Naval Facilities Engineering Systems Command
EXWC Engineering and Expeditionary Warfare Center

Remediation of PFAS-Impacted Solids

Jovan Popovic, PhD, NAVFAC EXWC
John Kornuc, PhD, NAVFAC EXWC

RITS 2025

Disclaimer

This seminar is intended to be informational and does not indicate endorsement of a particular product or technology by the Department of Defense or NAVFAC EXWC, nor should the presentation be construed as reflecting the official policy or position of any of those agencies. Mention of specific product names, vendors, or sources of information, trademarks, or manufacturers is for informational purposes only and does not constitute an endorsement or recommendation by the Department of Defense or NAVFAC EXWC. Although every attempt is made to provide reliable and accurate information, there is no warranty or representation as to the accuracy, adequacy, efficiency, or applicability of any product or technology discussed or mentioned during the seminar, including the suitability of any product or technology for a particular purpose.

Information in this presentation is current as of May 30, 2025.

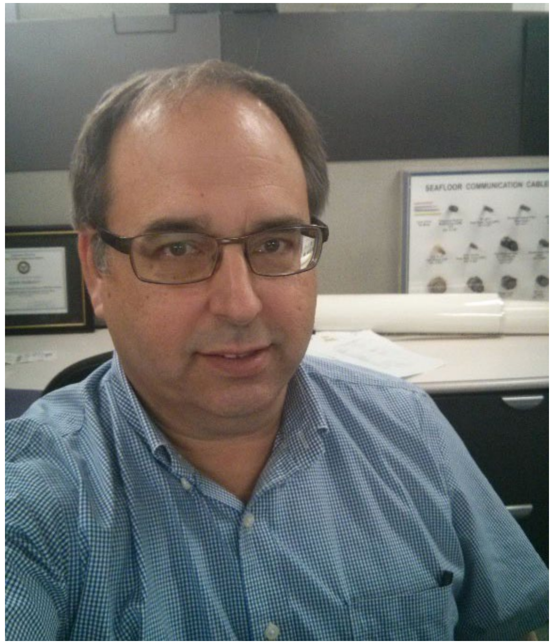
EXWC: Engineering and Expeditionary Warfare Center
NAVFAC: Naval Facilities Engineering Systems Command

Speaker Introduction

Jovan Popovic, PhD
NAVFAC EXWC

- Environmental Engineer
- ~10 years experience

John Kornuc, PhD
NAVFAC EXWC



- Scientist
- ~40 years experience

Presentation Overview

- Introduction
- Technologies for Solids Treatment
  - Established Technologies for PFAS-Impacted Solids
  - On-Base Pilot Study Testing for PFAS Technologies
- Case Studies
- Guidelines for Selecting Solids Treatment Technologies
- Summary/Key Takeaways

Past PFAS RITS

2015
- Emerging Information on Emerging Chemicals

2016
- Managing Per- and Polyfluoroalkyl Substances (PFAS) at Navy Sites

2017
- Risk Communication for PFAS Sites

2018
- PFAS Remediation: Technologies, Guidance, and Application

2019
- Managing Emerging Chemicals at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Sites
- PFAS Site Characterization

2021
- Best Practices for Conducting PFAS Remedial Investigations

2022
- Navigating the 2021 EPA PFAS Strategic Roadmap
- Emerging Technologies for PFAS Treatment

2023
- Best Practices for PFAS Sampling and Data Interpretation

2024
- Considerations for Conducting Ecological Risk Assessments (ERAs) at PFAS sites
- Considerations for Human Health Risk Assessments (HHRAs) During Remedial Investigations at PFAS Sites

Purpose of Presentation

- Inform audience on emerging strategies for managing PFAS-impacted soils/solids, considering existing constraints

(National Archives 2017)

(National Archives 2011)

Commonly Encountered Sources of PFAS-Impacted Solids

When might we encounter PFAS-impacted solids?

- Remediation under CERCLA
- TCRAs and NTCRAs
- IDW
- Excavations

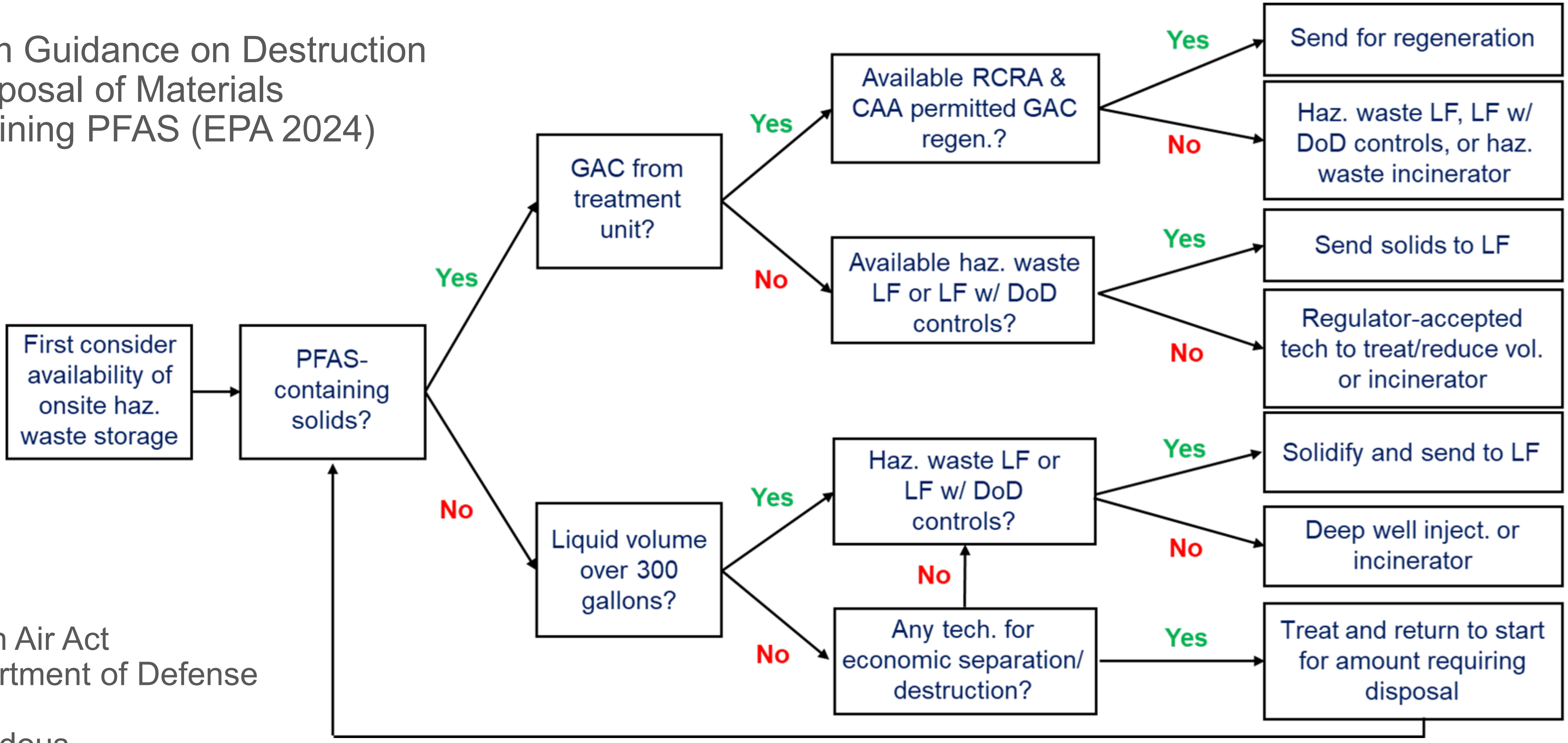
What types of solids may we encounter?

- Soils and sediments; in place or excavated
- Spent filtration media (e.g., GAC, ion exchange resin)
- IDW soils
- Excavated solids; concrete and asphalt
- Biosolids
- Bag filters
- Other materials with residual AFFF

AFFF: Aqueous Film Forming Foam
GAC: granular activated carbon
IDW: investigation-derived waste
NTRCA: Non-Time-Critical Removal Action
TCRA: Time-Critical Removal Action

Interim PFAS Disposal Decision Tree

- Interim Guidance on Destruction or Disposal of Materials Containing PFAS (EPA 2024)



CAA: Clean Air Act
DoD: Department of Defense
LF: landfill
haz.: hazardous
inject.: injection
RCRA: Resource Conservation and Recovery Act
regen.: regeneration

KEY POINT **There is a temporary moratorium on incineration of PFAS-impacted material (2022 NDAA, Sect. 343).**

Presentation Overview

- Introduction
- Technologies for Solids Treatment or Disposal
  - Established Technologies for PFAS-Impacted Solids
  - On-Base Pilot Study Testing for PFAS Technologies
- Case Studies
- Guidelines for Selecting Solids Treatment Technologies
- Summary/Key Takeaways

Currently Available Technologies for Solids Treatment and Disposal

- Established Technologies
  - Landfilling
  - Incineration*

(National Archives 2007)

- Technologies at Pilot Study Level for PFAS
  - Thermal desorption
  - Smoldering
  - Soil washing
  - Stabilization

* Not covered in this presentation

Presentation Overview

- Introduction
- Technologies for Solids Treatment or Disposal
  - Established Technologies for PFAS-Impacted Solids
  - On-Base Pilot Study Testing for PFAS Technologies
- Case Studies
- Guidelines for Selecting Solids Treatment Technologies
- Summary/Key Takeaways

Landfilling

- Disposal in permitted hazardous or solid waste landfill with controls specified in DoD PFAS guidance
  - Consult DLA Qualified Facilities List
- Waste can be landfilled as is or stabilized prior to landfilling
  - Note: stabilization to be covered in subsequent section
- Waste must be profiled (parameters may vary by receiving facility)
  - PFAS
  - VOCs
  - SVOCs
  - PCBs
  - CN + S reactivity
  - Total solids
  - RCRA 8 metals (mercury, arsenic, barium, cadmium, chromium, lead, selenium, silver)
  - Ignitability
  - pH

CN + S: cyanide and sulfide
DLA: Defense Logistics Agency
PCB: polychlorinated biphenyl
SVOC: semivolatile organic compound
VOC: volatile organic compound

Landfilling

Challenges	Best Practices
• ***Make contact with facility to determine requirements!*** • Can be expensive (increase in cost specifically for PFAS-impacted waste) • No definitive answers on acceptable levels for landfills • Landfill can change their mind • Limited landfills available • Landfills sometimes limit quantities and concentrations • Logistics to multiple landfills based on level also a challenge	• If possible, separate high concentration materials • Waste profiling required varies by landfill, so communicate with landfill early • Consider closest landfills first to avoid higher transportation costs

Good to know

- Landfills are implementing back-end leachate management
- Landscape may change depending on leachate regulations

Naval Auxiliary Landing Field Fentress (Virginia)

- Source of soil: NALF Fentress Soil removed from inside a caisson to 29.5 ft bgs to install the gate (large monitoring well)
- Volume of soil: 14.37 tons
- Average Target PFAS concentration: ~30 µg/kg
- Soil treatment: Stabilization
- Landfill used: Sent to a Subtitle D Landfill (PFAS detections below landfill limit)
- Waste profiling requirements: Flash point, pH, reactive, TPH, PFAS
- Cost (2024): ~$5,400.00 (just treatment and disposal)
- General: Easy process worked with contractor. Disposal was fast.

