Thank you for signing in early

The webinar will begin promptly at
12:00 pm ET, 9:00 am PT

SERDP DOD • EPA • DOE | ESTCP

SERDP and ESTCP Webinar Series

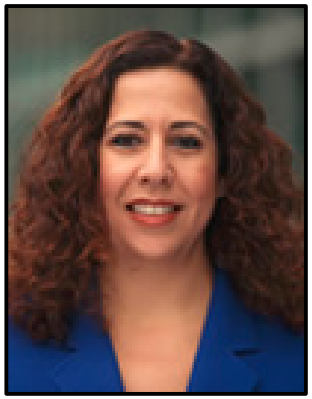
- The webinar will begin promptly at 12:00 pm ET, 9:00 am PT
- Two options for accessing the webinar audio
  - Listen to the broadcast audio if your computer is equipped with speakers
  - Call into the conference line
    - (669) 900-6833 or (929) 205-6099
    - Required webinar ID: 517-824-777
- For questions or technical issues, please email serdp-estcp@noblis.org or call 571-372-6565

Status of SERDP and ESTCP Efforts on PFAS and Innovative Approaches for the Treatment of Waste Derived from PFAS Subsurface Investigations

November 7, 2019

SERDP DOD • EPA • DOE | ESTCP

Welcome and Introductions



Rula A. Deeb, Ph.D.
Webinar Coordinator

Webinar Agenda

- **Webinar Logistics** (5 minutes)
  Dr. Rula Deeb, Geosyntec Consultants
- **Overview of SERDP and ESTCP** (5 minutes)
  Current Status of SERDP and ESTCP Efforts on PFAS (25 minutes + Q&A)
  Dr. Andrea Leeson, SERDP and ESTCP
- **Demonstration of Smoldering Combustion Treatment of PFAS-Impacted Investigation Derived Waste** (25 minutes + Q&A)
  Dr. Dave Major, Savron
- **Final Q&A session**

In Case of Technical Difficulties

- Use a compatible browser (Firefox, IE or Edge)
- If material is not showing on your screen or if screen freezes
  - Key in Ctrl + F5 to do a hard refresh of your browser
- If connecting to computer audio
  - Click the arrow next to the "*Join Audio*" button
  - Select test "*Speaker and Microphone*"
  - Follow prompts
- If you continue to experience difficulties, call into the conference line
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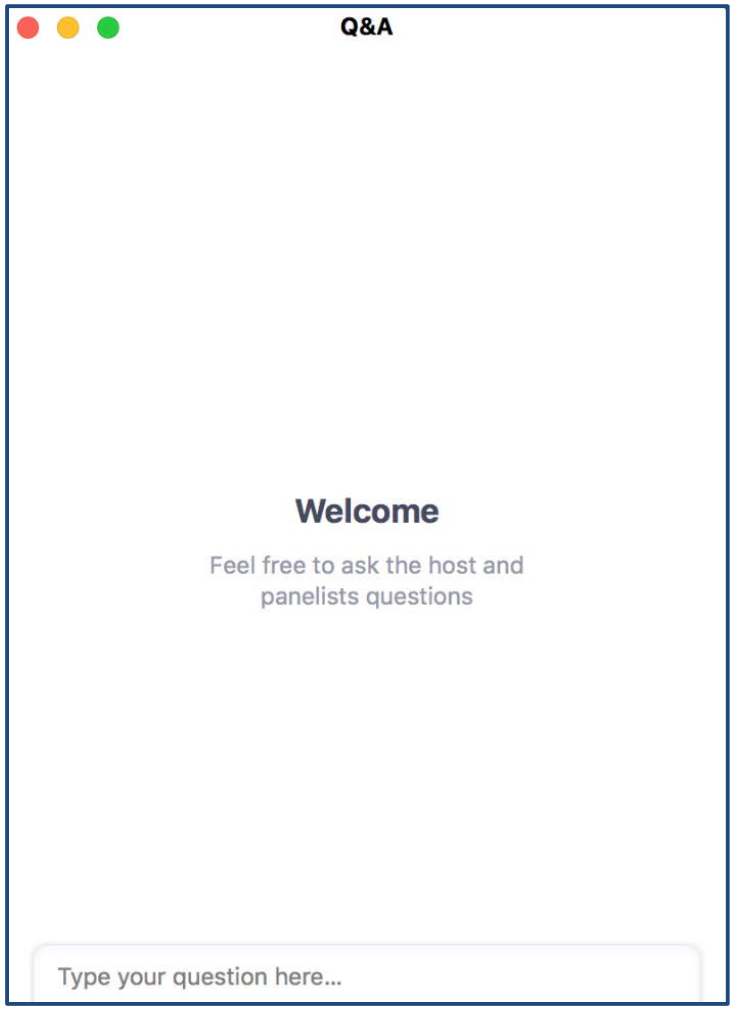
How to Ask Questions

- Find the Q&A button on your control bar and type in your question(s)
- Make sure to add your organization name at the end of your question so that we can identify you during the Q&A sessions



SERDP and ESTCP Overview

Andrea Leeson, Ph.D.
SERDP and ESTCP

DoD's Environmental Technology Programs

Science and Technology

- Statutory program established 1991
- DoD, DOE, EPA partnership
  - Advanced technology development to address near-term needs
  - Fundamental research to impact real world environmental management

Demonstration and Validation

- Demonstrate innovative cost-effective environmental and energy technologies
  - Transition technology out of the lab
  - Establish cost and performance
  - Partner with end user and regulator
  - Technology transfer
    - Accelerate commercialization or broader adoption
    - Direct technology insertion

Environmental Drivers

Sustaining Ranges, Facilities and Operations

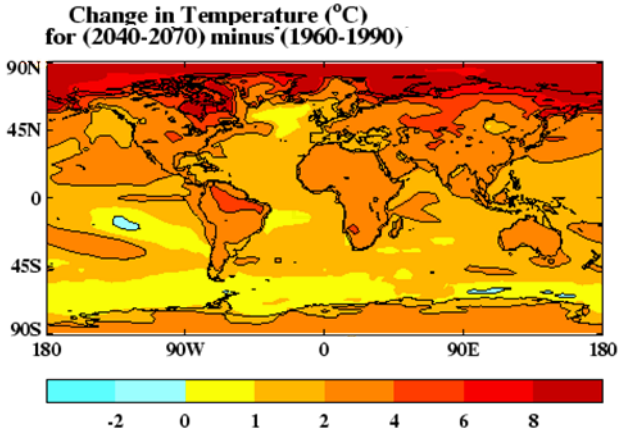
Maritime Sustainability
Threatened and Endangered Species

Toxic Air Emissions and Dust

UXO and Munitions Constituents

Noise

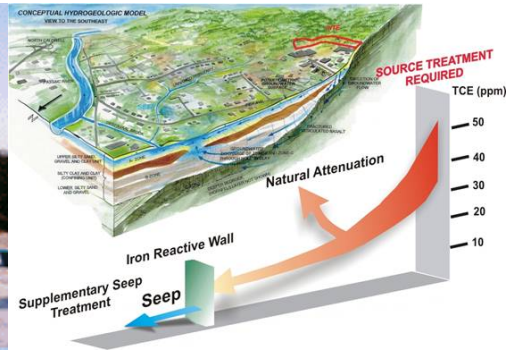
Sustainable FOB



Environmental Drivers

Reducing Current and Future Liability

Contamination from Past Practices

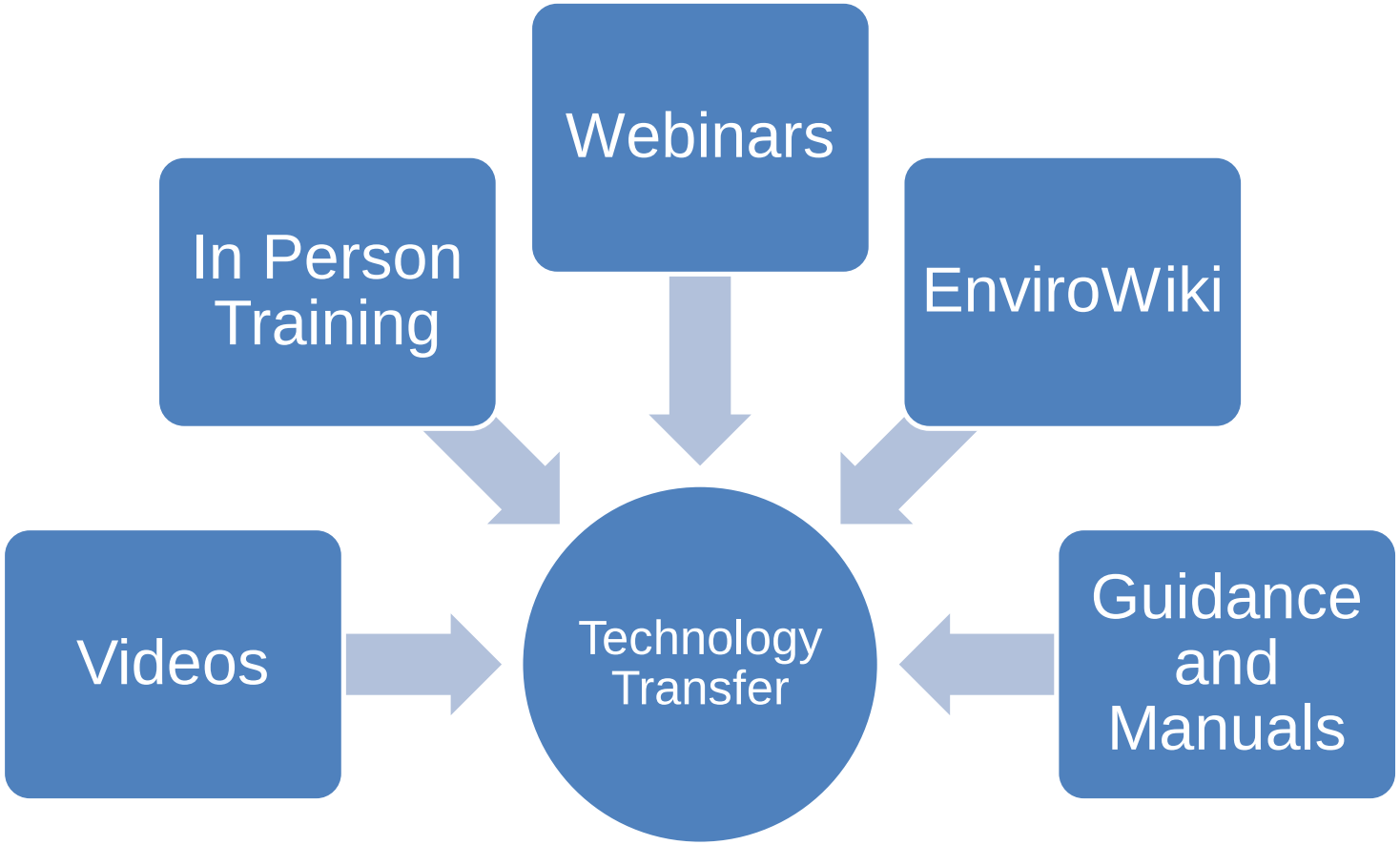


- Groundwater, soils and sediments
- Large UXO liability
- Emerging contaminants

Pollution Prevention to Control Life Cycle Costs

- Elimination of pollutants and hazardous materials in manufacturing, maintenance, and operations
- Achieve compliance through pollution prevention

www.serdp-estcp.org



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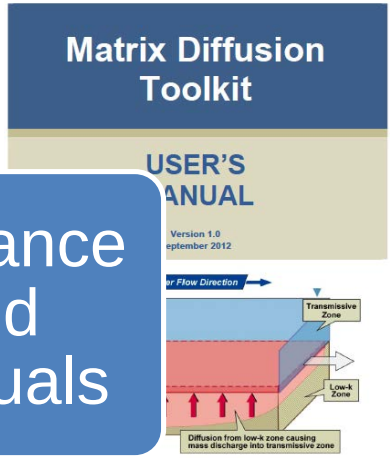
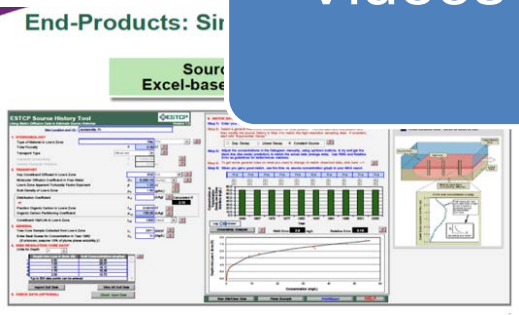




Webinars

In Person Training

EnviroWiki

Videos

Technology Transfer

Guidance and Manuals

SERDP and ESTCP Webinar Series

Date	Topic
December 12, 2019	Monitoring and Remediating Groundwater Contaminated with Chlorinated Solvents

- A list of 2020 webinars with registration information will be released soon at http://serdp-estcp.org/Tools-and-Training/Webinar-Series

Save the Date

SERDP • ESTCP
SYMPOSIUM

A three-day symposium showcasing the latest technologies that enhance DoD's mission through improved environmental and energy performance

December 3-5, 2019

Washington Marriott Wardman Park

Registration is open!

