DESOTEC

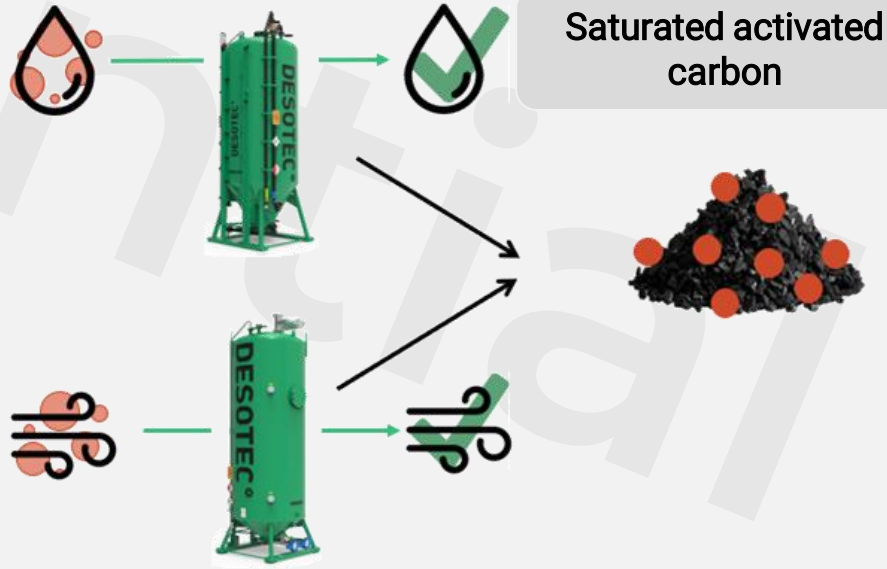
Sustainable mobile
filtration solutions

Removal and Complete Destruction of PFAS on Activated Carbon

Results from Measurement Campaigns and Industrial Validation

Compliance journey

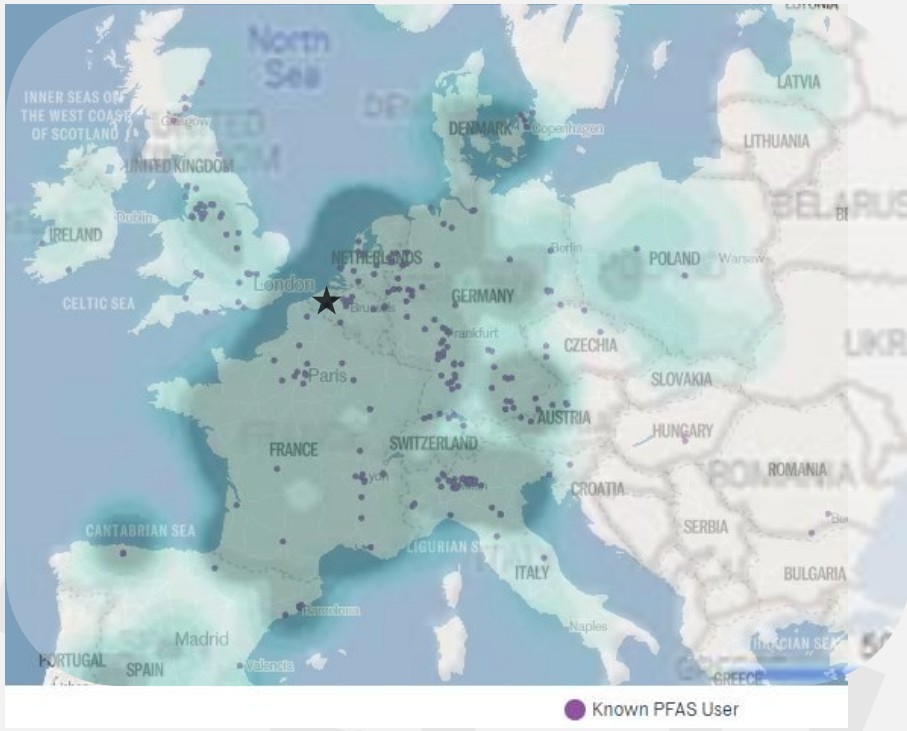
Air/ water filtration



Compliance journey

Air/ water filtration

PFAS Awareness



Source: Datasets | PFAS Data Hub (Forever Pollution Project), accessed March 2025

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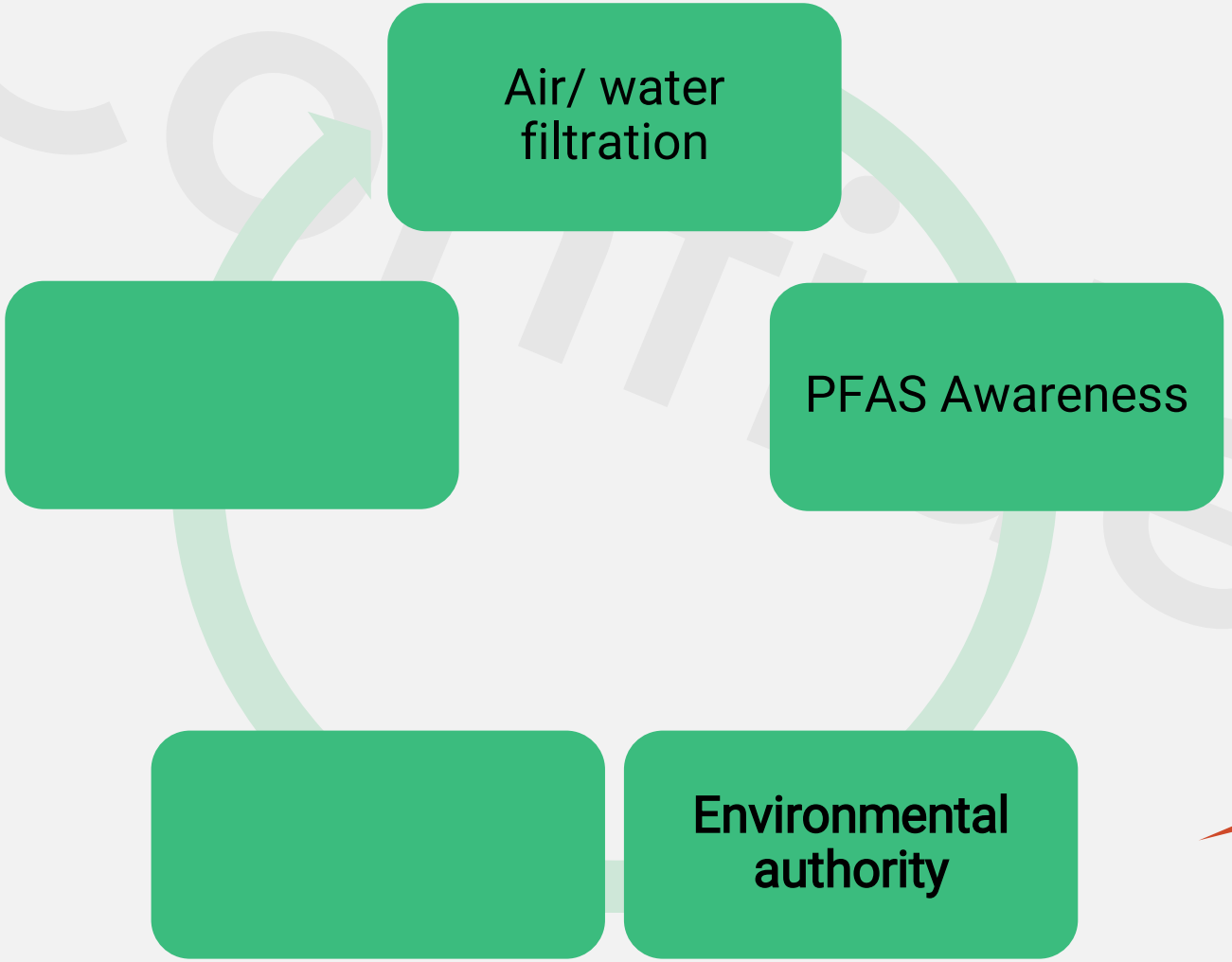
Compliance journey