KEY POINT

Communicate with contractor and landfill early to understand requirements and availability.

µg/kg: micrograms per kilogram
ft bgs: feet below ground surface
NALF: Naval Auxiliary Landing Field
TPH: total petroleum hydrocarbons

Naval Station Newport: Tank Farm 5 (Rhode Island)

- Source of soil: Excavated materials at Naval Station Newport at Tank Farm 5 property
- Volume of soil: 52,342 tons
- PFAS concentration: Ranged from nondetect to 5 µg/kg
- Landfill used: 17,978 tons to Subtitle C, 14,455 tons to Subtitle D #1, 19,910 tons to Subtitle D #2
- Waste profiling requirements: Composite PFAS waste characterization samples were collected at 1/400 cubic yards, and discrete PCB samples were collected at 1/200 cubic yards

- Cost (2022–2023)
  - $17,092,440 (CTO total)
  - $14,520,043 (T&D)
- General
  - Sub D landfill #1 had stricter limits with restricted PFAS levels
  - Sub D landfill #2 still has availability, but limited to ppt levels
  - Sub C landfill used currently accepts on case-by-case basis (<1 ppm)

KEY POINT

Use of multiple landfills or landfill types may be required.

CTO: contract task order
ppm: parts per million
ppt: parts per trillion
T&D: transport and disposal

Cutler Site 10 NSA Fire Station (Maine)

- Source of soil: Site 10 PFAS RI fieldwork activities (drilling [soil/rock cutting], debris remaining from IDW activities)
- Volume of soil: 8 tons
- PFAS concentration: IDW soil sample collected had nondetect results for the 29 PFAS compounds analyzed. RI maximum concentration: 78 µg/kg
- Landfill used: Disposal as non-RCRA, non-DOT Regulated Material (containing PFAS; Subtitle C landfill)
- Waste profiling requirements: PFAS, VOCs, SVOCs, PCBs, CN + S reactivity, total solids, RCRA 8 metals (mercury, arsenic, barium, cadmium, chromium, lead, selenium, silver), ignitability, pH
- Cost (2022–2023): Approximately $27,300 (includes rolloff rental, delivery and removal of rolloff containers, waste characterization, and load and disposal of rolloff soils)
- General: Expensive/high cost due to remote Cutler, Maine, location and limited disposal facilities accepting PFAS waste at that time

KEY POINT

Michigan was the closest state that accepted PFAS-impacted soil (~1,000 miles away).

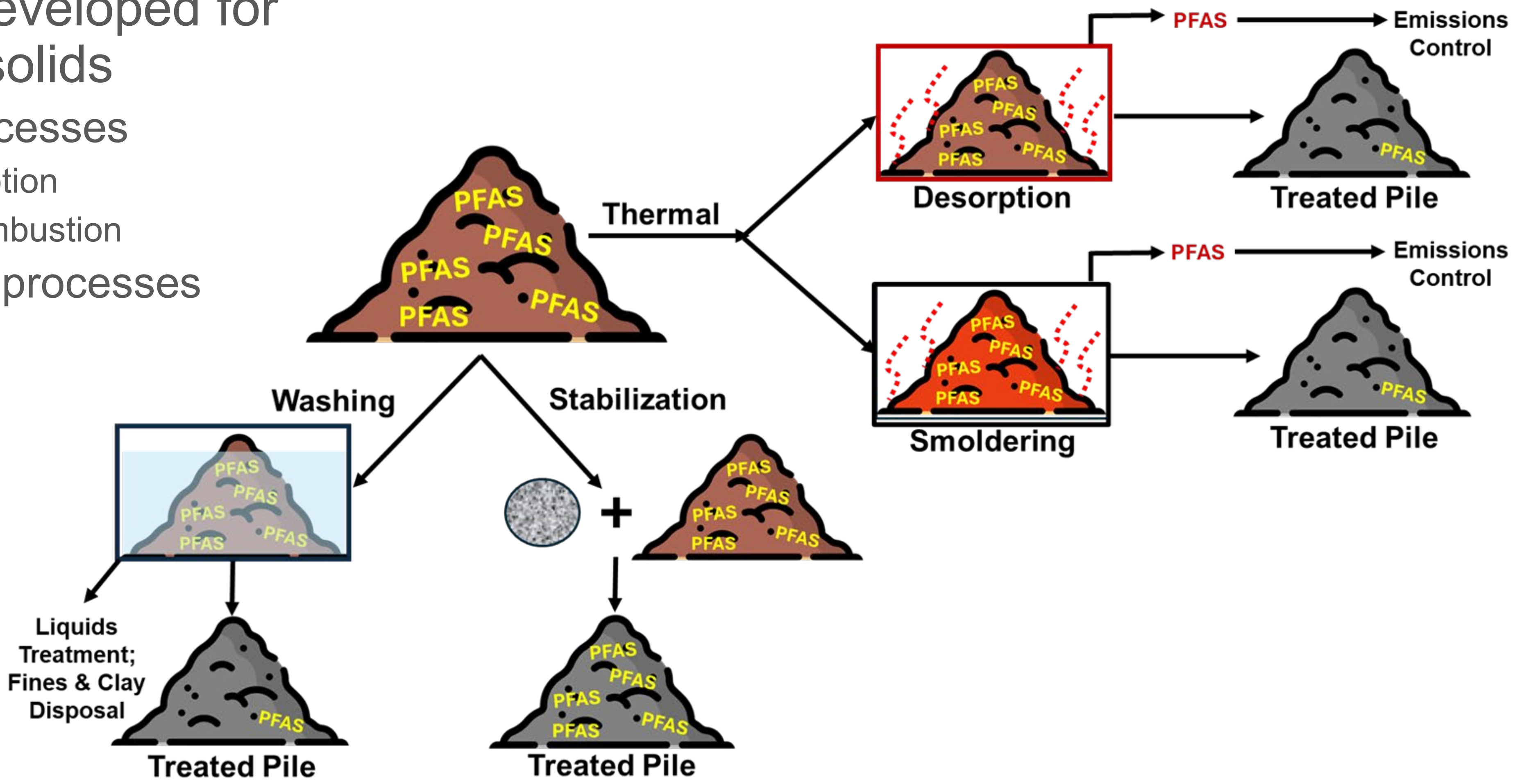
DOT: Department of Transportation
NSA: Naval Support Action
RI: remedial investigation

Presentation Overview

- Introduction
- Technologies for Solids Treatment or Disposal
  - Established Technologies for PFAS-Impacted Solids
  - On-Base Pilot Study Testing for PFAS Technologies
- Case Studies
- Guidelines for Selecting Solids Treatment Technologies
- Summary/Key Takeaways

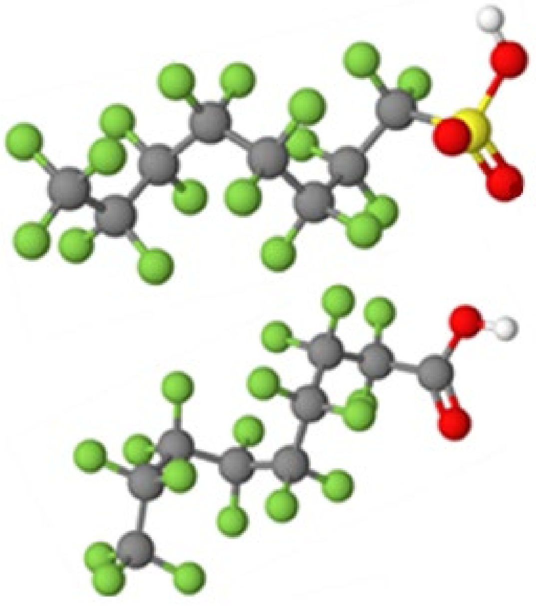
Solids Treatment Technologies Under Development

- Covering four technologies currently being developed for PFAS-impacted solids
  - Two thermal processes
    - Thermal desorption
    - Smoldering combustion
  - Two nonthermal processes
    - Stabilization
    - Soil washing
- What are some considerations when assessing performance?



Solids Treatment Performance Monitoring

- Considerations for factors affecting treatment performance
  - Thermal desorption/destruction-specific
    - Moisture content and effects on process efficiency
    - Monitoring vapor emissions for desorbed PFAS, unintended decomposition products (e.g., PICs/PIDs);
    - HF production (e.g., Method 26A, Hydrogen Halide and Halogen - Isokinetic Method)
      - Fluorine mass balance
      - Emissions and compromised reactor integrity (corrosivity)
    - Co-contaminants affecting desorption/destruction efficiencies
  - Stabilization/sequestration-specific
    - Presence/absence of certain soil constituents may impact PFAS leaching
  - Presence of precursors
    - Variability with destruction and removal efficiency (e.g., transformation into target analytes)
    - Screening may help elucidate certain performance limitations



PIC(s)/PID(s): product(s) of incomplete combustion/destruction
HF: hydrofluoric acid

Solids Treatment Performance Monitoring

- Leachability as a performance measurement for treated solids
  - Behavior of impacted solids; assess “long-term” stability of solids in presence and absence of amendment and/or treatment
  - Implications associated with storing impacted materials, reuse, and disposal options
  - State standards vs. K_{oc} for screening (e.g., NJDEP 2023)
- Many bench-scale, “standardized” leachability methods may not be representative of conditions encountered in the field, leading to overprediction
  - Disruptions to soil structure and air-water interfacial accumulation
  - Use of synthetic reagents or reagent water to simulate leaching
  - No validated methods for PFAS leaching yet, but some tests may provide valuable data for performance, especially if many describe “worst case” scenario

KEY POINT

Multivalidation lab studies underway for adapted LEAF leachability methods. Current recommendation is to not use leachability methods at this time.

