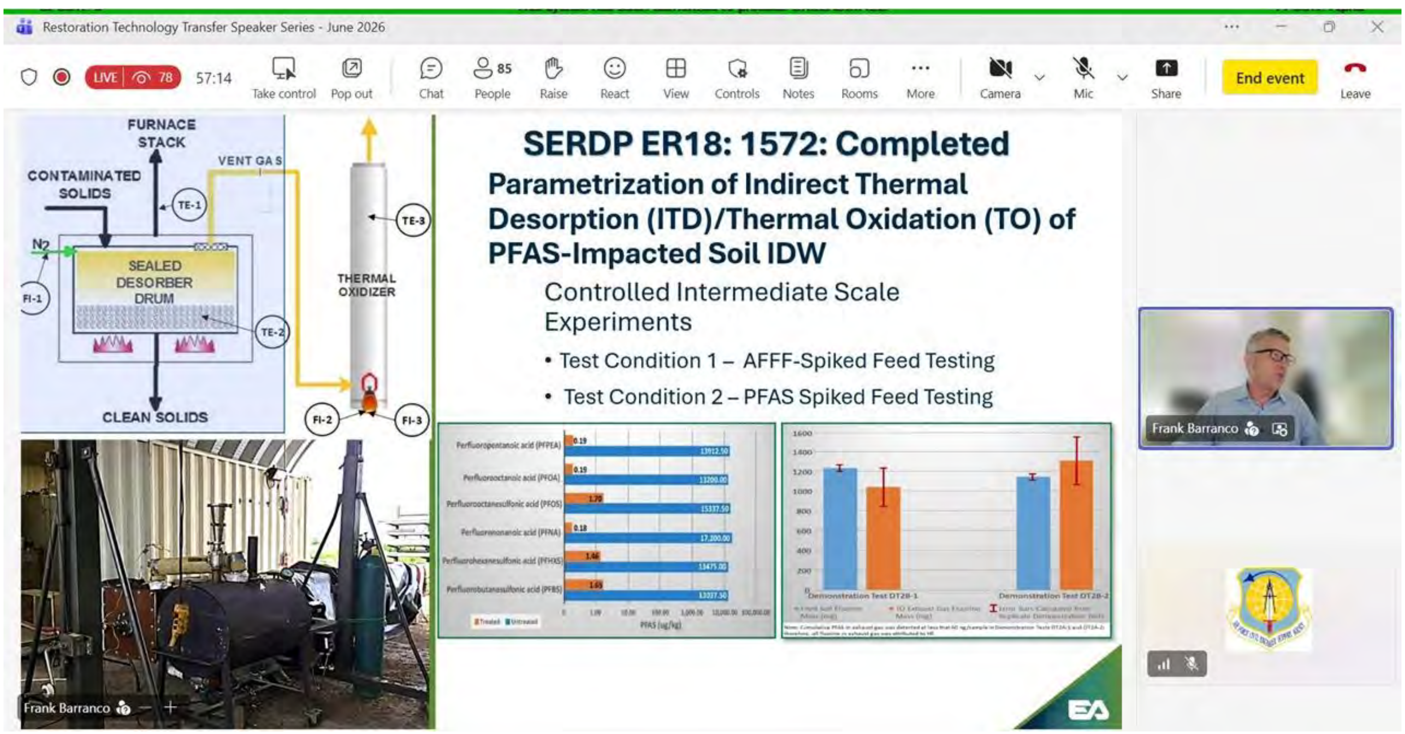
Restoration Technology Transfer Speakers Series
June 2026

Ex Situ Treatment of PFAS-Impacted Solid Media Using Indirect Thermal Desorption Coupled with Thermal Oxidation

Presenters: Dr. Frank Barranco (EA Engineering Science and Technology, Inc.)

This webinar highlighted results from an ESTCP Project ER23-8439 demonstration of a mobile indirect thermal desorption and thermal oxidation (ITD/TO) technology for ex situ treatment of PFAS impacted solid media, including sediments, soils, and biosolids. Using contaminated material from Schriever Space Force Base as a case study, the presentation illustrated the deployment of a batch fed High Performance Thermal Desorption Unit with integrated particulate filtration, high temperature oxidation, and controlled quenching. Performance testing results showed >99.99% destruction and removal efficiency across multiple runs at temperatures ranging from 450-650°C, along with fluorine mass balance closure between 98.5–99.9%. Treated solids exhibited non detectable PFAS levels by EPA Method 1633, demonstrating the technology's reliability, field deployability, and potential to reduce dependence on off-site disposal, lower long term liabilities, and support regulatory confidence in scalable PFAS remediation.



Dr. Barranco discusses intermediate scale experiments of thermal desorption and oxidation technology.

This event and future events are updated and posted on the AFIT website at: https://www.afit.edu/CE/index.cfm.

