A Smoldering Solution for PFAS and Other Organic Contaminants

Moderator: Justin Knight, Geosyntec

Speakers:

- Gavin Grant, Managing Director, Savron
- Laura Kinsman, Project Professional, Savron

May 15, 2024, 4:30 p.m.

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MAY 14-16, 2024
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- PFAS Industry and Government Engagement (IGE) Project
- Post Support and Interaction
- Monthly ECOI - LINK to monthly call is on SAME ECOI webpage - SAME ECOI Monthly Call
  - Call currently third Wednesday of the month 1500-1600 hrs. May Change in Future
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MODERATOR

Justin Knight

Geosyntec

Principal

Fun Facts

- Close to my 700th Peloton Bike Workout (my wife is at over 1,200!)

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SPEAKER

Gavin Grant

Savron

Managing Director

Fun Facts

- 6-time City of Toronto Dodgeball Champion

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SPEAKER

Laura Kinsman

Savron

Project Professional

Fun Facts

- Loves Alpacas! And hiking.
- Currently learning how to juggle

Live Content Slide

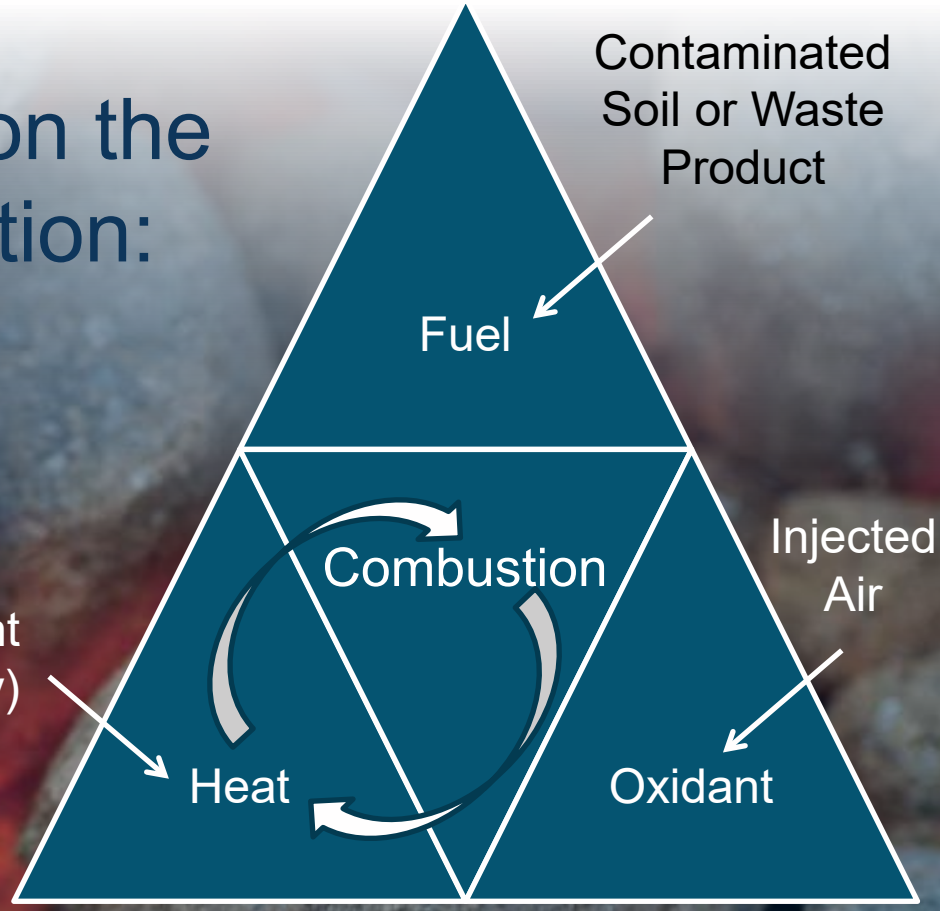
Poll: Have you heard of smoldering?

Smoldering Combustion

Smoldering Combustion

- **STAR and STARx** are based on the process of smoldering combustion:

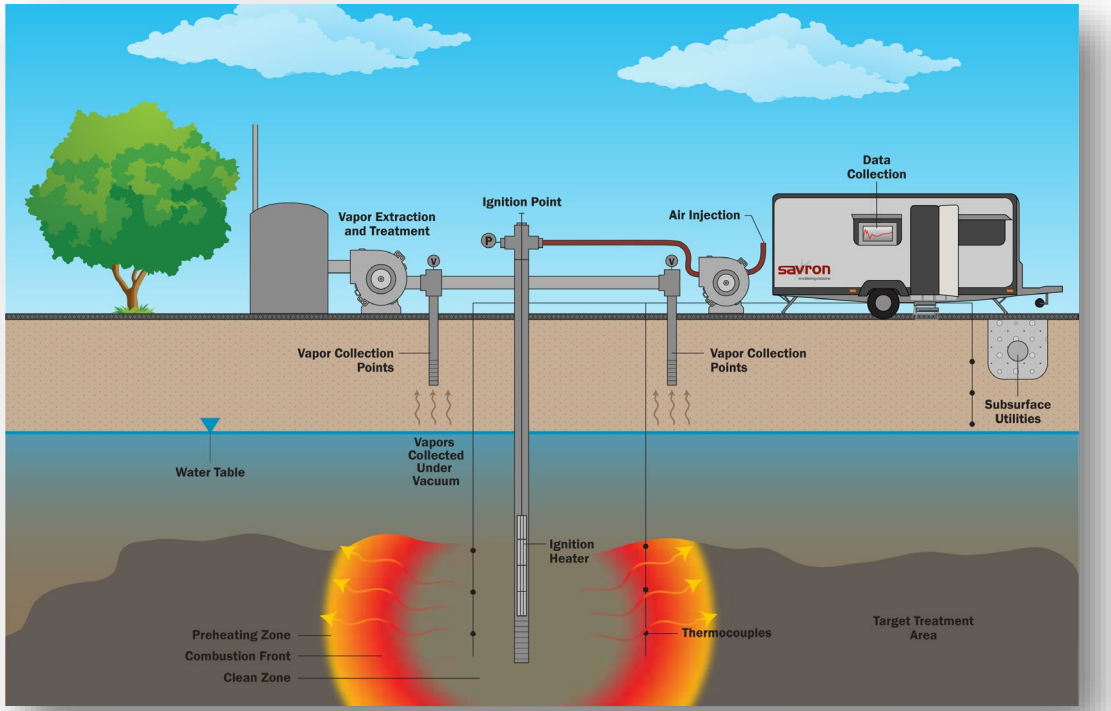
  Exothermic reaction converting carbon compounds to $CO_2 + H_2O$



