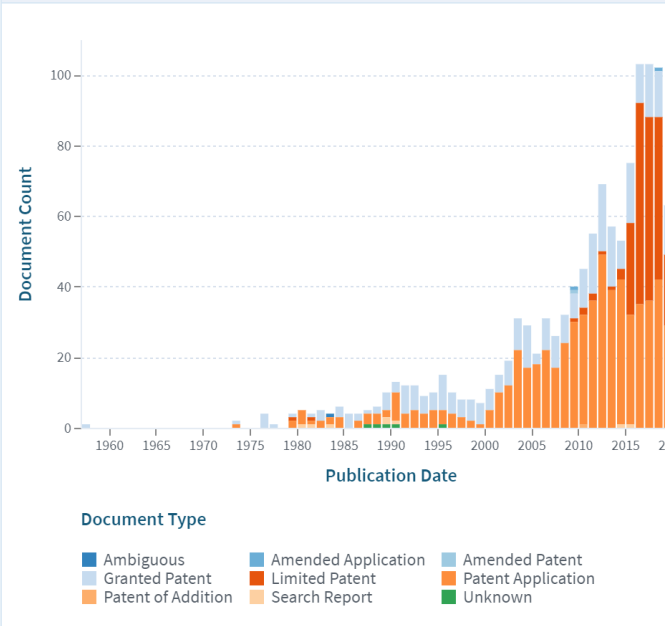
66 Staff

17 COUNTRIES OF ORIGIN

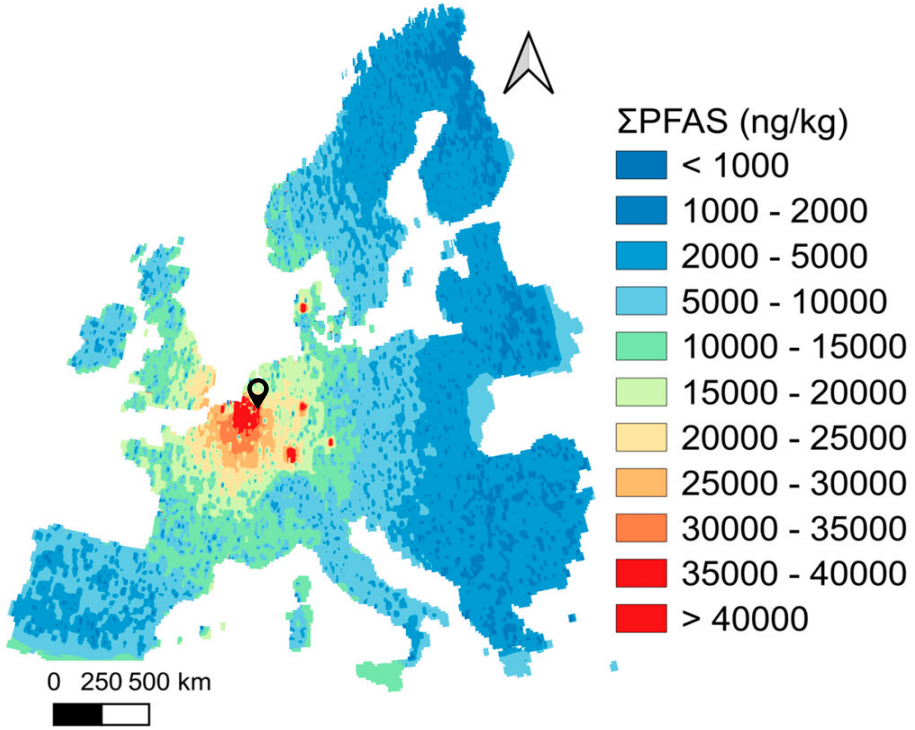
36 Average Age

02 PFAS – STATE OF THE ART

A very hot topic



More and more scientifically represented, ...



