Pilot Scale Thermal Soil PFAS Remediation test

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Background

Pilot test site with AFFF contaminated soil: Mainly PFOS.

Lab testing and industry ”standard”: Target treatment temperature of at least 350°C

Lab testing results indicate degradation and mineralization

Test purpose

Demonstrate treatability of PFAS contaminated soil at “standard” 350°C

Optimize PFAS mineralization

Follow PFAS through detailed analytical program

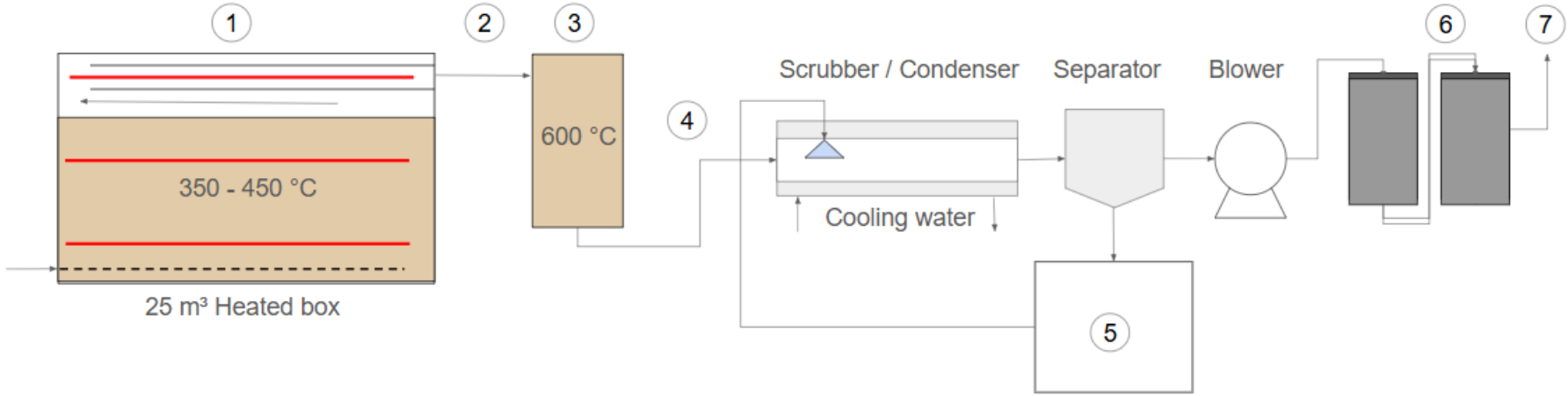
- Non Target Screening (NTS)
- OTM 45 and OTM 50
- Real time HRMS

Test vapor treatment plant design

Test set-up

Heated box with DeFluorinator and condensing front end vapor treatment plant

DeFluorinator is by-passed until soil is dry



Test design

Limit energy consumption - reach soil criteria - optimize mineralization

- Soil temperature > 350°C - hold for 2-4 weeks
- Limit over-temperature by heater temperature <550°C
- DeFluorinator operated at 600°C
- Avoid thermal treatment of water vapor

Controlled heating optimizing PFAS residence time in the hot soil

- Avoiding high temperatures i.e. heaters <250°C during dry out step
- Low 1 m^3/h ventilation rate for optimal residence time and minimal dilution during high temperature step

Does it work?

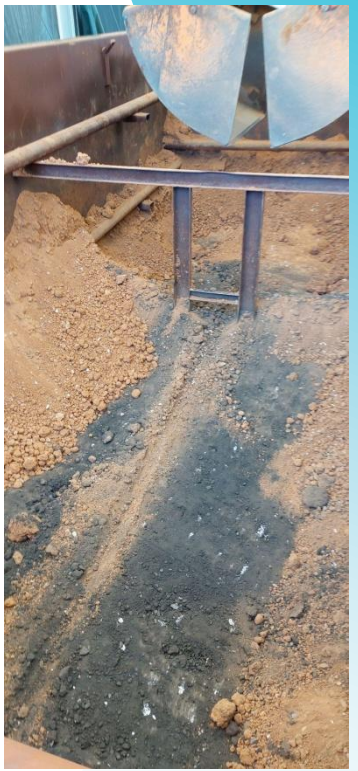
Yes!