Processing EU's waste, how much PFAS is emitted locally and what are the risks?

Stay within your operation permit.

Inform authority and community!

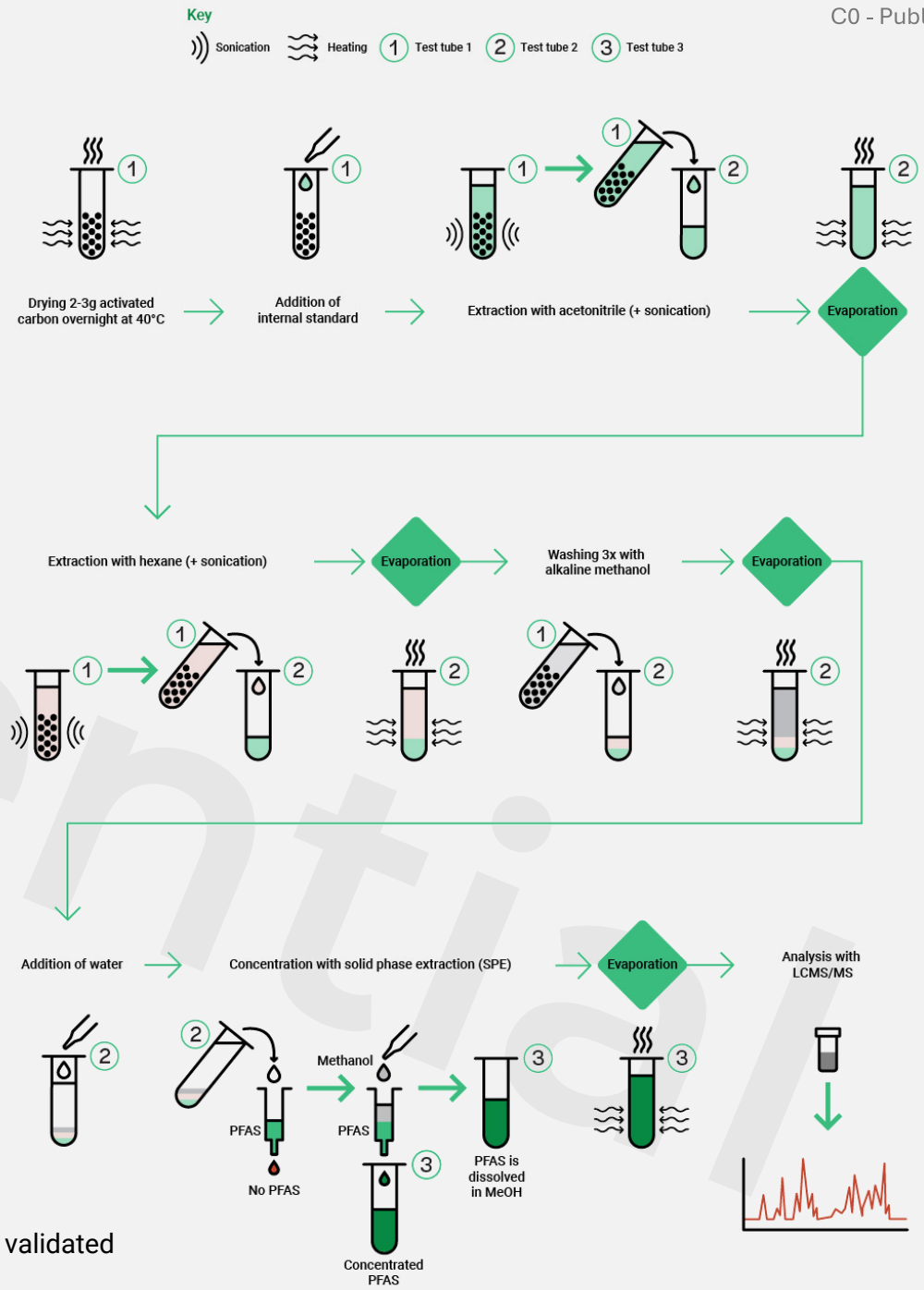
Compliance journey

Air/ water filtration

PFAS Awareness

Environmental authority

PFAS Analysis*



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* Method to measure PFAS concentration on Activated Carbon developed by DESOTEC and validated by Flemish government-related VITO → official preliminary method for Flanders CMA_3_D