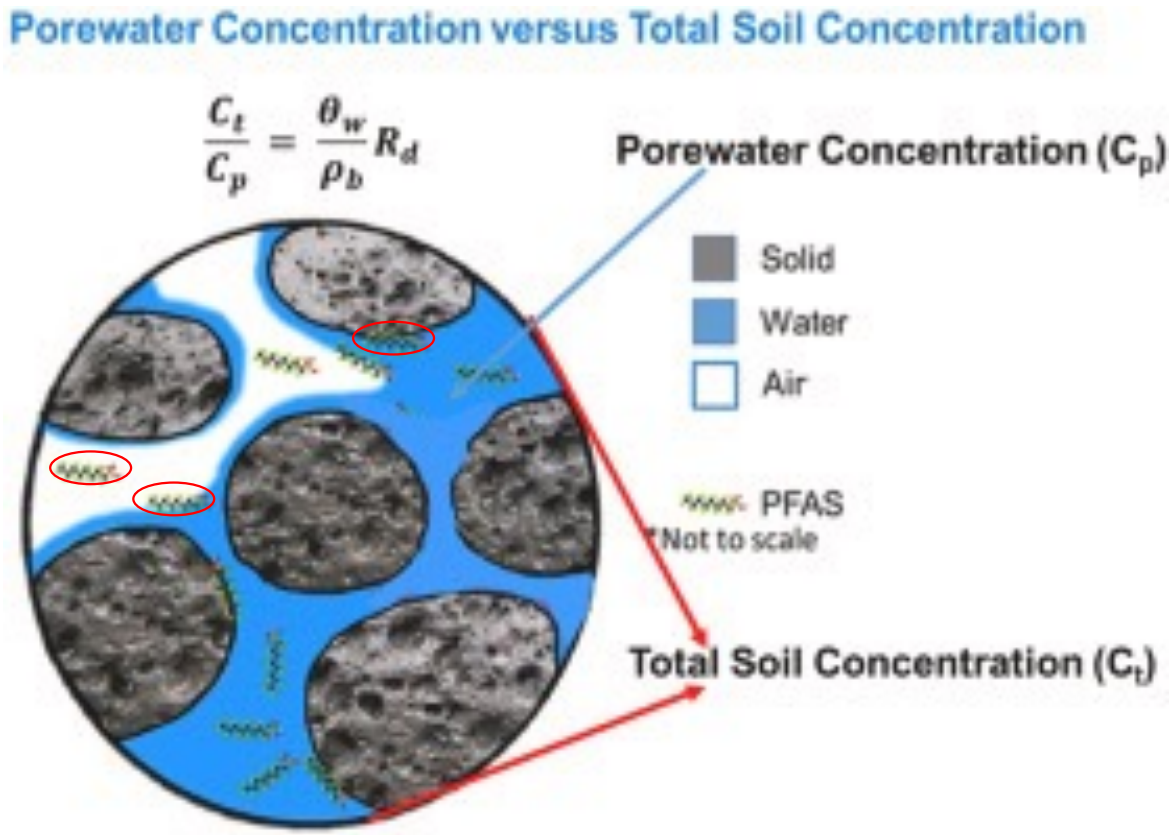
And geographically

PFAS various properties

	Log K_{ow}
PFCA'er	2,82
	3,43
	4,08
	4,67
	5,3
	5,92
	6,5
	7,15
	7,77
	8,25
PFSA'er	3,9
	3,38
	5,17
	4,81
	6,43
	6,78
	7,66
	6,49
	7,07
	7,44
Andre PFAS Precursorer	5,62
	4,44
FTOH'er Precursorer	4,54
	5,58
	6,63
	9,76
FTS Precursorer	3,21
	5,66
	6,91
Sulfonamid/ Sulfonamid-ethanoler	6,07
	6,71
	6,00
Sulfonamid-eddikesyrer Precursorer	6,52
	-
	6,22
Nye PFAS (Erstatter de tidligere anvendt Precursorer	4,24
	4,97
	7,41
	7,03
Andre typiske forureninger	*2,13*
	2,42
	1,46
	1,77

- Solubility depends on the compounds
- Affinity with organic surfaces

PFAS soil distribution

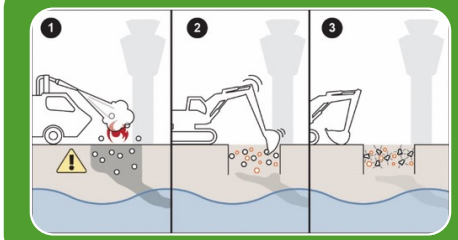


Distribution can be very different depending on the type of PFAS molecule and type of soil