STAR / STARx is a flameless combustion process: only smoldering is possible within a porous matrix (i.e., soil)

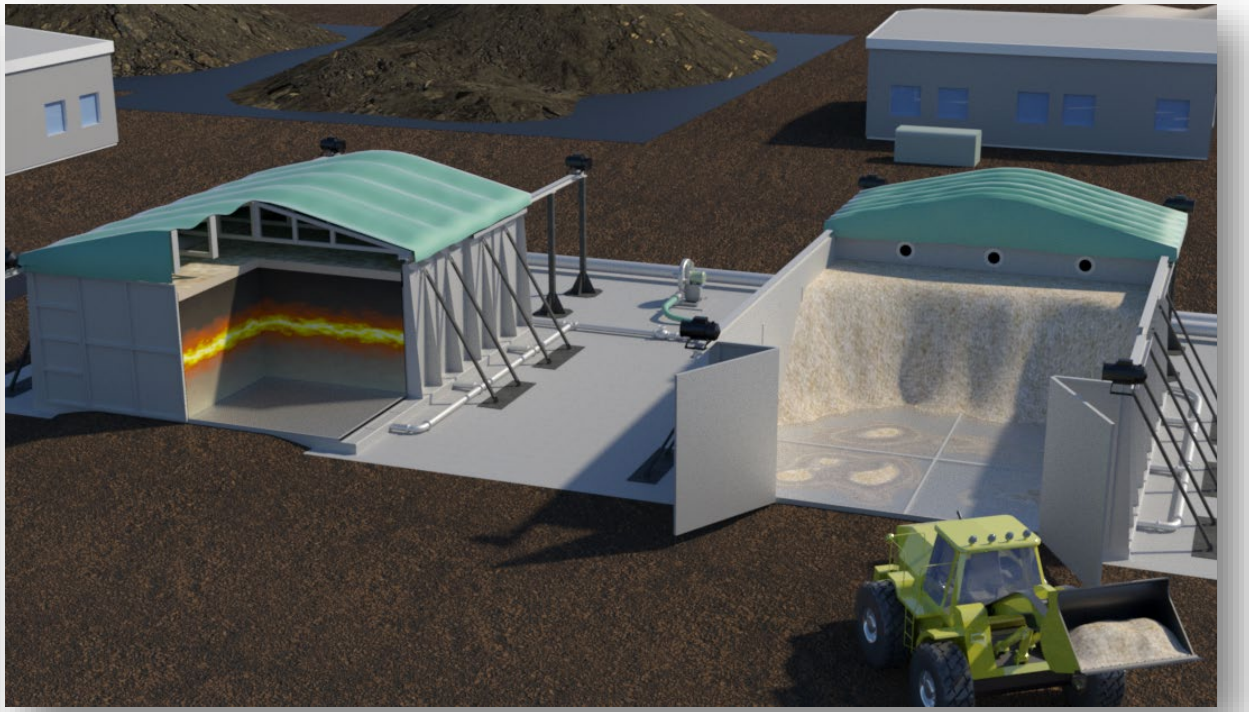
STAR

- **In situ (vadose zone & below water table)**
  - Applied via ignition points and portable heaters



STARx

- **Ex situ (above ground)**
  - Soil piles placed on Hottpad™ or in STARxpress™ mobile treatment units



STAR

STARx

Full scale systems implemented at sites around the world for treating hydrocarbon-impacted soils and sludges

What About PFAS?

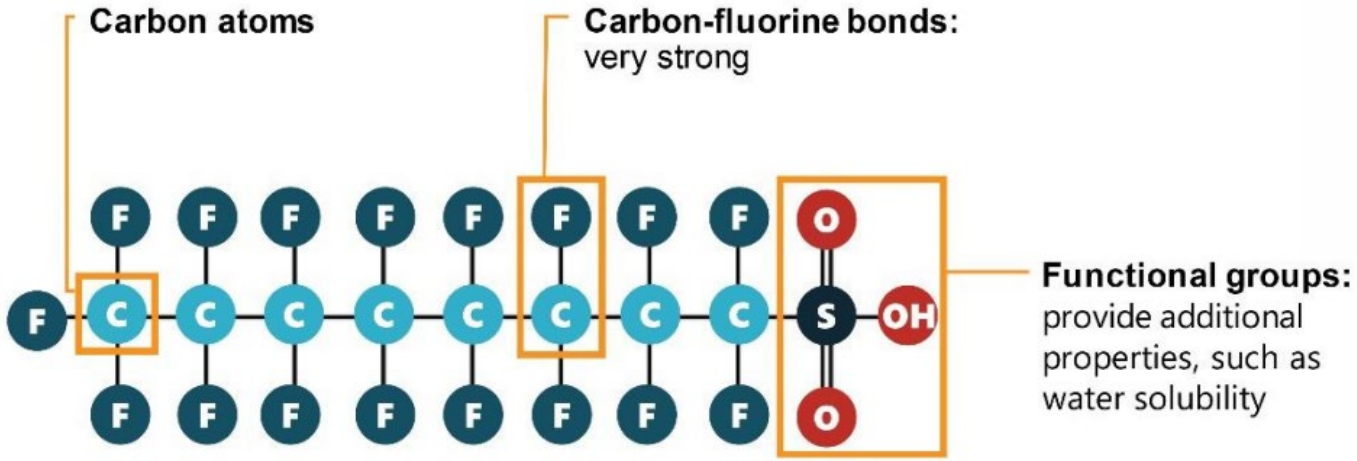
SPOILER ALERT: Yes! We can smolder PFAS.