Compliance journey

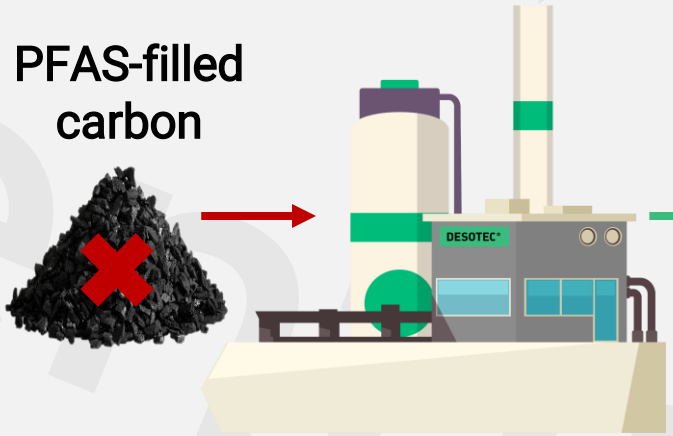
Air/ water filtration

PFAS Awareness

Environmental authority

PFAS Analysis

Compliance



PFAS-filled carbon

Reactivated carbon

Flue gas

LUC/VI/003

CMA_3_D

EU: 2019/1021
(EU POP Regulation)
US: RCRA (Resource Conservation and Recovery Act)

Flue gas salts

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Compliance journey

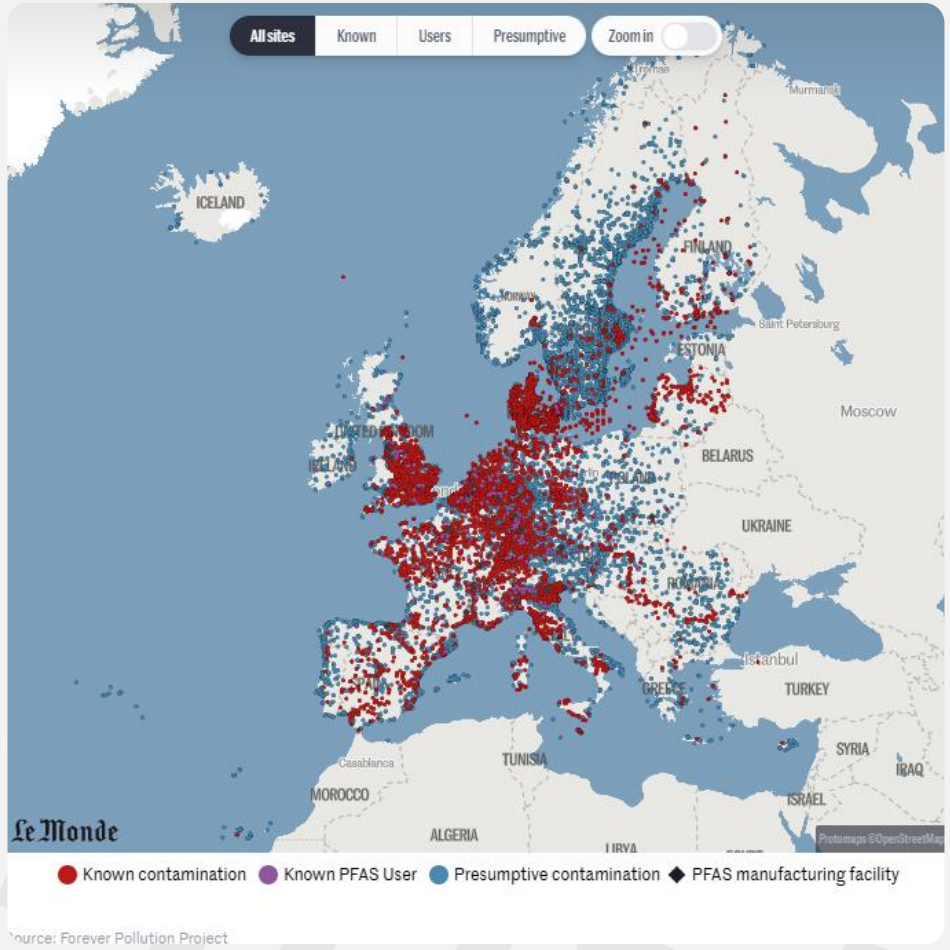
Compliant PFAS Air/ water filtration

Compliance

PFAS Awareness

PFAS Analysis

Environmental authority



Stay within your operation permit, measure regularly.

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Source: Forever Pollution Project, accessed March 2025

Literature confirms reactivation effectiveness

ENVIRONMENTAL Science & Technology
pubs.acs.org/est
Critical Review

Thermal Regeneration of Spent Granular Activated Carbon Presents an Opportunity to Break the Forever PFAS Cycle

Busra Sonmez Baghirzade, Yi Zhang, James F. Reuther, Navid B. Saleh, Arjun K. Venkatesan, and Onur G. Apul*

Table 1. Qualitative Summary of PFAS Decomposition/Defluorination and Changes in GAC Characteristics at Various Regeneration Temperatures[a]

	perfluoroalkyl carboxylic acids (PFCA)		perfluoroalkyl sulfonic acids (PFSA)		GAC properties	
temperature (°C)	decomposition	defluorination	decomposition	defluorination	surface area recovery	micropore recovery
175	high	-	low	-	-	-
200	high	-	low	-	-	-
300	high	-	-	-	low	low
400	high	-	-	-	low	-
500	high	-	high	-	-	moderate
600	high	-	-	-	moderate	moderate to high
700	high	moderate	-	moderate to high	moderate to high	moderate to high
Furnace range 800	-	moderate to high	-	high	high	high
900	-	moderate to high	-	high	moderate to high	high
1000	-	high	-	high	moderate to high	high
1200	-	-	-	-	moderate to high	high