K_{oc}: organic carbon partition coefficient
LEAF: Leaching Environmental Assessment Framework

Emissions Sampling for PFAS (Thermal)

	Emerging PFAS Emissions Sampling Methods OTM-45	OTM-50	"Future" OTM-55
PFAS/ Analytes Sampled	- EPA 1633 analytes - Polar semi-volatile and particulate-bound PFAS - "Whole" PFAS	- Partial degradation products (e.g., PICs/PIDs) - Volatile fluorinated compounds	- Targeted analysis for nonpolar semivolatile PFAS (e.g., fluorotelomer alcohols) - Methylene chloride
Application Notes	- Not intended for processes where transformation or partial destruction encountered	- Includes non-targeted analysis; uses NIST library - Not for completely mineralized PFAS - Impingers used if acid gas and/or >3% H_2O present in vapor	- In development
Analysis	- LC-MS/MS for target analytes	- Passivated stainless canister sampling with GC-MS analysis	- Method 0010 sampling with Method 8270 analysis
Potential Streams	- Stack sampling of thermal desorption systems	- Stack sampling of thermal desorption systems, smoldering, incinerator, etc.	- Stack sampling thermal and incinerator systems

ELAP: Environmental Laboratory Accreditation Program
EPA: United States Environmental Protection Agency
GC-MS: gas chromatograph-mass spectrometry
LC-MS/MS: liquid chromatography tandem mass spectrometer
NIST: National Institute of Standards and Technology
OTM: Other Test Method

KEY POINT

There are no DoD ELAP laboratories currently accredited for any "OTM" methods.

Knowledge Check

What is the name of the method that is used to isokinetically sample hydrofluoric acid emissions?

A. “Future” OTM-55
B. 26A
C. 1633
D. OTM-50

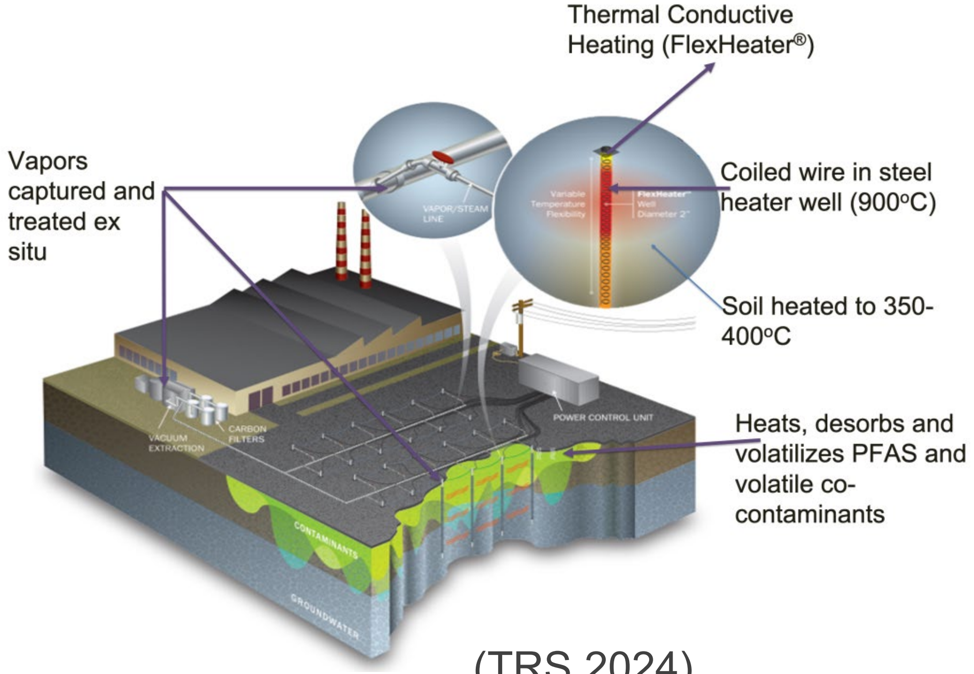
Knowledge Check

What is the name of the method that is used to isokinetically sample hydrofluoric acid emissions?

A. “Future” OTM-55
B. 26A
C. 1633
D. OTM-50

Thermal Desorption

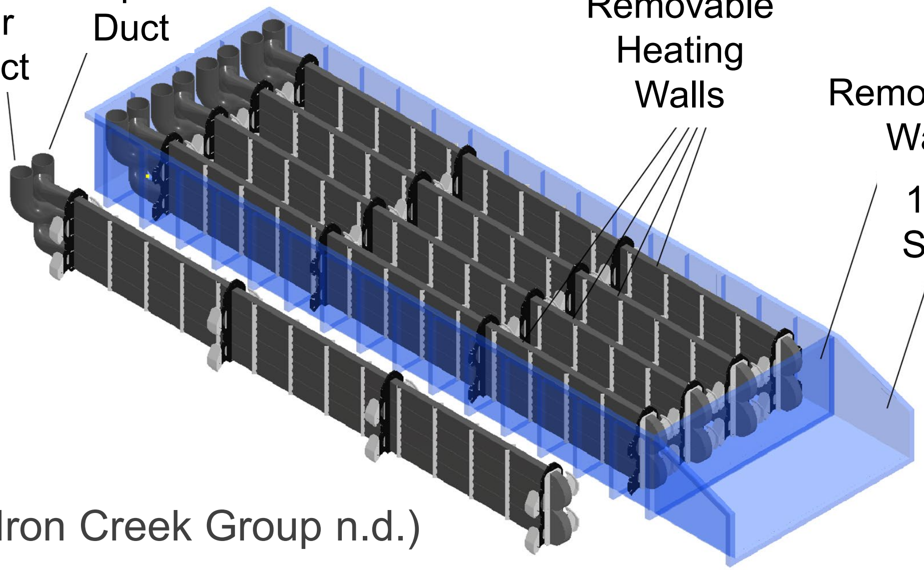
- Process where PFAS-impacted media (e.g., soil, GAC) is heated to temperatures of ~350–600 ºC to drive PFAS into the vapor phase; vapor phase generally captured and treated
  - Destruction not characteristic of thermal desorption processes, but partial decomposition products may form to some extent
  - Alkali salt (e.g., $Ca[OH]_2$, CaO) supplementation may promote low temperature mineralization of PFAS
- May be performed in situ or ex situ
  - Ex situ
    - Containerized systems (e.g., batch, rotary kiln)
    - Direct treatment of stockpiles with electric heating elements
  - In situ
    - Vadose zone treatment with electric heating elements (e.g., source area treatment)
- Potential waste streams include but are not limited to soils, GAC, biosolids



(TRS 2024)

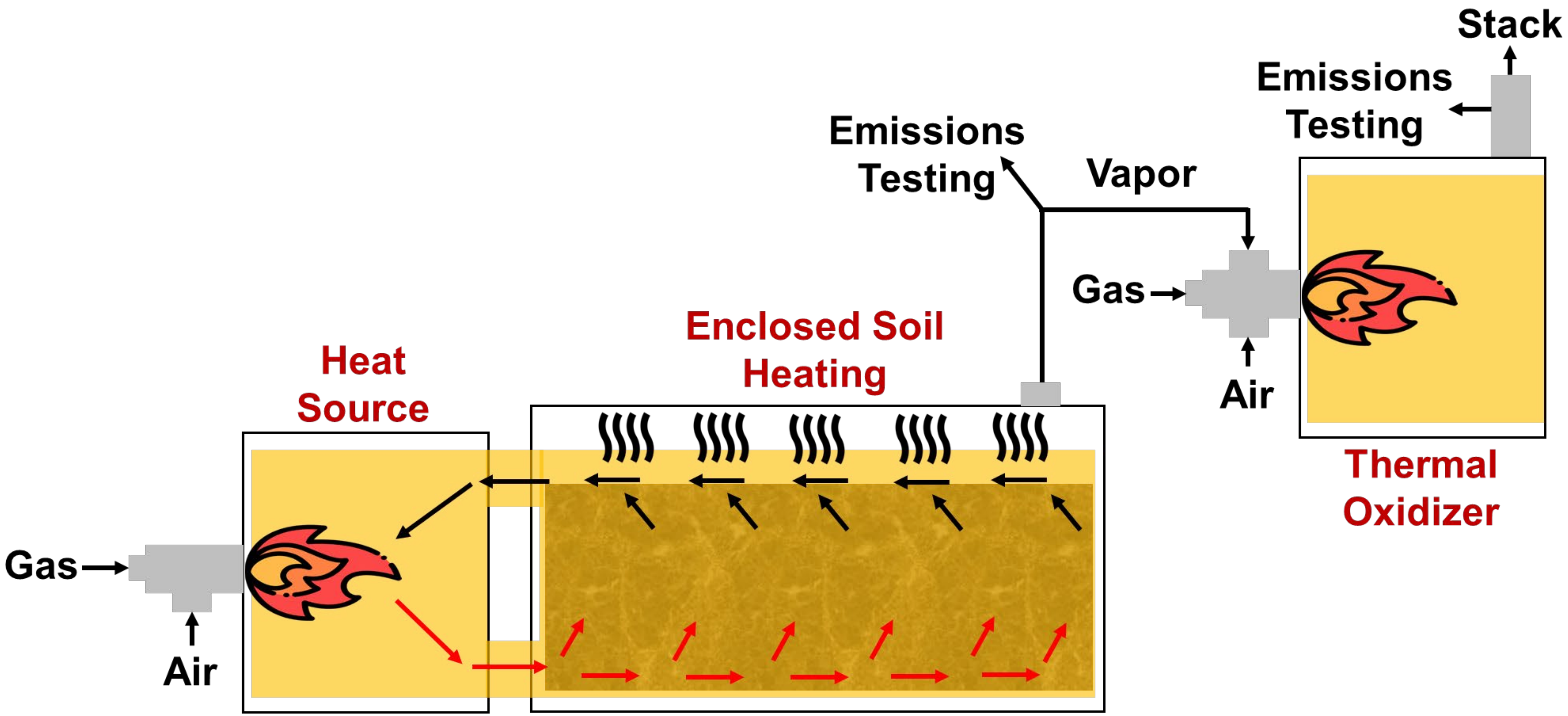
Thermal Desorption – Containerized Example

- Treats impacted material in an enclosed environment by heating a gas and pulling heated gas through rigid, hollow heating walls traversing the interior of heating chamber
- Bin is filled with impacted material, and bin is covered with an airtight seal
- Heated gas flows through heating walls, separate from impacted material, and returns to air heater to be reheated and recirculated
- 10 ft (width) x 40 ft (length) x 4 ft (height)
- Each bin has a capacity of approximately 47 cubic yards (36 cubic meters)