Challenges for PFAS Remediation

Challenges for PFAS Remediation

Chemical and thermal stability

$$PFAS \xrightarrow{HEAT} HF + shorter\ chain\ compounds$$



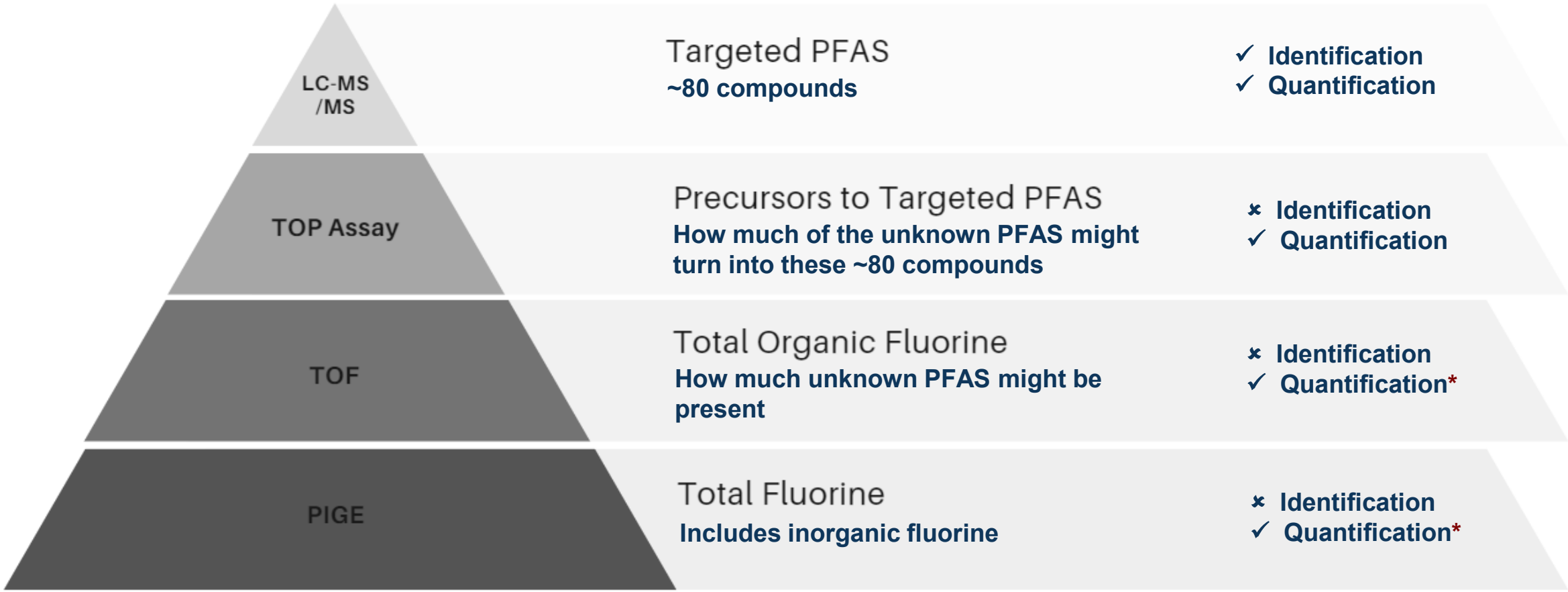
(AAAS, 2021)

Mineralization

- Increases with Temp > 700°C
- Maximizes at Temp > 900°C

How do we measure it?

- Identification – what PFAS compounds are present?
- Quantification – how much of it is present?