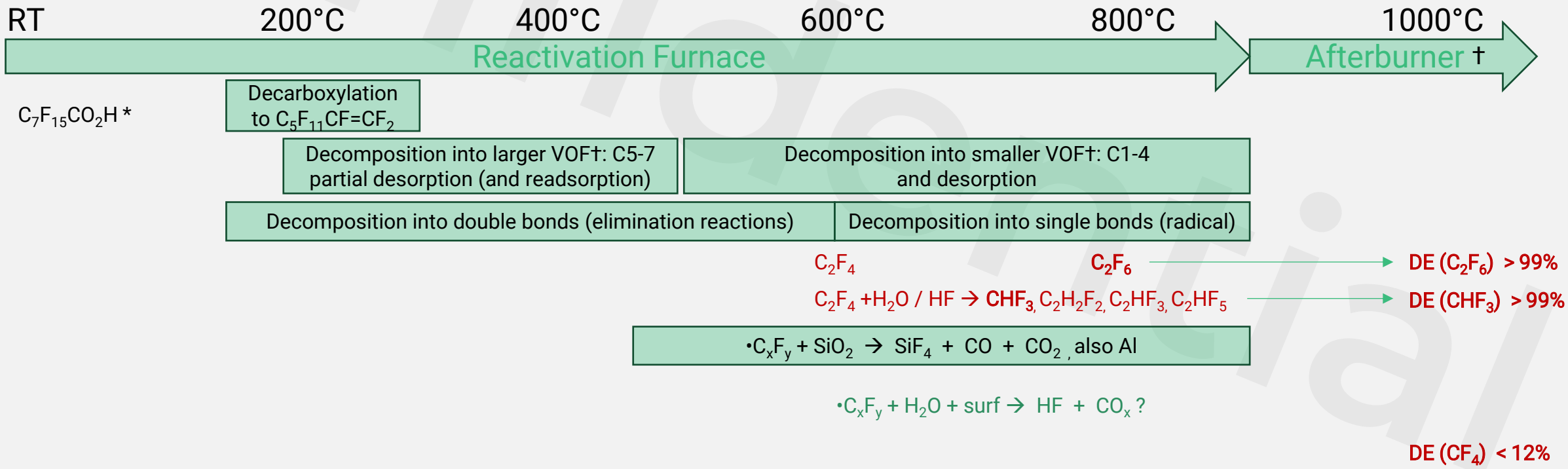
[a]The ranges in the above table are as folows: very low, < 20%; low, 20−40%; moderate, 40−60%; moderate to high, 60−80%; and high, 80−100%. Dash = No data.[22−24,27−29,101−103,105]

PFOA, PFHxA, and PFOS as single analytes are experimentally determined to be 30, 45, and 48% when pyrolyzed at 700 °C in N_2, respectively.[23] Interestingly, when these compounds adsorb onto GAC, percent defluorination increase to 51, 72, and 70%, respectively.[23] When thermolysis is conducted in a steam and NaOH mixture at 700 °C, the percent defluorinations for PFOA, PFHxA, and PFOS as single analytes are reported to increase from 28, 18, and 35% to 75, 90, and 80% as adsorbed onto GAC, respectively.[23] Another study indicates that PFOA volatilization takes place at 150 and 300 °C and defluorination takes place at 500 °C when the single analyte alone is thermolyzed in a N_2 and O_2 mixture. On the other hand, volatilization was inhibited at 150 and 300 °C when PFOA was adsorbed onto GAC and 150 and 300 °C were enough to achieve defluorination of PFOA.[25] The differences could be attributed to a PFAS−carbon interaction and the carbon's electronic structure catalyzing the thermolysis when the analyte is adsorbed onto the GAC surface. As previously mentioned, PFAS defluorination requires higher temperatures; however, these compounds could begin to volatilize at lower temperatures without being defluorinated. Therefore, GAC pores might act as traps and thus diminish the direct release of volatile substances into the off-gas until they are destroyed.[23,25] Thus, GAC's role on thermal degradation of PFAS must be examined systematically. Differences in thermolysis of PFAS alone versus when adsorbed onto GAC will likely be influenced by the thermolysis conditions as well as physicochemical properties of the GAC. Such studies to better evaluate the thermolysis of PFAS are necessary, and the existing literature is discussed in the subsequent section.

https://doi.org/10.1021/acs.est.0c08224

Reactivation furnace – afterburner system mechanism

- Destruction pathways for PFOA in function of furnace temperature
- Surface-mediated thermal decomposition



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* https://doi.org/10.1016/j.jhazmat.2024.135737,
† https://doi.org/10.1080/10962247.2021.2021317

Literature – PICs afterburner

Temperatures: 950 – 1050 °C, min. 2 seconds

- NG premix flame
- Compare port 8 (3 s), 4 (2 s) @ 40 kW

- Destruction efficiency (DE) **CHF_3 > 99%**
- **DE C_2F_6** 80-**99%** (950°C-1050°C)
- **DE CF_4 ~ 0%**

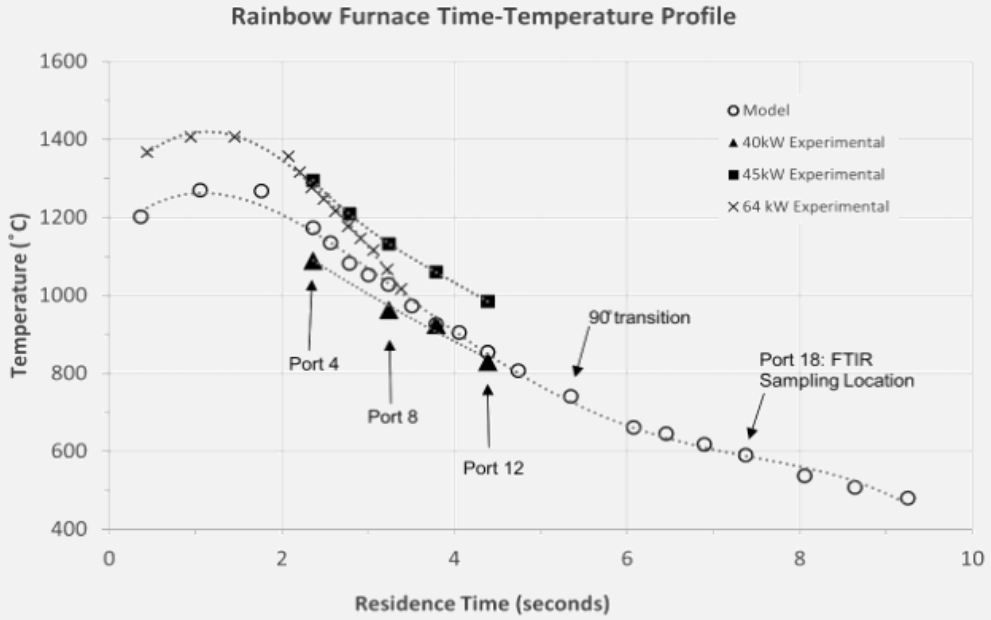

Table 2. Comparison of measured (Exp) and calculated (Model) PFAS destruction efficiencies (DEs) within the Rainbow furnace as a function of compound and injection location. Measurements performed by FTIR at Port 18 (see Figure 2).