Various treatment approaches

Physical separation

- Soil washing
- Thermal treatment



Chemical stabilization

- Reduced PFAS solubility

Molecular reaction

- Breaking C-F bonds
  - Bio / electron beam / incineration

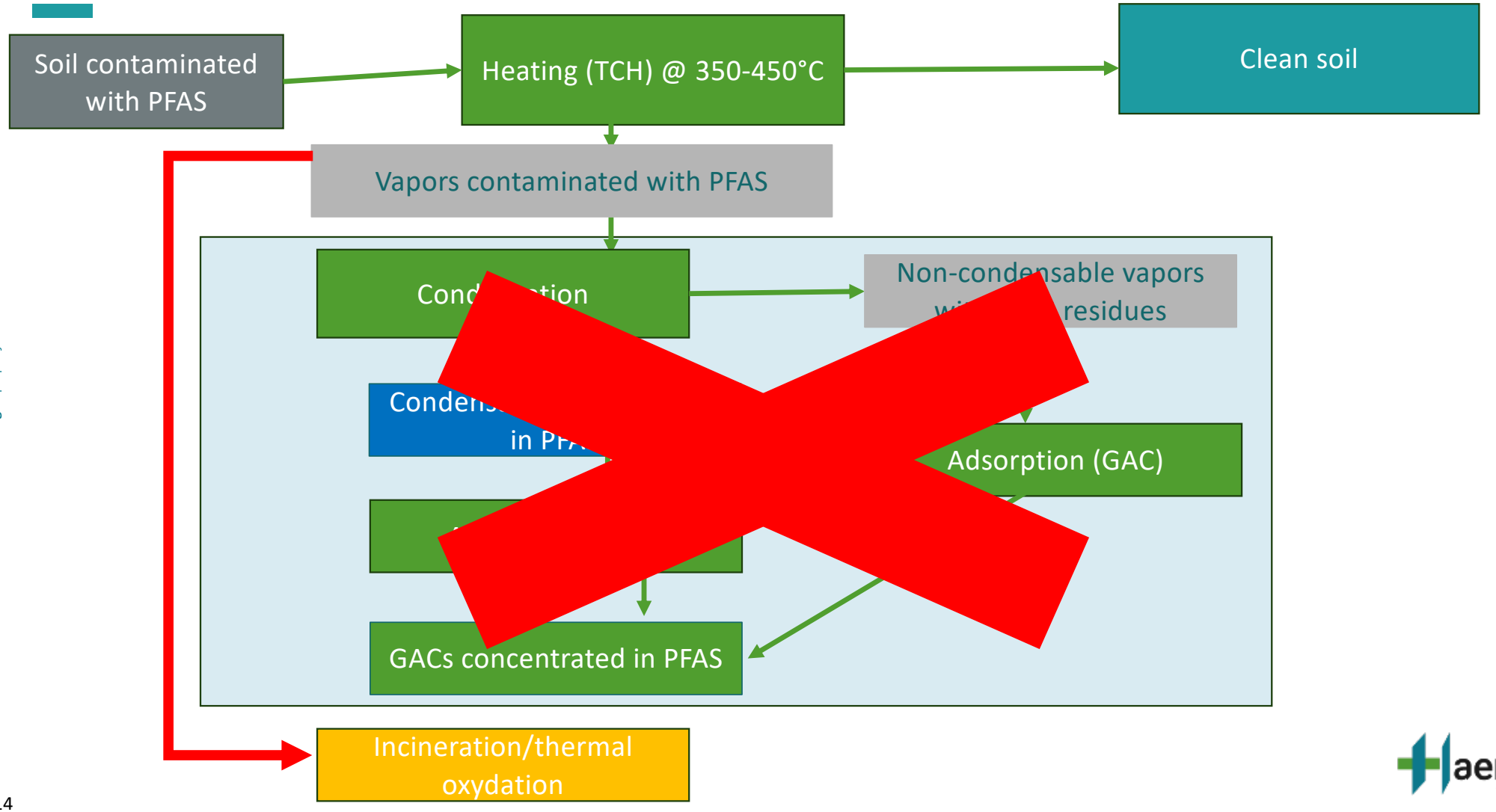
03 PFAS ARE TREATABLE WITH THERMAL

PFAS are volatilizable

Compound	Sample 0 (untreated sample)	Sample 2 (7 days/300°C)		Sample 3 (7 days/350°C)		Sample 4 (7 days/400°C)		Sample 7 (14 days/350°C)	
	µg/kg	µg/kg	% removal	µg/kg	% removal	µg/kg	% removal	µg/kg	% removal
PFBA	140	8.4	94.00%	0.14	99.90%	<0.0014	>99.999%	<0.00014	>99.9999%
PFPeA	236	15.3	93.50%	0.47	99.80%	<0.0024	>99.999%	<0.000236	>99.9999%
PFBS	152	59.3	61.00%	0.30	99.80%	<0.0015	>99.999%	<0.000152	>99.9999%
PFHxA	521	15.6	97.00%	0.52	99.90%	<0.0052	>99.999%	<0.000521	>99.9999%
PFHpA	236	22.4	90.50%	0.24	99.90%	<0.0024	>99.999%	<0.000236	>99.9999%
PFHxS	8,572	3,771.7	56.00%	8.57	99.90%	<0.0857	>99.999%	<0.008572	>99.9999%
PFOA	129	8.4	93.50%	1.29	99.00%	<0.0013	>99.999%	<0.000129	>99.9999%
PFNA	167	4.8	97.10%	1.67	99.00%	<0.0017	>99.999%	<0.000167	>99.9999%
PFOS	15,152	5,530.5	63.50%	15.15	99.90%	<0.1515	>99.999%	<0.015152	>99.9999%
PFDS	423	99.4	76.50%	0.42	99.90%	<0.0042	>99.999%	<0.000423	>99.9999%
ΣPFAS	25,728	9,535.8	63%	28.8	99.9%	0.257	99.999%	0.025	99.9999%

Crownover, Emily, Daniel Oberle, Mark Kluger, et Gorm Heron. 2019. « Perfluoroalkyl and Polyfluoroalkyl Substances Thermal Desorption Evaluation ». Remediation Journal 29

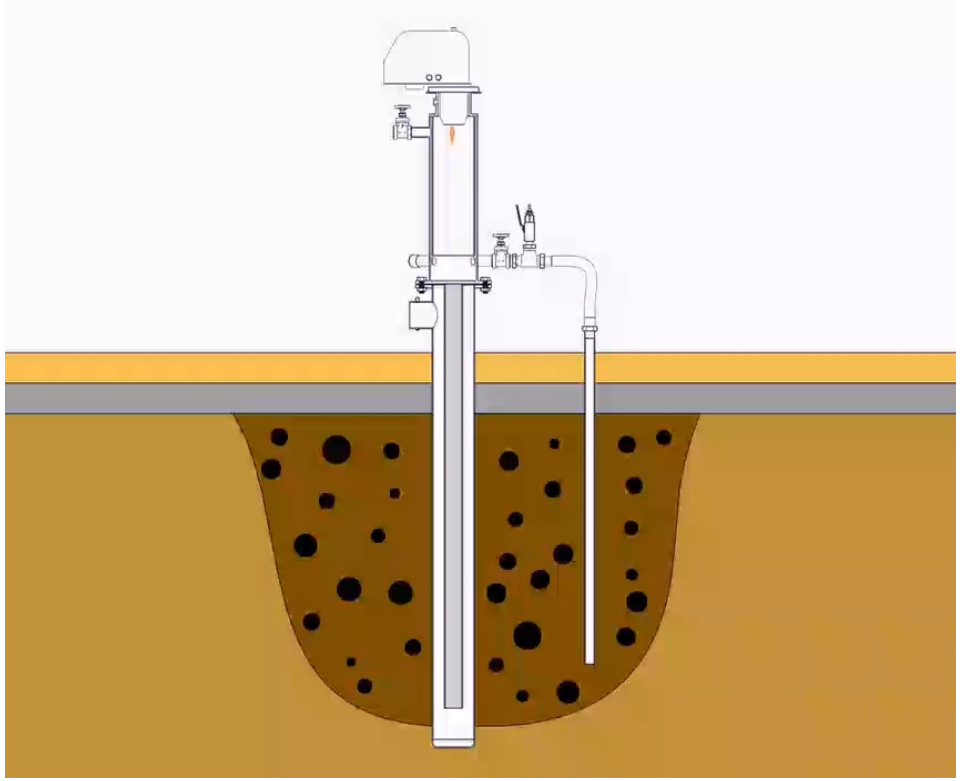
But what about vapor treatment ?



PFAS incineration conditions

PFAS	Temperature (°C)	Destruction rate(%)	Residence time(s)	Authors	Comments
Various PFAS	> 1.000	~99.9	≥2s	(Wallace et al. 2023)	Few by-products (<1%)
PFOS	> 700	> 99.99999	≥2s	(Weber et al. 2023)	Rapport H/F élevé, excès de vapeur et d'O2 nécessaires
	> 850	Complete Mineralization	≥2s	(Weber et al. 2023)	Rapport H/F élevé, excès de vapeur et d'O2 nécessaires
	900	Complete Mineralization	≥2s	(Wallace et al. 2023)	Conditions alcalines nécessaires