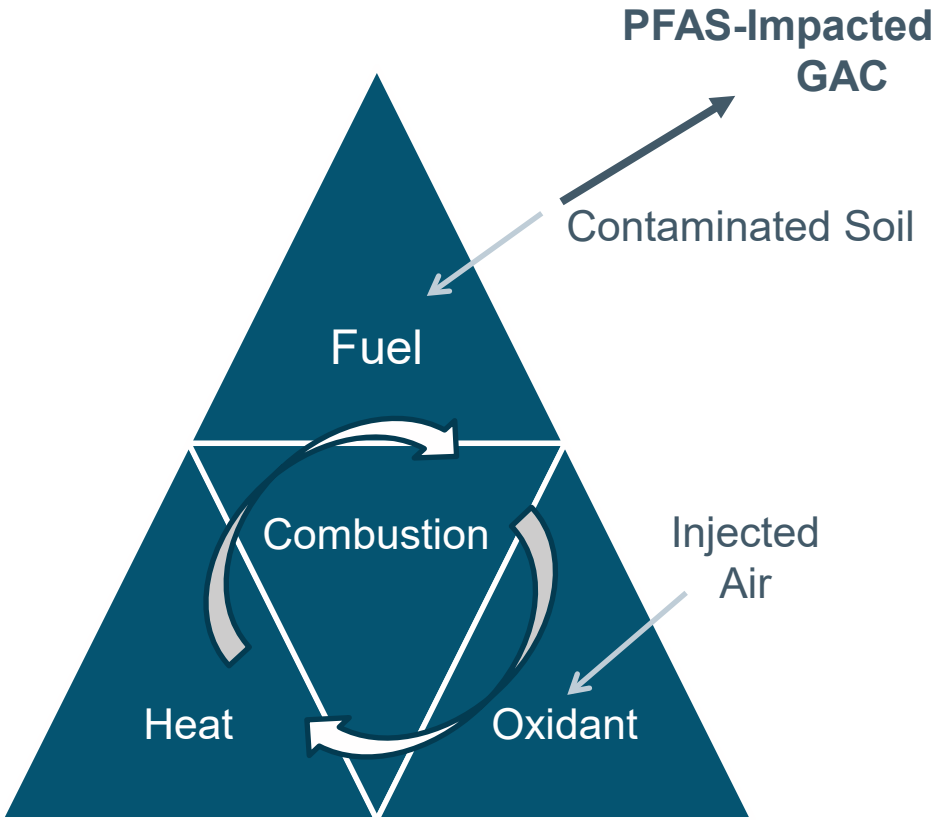


*Fluorinated compounds you are quantifying may or may not be PFAS

PFAS Smoldering: The Science

Smoldering: PFAS Applications

Same energy-efficient, flameless form of combustion as used for hydrocarbon applications

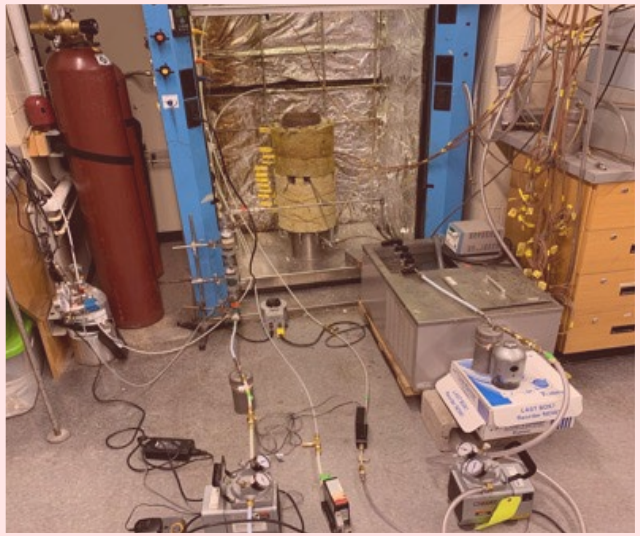


For PFAS applications:

Small quantities of surrogate fuel (e.g., clean or spent GAC) used to sustain reaction and reach the high temperatures required for PFAS destruction