	CF_4 DE (%)				CHF_3 DE (%)			C_2F_6 DE (%)		
PFAS injection location	Exp 1 40 kW	Exp 2 45 kW	Exp 3 64 kW	Model 45 kW	Exp 1 40 kW	Exp 2 45 kW	Model 45 kW	Exp 1 40 kW	Exp 2 45 kW	Model 45 kW
Natural gas	58.5	89.5	94.9	97.6	-	>99[4]	>99.9	>99[4]	>99[4]	>99.9
Combust air	–	82.6	88.7	n/a[1]		>99[4]	n/a[1]		>99[4]	n/a[1]
Port 4		13.7	–	~0[2]	>99[4]	>99[4]	>99.9	>99[4]	>99[4]	>99.9
Port 6		12.9	–	~0[2]		>99[4]	>99.9		>99[4]	99.5
Port 8	–	11.7	–	~0[2]	–	>99[4]	>99.9	78.2	>99[4]	63.9
Port 10	–	12.5	–	~0[2]	>99[4]	>99[4]	>99.9	25.5	>99[4]	8.0
Port 11	8.2	–	–	–	–	–	–	–	–	–
Port 12	–	–	–	–	94.3	>99[4]	98.5	~0[3]	86.2	~0[2]

[1]The PFR model assumes perfect mixing of reactants, separate PFAS introduction with the combustion air is not applicable (n/a). The model used an initial adiabatic flame temperature (2071°C) and a linear temperature decay to Port 1, after which the measured temperature profile was used.
[2]Due to numerical rounding in the model the calculated DE was slightly negative.
[3]Due to measurement uncertainty, the calculated DE was slightly negative.
[4]Measured FTIR concentration of target analyte was below the ASTM D6248 MDC3 value and considered non-detect.

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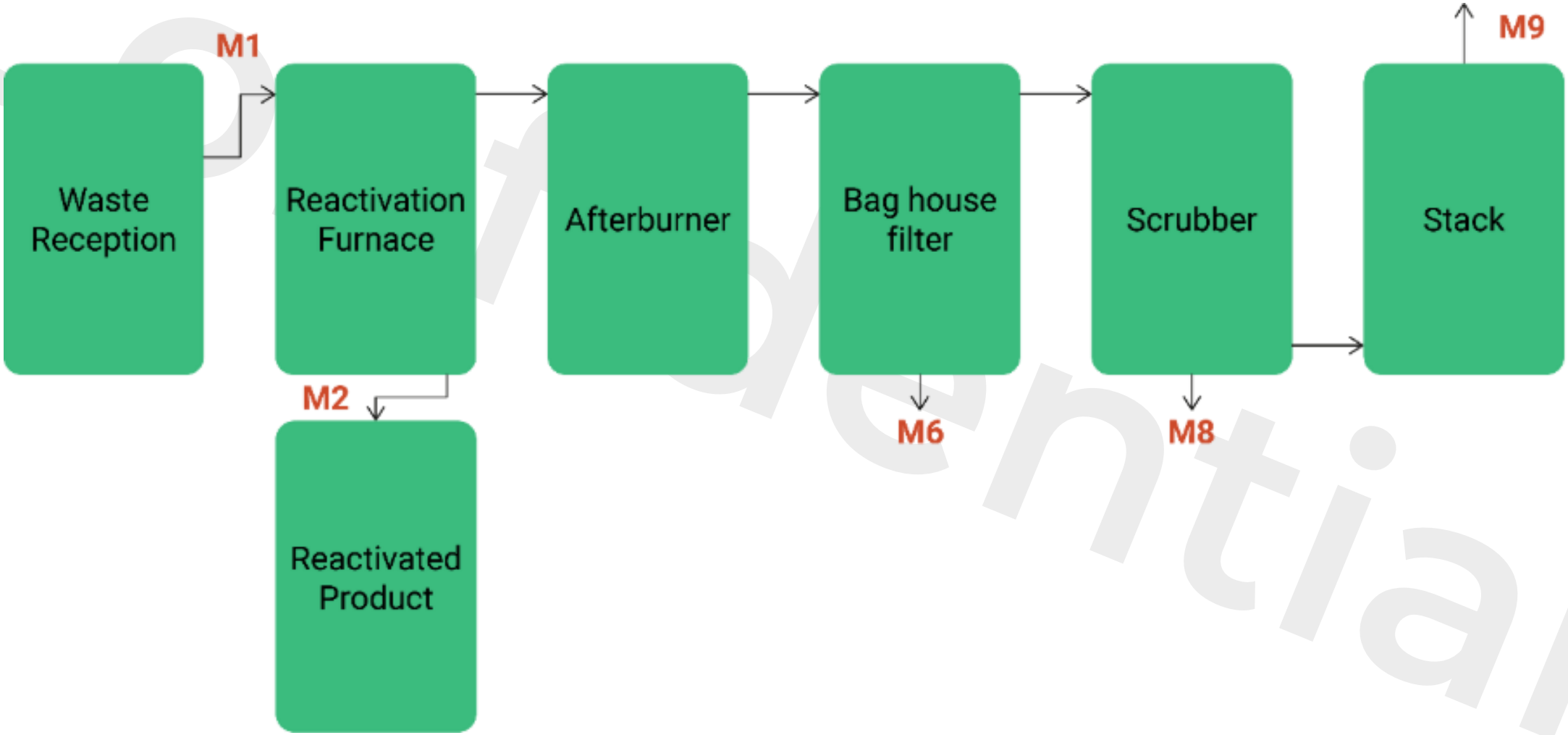
https://doi.org/10.1080/10962247.2021.2021317