Current Status of SERDP and ESTCP Efforts on PFAS

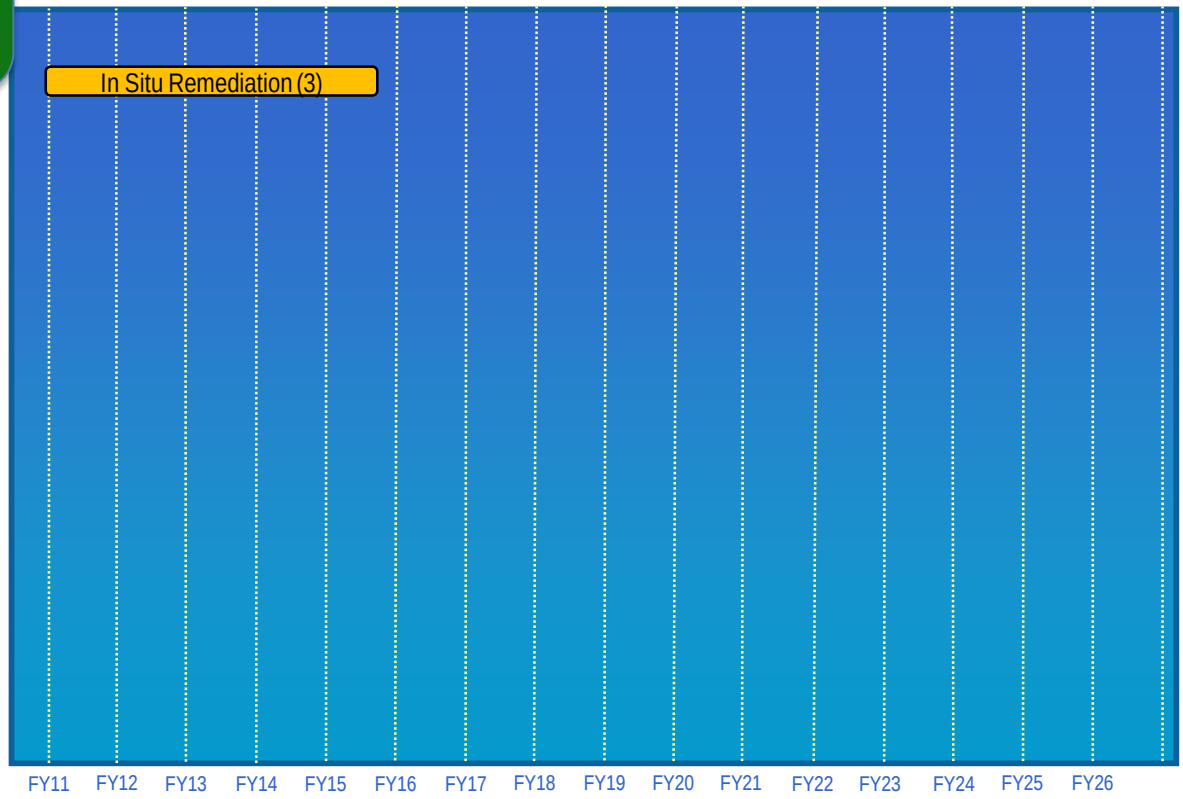
SERDP DOD • EPA • DOE | ESTCP

SERDP and ESTCP Efforts on PFAS

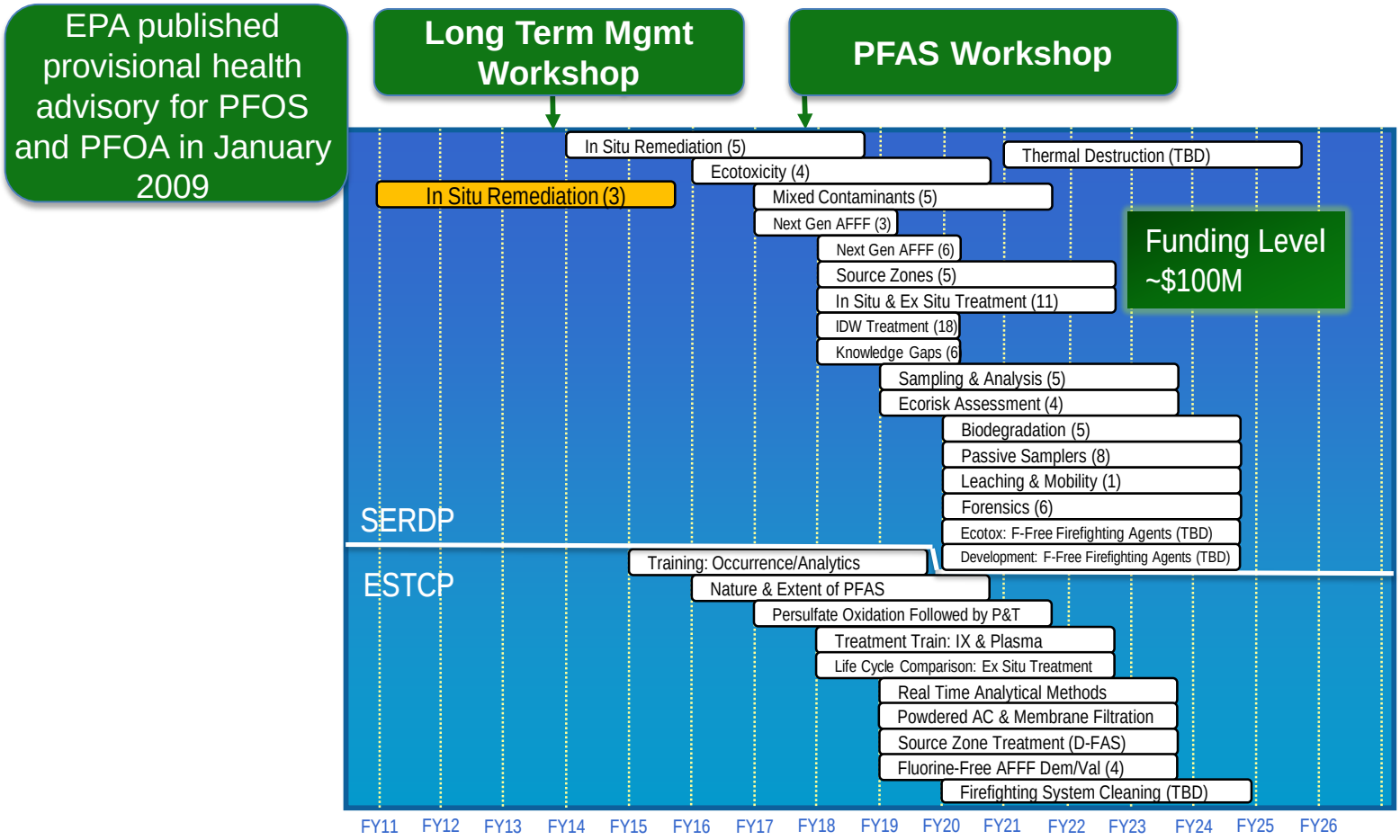
EPA published provisional health advisory for PFOS and PFOA in January 2009

SERDP and ESTCP Efforts on PFAS

EPA published provisional health advisory for PFOS and PFOA in January 2009



SERDP and ESTCP Efforts on PFAS



http://serdp-estcp-pfas.com/pfas_efforts/pfas_efforts.pdf

PFAS Workshop

- In May 2017, SERDP and ESTCP sponsored a two-day workshop titled "*Research and Development Needs for Management of DoD's PFAS Contaminated Sites*"
  - Review the current state of the science regarding PFAS contamination in general, and AFFF in particular
  - Evaluate current and potential characterization and remediation technologies
  - Prioritize research and demonstration opportunities that can improve remediation performance and efficiency, and ultimately reduce the costs to manage sites
  - Summarize findings in a workshop report

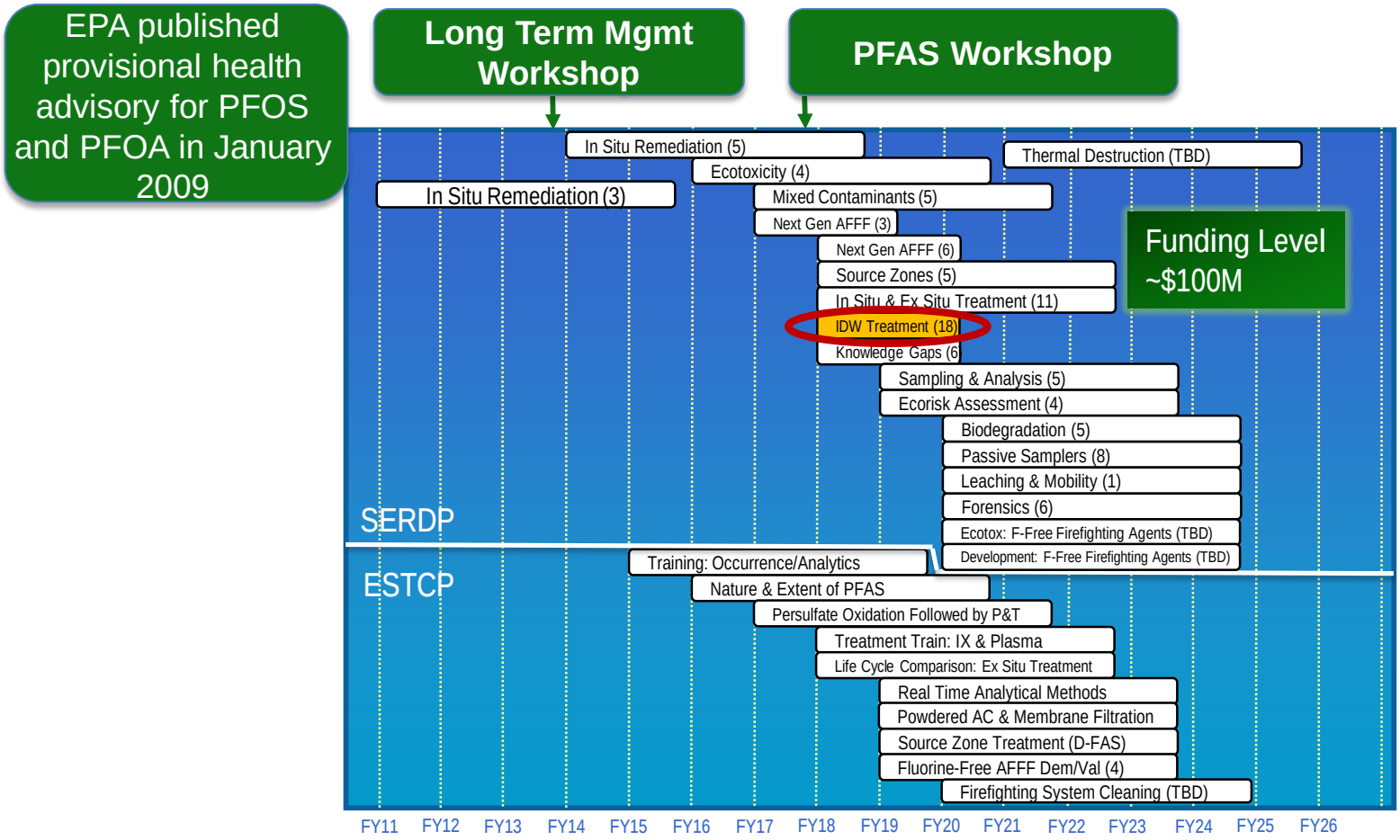
28 Research, Demonstration and Technology Transfer Needs Identified

https://serdp-estcp.org/content/download/45585/425201/file/PFAS%20Workshop%20Report%20Final%20September%202017.pdf

PFAS Workshop: Major Findings

- Fate and transport properties
- Bioavailability, biomagnification
- Toxicity
- Development of on-site technologies for concentrated PFAS waste streams
- PFAS forensics
- Sampling
- Treatment technology demonstrations
- Technology transfer needs

SERDP and ESTCP Efforts on PFAS



http://serdp-estcp-pfas.com/pfas_efforts/pfas_efforts.pdf

FY18 SERDP Solicitation

- Innovative Approaches for Treatment of Waste Derived from PFAS Subsurface Investigations
  - Proof of concept projects addressing treatment of materials such as excess soil cuttings, purge water from groundwater sampling, fluid from decontamination of drilling equipment, etc.
  - Preference for destructive technologies
    - Potential to permit unrestricted disposal, discharge, and/or reuse of IDW on-site
    - Mobile or temporary treatment systems that can be deployed easily
    - Cost effective compared to current disposal methods