SERDP Project

PROJECT OF THE YEAR 2021 SERDP ENVIRONMENTAL RESTORATION



Phase 1:
Lab Column Tests

- Fluorine Mass Balance
- Optimization

Phase 2:
Pilot Scale Tests

- Scale Up
- Evaluate Field Soils

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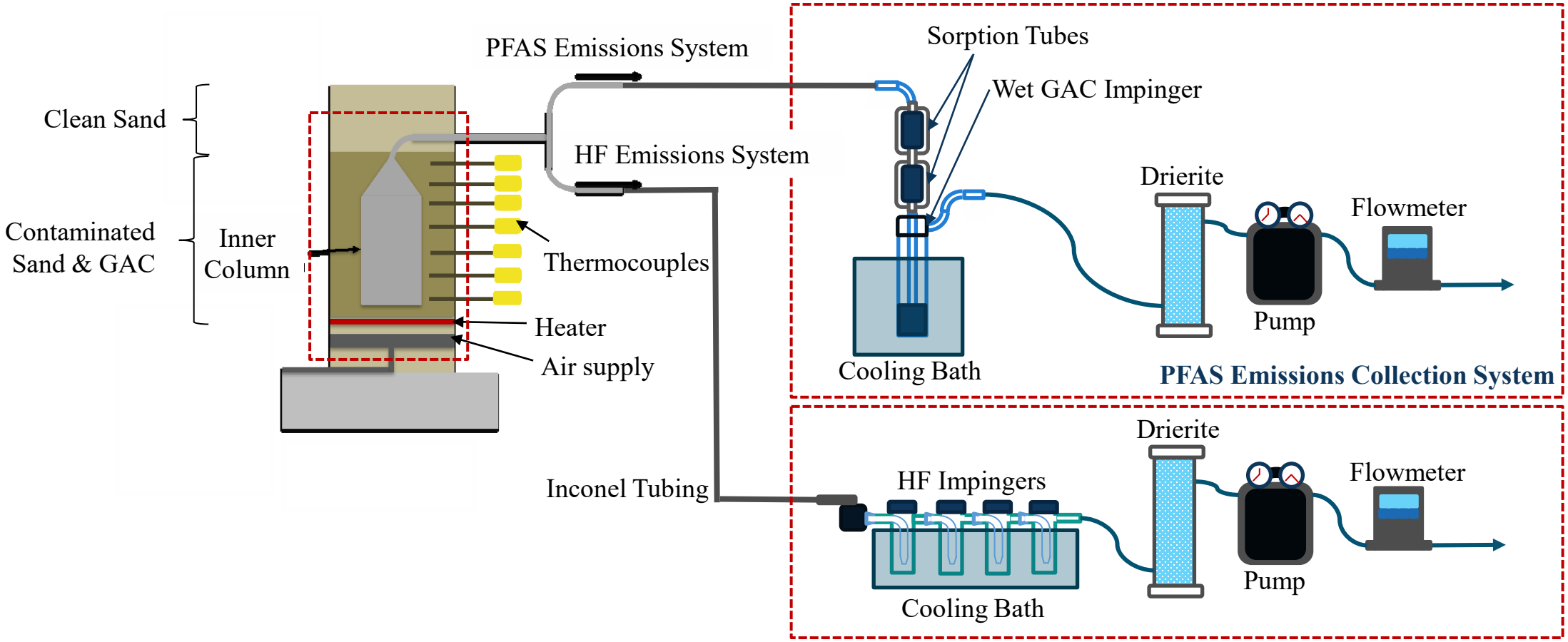
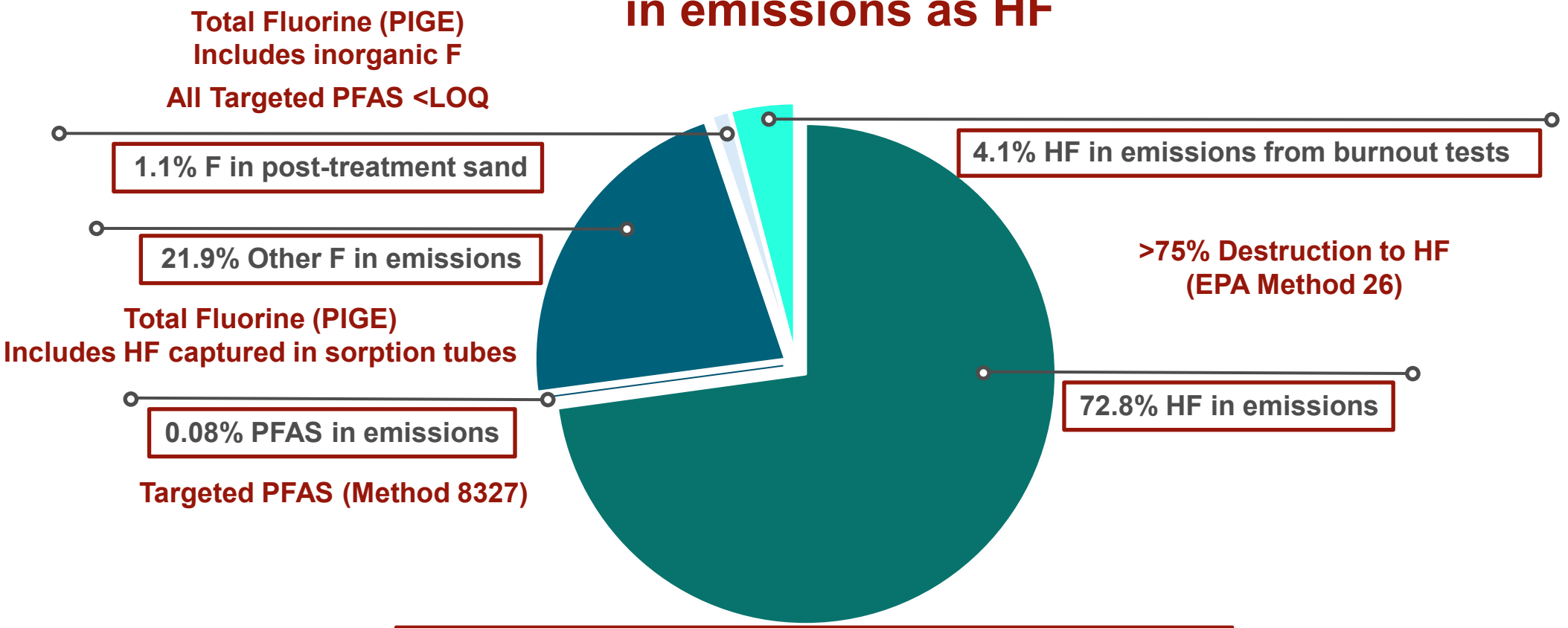
Phase 1 – Mass Balance

Novel experimental design employed for detailed emissions analysis



Phase 1 – Mass Balance

Fluorine mass balance for base case tests (50 g/kg GAC) found significant F in emissions as HF



68 – 109% Fluorine Mass Balance

Phase 1 – CaO Amendment Optimization

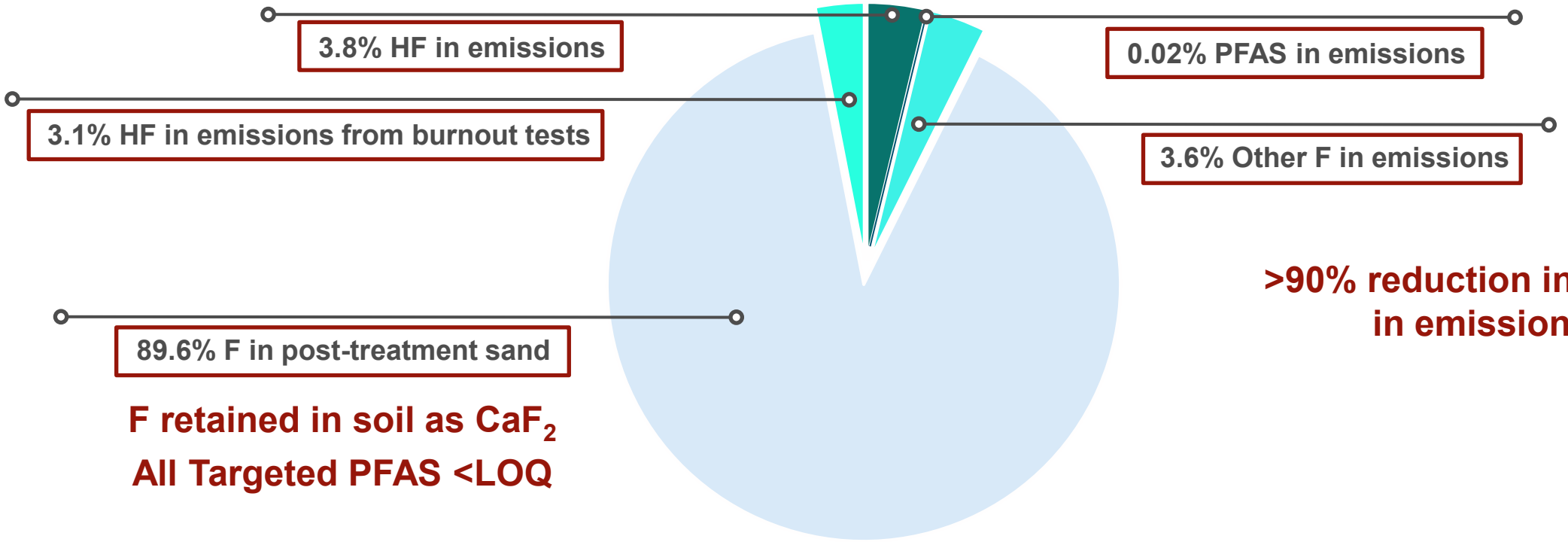
Calcium oxide can be used to improve PFAS destruction and minimize byproducts in emissions

$$PFAS \xrightarrow{HEAT} HF + shorter\ chain\ compounds$$

$$PFAS + CaO \xrightarrow{HEAT} CaF_2 + \downarrow HF + \downarrow shorter\ chain\ compounds$$