DESOTEC's process flow sheet



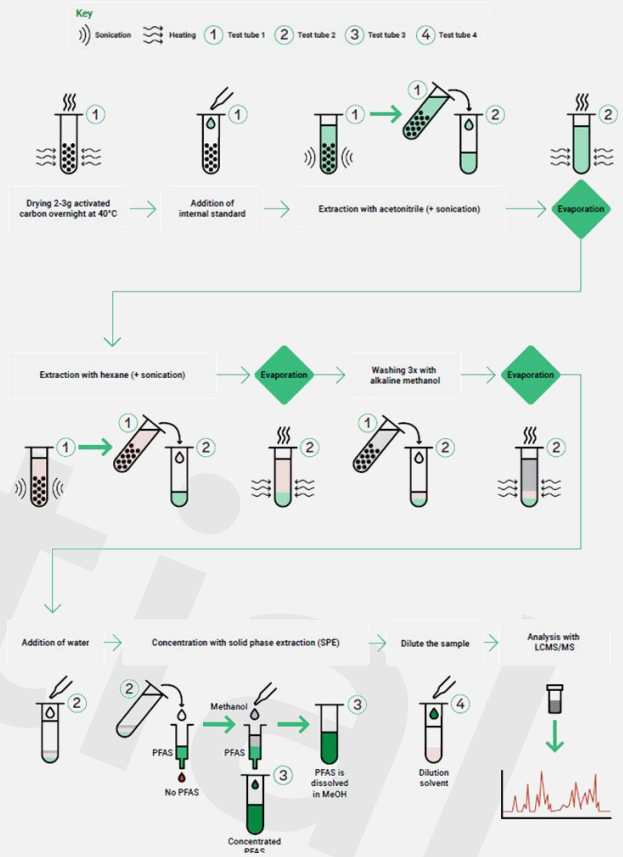
PFAS mass balance – details (furnace)

- Removal of PFAS on the carbon under DL
- Removal efficiency total F on AC ~ 80%

Fluorine balance (mg/kg)		
	M1	M2
Total F (CIC)	580	110
Non-target organic F	75	<0,2

	F4		
	M1 input (µg/kg)	M2 output (µg/kg)	Minimal Observed Removal efficiency
6:2 FTS	33 640,4	<1,9	99,99%
4:2FTS	4 585,8	<0,5	99,99%
DONA	<15	<0,5	-
Gen-X	<15	<0,5	-
PFBA	549,3	<0,5	99,91%
PFBS	<15	<0,5	-
PFDA	<15	<0,5	-
PFDoDA	30,1	<0,5	98,34%
PFDoS	<15	<1,7	-
PFDS	<15	<0,5	-
PFHpA	73,5	<0,5	99,32%
PFHpS	<15	<0,5	-
PFHxA	8 525,7	<0,5	99,99%
PFHxS	<15	<0,5	-
PFNA	<15	<0,5	-
PFNS	<15	<0,5	-
PFOA	<15	<0,5	-
PFOS	<15	<0,5	-
PFPEA	1 839,0	<0,5	99,97%
PFPeS	<15	<0,5	-
PFTrDA	<15	<1,7	-
PFTrDS	<15	<1,7	-
PFUnDA	<15	<0,5	-
PFUnDS	<15	<1,7	-
SUM(20)	11 242,7	<14,8	99,87%
SUM	49 498,8	<18,2	99,97%

An updated, robust analytical methodology to quantify PFAS adsorbed on diverse activated carbon matrices *



* Method to measure PFAS concentration on Activated Carbon developed by DESOTEC and validated by Flemish government-related VITO → official method for Flanders CMA_3_D

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PFAS mass balance – details (off-gas)

- Trace amounts in FGS, representing only 0,0002%
- PFAS in scrubber water all under detection limit
- Elevated fluorine levels in FGS and scrubber

	M6 - Flue gas salts (µg/kg)	M8 – Scrubber water (ng/L)
6:2 FTS	0,2270	<10
4:2 FTS	<0,0493	<10
DONA	<0,0985	<10
Gen-X	0,0857	<10
PFBA	0,0857	<10
PFBS	0,0510	<10
PFDA	0,2	<10
PFDoDA	<0,0493	<10
PFDoS	<0,0985	<10
PFDS	<0,0493	<10
PFHpA	0,1060	<10
PFHpS	<0,0493	<10
PFHxA	0,5860	<10
PFHxS	<0,0493	<10
PFNA	0,0660	<10
PFNS	<0,0985	<10
PFOA	0,6800	<10
PFOS	<0,0493	<10
PFPEA	0,0664	<10
PFPeS	<0,0493	<10
PFTrDA	<0,0493	<10
PFTrDS	<0,0985	<10
PFUnDA	<0,0493	<10
PFUnDS	<0,0985	<10

Fluorine analyses	
Fluorine (CIC) M6	4967 mg/kg
Fluorine (ISE) M8	15 mg/L/h

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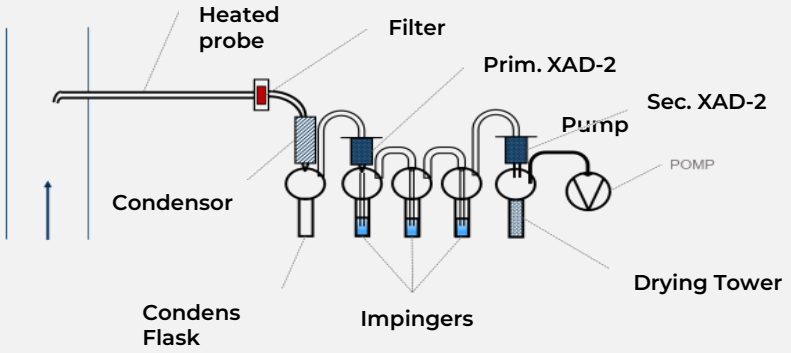
PFAS mass balance – details (exhaust)