Treatment Projects Overview

Advanced oxidation-reduction membrane concentration (Liu; UC Riverside)	Modified SiC based catalysts (Hendren; Research Triangle Institute)	Reductive defluorination by hydrated electrons (Dong; Miami)	Thermal treatment (Koster van Groos; APTIM)	Nonthermal plasma technology (Sales; Drexel)
Combined photo/electrochemical reduction (Jassby; UCLA)	Electron beam technology (Pillai; Texas A&M)	Plasma based treatment (Holsen; Clarkson)	Hydrothermal technologies (Strathmann; Colorado School of Mines)	Indirect thermal desorption with thermal oxidation (Barranco; EA Engineering)
Treatment train: chem decomposition and physical adsorption (Choi; UT Arlington)	Reactive electrochemical membrane (Chaplin; Univ of Illinois Chicago)	Composite AC based material with photocatalyst (Zhao; Auburn Univ)	Peroxone activated persulfate (Boving; Univ of Rhode Island)	Smoldering combustion (Major; Savron)
$BiPO_4$ CATALYSTS (Cates; Clemson)	Infrared thermal treatment (Hatton; Jacobs)	Absorbant + ultrasound (Yu; Amriton)		

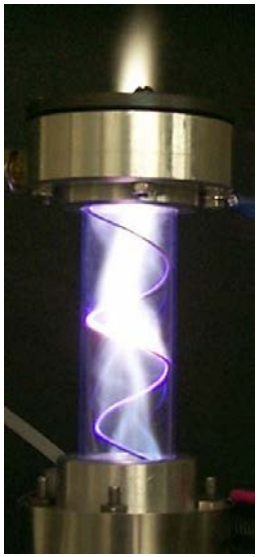
Ongoing

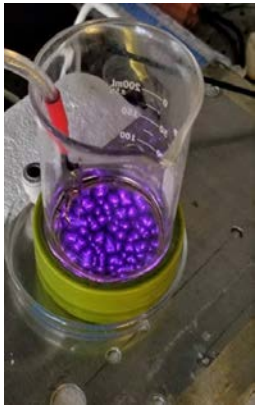
Complete; Under Review

Complete; Follow On Effort Underway

***ER18-1570**: Application of Non-Thermal Plasma Technology for Removal of PFAS from IDW*

- Performers
  - Christopher M. Sales (PI), Alexander Fridman, Alexander Rabinovich (Drexel University); Erica R. McKenzie (Temple University)
- Technology focus
  - Demonstrate, as a proof-of-concept, the application of non-thermal plasma technologies for the removal of PFAS from investigation derived wastes
- Research objectives
  - Develop non-thermal plasma technology for treating PFAS contaminated liquids and solids
  - Examine degradation and defluorination of PFAS and estimate associated energy costs for treatment





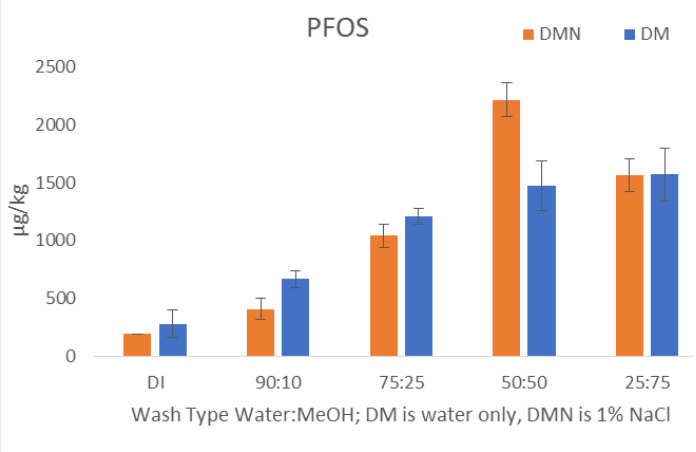
***ER18-1570**: Application of Non-Thermal Plasma Technology for Removal of PFAS from IDW*

- Project progress and results
  - Demonstrated air plasma can rapidly degrade PFCA, PFSA, and FtS compounds
- Future efforts
  - Determine mechanisms and identify transformation products of air plasma degradation of PFAS
  - Improve engineering and design of plasma technologies for enabling effectively robust and energy efficient large-scale applications

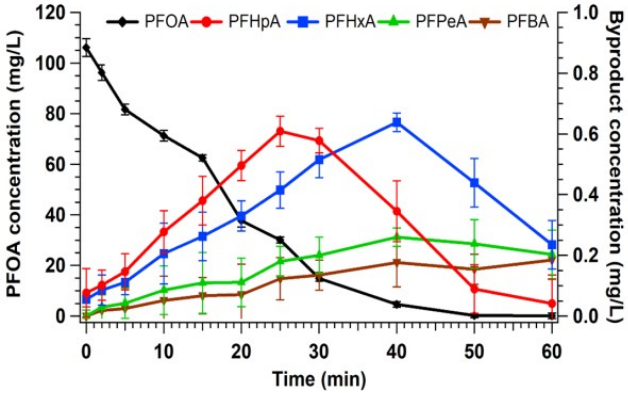
ER18-1624: Plasma Based Treatment Processes for PFAS IDW

- Performers
  - Thomas M. Holsen, Selma Thagard Mededovic, Michelle Crimi, Clarkson University; Stephen D. Richardson, Poonam R. Kulkarni, GSI Environmental; Steven Woodard, John C. Berry ECT2
- Technology focus
  - Removal and destruction of PFAS from soil investigation derived waste
- Research objectives
  - Investigate soil washing followed by treatment of the washing solution in an enhanced contact plasma reactor to destroy the desorbed PFAS

Soil washing results



Plasma treatment results (PFOA containing lab water - NaCl concentration of 4%)

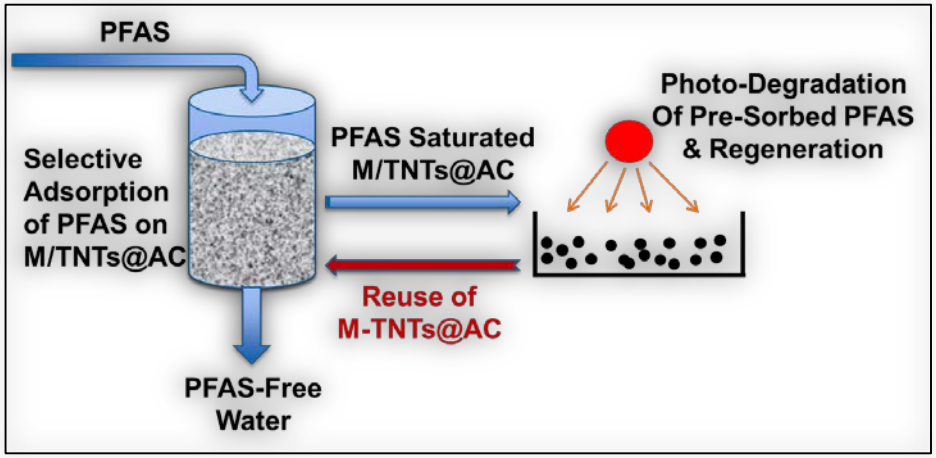


***ER18-1624**: Plasma Based Treatment Processes for PFAS IDW*

- Project progress and results
  - Water alone removed a large amount of PFAS. The addition of NaCl and MeOH resulted in better removal. The vast majority of the PFAS was removed in the first wash. Removal of PFAS was fast (minutes)
  - Plasma treatment is effective at destroying desorbed PFAS. Plasma treatment is relatively insensitive to salt concentration and the presence of small amounts of MeOH. Precursors present in the soil washing solution extended the required treatment times
- Future efforts
  - Perform soil washing tests under more realistic conditions
  - Evaluate other washing solutions
  - Determine if pretreatment of precursors is beneficial
  - Design a pilot-scale system
  - Develop and test the pilot-scale system using DoD site media
  - Estimate costs of commercial scale soil washing with plasma destruction

***ER18-1515**: A Cost-Effective Technology for Destruction of PFAS from DoD Subsurface IDW*

- Performers
  - Don Zhao (Auburn University)
- Technology focus
  - A new "Concentrate-&-Destroy" technique using innovative adsorptive photocatalysts for removal and degradation of PFAS in water and soil



- Research objectives
  - Develop new class of adsorptive photocatalysts that can adsorb and photodegrade PFAS in situ from DoD's subsurface IDWs
  - Test effectiveness and reusability of the new materials for treating PFAS in DoD site water and soil

***ER18-1515**: A Cost-Effective Technology for Destruction of PFAS from DoD Subsurface IDW*

- Project progress and results
  - Three novel adsorptive photocatalysts were synthesized and tested
  - The new materials showed excellent adsorption rates and high photocatalytic activity towards PFOA and PFOS under UV or solar light
  - The materials can be reused in multiple cycles without additional regeneration
  - A low-cost dispersant (Corexit EC9500A) can effectively extract PFOS from a DoD field soil, and desorbed PFOS can be reloaded on the composite material and degraded
  - Soluble soil components may inhibit the photodegradation

***ER18-1593**: Demonstration of Smoldering Combustion Treatment of PFAS-Impacted IDW*

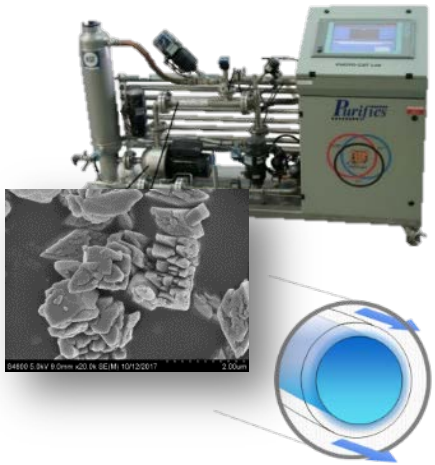
- Performers
  - Savron, Geosyntec Consultants, University of Western Ontario, Royal Military Collage of Canada
- Technology focus
  - PFAS destruction in Investigative Derived Wastes through smoldering combustion
- Research objectives
  - Demonstrate that common or waste fuels can support smoldering combustion at temperatures that destroy PFAS-impacted IDW or soils, or spent activated carbon (GAC)

***ER18-1593**: Demonstration of Smoldering Combustion Treatment of PFAS-Impacted IDW*

- Project progress and results
  - GAC added to soils between 40 and 60 g/Kg will support smoldering combustion and achieve temperatures that result in the destruction of PFAS on the GAC or adsorbed to surrogate soil mixture
- Future efforts
  - Additional testing to optimize the application to address heterogeneity, soil types, using real site soils
  - Pilot testing at a DoD Facility

***ER18-1599**: Pilot Scale Assessment of a Deployable Photocatalytic Treatment System Modified with $BiPO_4$/BOHP Catalyst Particles for PFAS Destruction in Investigation-Derived Wastewaters*

- Performers
  - Ezra L. Cates, Clemson University; US Navy EXWC; Battelle
- Technology focus
  - Development of photocatalytic materials for PFAS destruction, incorporation into an existing commercial deployable reactor system, and process optimization and assessment
- Research objectives
  - Assemble a BOHP/UV photocatalytic pilot system
  - Obtain data on catalyst activity/degradation kinetics, impact of water constituents, catalyst stability, and overall system treatment efficiency for a range of PFAS
  - Demonstrate IDW treatment using field samples from two DoD AFFF-contaminated sites and assess full-scale cost feasibility
  - Complete proof-of-concept bench-scale demonstration of PFOS degradation by a complimentary photocatalytic reduction process



***ER18-1599**: Pilot Scale Assessment of a Deployable Photocatalytic Treatment System Modified with $BiPO_4$/BOHP Catalyst Particles for PFAS Destruction in Investigation-Derived Wastewaters*

- Project progress and results
  - Proof of concepts and IDW tests were successful and key process parameters identified
  - Result suggest combined BOHP/$BiPO_4$ process capable of degrading PFCAs, PFOS, and FTSs
  - Catalyst particle size/surface area identified as key limiting factor that impedes cost effectiveness
- Future efforts
  - Follow on research should employ simple particle size reduction strategies for higher catalyst surface area and quantify the enhancement in PFAS degradation efficiency. 10-20x enhancement in kinetics is anticipated. Use of pre-existing commercial hardware platform allows seamless technology transfer

FY20 ESTCP Supplemental Solicitation

- Demonstration and Validation of Environmentally Sustainable Methods to Clean Firefighting Delivery Systems
  - Projects are sought to demonstrate and validate environmentally sustainable methods to clean firefighting delivery systems in aircraft hangars or on firefighting vehicles
  - Also of interest are demonstrations of environmentally acceptable treatment of any rinsate or residue derived from the cleaning process
  - Proposals due 21 November 2019 NLT 2 PM
    - Go to https://www.serdp-estcp.org/Funding-Opportunities/ESTCP-Solicitations for submittal instructions