Phase 1 – CaO Amendment Optimization

With the addition of CaO, the majority of F is retained in post-treatment soils as inert CaF_2



>90% reduction in Total F in emissions

F retained in soil as CaF_2

All Targeted PFAS <LOQ

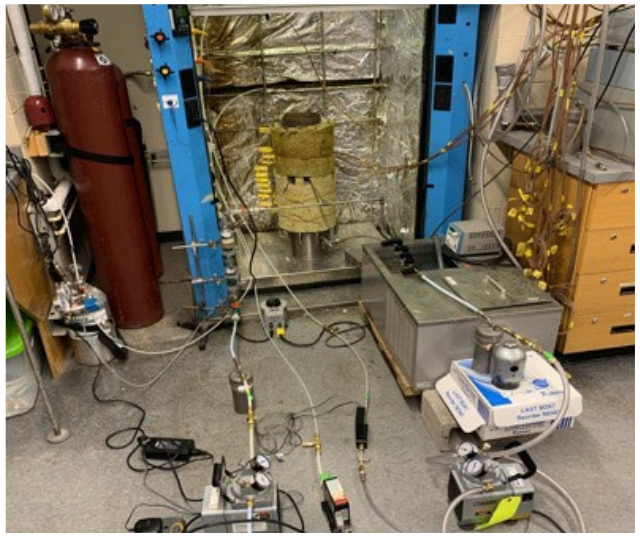
80 – 128% Fluorine Mass Balance

Phase 1 – Key Takeaways

- PFAS reduced to near or below detection limits
- By adding small quantities of amendments (e.g., CaO), fluorine is primarily retained in treated material as an inert mineral form (CaF_2)
- 80 – 128% fluorine mass balance achieved