Thermal desorption & Reburn



1. **HEAT** THE SOIL

Objective : vaporize the contaminant

2. **CATCH** THE CONTAMINANTS

Extraction of all contaminants

3. **TREAT** THE CONTAMINANTS

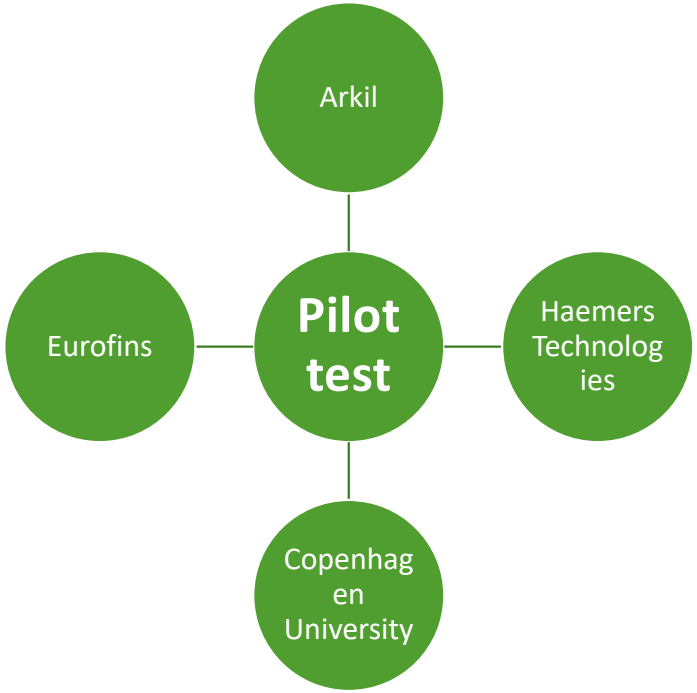
Direct injection of the contaminants into the flame

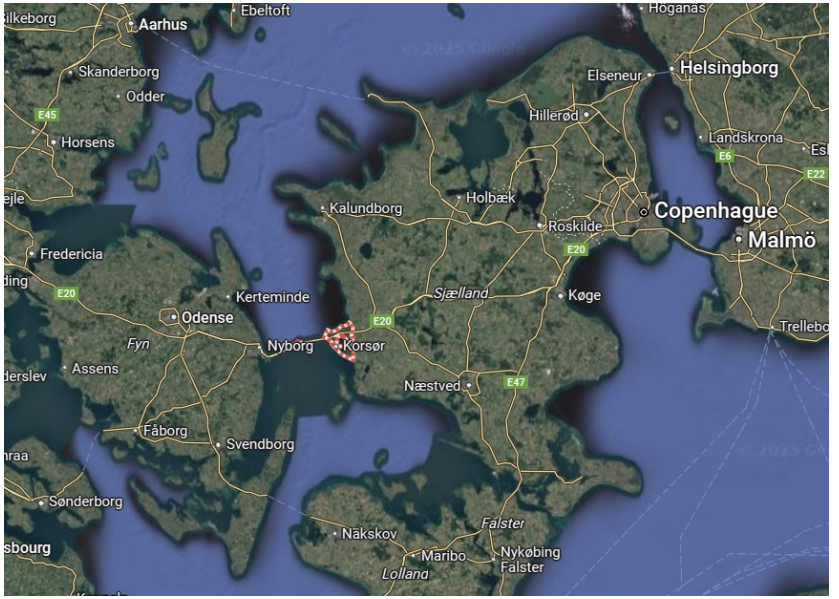
→ Thermal oxydation

04 PFAS TREATMENT PILOT

Project summary

- Korsör (Denmark)
- Pilot test for Korsør **firefighter school** site remediation
- Client : Region Hovestaden (**public**)

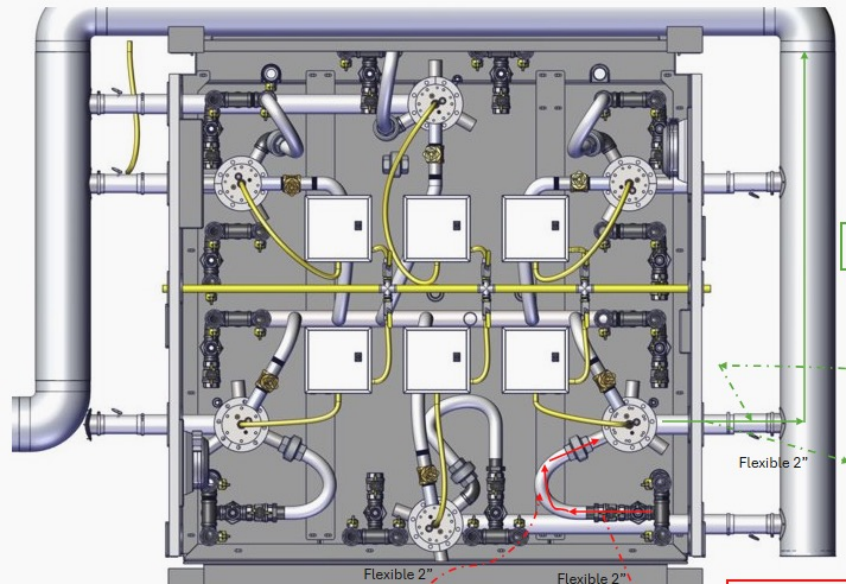


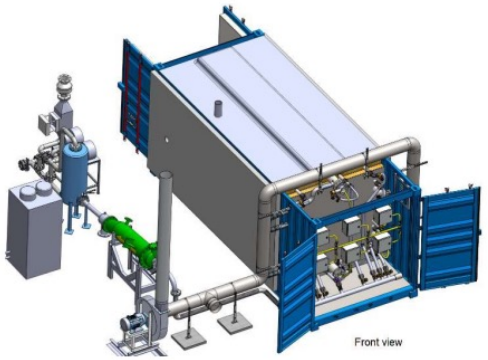


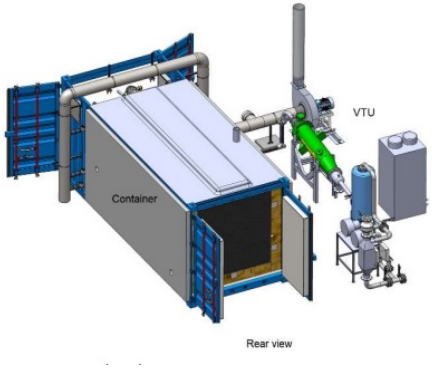
Project summary

Pilot test	**PFOS**/PFOA/**PFHxS**/PFNA = 200 µg/kg	Containerized treatment
32T of contaminated soil	6 burners	Objectives : 4 PFAS : 10 µg/kg 22PFAS : 400 µg/kg