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FY21 SERDP Solicitation

- Improved Understanding of Thermal Destruction Technologies for Materials Laden with PFAS
  - Develop new technologies or modifications to existing technologies that improve cost effectiveness and sustainability of how PFAS-laden materials are currently processed
  - Develop better understanding of incineration on materials of interest, to include full mass balance from inlet to outlet, as well as temperature requirements for destruction of PFAS
  - Improve understanding of PFAS fate during thermal reactivation of GAC and other carbon-based sorbents. Determine how reactivation impacts long-term effectiveness of sorbent, and extent to which any hazardous or toxic products are formed and subsequently released from sorbent
  - Assess fate and behavior of PFAS and co-contaminants during production and processing of residual product streams from various technologies such as ion exchange, nanofiltration, reverse osmosis, or regeneration of spent ion exchange resins

FY21 SERDP Solicitation

- Improved Understanding of Thermal Destruction Technologies for Materials Laden with PFAS (Cont'd)
  - Develop novel or modified sorbents that facilitate less intensive reactivation and more sustainable processes
  - Materials of interest include soils, spent GAC or other C-based sorbents, spent ion exchange resins; other materials include but not limited to munitions, demil materials, concentrated solutions

- Pre-proposals due 7 January 2020 NLT 2 PM
  - Go to https://www.serdp-estcp.org/Funding-Opportunities/SERDP-Solicitations for submittal instructions

FY21 SERDP Solicitation

- Improved Understanding of Thermal Destruction Technologies for Materials Laden with PFAS (Cont'd)
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- Pre-proposals due 7 January 2020 NLT 2 PM
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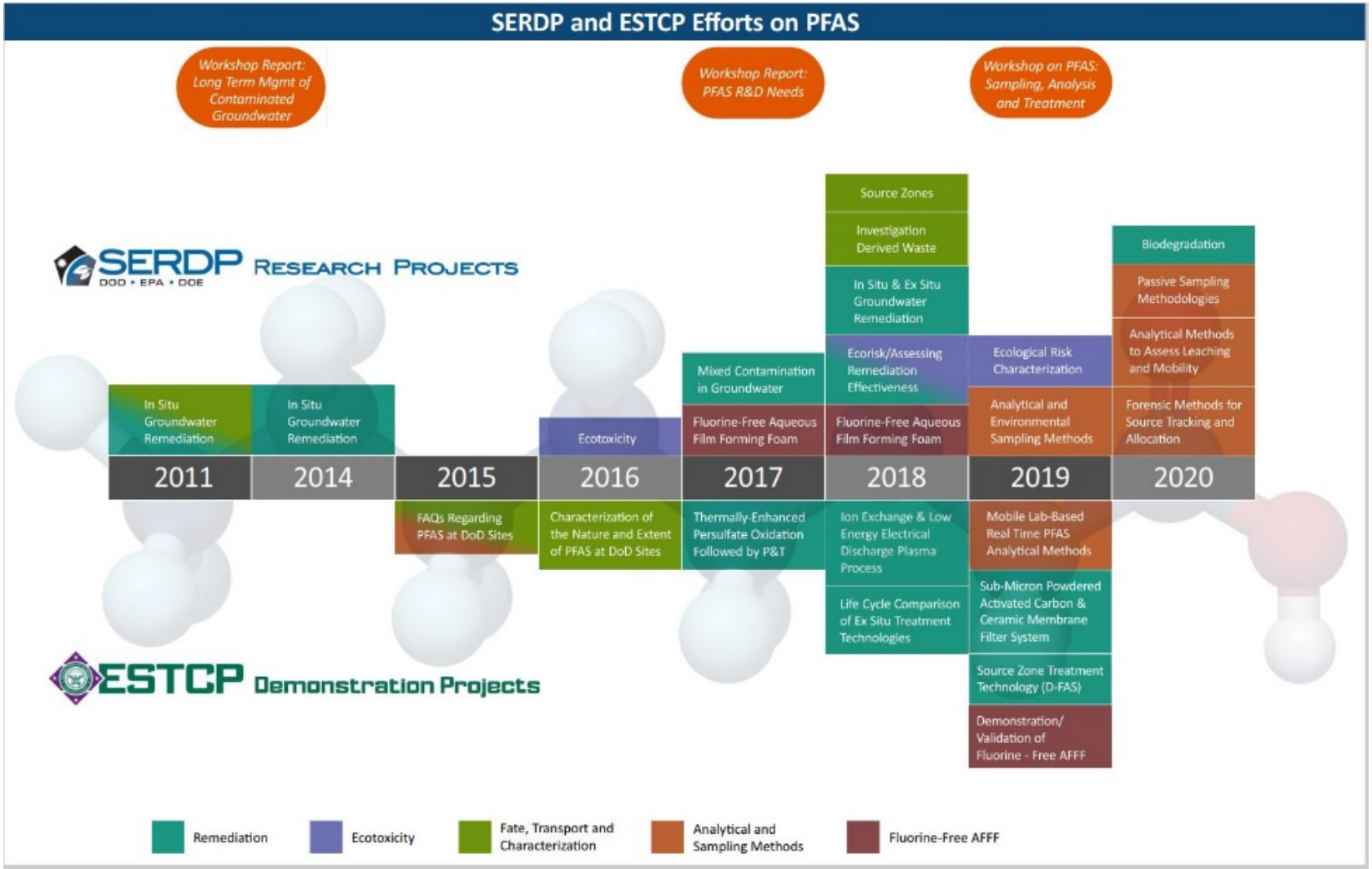
PFAS Resources

- Workshop report
  - https://serdp-estcp.org/content/download/45585/425201/file/PFAS%20Workshop%20Report%20Final%20September%202017.pdf

- PFAS FAQ and reference document
  - https://www.serdp-estcp.org/content/download/46353/431598/file/FAQ%20ER-201574%20September%202017.pdf
    - In what environmental media have PFAS been found?
    - What is the fate and transport of PFAS in the environment?
    - What characterization and remedial tools are available/effective for PFAS?
    - What are human and ecological exposure pathways and health effect?

PFAS Resources



https://map.serdp-estcp.org/Featured-Initiatives/Per-and-Polyfluoroalkyl-Substances-PFASs/pfas_efforts.pdf

For additional information, please visit
https://serdp-estcp.org/Featured-Initiatives/Per-and-Polyfluoroalkyl-Substances-PFASs

Speaker Contact Information

andrea.leeson.civ@mail.mil

SERDP DOD • EPA • DOE | ESTCP

Q&A Session 1

SERDP DOD • EPA • DOE | ESTCP

Demonstration of Smoldering Combustion Treatment of PFAS-Impacted Investigation Derived Waste

David Major, Ph.D.
Savron

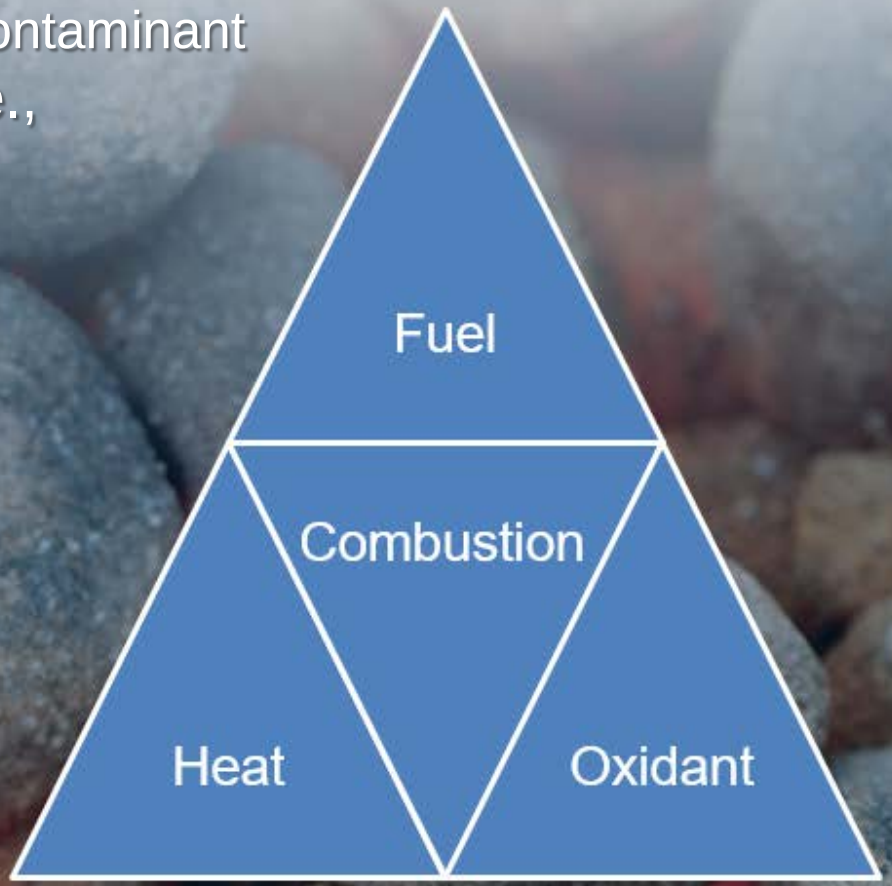
SERDP DOD • EPA • DOE | ESTCP

Agenda

- Smoldering combustion
- Overview of test and experimental setup
- Results
- Potential applications
- Future work
- Benefits to DoD

Smoldering Combustion (STAR)

- Flameless
- Energy efficient/self-sustaining
  - Process "powered" by contaminant
- Complete destruction (i.e., mineralization) possible



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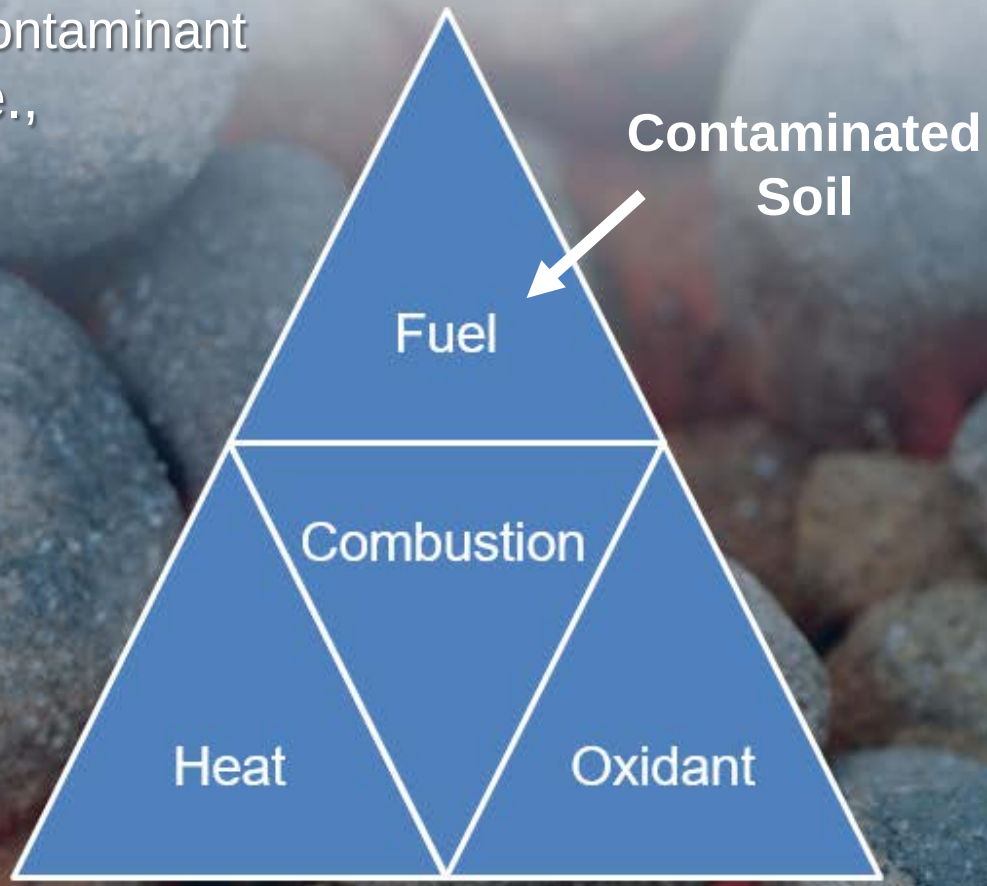