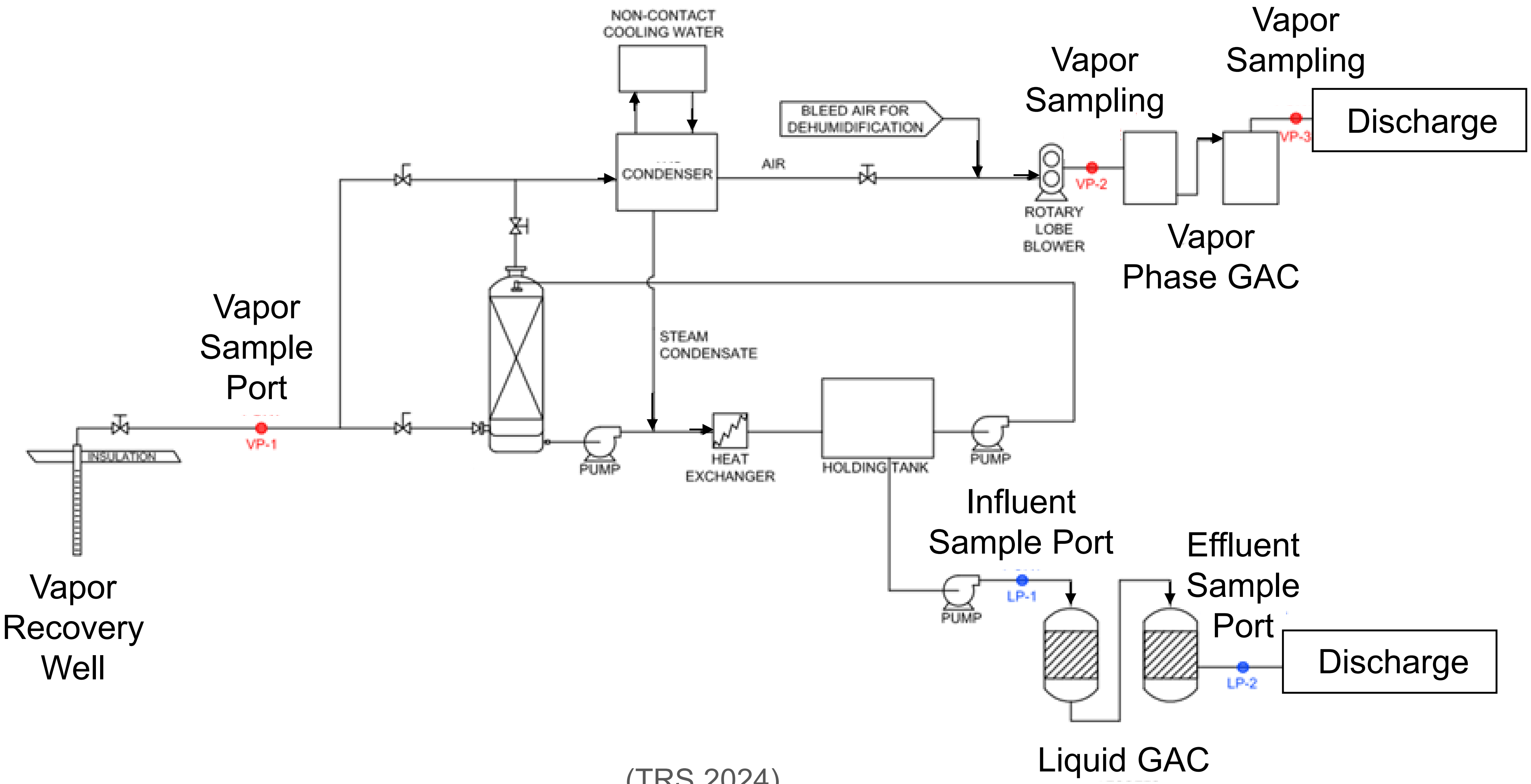
(Iron Creek Group n.d.)

Thermal Desorption – Containerized Example



(Modified from Iron Creek Group 2025)

Thermal Desorption – Example of In Situ Treatment Process Flow



(TRS 2024)

Thermal Desorption

- General factors affecting performance
  - Moisture content
  - Heat distribution
  - Natural PFAS retention in soils, GAC
- Other limitations
  - High energy requirements; increased requirements for media containing high moisture content
  - Unintentional generation of PICs/PIDs

Example of in situ thermal desorption application – Beale AFB
(TRS 2024)

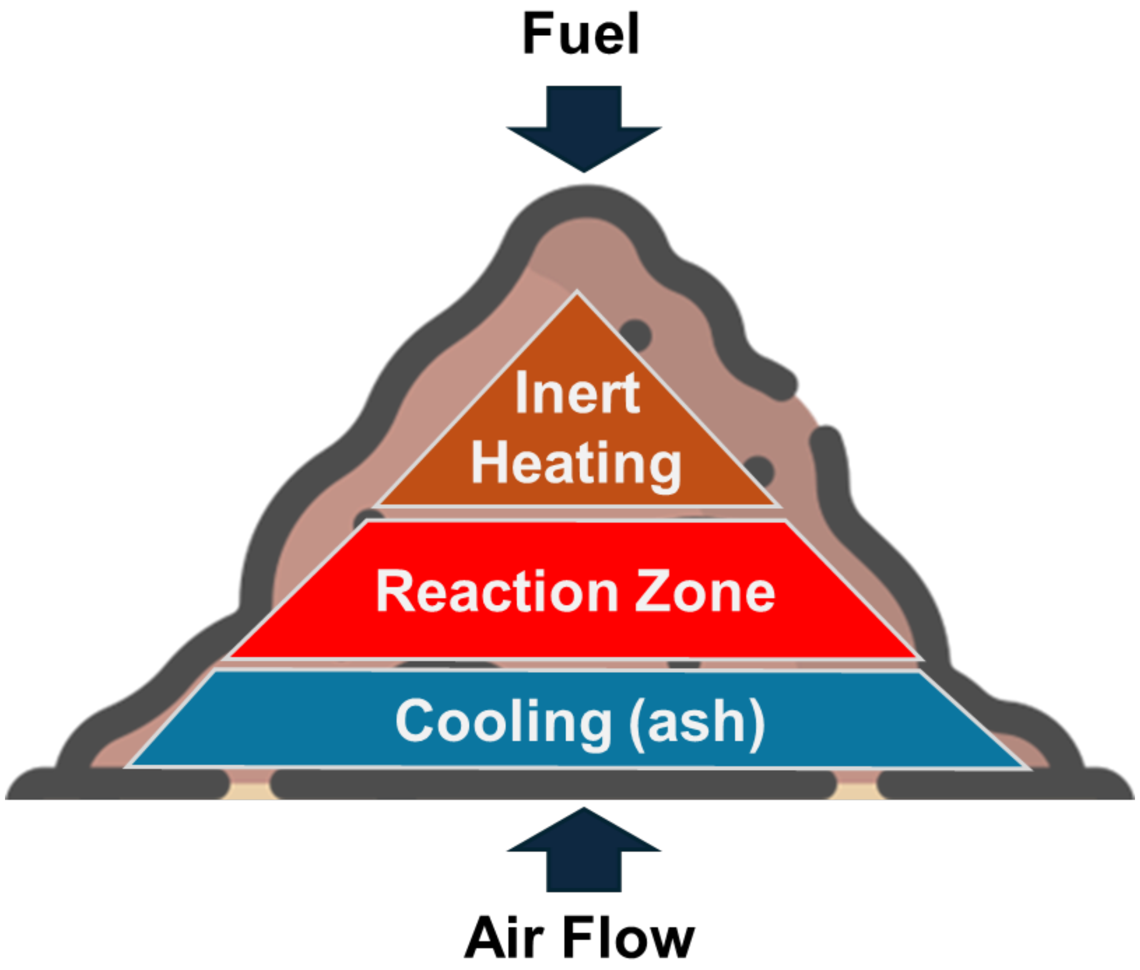
AFB: Air Force Base

Smoldering

- Thermal oxidation process that uses solid or liquid fuel, an oxidant, inert porous media (e.g., silica sand)
- Temperature ranges from ~500-1,200˚C, but maintaining >900˚C desirable for mineralization
- Potential waste streams: spent GAC, soils, wastewater solids
- Ex situ batch systems tested to date for PFAS-impacted materials; has been conducted in situ for other chemicals
  - Ex situ may allow for better mixing and optimization of treatment mixture

Smoldering

- Key zones in smoldering systems: inert heating, reaction, and cooling zones
  - Inert heating zone: endothermic, reaction-free region characterized by phase change processes
  - Reaction zone: oxidation, pyrolysis, gasification
  - Cooling zone: buffer against extinction
- GAC generally considered excellent fuel source for smoldering, but can be costly
- Sand and/or soils for better air flow/increasing smoldering front



Smoldering

- General factors affecting performance
  - Air flux
  - Fuel quantity and distribution in soil
  - Oxygen content
  - Fuel energy content
  - Heat losses
- Other limitations
  - Emissions
    - HF
      - Limestone may be added as emission control
    - PICs/PIDs
  - Potential for zones of uneven heating
  - Hazards associated with high temperature processes

HF: Hydrofluoric acid
PIC/PID: Products of incomplete combustion/destruction

Soil Washing

- Media transfer technology that separates PFAS from soils and transfers it to a liquid stream; liquid undergoes secondary treatment
- Surfactant and/or solvent may be used to increase desorption
- May be used as a strategy to reduce soil volume requiring offsite disposal
- Fine- and coarse-grained materials need to be separated and managed individually
  - PFAS affinity for clays, organics, silts in fines
  - Easier to desorb PFAS from gravel and sands

Soil Washing

- Key parameters
  - Soil characterization
    - Organic carbon content
    - Particle size distribution
      - 0.25–2 millimeters or < 25% silt and clay content is ideal
    - Cation exchange capacity
  - Soil washing throughput/retention time
  - Soil dewatering post-wash

(Denning n.d.)

Soil Washing

- General limitations affecting performance
  - High clay and moisture content
  - High silt
  - Soil heterogeneity and inconsistent feed
  - Difficulty separating coarse and fine soil particles
- Other limitations
  - High energy requirements
  - Large volumes of liquids requiring treatment
  - Fines will likely require offsite disposal

Stabilization

- Immobilization strategy to reduce PFAS leaching from soils using adsorbent amendment
  - Activated carbon (granular, powdered, colloidal), organoclays, ion exchange resins, polymers
- Electrostatic and/or hydrophobic interactions imparted by adsorbent bind to PFAS, similar to liquids treatment process with filtration media

- May be applied ex situ or in situ
  - Ex situ
    - Mixing adsorbent with soil piles to limit leaching
  - In situ
    - Injection (e.g., CAC, PAC)
    - Soil mixing
    - Trenching
- Solidification agent may be used in conjunction with stabilizers to create a “monolith,” further reducing leaching potential by limiting soil permeability
  - Offsite disposal
  - In situ soil mixing

CAC: colloidal activated carbon
PAC: powdered activated carbon

Stabilization

- Performance evaluations and amendment dose optimization should be conducted at bench and pilot scales prior to full-scale implementation
  - Bench scale
    - Leachability testing to determine appropriate amendments and doses using site-derived media
  - Potential approaches for field pilot performance monitoring of in situ stabilization amendments
    - Porewater concentrations via lysimeters
    - Time integrated/passive samplers
    - Groundwater monitoring
    - “Radius of influence” determination for in situ injections
      - Soil cores and TOC for colloidal activated carbon distribution

TOC: total organic carbon

Stabilization

- General limitations affecting performance
  - Soil constituents competing for sorption sites
  - Uncertainties with amendment distribution, especially for in situ injection into complex formations, may affect effective treatment radius
- Other limitations
  - Uncertainties with long-term stability
  - Increased solids volume

Knowledge Check

Which property has the most deleterious effect on thermal desorption process performance?