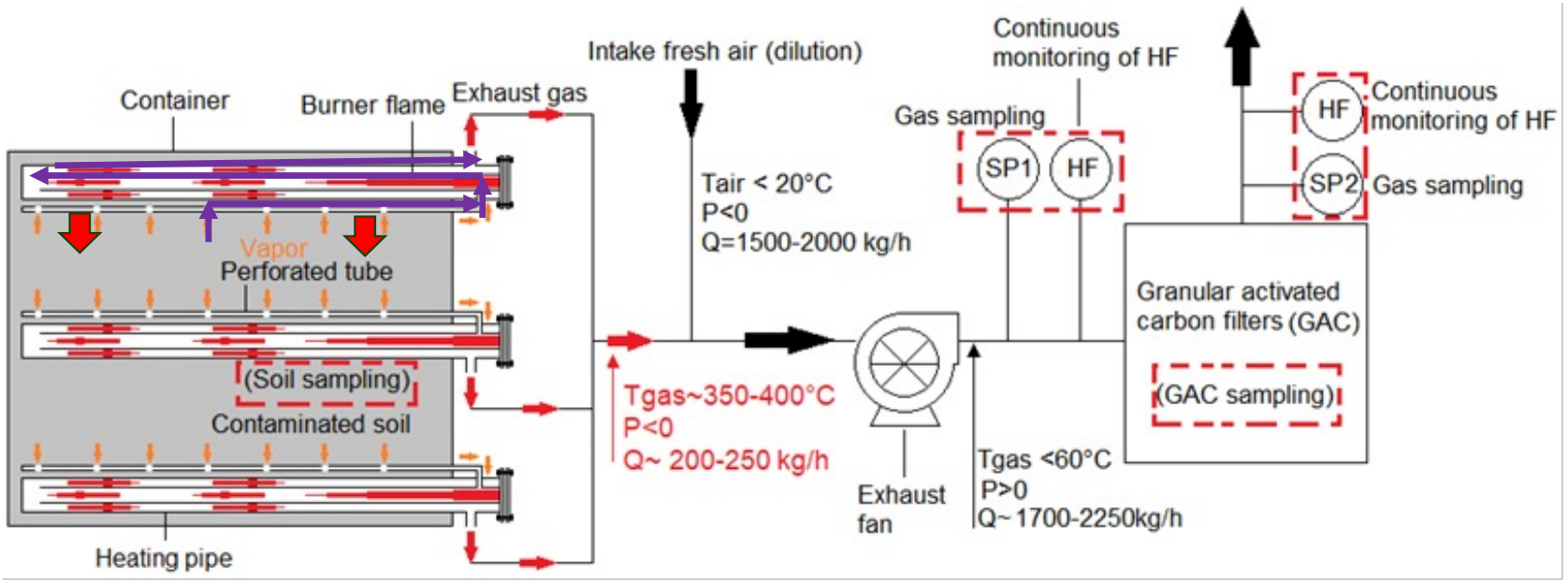
Design





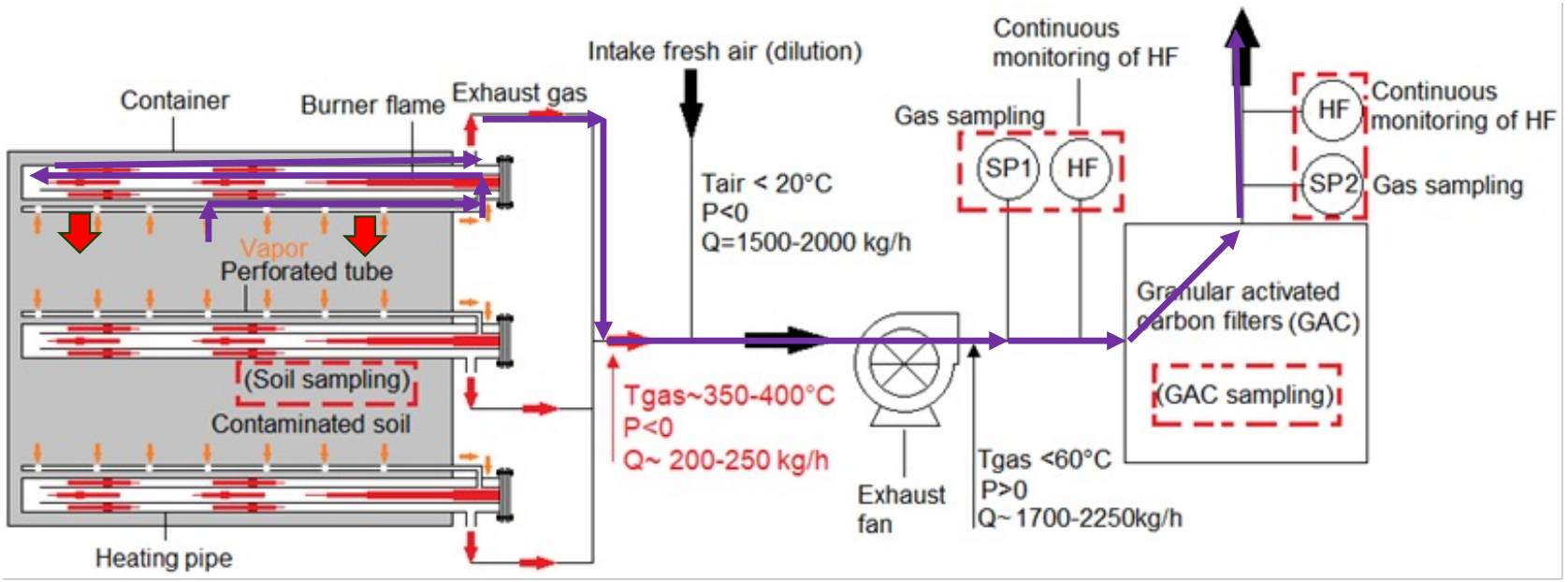


Flux & Reburn



Soil is heated to 350°C → PFAS vaporization and extraction → Insertion of vapours into the flame