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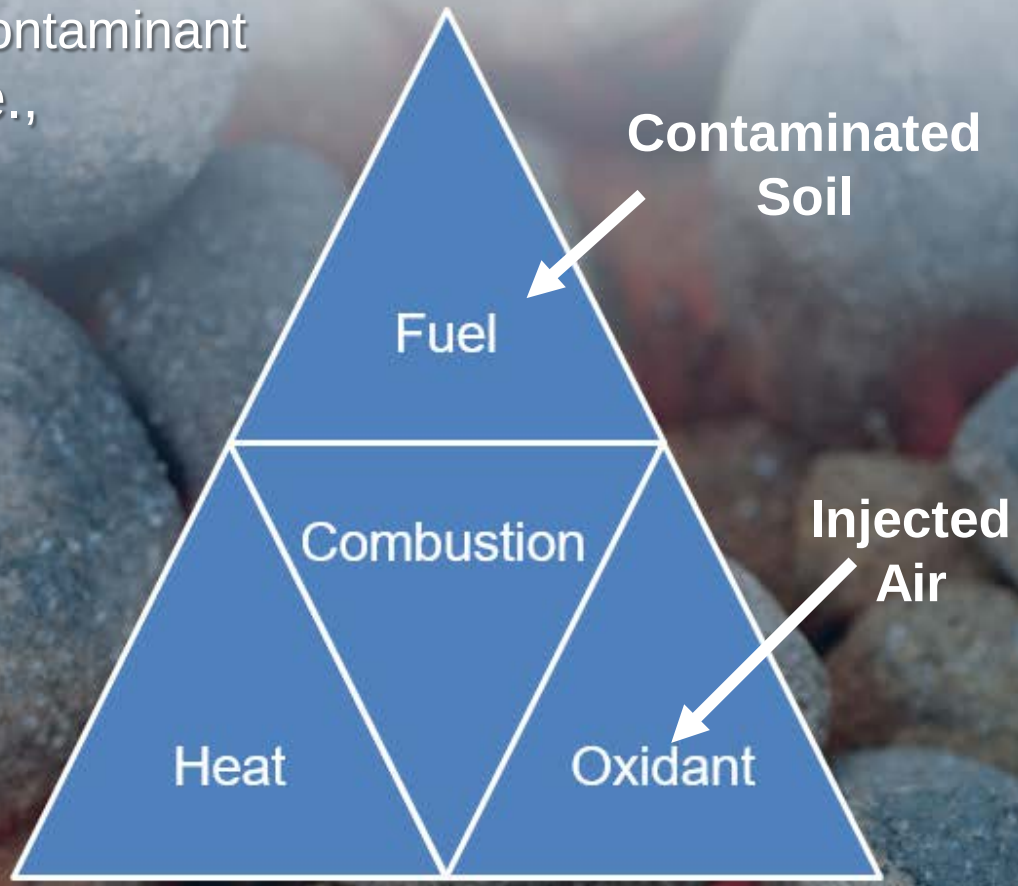

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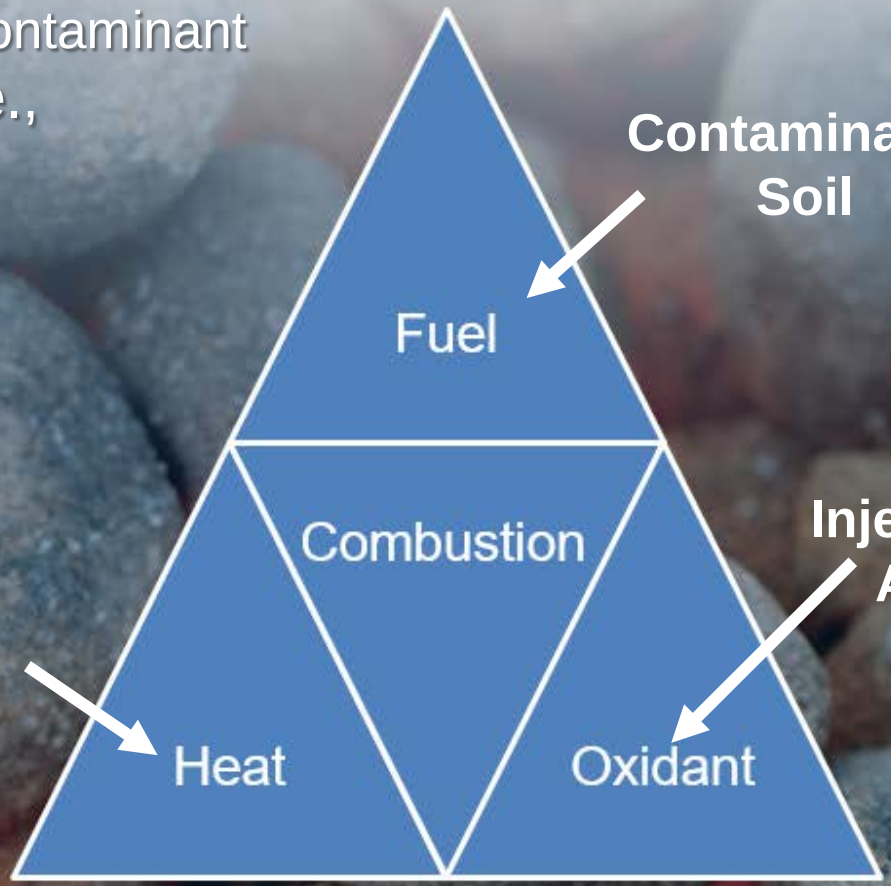

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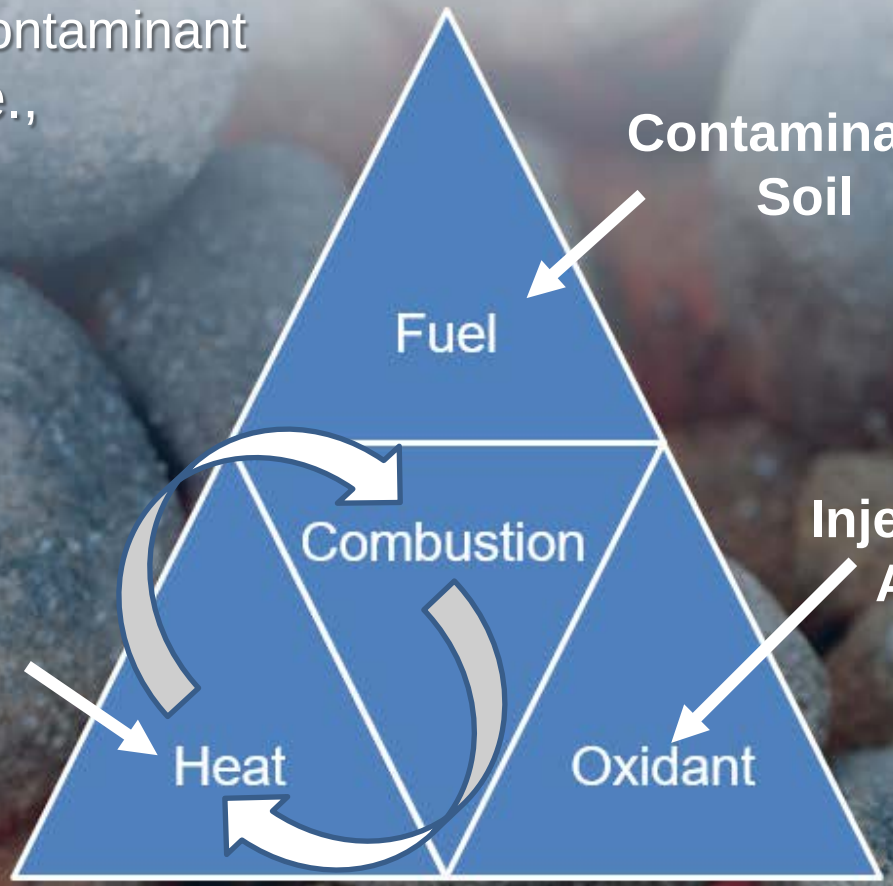

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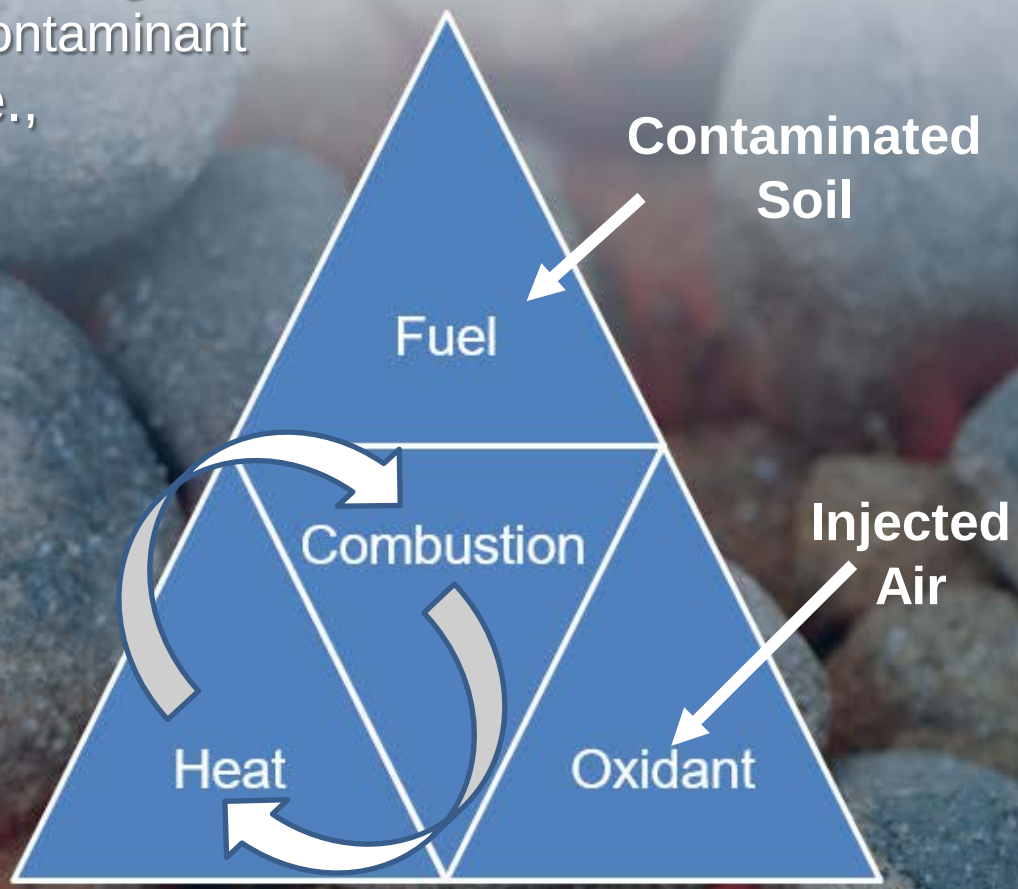
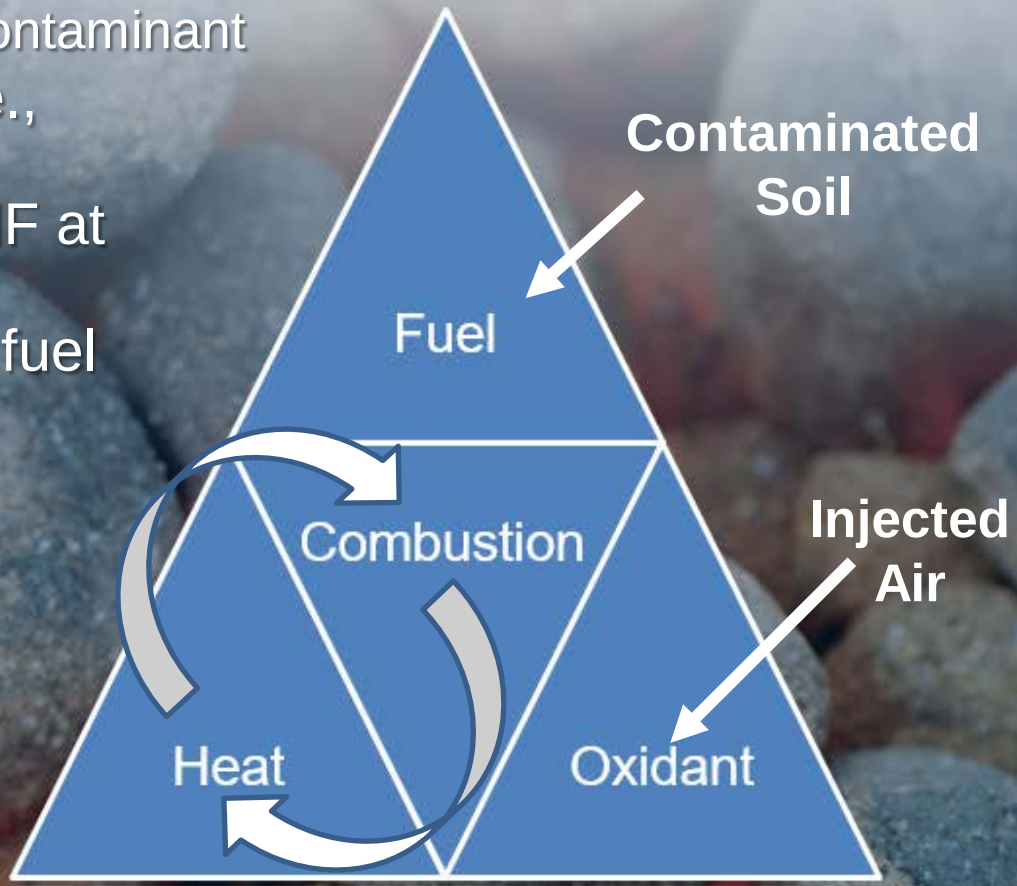