A. Coarse grain size
B. Inert Porous Media (IPM)
C. Moisture

Knowledge Check

Which property has the most deleterious effect on thermal desorption process performance?

A. Coarse grain size

B. Inert Porous Media (IPM)

C. Moisture

Knowledge Check

The smoldering combustion process is comprised of inert heating, reaction, and __________ zones

Knowledge Check

*The smoldering combustion process is comprised of inert heating, reaction, and **cooling** zones*

Summary of Solids Treatment Technologies

	Thermal Desorption	Smoldering Combustion	Soil Washing	Stabilization/ Solidification
Technology Readiness Level (TRL) for PFAS-Impacted Solids	**~8**; Multiple pilot projects completed	**~8**; Multiple pilot projects completed	**~7**; System prototypes tested domestically	**9**; Broad application to impacted solids
Availability	- Multiple vendors with commercially available or pilot-scale units	- Vendor with commercially available or pilot-scale units	- Vendor with commercially available or pilot-scale units	- Multiple US vendors
Advantages	- Removes PFAS from solids	- Removes PFAS from solids and may promote mineralization	- Transfers PFAS from solids to liquid phase	- Generally low mass of stabilizer required - Many stabilizer choices
Summary of Limitations	- High energy requirements, exacerbated by soil moisture - Uneven heating or reaction zones may result in untreated areas - Potential for PIC/PID and HF formation (emissions) - Vapor phase capture and treatment requirement	- Uneven heating or reaction zones may result in untreated areas - May require amendment of fuel and inert porous material - Potential for PIC/PID and HF formation - Vapor phase capture and treatment requirement	- Large process infrastructure - May only be effective for reducing PFAS in coarse materials; disposal of fines - Large volumes of PFAS-impacted water generated & associated treatment - May require addition of co-solvent or surfactant - Efficacy/utility still not fully understood	- Does not remove or destroy PFAS - Long-term stability uncertain - May require reapplication - Increases disposal volumes

Summary of Solids Treatment Technologies

	Thermal Desorption	Smoldering Combustion	Soil Washing	Stabilization/ Solidification
Cost Estimate*	~$500 per ton (variable; TRS, 2023)	~$260-330 per ton (2016 estimate; Vidonish et al. 2016)	~$100-$200 per ton, excluding residuals treatment and disposal (ESTCP ER20-5258)	~$100-150 per ton, assuming 2% (w/w) amendment

* Costs vary depending on site conditions, technology related factors, and soil volume treated. More accurate cost estimates should be developed on a project-by-project basis.

Naval Facilities Engineering Systems Command

EXWC Engineering and Expeditionary Warfare Center

Break

Presentation Overview

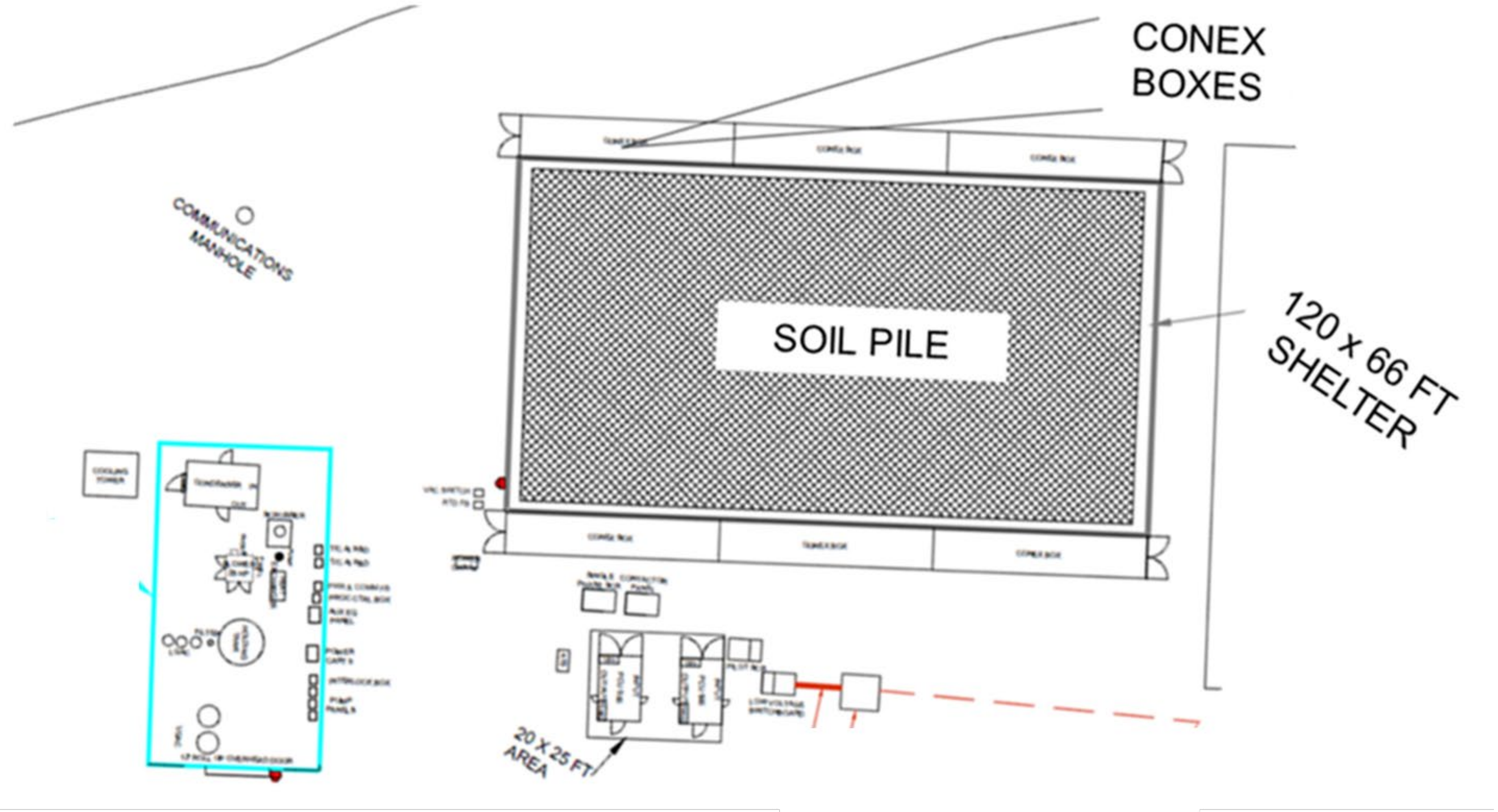
- Introduction
- Technologies for Solids Treatment or Disposal
  - Established Technologies for PFAS-Impacted Solids
  - On-Base Pilot Study Testing for PFAS Technologies
- Case Studies
- Guidelines for Selecting Solids Treatment Technologies
- Summary/Key Takeaways

Thermal Desorption

- Conducted under ESTCP ER23-8369 (Ongoing)
  - Joint Base Elmendorf-Richardson (JBER)
- Demonstrate ex situ thermal treatment of PFAS applying thermal conduction heating
- Objectives
  - PFAS removal in soil to below EPA Residential and ADEC RSLs
  - Treatment of PFAS in extracted vapors and process water

ADEC: Alaska Department of Environmental Conservation
ESTCP: Environmental Security Technology Certification Program
RSL: Regional Screening Level

Equipment Layout (Top View)

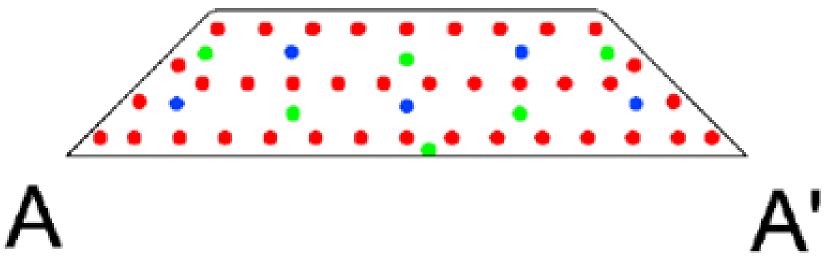


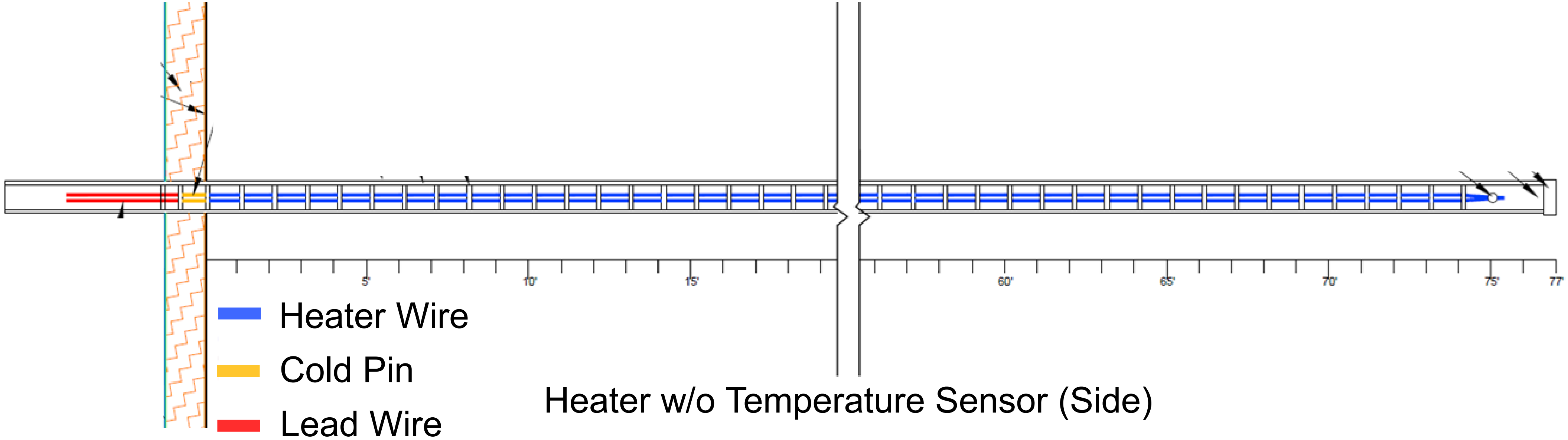
(TRS 2024)

Horizontal Heater Layout

- Heater
- Sampling and Temp Monitoring
- Soil Vapor Extraction Point

(Front)