PFAS Smoldering: At Scale

SERDP Project



Phase 1:
Lab Column Tests

- Fluorine Mass Balance
- Optimization

Phase 2:
Pilot Scale Tests

- Scale Up
- Evaluate Field Soils

Phase 2 – Pilot Test

Project Site: Military base in eastern Ontario, Canada

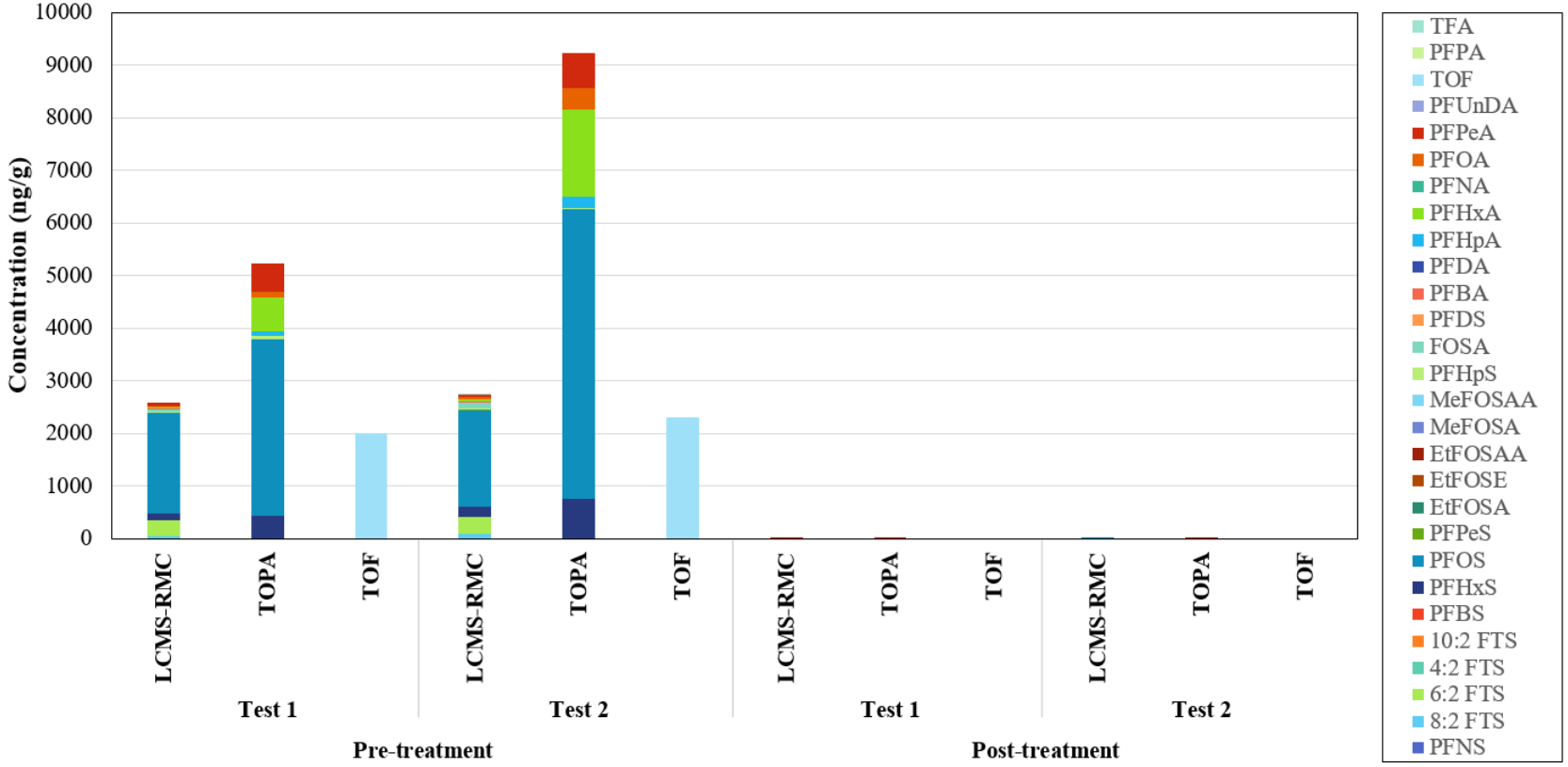
Equipment: 10 m^3 Pilot Scale Hottpad™

Feedstock: PFAS Contaminated Site Soils (20 m^3 total)

Phase 2 – Mixing / Loading

Phase 2 – Unloading

Phase 2 – Pilot Test Results



Soil Results

- PFAS reduced to near or below detection limits
- Fluorine primarily retained as CaF_2

Emissions Results

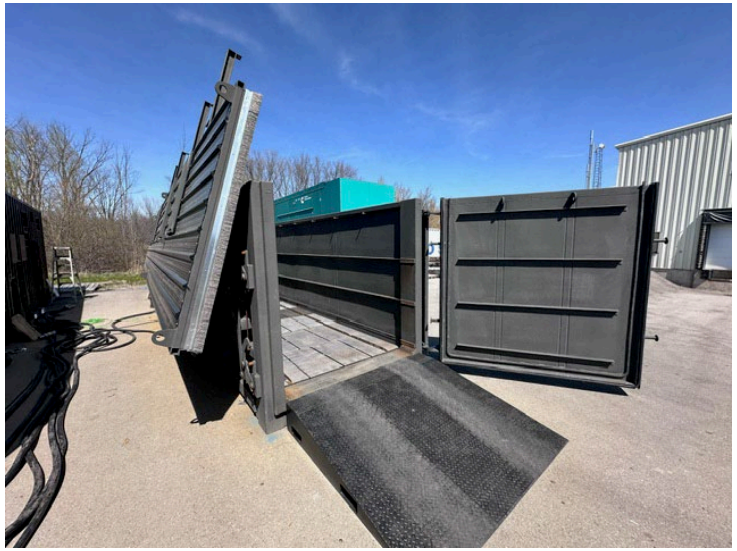
- <0.2% of total fluorine emitted as PFAS
- <2% of total fluorine emitted as HF
- Fluorinated breakdown products can be captured via vapor-phase GAC

Advantages and Limitations

Advantages

Rapid On-Site Treatment

Pilot (10 m^3)



STARxpress (35 m^3)

HP-250 (250 m^3)

Scalable Solutions

Energy Efficient

Self-sustaining

Destructive Technology

Minimal residuals remaining after treatment

Ex Situ and In Situ Options

STAR

STARx

Limitations

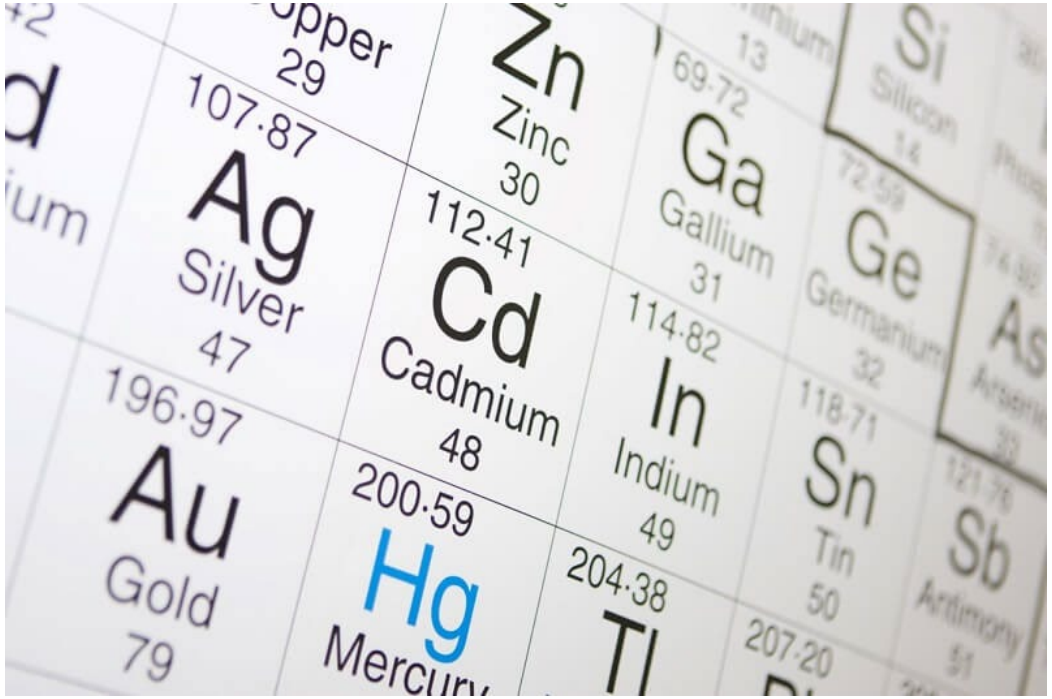
Sufficient Permeability Required for Air Injection

Typically silty sands or coarser; blending or bulking may be required for finer grained soils

Sufficient Low Volatility Fuel Required

Surrogate fuel (e.g., anthracite, spent GAC) may be added to support smoldering

Limited Treatment of Metals



Metal co-contaminants (if present) typically remain in post-treatment soil

Is Smoldering Right for My Site?