Smoldering Combustion (STAR)

- Flameless
- Energy efficient/self-sustaining
  - Process "powered" by contaminant
- Complete destruction (i.e., mineralization) possible
- PFAS mineralization to HF at temperature > 900ºC
- PFAS not a smolderable fuel
  - Requires fuel surrogate



Smoldering Combustion (STAR)

- Flameless
- Energy efficient/self-sustaining
  - Process "powered" by contaminant
- Complete destruction (i.e., mineralization) possible
- PFAS mineralization to HF at temperature > 900ºC
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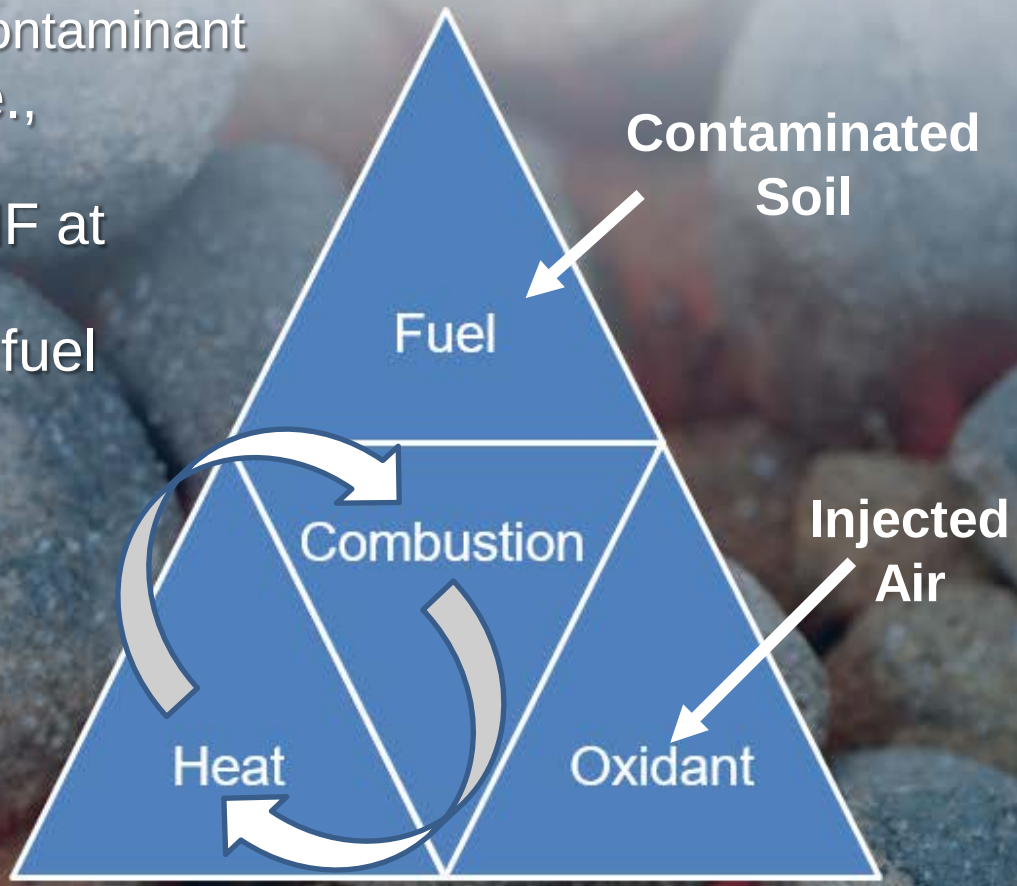

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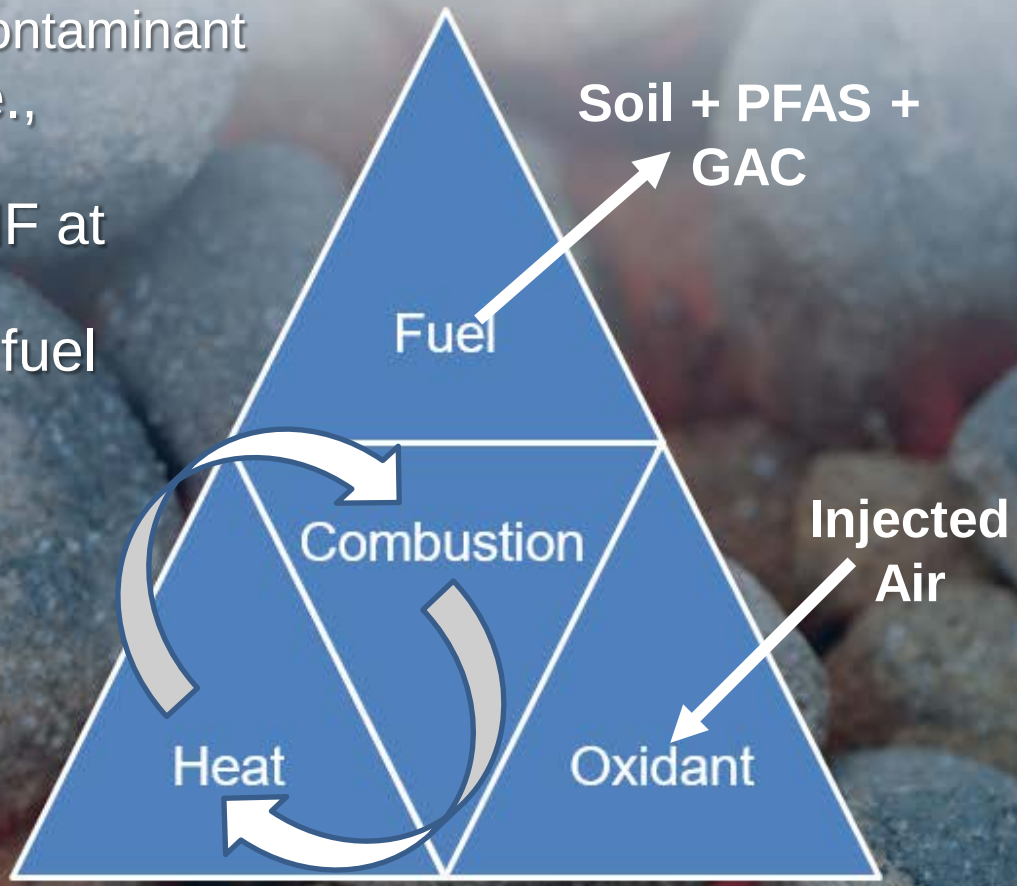

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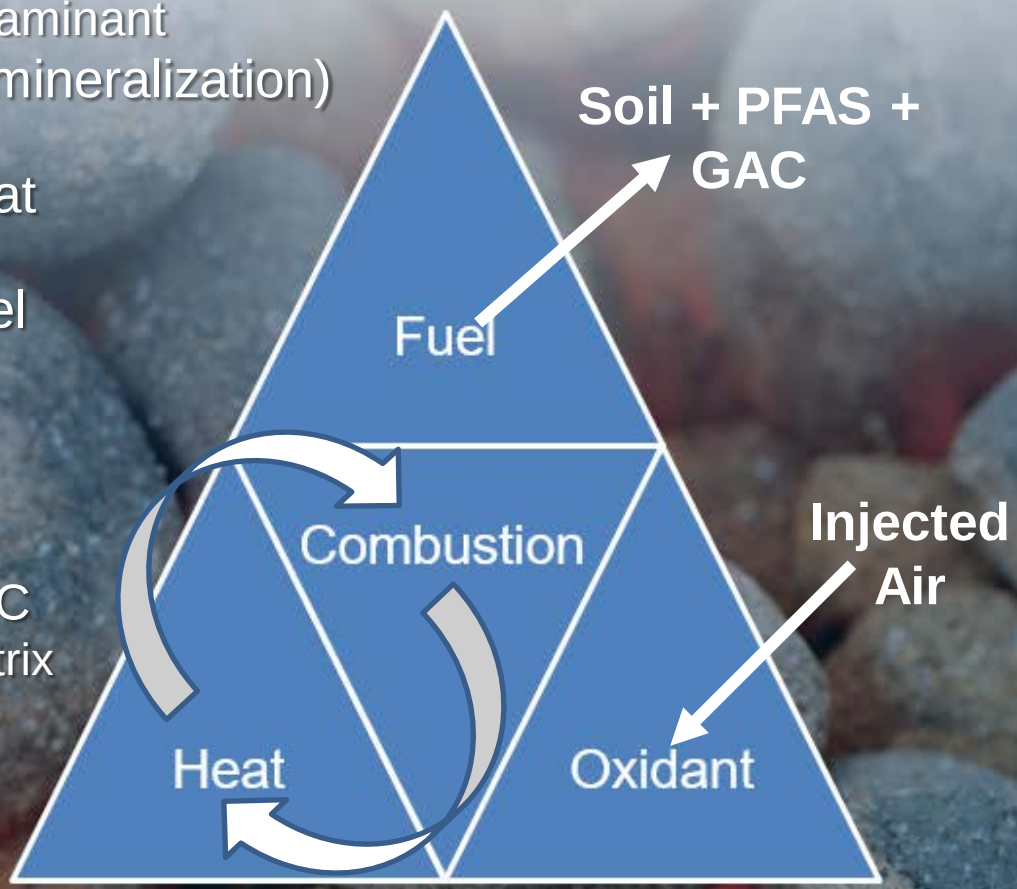
  - GAC??
- Smolder PFAS-impacted soil
  - Add GAC as surrogate fuel
- Smolder PFAS-impacted GAC
  - Add sand as inert porous matrix
- Co-treat
  - Mix PFAS-impacted soil and PFAS-impacted GAC



Overview of Testing

GAC

Sand

Test 1

- Clean GAC/sand mixture

Key data

- Temperature/combustion gas profile over range of GAC/sand ratios

Overview of Testing

GAC

Sand

PFOA	PFOS	PFHxS
VWR (95%)	Sigma (≥ 98%)	Sigma (≥ 98%)

Tests 2 and 3

- PFAS adsorbed to GAG and mixed with clean sand

Key data

- Concentration of PFAS before and after smoldering

Overview of Testing

PFOA	PFOS	PFHxS
VWR (95%)	Sigma (≥ 98%)	Sigma (≥ 98%)

Test 4

- 3 PFAS adsorbed to surrogate soil and mixed with clean GAC

Overview of Testing

PFOA	PFOS	PFHxS
VWR (95%)	Sigma (≥ 98%)	Sigma (≥ 98%)

PFNA	PFHpA	PFBS
Sigma (97%)	Sigma (99%)	Sigma (99%)