Heater w/o Temperature Sensor (Side)

(TRS 2024)

Soil Stockpile Treatment Cell Construction

(TRS 2024)

Completed Soil Stockpile Treatment Cell

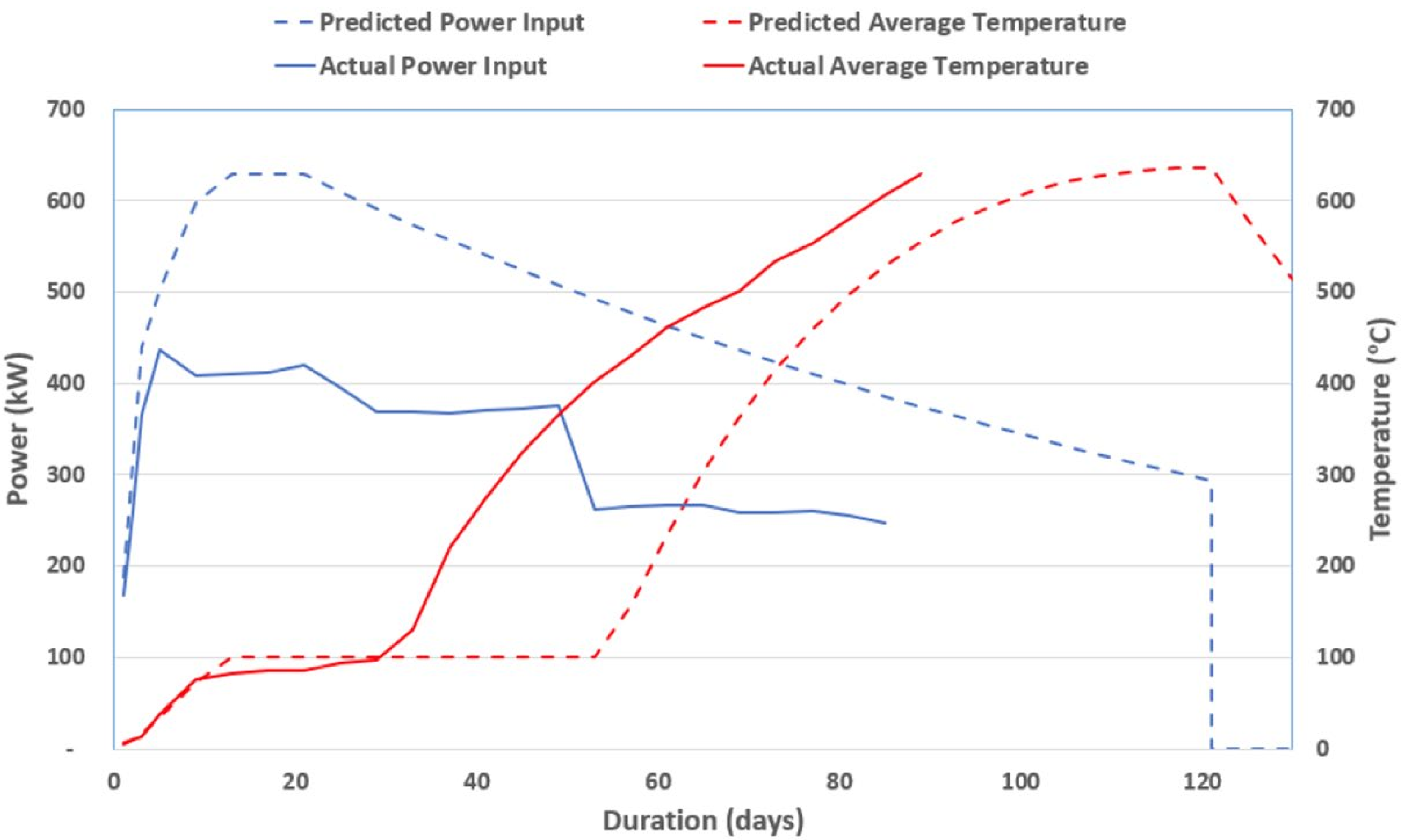
(TRS 2024)

Summary of Test Conditions

Title	Ex Situ JBER
Max Total PFAS Concentration (µg/kg)	50
Volume soil treated (yd^3)	2,000
Heated Zone Thickness/Height (ft)	13
Heater Orientation	Horizontal
Linear Heater Length (ft)	5,230
Linear Vapor Recovery Screen Length (ft)	360
Temperature Monitoring Sensors	30

yd^3: cubic yards

Thermal Desorption Results



kW: kilowatt

(TRS 2024)

Thermal Desorption Results

Analyte	JBER Soil - Post TCH Max Concentrations (µg/kg)	Sample Location(s) Above ND	EPA Residential Soil RSL (TR 1E-06, THQ 0.1) (µg/kg)	ADEC MTG Soil Cleanup Level (µg/kg)	Laboratory Detection Limit (µg/kg)
PFBA	ND	-	7800	-	0.15 - 0.18
PFPeA	ND	-	-	-	0.0088 - 0.011
PFHxA	0.027 J	F04-60.8	3200	-	0.014 - 0.17
PFHpA	ND	-	-	-	0.02 - 0.026
PFOA	ND	-	0.019	1.7	0.07 - 0.085
PFNA	ND	-	19	-	0.05 - 0.066
PFDA	ND	-	-	-	0.039 - 0.051
PFBS	ND	-	1900	-	0.006 - 0.0079
PFPeS	ND	-	-	-	0.017 - 0.023
PFHxS	ND	-	130	-	0.018 - 0.024
PFOS	ND	-	0.63	3	0.023 - 0.028
6:2 FTS	ND	-	-	-	0.051 - 0.067
8:2 FTS	ND	-	-	-	0.049 - 0.065
PFOSA	ND	-	-	-	0.026 - 0.034
ADONA	0.16 J	D04-35.6	-	-	0.0079 - 0.011
PFMPA	ND	-	-	-	0.0052 - 0.0069
5:3 FTCA	ND	-	-	-	0.09 - 0.12
7:3 FTCA	ND	-	-	-	0.14 - 0.19

(TRS 2024)

MTG: migration to groundwater
ND: nondetect
TCH: thermal conduction heating
THQ: target hazard quotient
TR: target risk

KEY POINT

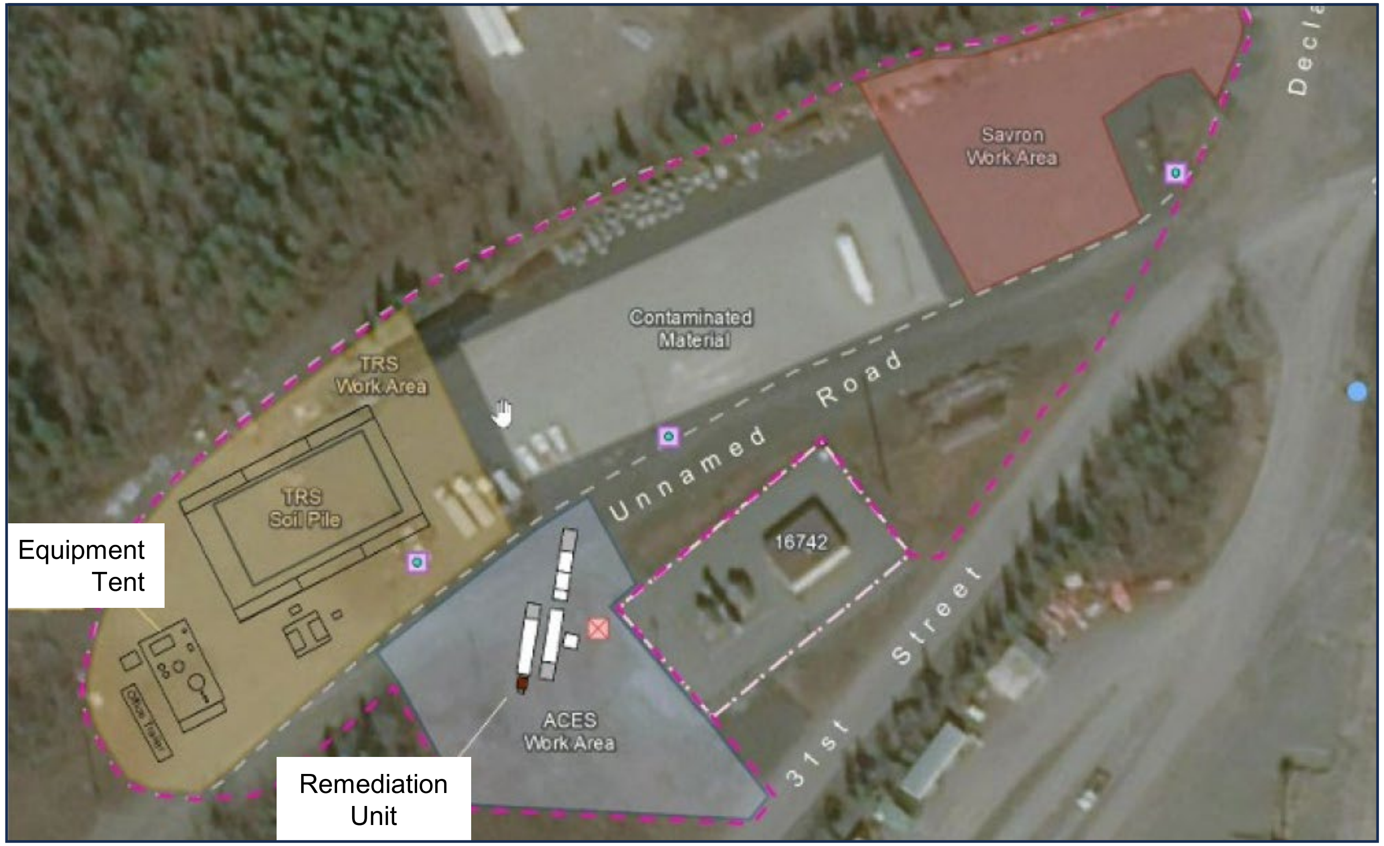
All locations tested below Alaska DEC standards and EPA Residential RSLs.