Initial Site Screening Conditions

- ✓ Silty sands or coarser
- ✓ PFAS, heavy hydrocarbons, or other recalcitrant compounds

Other considerations:

- Treatment volume / timeframe
- Depth of contamination
- Power, space availability
- Water table depth, contaminant distribution (for in situ)

Current PFAS Projects

US Air Force STARx

- Demonstration / validation of STARx for variable feedstocks (soil type, moisture content, co-contaminants, etc.)
- Co-treatment of spent GAC
- 10 x 10 m^3 pilot tests

DIU / ESTCP STARxpress

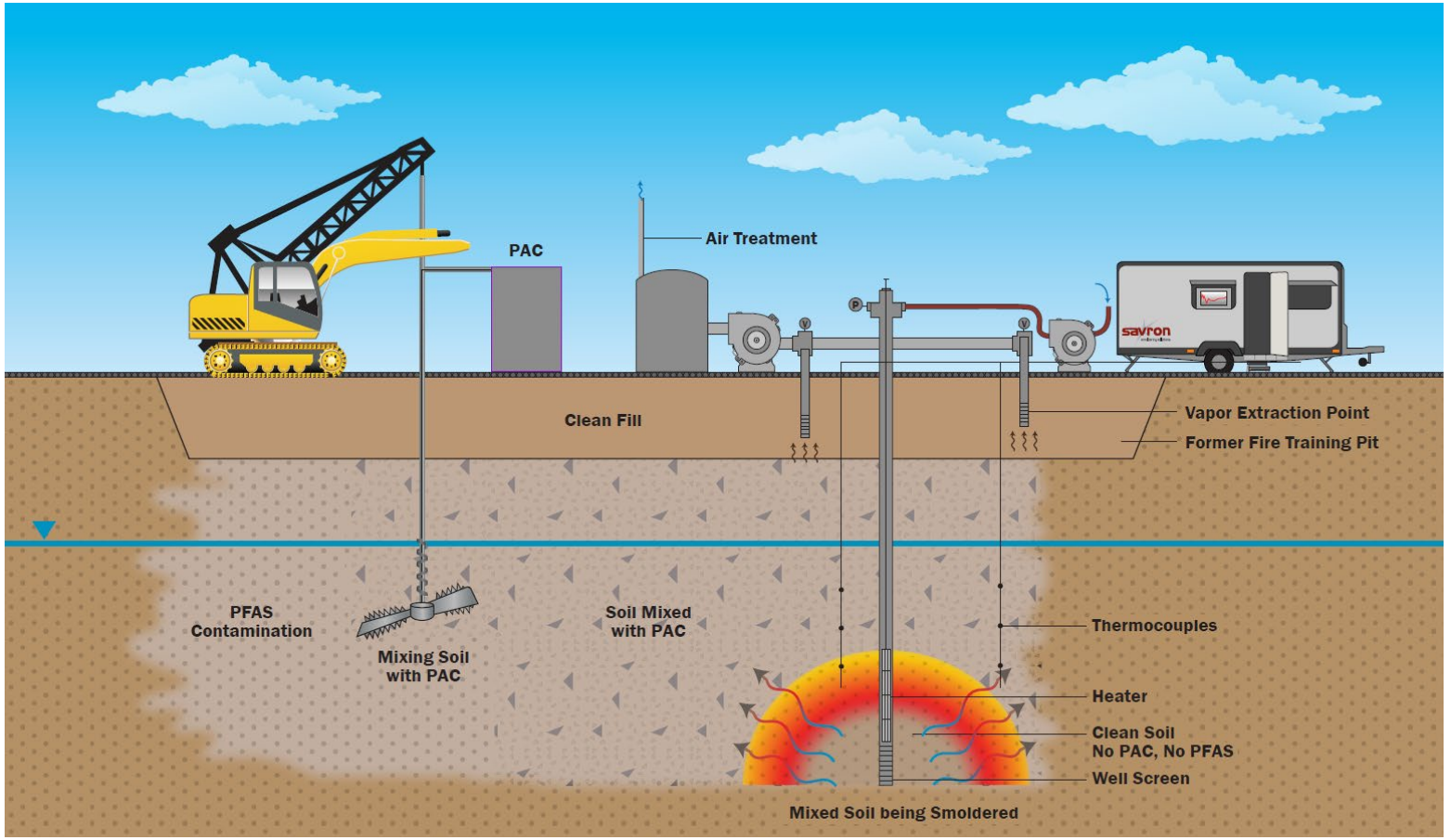
- Design / fabricate two rapidly deployable 35 m^3 ex situ systems (STARxpress™)
- Demonstration at DoD site in Alaska to treat PFAS-impacted soil stockpile

Objectives

- Demonstrate can meet soil cleanup criteria
- Compare cost / performance to two other soil treatment technologies
- Emissions characterization using OTM-45 and 50

ESTCP In Situ STAR

- Demonstration of PFAS destruction in source zone
- 4 ignition points, 500 m^3 soil volume
- In-situ soil mixing for carbon amendment



ESTCP In Situ STAR

- Fuel mixture development testing completed
- Field mobilization ~August 2024

Summary

- PFAS can be successfully destroyed using smoldering, leaving minimal treatment residuals
  - Surrogate fuel is used to achieve high temperatures required for PFAS destruction
  - PFAS in post-treatment soils reduced to below regulatory criteria
  - <1% of of total fluorine emitted as PFAS
  - CaO enhances PFAS destruction at lower temperatures and simplifies vapor treatment requirements
- Co-treatment of contaminated GAC and soils can increase net treatment
- Additional ex situ and in situ field demonstrations currently in progress

Acknowledgements

SERDP ESTCP

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A Smoldering Solution for PFAS and Other Organic Contaminants

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