Flux & Reburn



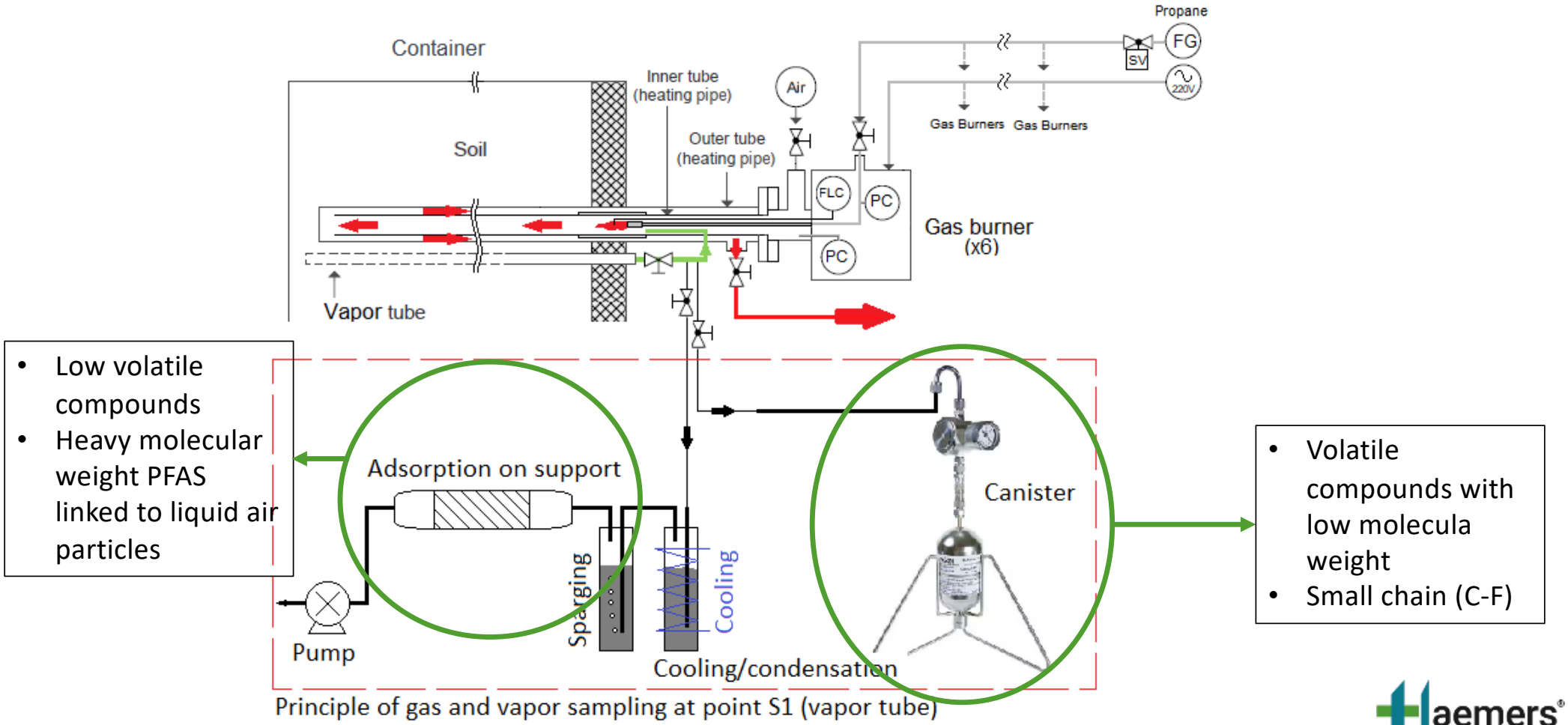
Vapor cooled down at 60°C → Sampling before CA → Presence of a GAC to prevent from uncontrolled emissions

Sampling (various methodologies)

Analysis	Soil Before and after treatment	GAC Before and after treatment	Condensate After treatment	Vapors (OTM45) During treatment
PFAS 35	+	+	+	+
AOF (Adsorbable Organofluorines)	+	+	+	+
EOF (Extractable Organofluorines)	+	+	+	+
TOF (Total Organofluorines)	+	+	+	+
Total Fluorine	+	+	+	+
Volatile organic fluorine (VOF) such as (CF4), (C2F6), (C3F8), (C4F10)	-	-	-	+
Mineralized fluor (HF)	-	-	-	+
Total sulfur	+	+	+	-
Total chlorine	+	-	-	-

Sampling (OTM45)

Sampling (OTM45)

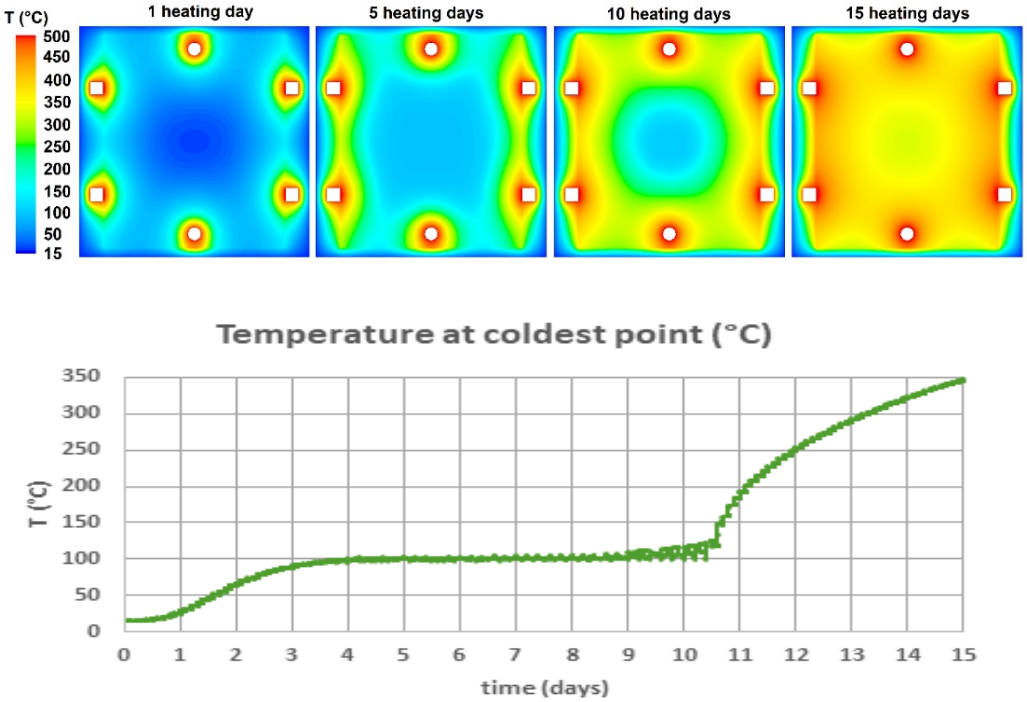


- Low volatile compounds
- Heavy molecular weight PFAS linked to liquid air particles