Thermal Desorption Summary

- Highly scalable and adaptable technology to handle variable treatment scenarios
  - May be operated both in situ and ex situ
  - Large soil volumes may be easily addressed through additional electrode placement
- Soil treated to below Alaska DEC soil cleanup levels and EPA Residential RSLs
- Combined PFOA and PFOS concentrations in discharge process water below 4 ng/L

ng/L: nanograms per liter
PFOA: perfluorooctanoic acid
PFOS: perfluorooctanesulfonic acid

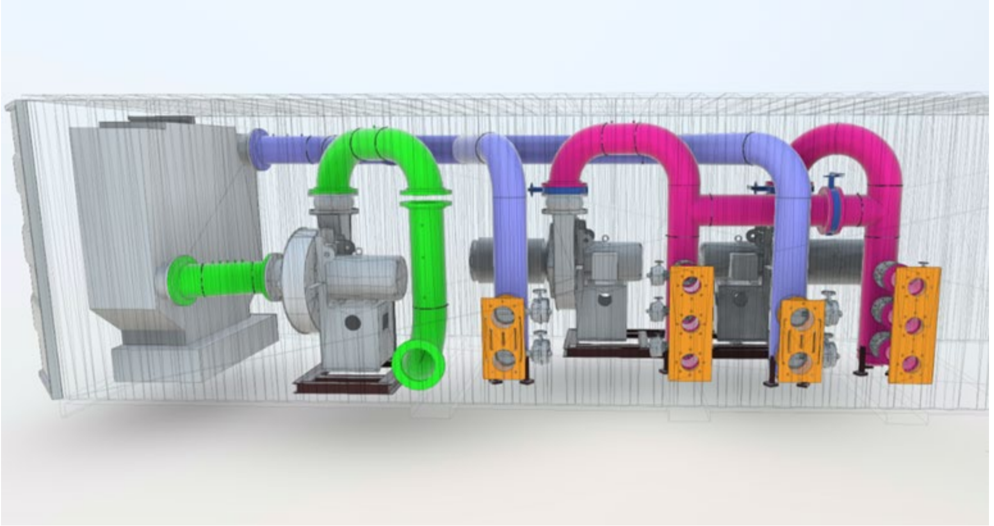
Smoldering Combustion Conducted at JBER



(Savron 2024)

- Design/fabricate system consisting of two 35-cubic-meter treatment vessels
- Demonstrate treatment of PFAS-impacted soil to below ADEC MTG criteria for PFOS and PFOA
- Generate technology performance data

System Fabrication



(Savron 2024)

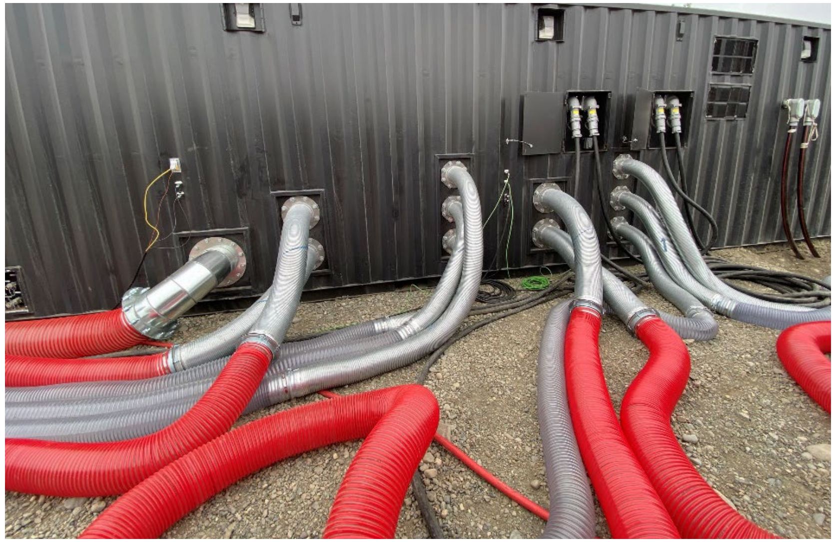
System Fabrication

(Savron 2024)

Smoldering Combustion Field Implementation

(Savron 2024)

Smoldering Combustion Field Implementation



(Savron 2024)

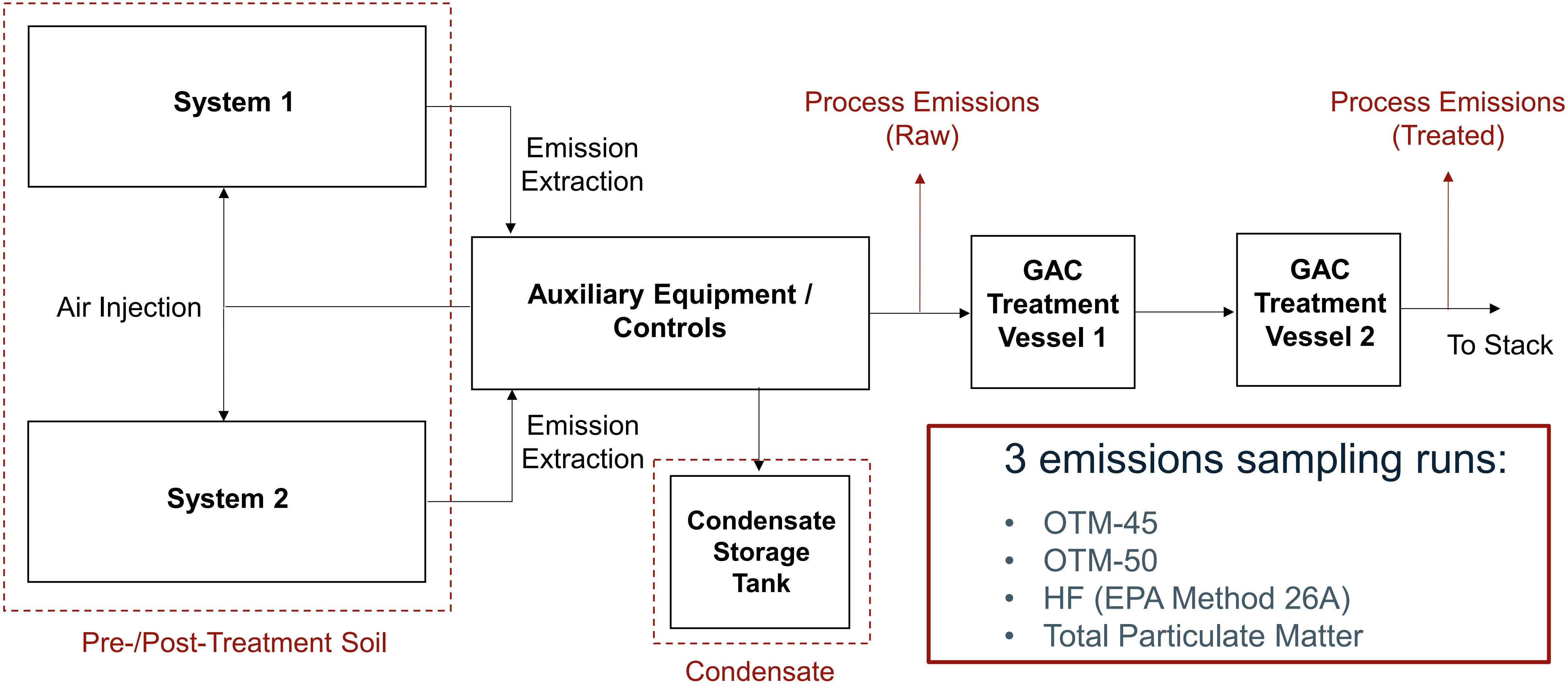
Smoldering Combustion Field Implementation

(Savron 2024)

Smoldering Combustion Field Implementation

(Savron 2024)

Smoldering Combustion Sampling



3 emissions sampling runs:

- OTM-45
- OTM-50
- HF (EPA Method 26A)
- Total Particulate Matter

(Deeb et al. 2023)

Smoldering Combustion Results Summary

(Savron 2024)

Soil Results

- > 99.9% reduction of PFAS (to near or below detection limits)
- Fluorine primarily retained as calcium fluoride (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

Presentation Overview

- Introduction
- Technologies for Solids Treatment or Disposal
  - Established Technologies for PFAS-Impacted Solids
  - On-Base Pilot Study Testing for PFAS Technologies
- Case Studies
- Guidelines for Selecting Solids Treatment Technologies
- Summary/Key Takeaways

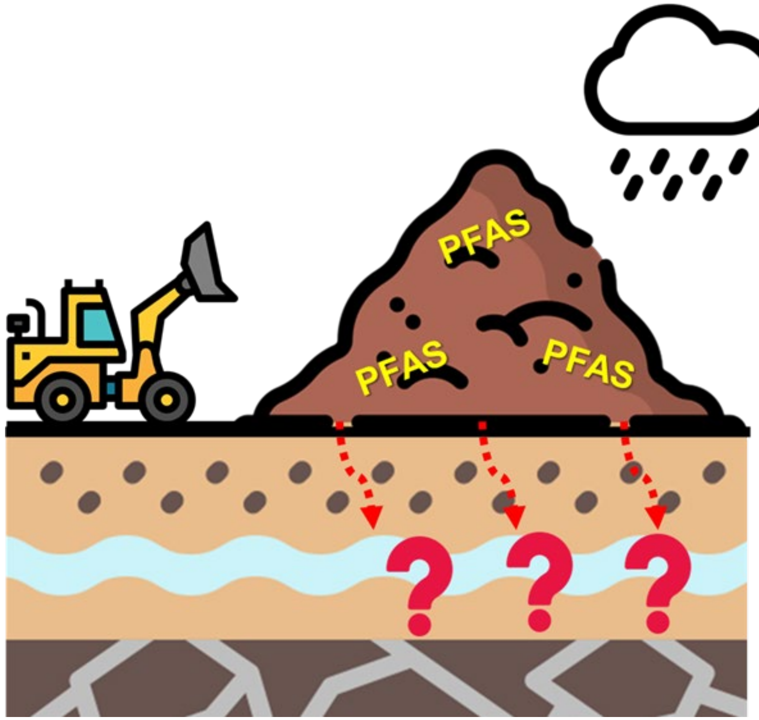
Guidelines for Selecting/Implementing Technologies

- Ensure remedy can achieve protectiveness of human health and environment through eliminating exposure pathways or preventing contact with receptors
  - Understand that containment, institutional controls, etc., may be only technically practicable strategy
- Leverage historical data from treatability studies and past implementation at the installation (or under similar conditions)
- Conduct bench-scale and on-site pilot treatability studies if sufficient information for technology cost and performance is not available for conditions specific to your site
  - May be conducted under FS, remedial design/remedial action phases
- Perform alternatives analysis (Chapter 8; Navy ERP Manual)
- Collaborate with baselevel management offices
  - Technology footprint and setup may require additional permissions
- Develop contingencies (alternative handling or disposal methods and costs) of managing the treated soil, if it does not meet applicable screening criteria for unrestricted or planned use

ERP: Environmental Restoration Program
FS: feasibility study
Navy: Department of the Navy