- OTM-45 measurements both inhouse and by third parties
- All molecules under detection limits



	ng/Nm3	Mass flow (µg/h)
PFBA	<0,245	<2
PFBS	<0,245	<2
PFDA	<0,245	<2
PFDoDA	<0,245	<2
PFDoS	<0,664	<4
PFDS	<0,245	<2
PFHpA	<0,245	<2
PFHpS	<0,245	<2
PFHxA	<0,245	<2
PFHxS	<0,245	<2
PFNA	<0,245	<2
PFNS	<0,245	<2
PFOA	<0,245	<2
PFOS	<0,245	<2
PFPEA	<0,245	<2
PFPeS	<0,245	<2
PFTrDA	<0,245	<2
PFTrDS	<0,664	<4
PFUnDA	<0,245	<2
PFUnDS	<0,664	<4
PFTeDA	<0,245	<2
PFHxDA	<0,664	<5
PFODA	<0,664	<5
F-53 B major	<0,664	<5
F-53 B minor	<0,664	<5
GenX	<0,629	<5
ADONA	<0,629	<5
PF-3,7DMOA	<0,489	<4
4:2 FTS	<0,629	<5
6:2 FTS	<0,629	<5
8:2 FTS	<0,664	<5
10:2 FTS	<0,664	<5
PFOSA	<0,245	<2
N-MeFOSA	<0,629	<5
N-EtFOSA	<0,629	<5
N-MeFOSE	<0,664	<5
N-EtFOSE	<0,664	<5
N-MeFOSAA	<0,629	<5
N-EtFOSAA	<0,629	<5

DRE - per species

Destruction and Removal Efficiency (DRE)

$$\frac{\left(PFAS\ spent\ \left(\frac{\mu g}{kg}\right) * AC\ feed\ rate\ \left(\frac{kg}{h}\right)\right) - \left(PFAS\ react\ \left(\frac{\mu g}{kg}\right) * AC\ output\ rate\ \left(\frac{kg}{h}\right)\right) - \left(PFAS\ emission\ \left(\frac{\mu g}{m^3}\right) * flow\ stack\ \left(\frac{m^3}{h}\right)\right)}{\left(PFAS\ concentration\ \left(\frac{\mu g}{kg}\right) * AC\ feed\ rate\ \left(\frac{kg}{h}\right)\right)}$$

	DRE (%)*
PFBA (C_4)	>99,91121%
PFDoDA (C_{11})	>98,37959%
PFHpA (C_7)	>99,33641%
PFHxA (C_6)	>99,99428%
PFPEA (C_5)	>99,97348%
4:2 FTS (C_6)	>99,98928%
6:2 FTS (C_8)	>99,99450%

Destruction and Removal efficiency (DRE) – only considering exhaust

$$\frac{\left(PFAS\ spent\ \left(\frac{\mu g}{kg}\right) * AC\ feed\ rate\ \left(\frac{kg}{h}\right)\right) - \left(PFAS\ emission\ \left(\frac{\mu g}{m^3}\right) * flow\ stack\ \left(\frac{m^3}{h}\right)\right)}{\left(PFAS\ concentration\ \left(\frac{\mu g}{kg}\right) * AC\ feed\ rate\ \left(\frac{kg}{h}\right)\right)}$$

	DRE (%)*
PFBA (C_4)	>99,999569%
PFDoDA (C_{11})	>99,992819%
PFHpA (C_7)	>99,996780%
PFHxA (C_6)	>99,999972%
PFPEA (C_5)	>99,999871%
4:2 FTS (C_6)	>99,999948%
6:2 FTS (C_8)	>99,999993%

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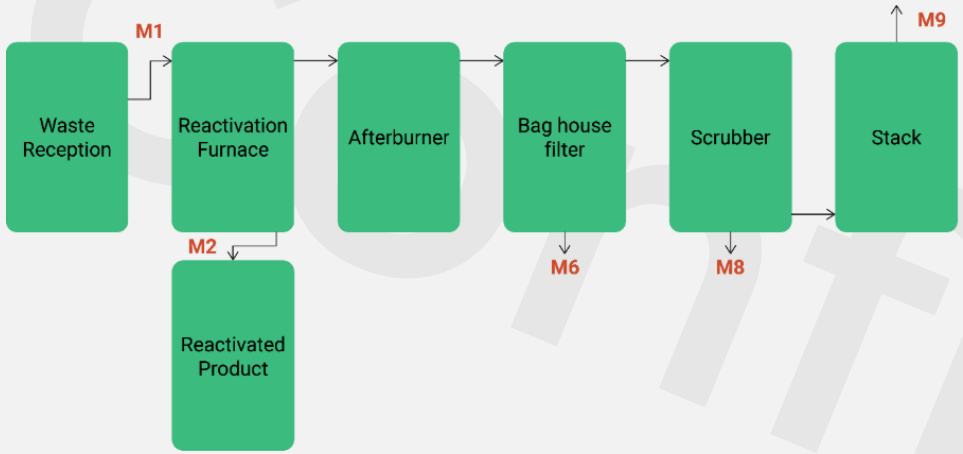
*conservative approach, c=LOQ

PFAS mass balance



1) Average **DRE > 99.97%** (conservative approach, c=LOQ*), based on sum DWD PFAS(20) + 4 technical PFAS (6:2 FTS, 4:2 FTS, ADONA, Gen-X)

2) F mass balance closure 96% (AC, scrubber water, flue gas salts via total F (CIC) in / µg/h)

3) Stack: No target PFAS (OTM-45) could be measured

4) Several Measurement Campaigns, by third parties confirm DRE

5) Own measurements and literature hypothesis: PFAS disintegration/mineralisation already on AC surface (electronic interation and longer residence time and high T)

	M1 (feed)	M2 (react)	M6 (FGS)	M8 (SC)	M9 (Stack)
Flow solids (kg/h)	752	730	23,6	-	-
Internal circulation (m^3)				16,35	
Exhaust (Nm3/h)	-	-	-	-	7274
PFAS Sum20 + 4 (mg/kg) (mg/Nm3)	49.5	<$1.8 \cdot 10^{-2}$*	<$3{,}0 \cdot 10^{-3}$*	<$2{,}4 \cdot 10^{-4}$*	<$8{,}7 \cdot 10^{-6}$*
PFAS mass flow (mg/h)	37 224	<13,14*	<0,07*	-	<0,06*