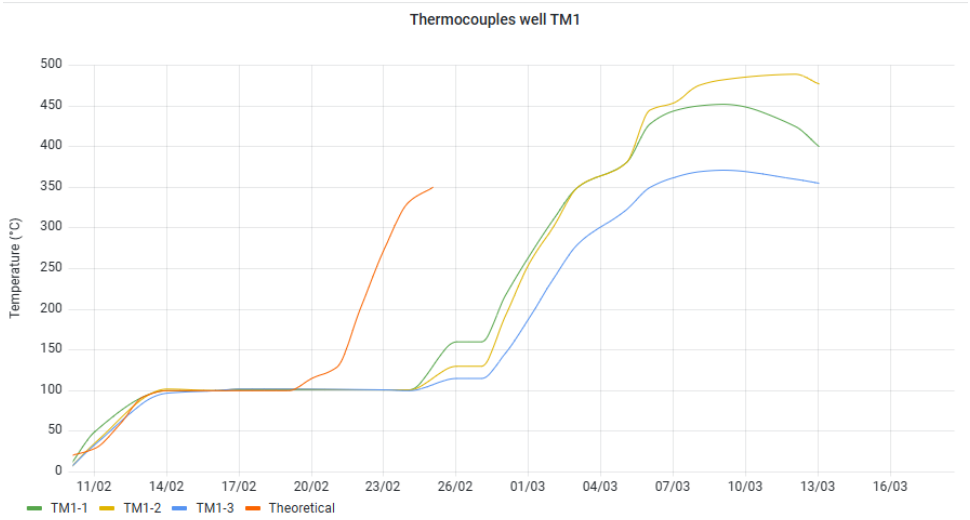
- Volatile compounds with low molecula weight
- Small chain (C-F)

Principle of gas and vapor sampling at point S1 (vapor tube)