Preliminary Considerations for Excavated Soils Management

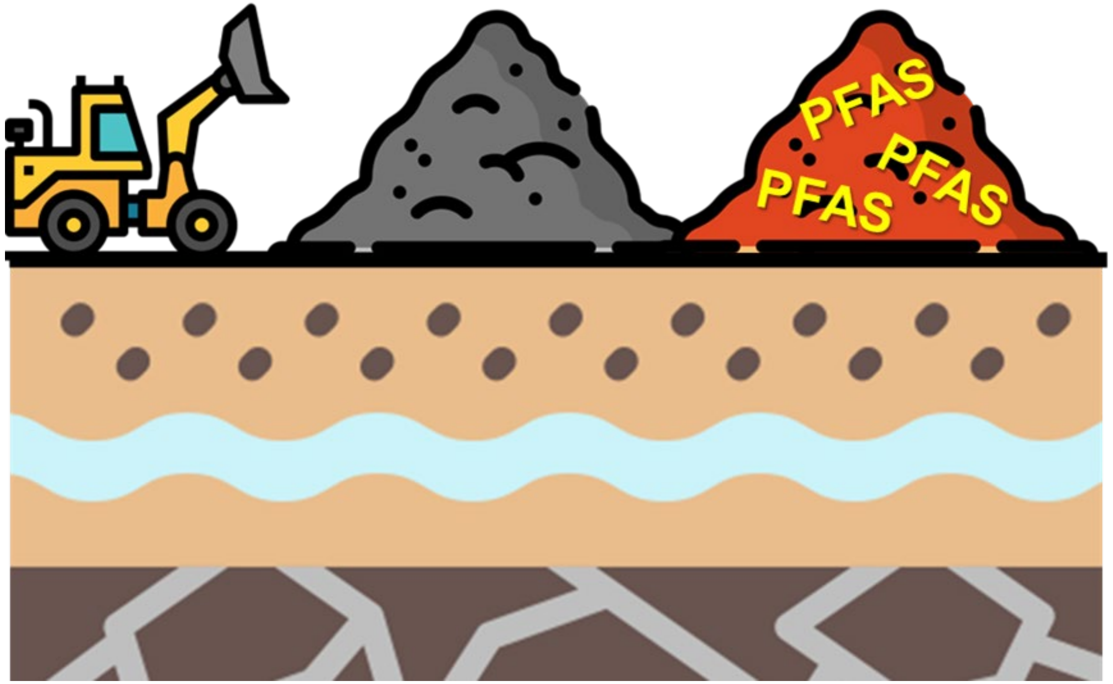
- Prior to Excavation
  - If available, leverage data from previous investigations (e.g., PA/SI, RI, etc.) to inform potential impacts to soils prior to excavation
  - If no data are available but there is suspected PFAS release in targeted excavation area, explore possibility for screening or characterization of excavated area
  - If excavated soil is to be stockpiled away from excavation site, identify whether any potential receiving groundwater and surface waters may be affected
    - Consider alternative storage areas
  - Maintenance of impermeable coverings and underlining



PA/SI: Preliminary Assessment/Site Inspection

Preliminary Considerations for Excavated Soils Management

- During & Post-Excavation
  - If available, use characterization data to segregate soils based on high vs low concentrations/non-detect to promote more cost-effective management
  - Keep other construction debris (e.g., asphalt or concrete) separate from soils



Presentation Overview

- Introduction
- Technologies for Solids Treatment or Disposal
  - Established Technologies for PFAS-Impacted Solids
  - On-Base Pilot Study Testing for PFAS Technologies
- Case Studies
- Guidelines for Selecting Solids Treatment Technologies
- Summary/Key Takeaways

Summary and Key Takeaways

- Management of PFAS-impacted soils and other impacted materials (e.g., aggregate) are an ongoing issue at multiple installations
  - To date: Limited availability of effective technologies for removing PFAS from soils; some strategies show promise and have more advanced Technology Readiness Levels (TRLs)
- Presented existing and developing strategies for PFAS-impacted solids management
  - Mature
    - Landfilling (off-site)
  - Developing
    - Thermal (on-site)
      - Desorption
      - Smoldering Combustion
    - Soil washing (on-site; likely requires off-site disposal for some components)
    - Stabilization

Summary and Key Takeaways

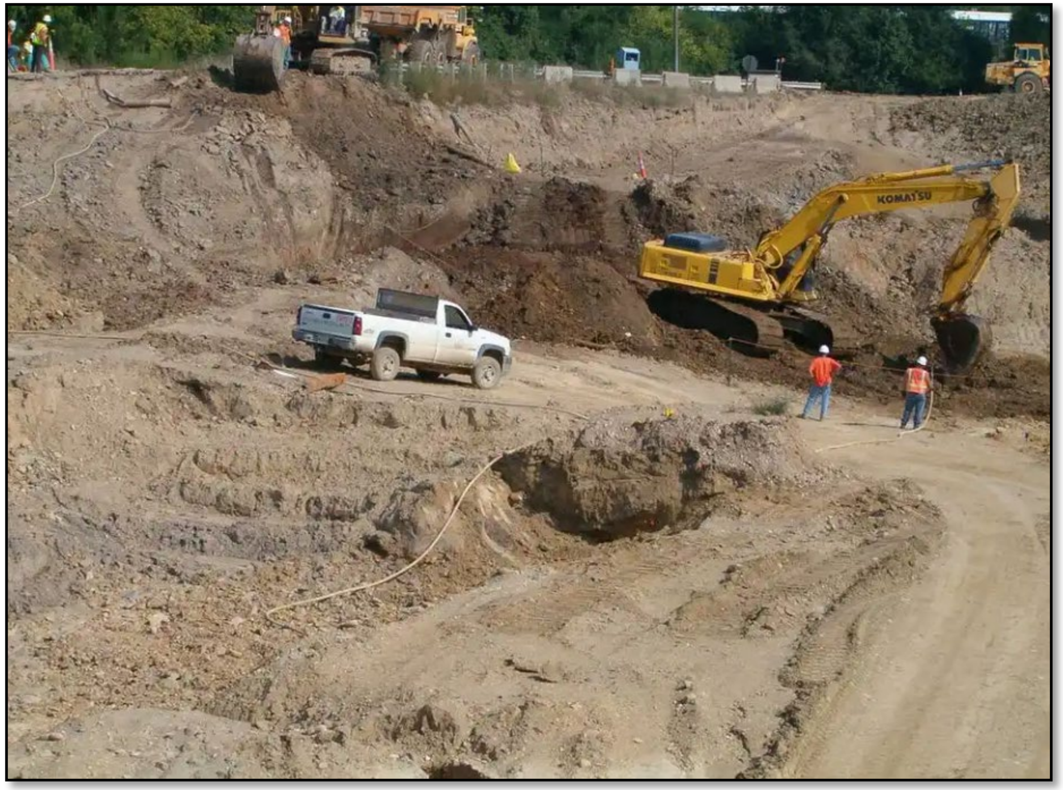
- Both Thermal Desorption and Smoldering Combustion processes demonstrated considerable removal performance with PFAS-impacted JBER soils
  - PFAS removal to non-detect for most target analytes in treated soils*
- Described process limitations, emissions considerations

(National Archives 1988)

*Target analyte list could grow in the future, as analytical methods improve

Summary and Key Takeaways

- Landfilling: Make early contact with disposal facilities to determine requirements and availability
- Coordinate technology use with regulators prior to demonstration or implementation at your site
- OSD plans to update relevant disposal guidance; RPMs should always follow Navy and OSD PFAS policy
- Develop applicable screening criteria and alternative handling or disposal methods for treated soil before project starts



(National Archives 2010)

OSD: Office of the Secretary of Defense
RPM: remedial project manager

References

ASD. July 2023. Interim Guidance on Destruction or Disposal of Materials Containing PFAS

Clean Harbors. (n.d.). Incineration Facilities. Retrieved February 16, 2025. https://www.cleanharbors.com/services/technical-services/waste-disposal-services/incineration

Crisenbery, M., 2023. Clean Harbors Aragonite PFAS Test Program Results (Seminar). August.

Deeb, R., Leeson, A., Wong, M., and Major, D. Management of PFAS in the Environment: Research & Demonstrations. SERDP & ESTCP Webinar Series (#197). November 2023. https://serdp-estcp.mil/resources/details/e633cc36-2973-40a8-8530-10ffb75b6b91/advances-in-pfas-destructive-technologies

EPA. "How-To" Guide for the Leaching Environmental Assessment Framework. 2019. https://www.epa.gov/sites/default/files/2019-05/documents/final_leaching_environmental_assessment_framework_leaf_how-to_guide.pdf

EPA. Interim Guidance on the Destruction and Disposal of PFAS and materials containing PFAS. 2024. https://www.epa.gov/pfas/interim-guidance-destruction-and-disposal-pfas-and-materials-containing-pfas

EPA. Other Test Method 50 (OTM-50) Sampling and Analysis of Volatile Fluorinated Compounds from Stationary Sources Using Passivated Stainless-Steel Canisters. January 2025. https://www.epa.gov/system/files/documents/2025-01/otm-50-release-1-r1.pdf

EPA. Revision 0 (1/13/2021) Other Test Method 45 (OTM-45). 2021. https://www.epa.gov/sites/default/files/2021-01/documents/otm_45_semivolatile_pfas_1-13-21.pdf

Iery, R, Crownover, E, and Heron, G., 2024. Thermal Remediation of PFAS in Soil. Navy Lunch and Learn with TRS (Seminar). October.

NJDEP, 2023. PFAS Soil and Soil Leachate Remediation Standards Basis & Background. for the Migration to Ground Water Exposure Pathway for Perfluorononanoic Acid (PFNA), Perfluorooctanoic Acid (PFOA), Perfluorooctane Sulfonate (PFOS) and Hexafluoropropylene Oxide Dimer Acid and its Ammonium Salt (GenX). June.

Rashwan, T.L., Fournie, T., Green, M., Duchesne, A.L., Brown, J.K., Grant, G.P., Torero, J.L. and Gerhard, J.I., 2023. Applied smouldering for co-waste management: Benefits and trade-offs. Fuel Processing Technology, 240, p.107542.

Scholes, G., April 2021. Smoldering Combustion (STARx) for the Treatment of Contaminated Soils and Liquid Organic Wastes–From Prototype to Full Scale Application. https://esaa.org/wp-content/uploads/2021/04/17-Scholes.pdf

Weber, N.H., Grimison, C.C., Lucas, J.A., Mackie, J.C., Stockenhuber, M. and Kennedy, E.M., 2024. Influence of reactor composition on the thermal decomposition of perfluorooctanesulfonic acid (PFOS). Journal of Hazardous Materials, 461, p.132665.

Points of Contact

Presenters

Jovan Popovic

NAVFAC EXWC

jovan.popovic.civ@us.navy.mil

John Kornuc

NAVFAC EXWC

john.j.kornuc.civ@us.navy.mil

Topic Champion

Grace Petersen

NAVFAC EXWC

sarah.g.petersen.civ@us.navy.mil

Naval Facilities Engineering Systems Command
EXWC Engineering and Expeditionary Warfare Center

Questions