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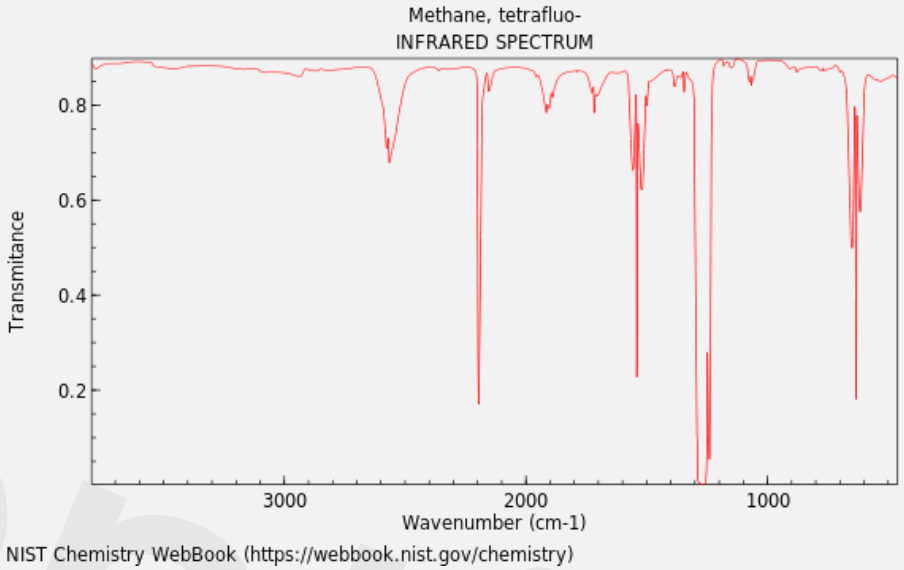
* LOQ Level of Quantification

CF4 and PIC monitoring

→ Confirm total mineralization hypothesis

	FTIR 5/06/2023	FTIR 7/06/2023	FTIR 9/06/2023	OTM-50 18/02/2025	OTM-50 17/03/2026
	mg/Nm3	mg/Nm3	mg/Nm3	µg/Nm3	µg/Nm3
Tetrafluoromethane	<0,5	<0,5	<0,5	<2	<1,80
Hexafluoroethane				<2	<1,70
Chlorotrifluoromethane				<2	<1,30
Tetrafluoroethylene				<2	2,70*
Trifluoromethane				<2	<0,80
Difluoromethane				<2	<1,10
Fluoromethane				<2	<2,10
Octafluoropropane				<2	<2,30
Pentafluoroethane				<2	<1,40
1,1,1-Trifluoroethane				<2	<1,00
Chlorodifluoromethane				<2	<1,00
Hexafluoropropene				x	<1,80
Octafluorocyclobutane				<2	<2,40
1,1,1,2-Tetrafluoroethane				<2	<1,20
Perfluorobutane				<2	<2,90
1H-Heptafluoropropane					<2,10
Trichlorofluoromethane					<1,70
Perfluoropentane					<3,50
Octafluorocyclopentene					<2,60
1H-Nonafluorobutane					<2,70
Perfluorohexane					<4,10
1H-Perfluoropentane					<3,30
Heptafluoropropyl-1,2,2,2-tetrafluoroethyl ether					<3,50
Perfluoroheptane					<4,70
1H-Perfluorohexane					<3,90
Perfluorooctane					<5,30
1H-Perfluoroheptane					<4,50
2H-Perfluoro-5-methyl-3,6-dioxanonane					<5,50
1H-Perfluorooctane					<5,10
Hexafluoropropene oxide					<501,00



NIST Chemistry WebBook (https://webbook.nist.gov/chemistry)

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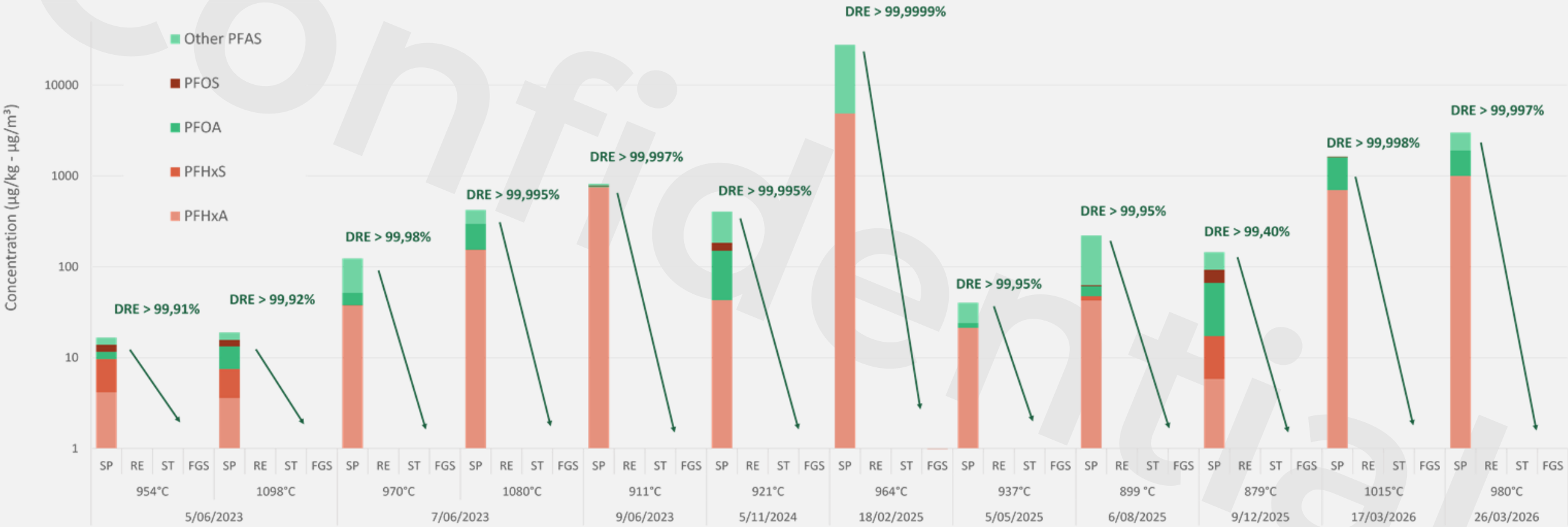
* Possible contamination confirmed by the external lab

Multiple Measurement Campaigns



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The 3 key take aways for you

Activated carbon is more than a removal technology

Industrial reactivation enables complete PFAS destruction

PFAS are effectively mineralized, not transferred

Thank you for your attention!

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