Heating



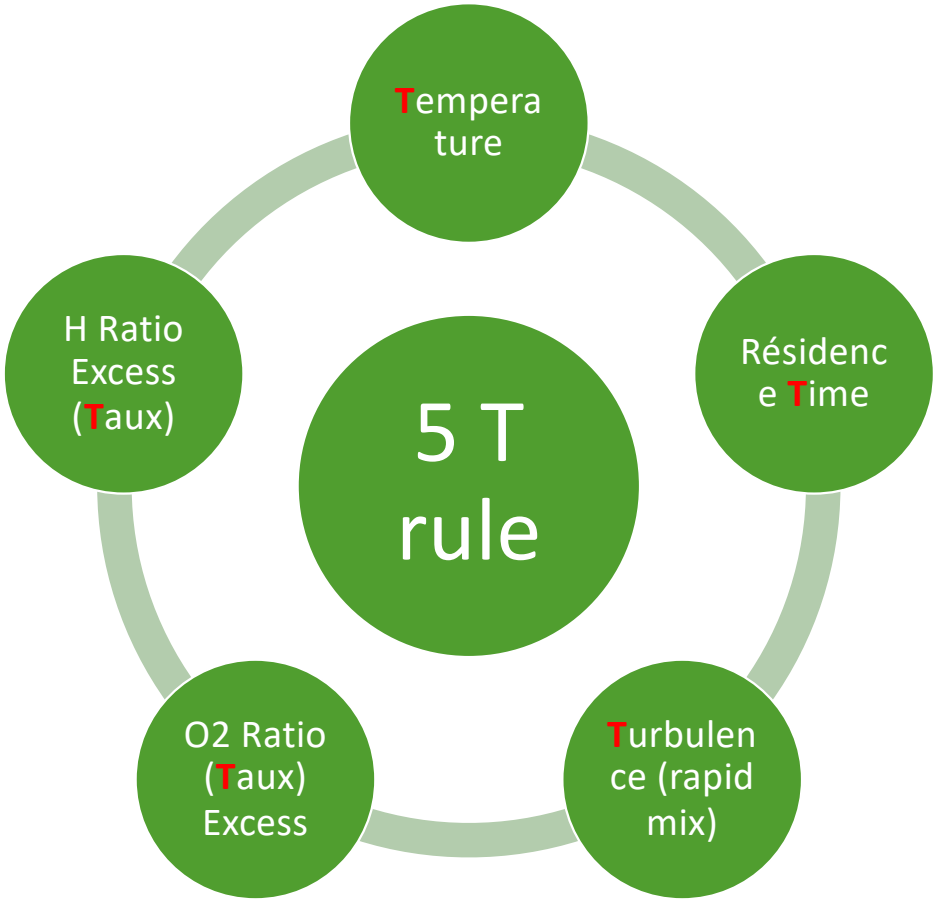
Modeling



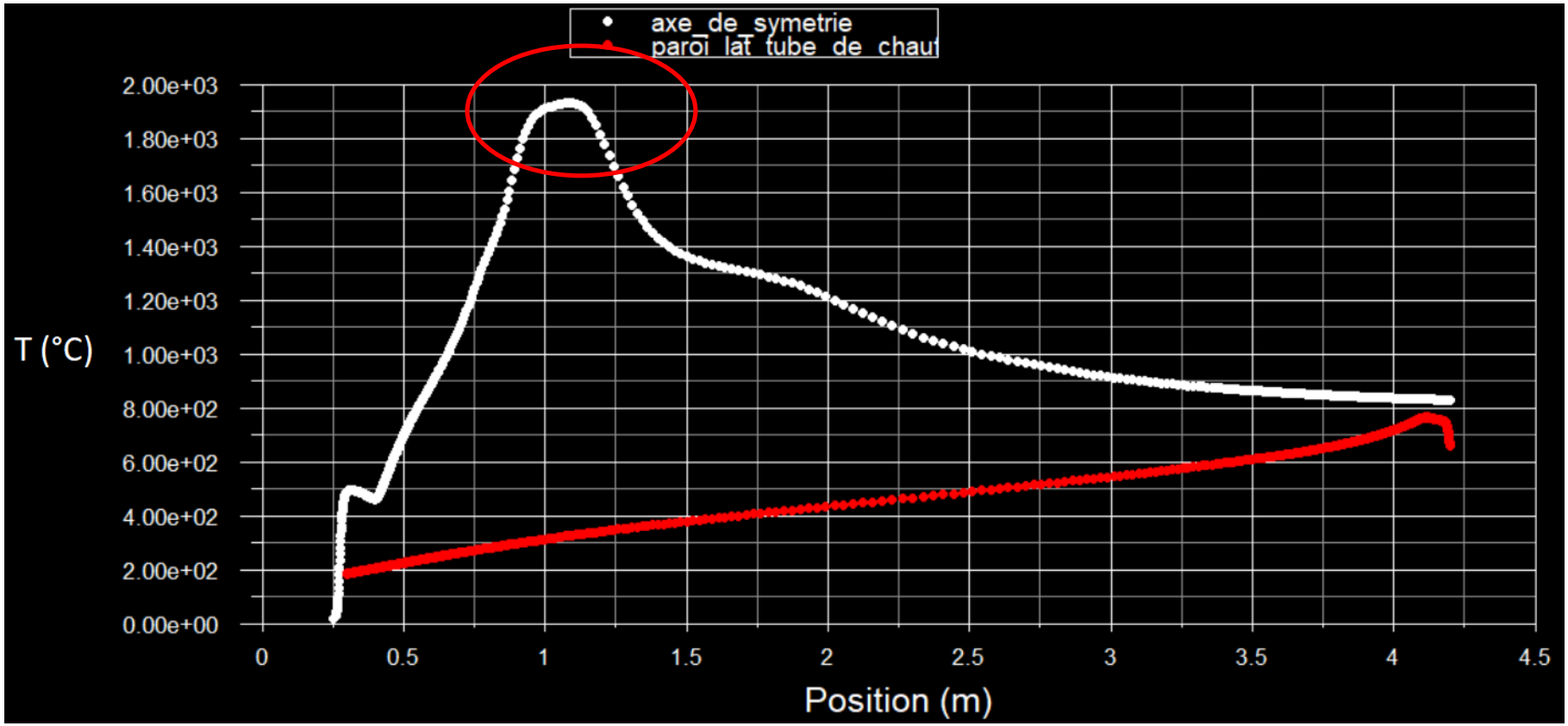
Onsite heating

- Onsite heating
- 26 days treatment time

PFAS incineration conditions



Design adaptation (temperature)



Vapors heated to T > 1.800 °C

Design adaptation (residence time)

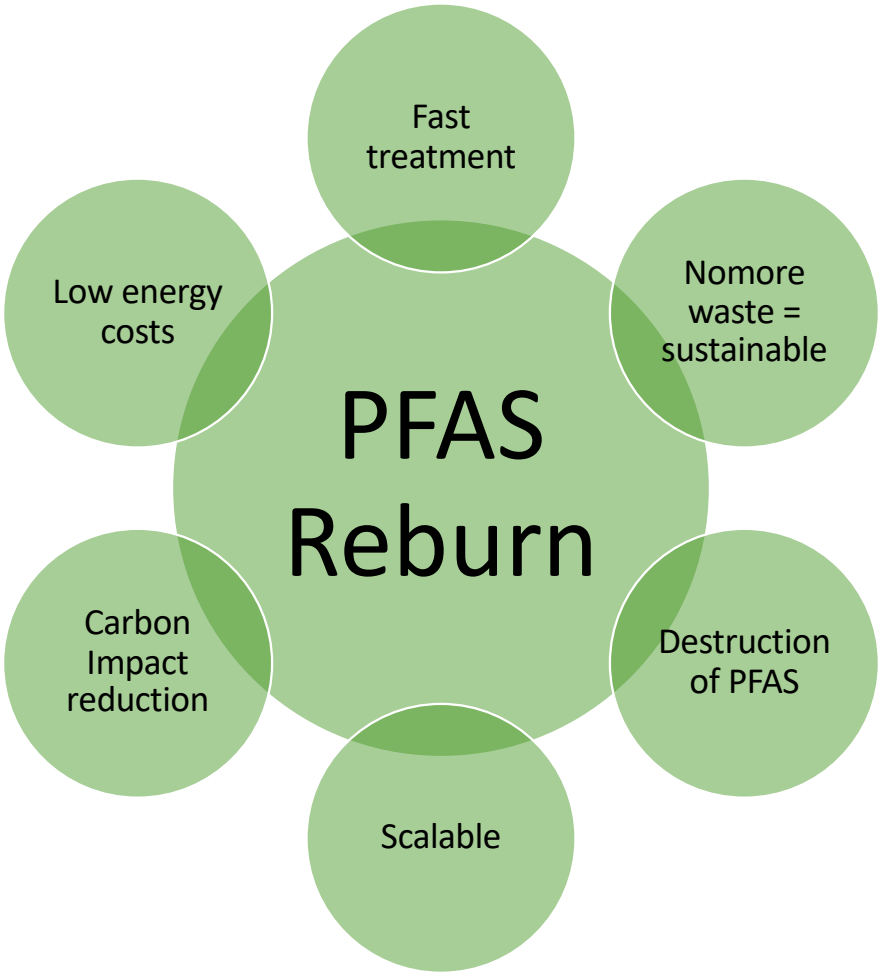
Change of heating tube design
O2 injection (40% total volume) to decrease total flow
→ ↗ Residence time

→ But won't be necessary with longer heating tubes

Results

05 CONCLUSION

A destructive treatment method




Haemers®
technologies