Test 4

- 3 PFAS adsorbed to surrogate soil and mixed with clean GAC

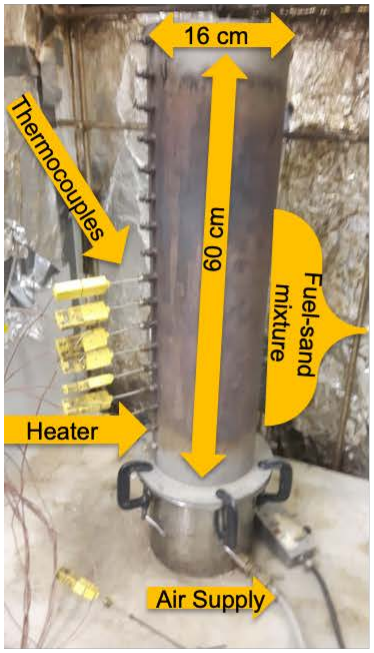
Test 5

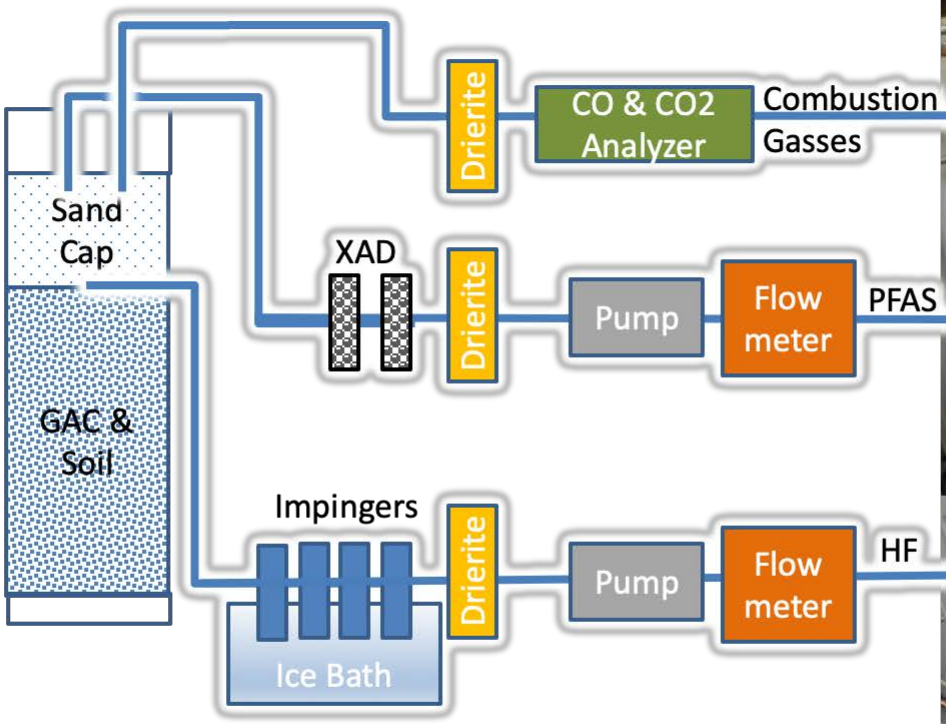
- PFAS adsorbed to surrogate soil and mixed with clean GAC

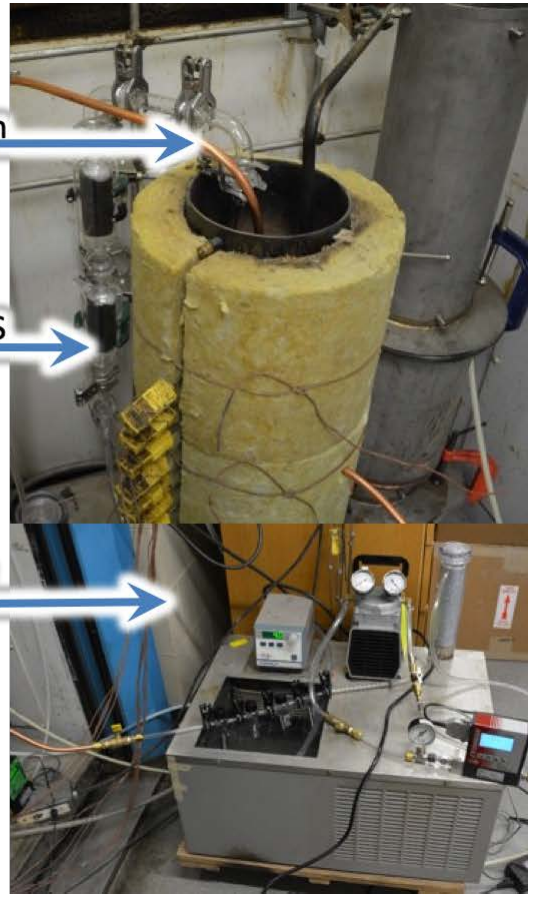
Key data

- Concentration of PFAS before and after smoldering
- HF and PFAS in emissions

Experimental Setup

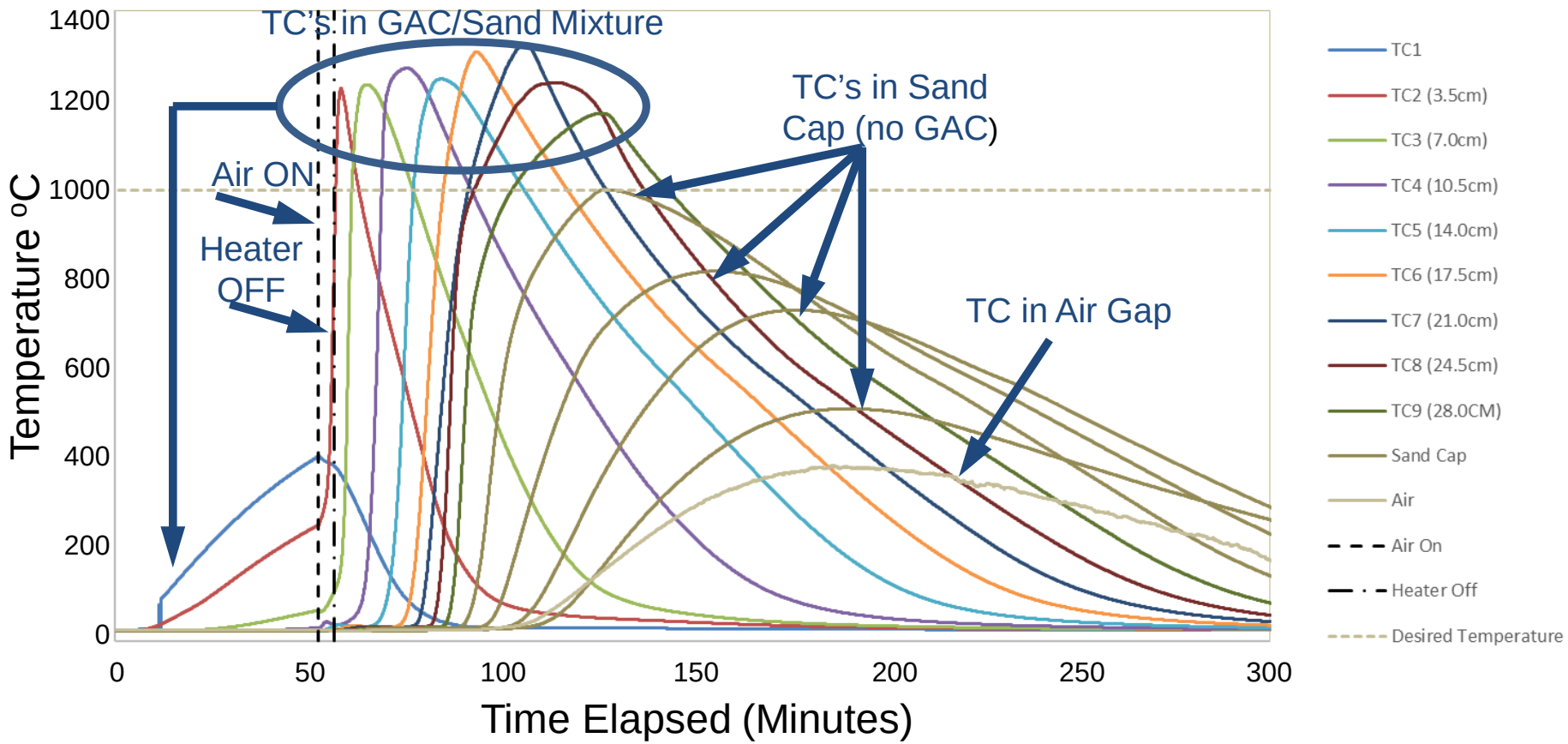






Test 1

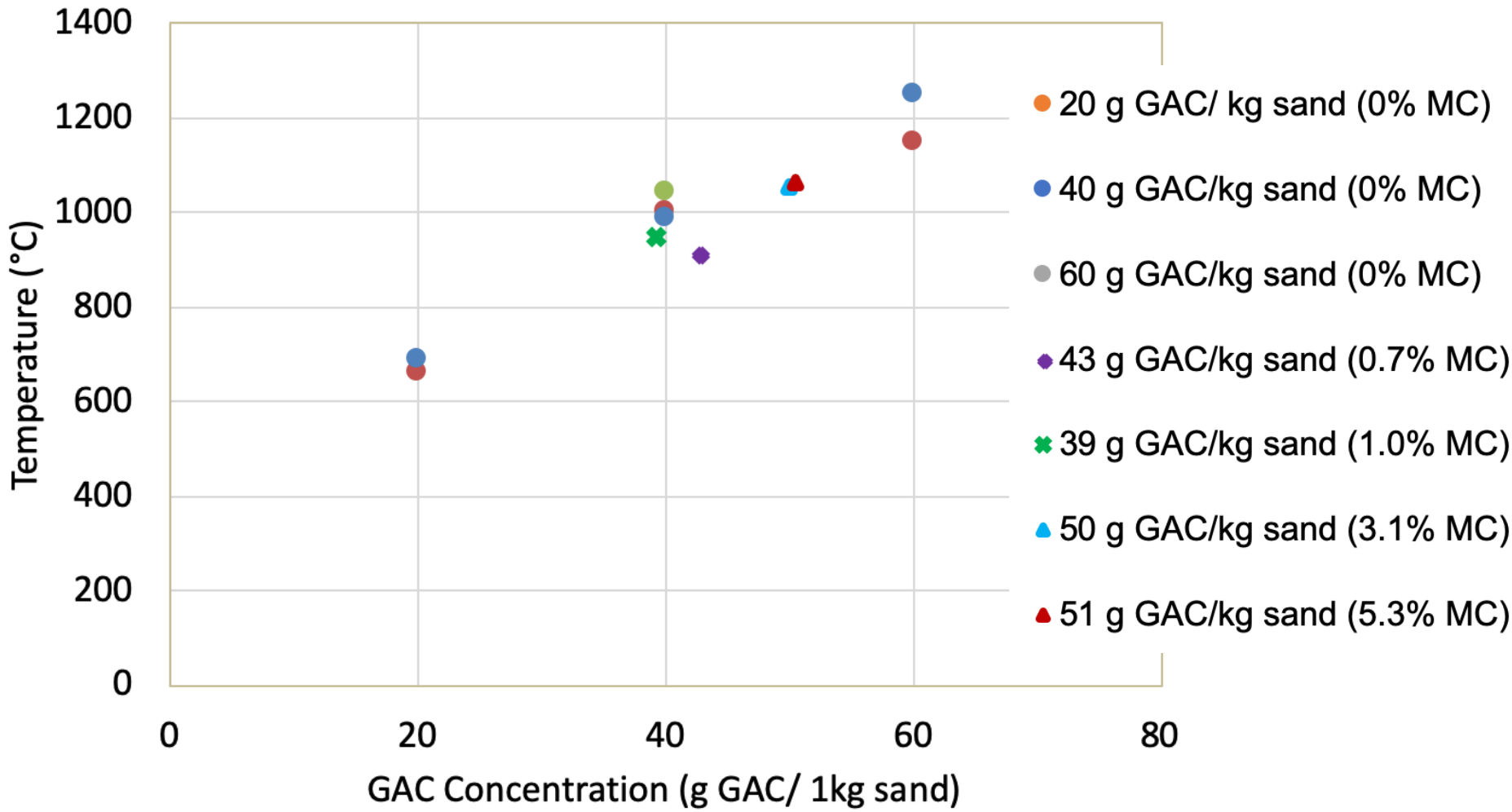
Example GAC/Sand Run (60 g GAC/kg Sand, 5.0 cm/s Air Flux)