Soil treated at ≥350°C for 4 weeks has:

- PFAS 35 and PFAS 35 TOP below detection limit (2 samples)
- PFAS 22 below detection limit (1 sample per ton)
- PFAS 22 Leachability test (L/S = 2) below detection limit

Soil treated at 250-300°C for 4 weeks has:

- 0.5 μg/kg PFOS and 0.1 μg/kg PFHxS
- All remaining PFAS 35 and PFAS 35 TOP below detection limit



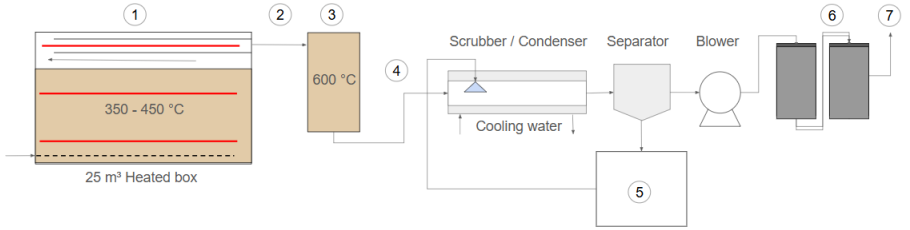
Is there more to the story than soil target PFAS concentrations?

Indeed! Lot of data collected:

- Soil temperatures, real time mass spectre
- Temperature and time dependence
- PFAS mass balances
- Vapor treatment train experiences

Come and discuss!

Analysis



Soil (1)	PFAS 22, PFAS 35 TOPA, NTS, EOF, water soluble F^-
Air (2, 4, 7)	OTM 45, OTM 50, NTS of OTM 45 extract, HRMS real time
Catalyst (3)	PFAS 35, EOF, water soluble F^-
Condensate (5)	PFAS 22, PFAS 35 TOPA, NTS, AOF, dissolved F^-
Activated carbon (6)	PFAS 22

PFAS fate

PFAS 35 (TOP) in untreated soil:	4800 (6500) mg	
PFAS 35 (TOP) in treated soil:	0.17 (0.13) mg	0.004%
PFAS 35 in spent catalyst:	– (< DL)	–
PFAS 35 (TOP) in condensate:	0.58 (0.79) mg	0.012%
PFAS 22 in spent GAC:	110 mg	2.3%
PFAS 22 in air (OTM 45)	0.0003 mg	–
Other degradation products	estm. 200 mg	estm. 3% of total F

Thoughts on Implementation

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Container scale treatment

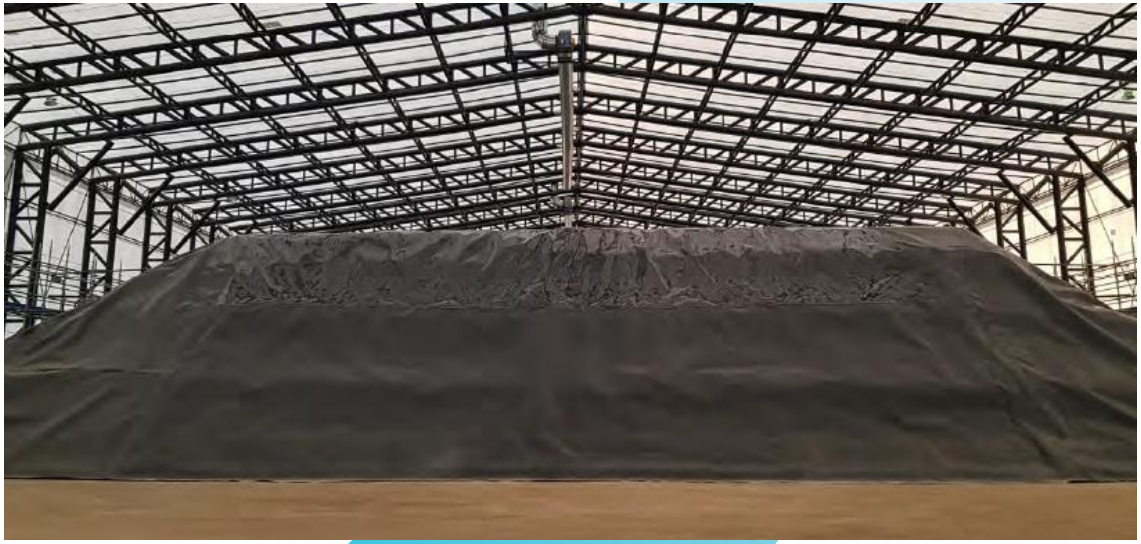
20 m^3 scale is too small for most applications => too many batches

Large heat loss > 80%

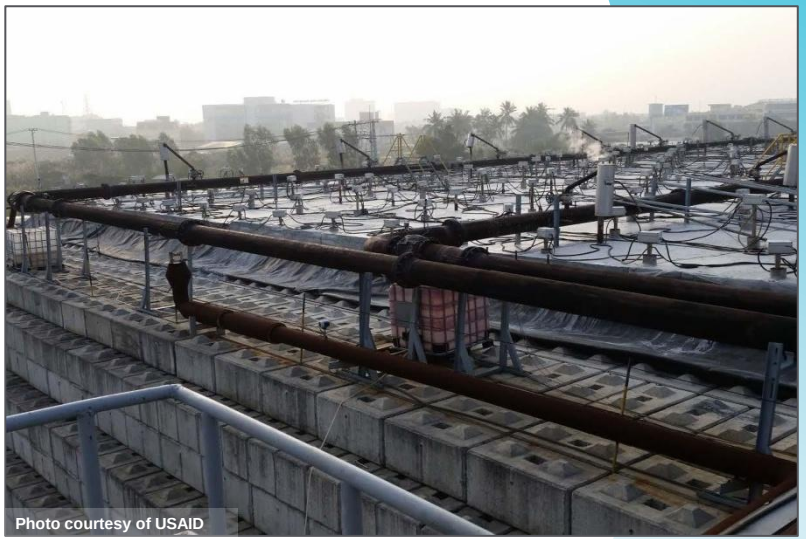
Same operation and monitoring effort as larger scale

Piles build to fit project scale

1000 - 10000 m^3
Single or a few batches
~50% heat loss



Da Nang Airport, Vietnam, Phase 2: 45 000 m³ IPTD

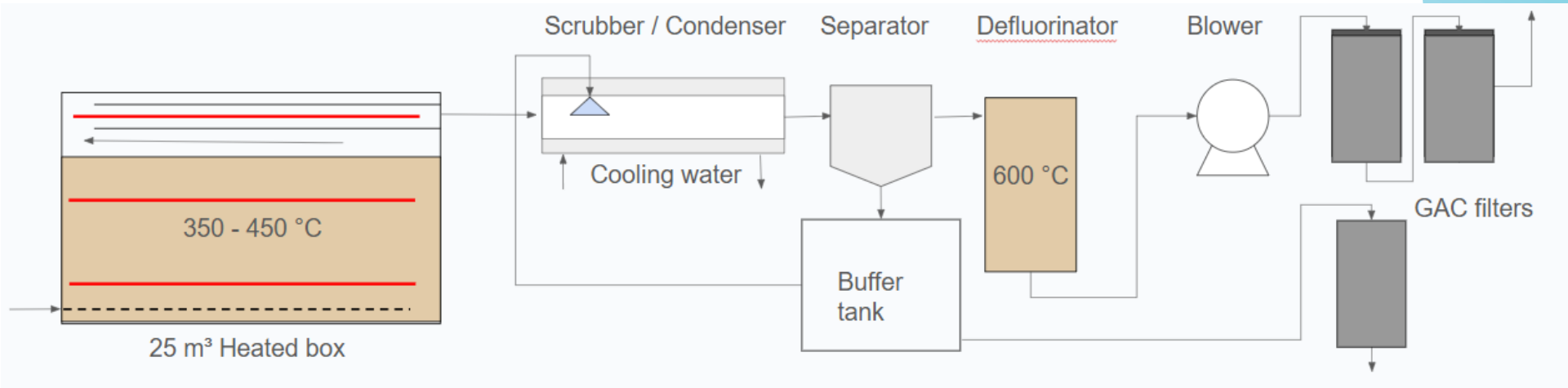


COCs	Volume	Pile Dimensions	Goal	Duration	Results
Dioxins (2,3,7,8-TCDD)	48.778 m³	105m by 70m by 6m	150 ppt for Dioxins (2,3,7,8-TCDD)-TEQ	9 months of operations	Dioxin concentrations reduced to average of 0.199 ppt 750 times lower

Vapor treatment plant

GAC filtration of water

Thermal defluorination of dryed vapors



Operation

Continuous/fast response analysis of vapor discharge

Continuous/fast response analysis of liquid discharge

Fast detection of remediation end point to conserve energy

Conclusions

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Conclusions

Heated box set-up works well

Limited evaporation of 35 PFAS

A number of PFAS compounds detected in treatment system, e.g. PFBA, PFPeA, PFHxA, PFHxS, 6:2 FTS, 1H-perfluoropentane and 1H-perfluorohexane

Real time HRMS detected relevant compounds

- Hydrocarbons and carboxylic acids
- Short chain PFCAs
- Highly fluorinated fragments

PFAS compounds are different

Degradation

- Precursors e.g. 6:2 FTS PFHxA
- Long chain PFAS H-Perfluoropentane and H-Perfluorohexane

Evaporation

- PFHxA: 10% vs. PFOS: 0.006%

Detection limits in vapor

- H-Perfluoropentane: 35000 ng/m^3 vs. PFOS: 0.08 ng/m^3

Comparison with lab scale testing

Temperature & Time: Soil results improve going from 1 week to 4 weeks

Starting concentration: Similar results to lab scale test with up to 200 mg/kg total PFAS 30 TOP

PFAS Fate similar to lab scale tests in spite of differences:

- PFAS concentrations
- Ventilation rate

Thanks

Danish EPA: Financing the pilot test

Tofwerk: HRMS support

Colleagues at Krüger & Veolia

Thank you for your attention

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