Note: TC = Thermocouple

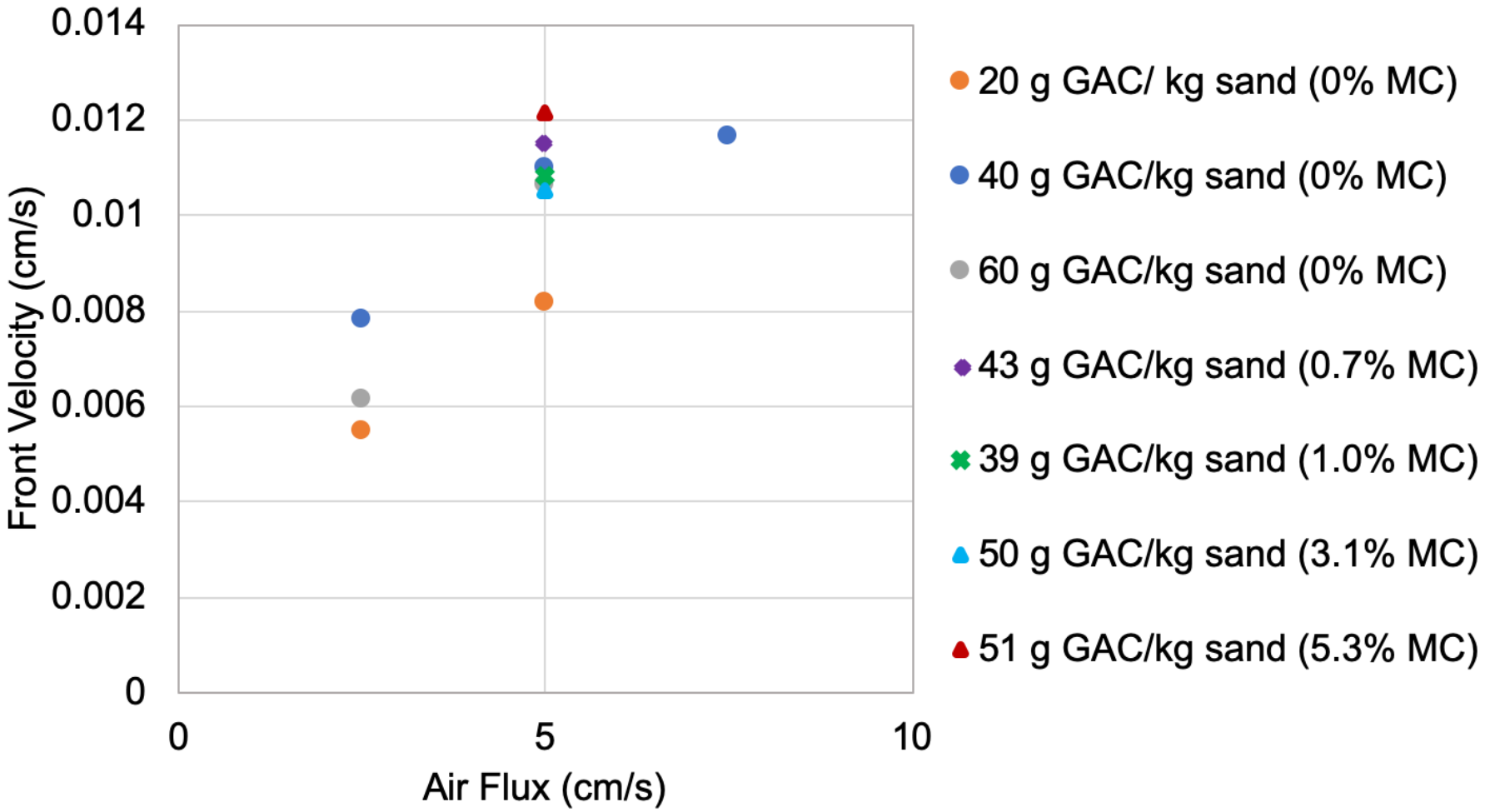
Test 1

Temperature vs. GAC Content/Clean Sand (No PFAS)



Test 1

Front Velocity vs. Air Flux



Tests 2 and 3

PFAS on GAC/Clean Sand

Test	% GAC (w/w)	MC (%)	Average Peak Temperature (°C)	Compound	Initial Concentration[1]	Post Treatment Concentration[2]
2	4.3	14	908	PFOA	591	<0.0004
				PFOS	142	<0.0004
				PFHxS	240	<0.0004
3	3.9	21	950	PFOA	507	<0.0004
				PFOS	122	<0.0004
				PFHxS	221	<0.0004

[1] mg PFAS/kg GAC
[2] mg PFAS/kg ash and sand

Test 4

PFAS on Soil/Clean GAC (3 Compounds)

Compound	% GAC (w/w)	Avg. Peak Temperature (°C)	Initial Concentration[1]	Post Treatment Concentration
PFOA	5.0	1054	13.41	<0.0001[a]
PFOS			23.30	<0.0001
PFHxS			16.86	<0.0001

[1] mg PFAS/kg soil; average of triplicate sample
[a] PFOA concentration of 0.0005 mg/kg in one (of three) samples
Average temperature > 1000°C

Total fluorine captured as HF in emission ~ 31%

Test 5

PFAS on Soil/Clean GAC (6 Compounds)

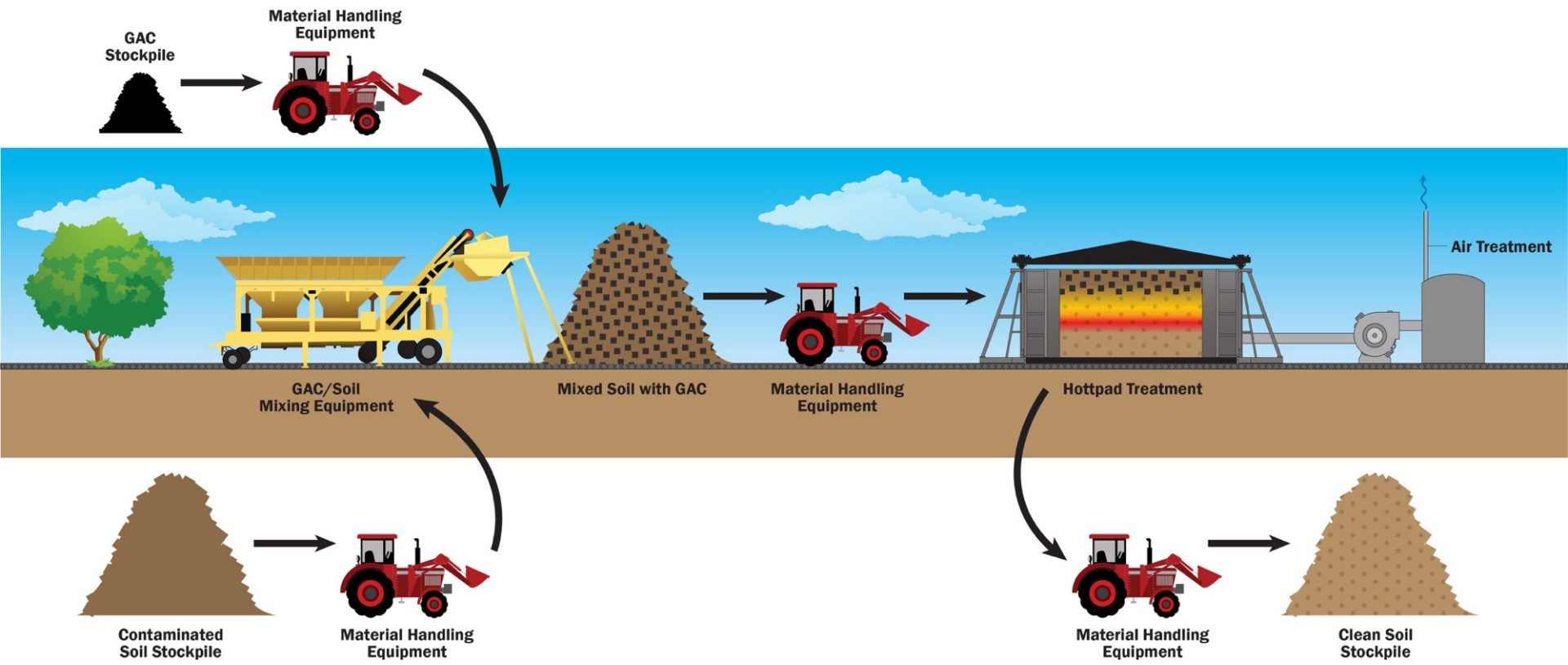
Compound	% GAC (w/w)	Avg. Peak Temperature (ºC)	Initial Concentration[1]	Post Treatment Concentration
PFOA	5.1	1064	14.91	<0.00005
PFOS			10.87	<0.00005
PFHxS			10.84	<0.00005
PFBS			3.19	<0.00005
PFHpA			13.32	<0.00005
PFNA			28.73	<0.00005

[1] mg PFAS/kg soil; average of triplicate sample

- Trace carboxylate PFAS detected in XAD tubes (but no sulfonates)
- PFAS could be captured in off gas by GAC that is recycled for treatment

Potential Application

Ex Situ: Soil or Waste GAC Treatment

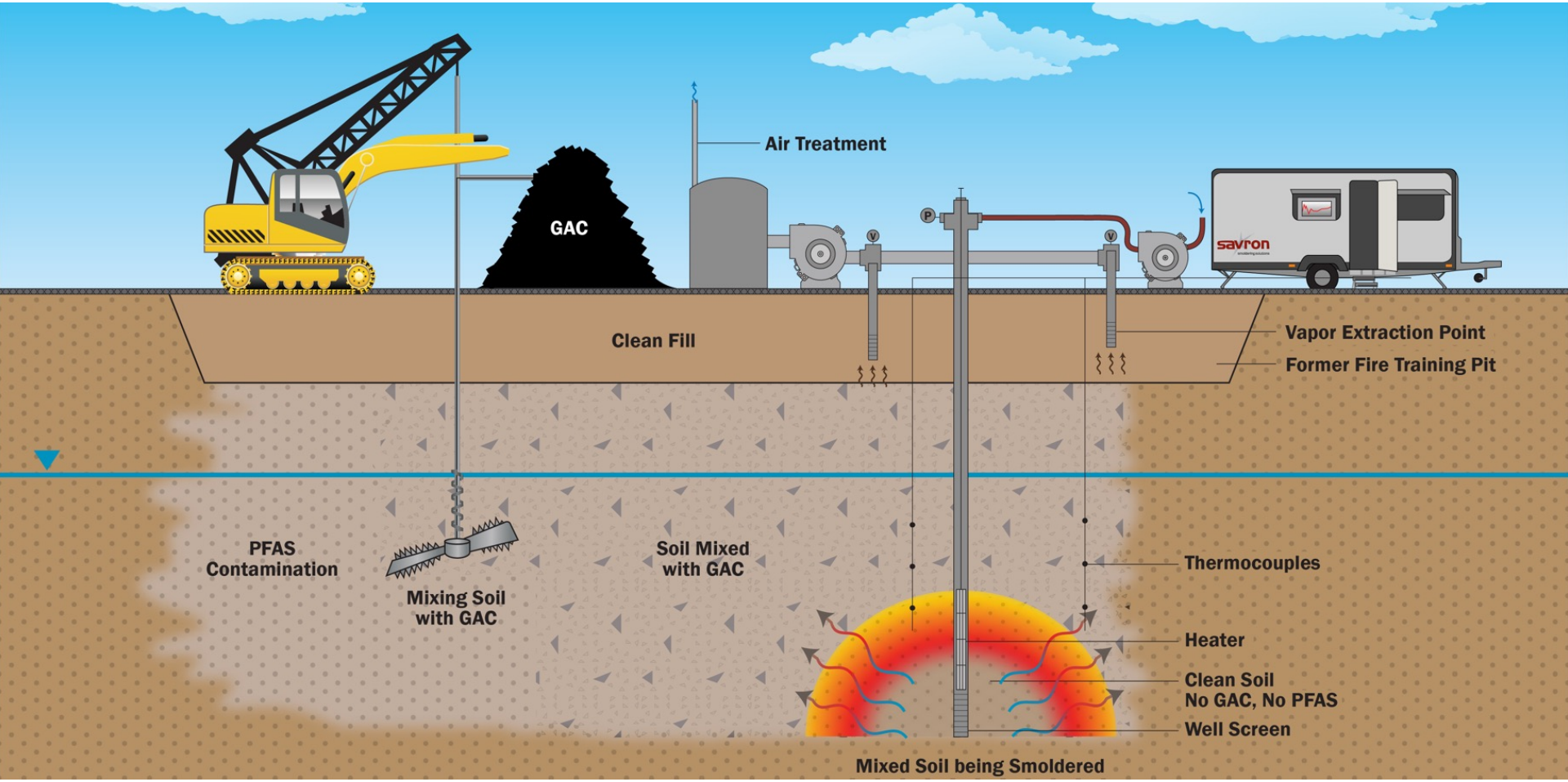


Potential Application

Ex Situ: Soil or Waste GAC Treatment

Potential Application

In Situ Source or Sorbant PRB Treatment



Potential Application

In Situ Source or Sorbant PRB Treatment

Key Takeaways

- Peak temperature is ~ linear with GAC concentration (dial in temperature)
- Smoldering front velocity is ~ linear with air flux
- GAC ~ 40 g/kg soil achieved temperatures > 900°C
- PFAS was below quantification levels in soils, sand and ash
- HF indicates decomposition
- Some PFAS may be present in emissions
  - Capture and re-treat is a viable solution
- In and ex situ applications

Future Work

- Improve mass balance
- Characterization of emissions
- Conditions to enhance mineralization to HF
- Impacts of scaling/heterogeneity
- Field demonstration

Benefits to DoD

- Vast amounts of PFAS-contaminated excavated soils and soil cuttings, and GAC from water treatment are being stockpiled
- Currently, only high cost off-site incineration capable to treat PFAS
- Smoldering could provide a low cost and on-site alternative

For additional information, please visit

https://serdp-estcp.org/Program-Areas/Environmental-Restoration/ER18-1593

Speaker Contact Information

dmajor@savronsolutions.com; 519-515-0860

Q&A Session 2

SERDP DOD • EPA • DOE | ESTCP

The next webinar is on December 12, 2019

Monitoring and Remediating Groundwater Contaminated with Chlorinated Solvents

SERDP DOD • EPA • DOE | ESTCP

Survey Reminder

Please take a moment to complete the survey that will pop up on your screen when the webinar ends

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