POCs:
Joseph Dimisa, AFIT (joseph.dimisa@us.af.mil)
Bethany Rowlett, CTR, Booz Allen Hamilton (Rowlett_Bethany@bah.com)
Kurt Lee, AFCEC/CZPR (kurt.lee.3@us.af.mil)

Webinar Structure

	[Restoration Technology Transfer Webinar Series – eDASH Archive]()
5 min	Welcome and Administrative Business
45 min	Main Presentation – *Treatment of PFAS-Impacted Solids Using Indirect Thermal Desorption Coupled With Thermal Oxidation*
10 min	Questions and Answers
5 min	Final Thoughts

Treatment of PFAS-Impacted Solids Using Indirect Thermal Desorption Coupled With Thermal Oxidation

Frank Barranco, PhD, PE, PG, CMQ/OE
EA Engineering, Science and Technology, Inc. PBC

June 2026

Treatment of PFAS-Impacted Solids Using Indirect Thermal Desorption Coupled With Thermal Oxidation

ESTCP ER23-8439

PI: Frank Barranco, PhD, PE, PG, CMQ/OE

Co-PI: Pavankumar Challa Sasi, PhD

June 10th 2026

EA Engineering, Science, and Technology, Inc., PBC

Agenda

- Project Team
- Past Work
- Technical and Performance Objectives
- Site and Equipment Overview
- Test Conditions and Operational Parameters
- Demonstration Test Results
- Next Steps

Project Leadership and Technical Partners

ESTCP

Frank Barranco, PhD – PI
Pavan Challa, PhD – Co-PI
Nate Jones, PE – Project Manager

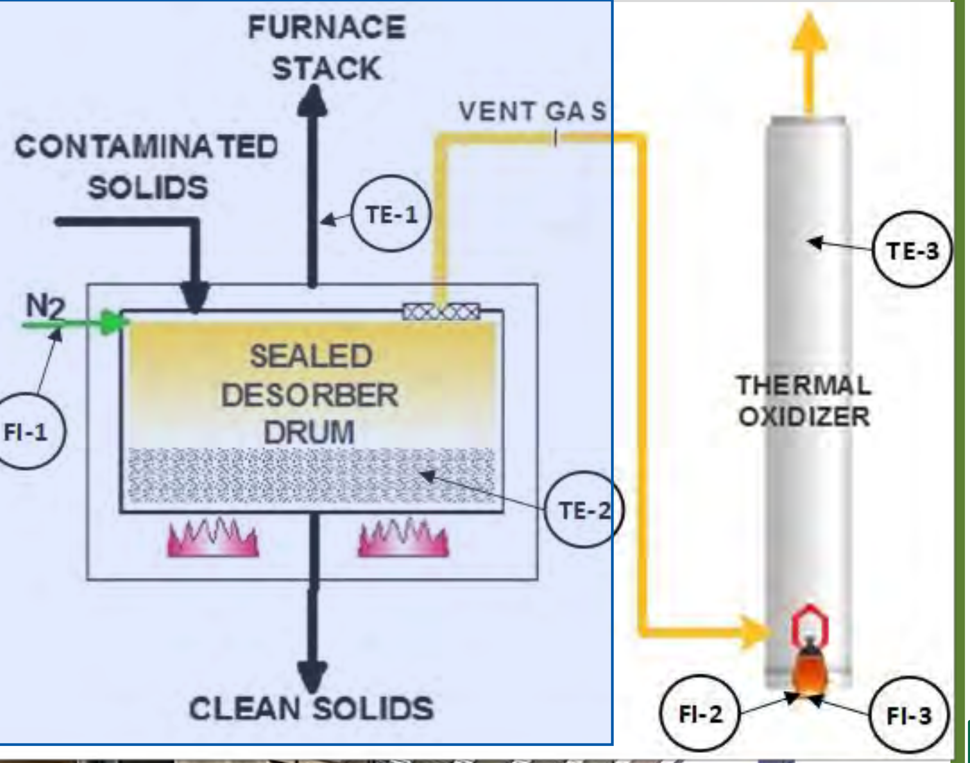
TD*X Associates

Mike Tambroni – Project Manager
Carl Palmer, PE – Thermal Design Engineer
George Hay, PE – Thermal Treatment SME

- Eurofins (commercial lab)
- Stack Testers

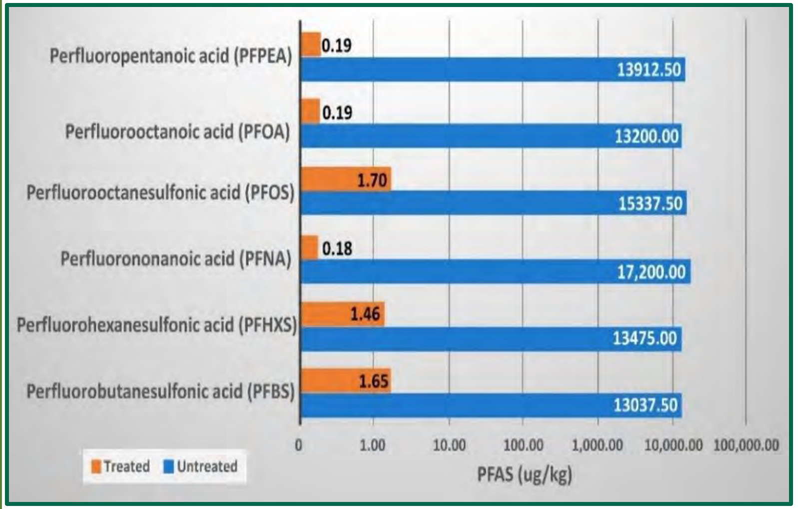
ER18: 1572

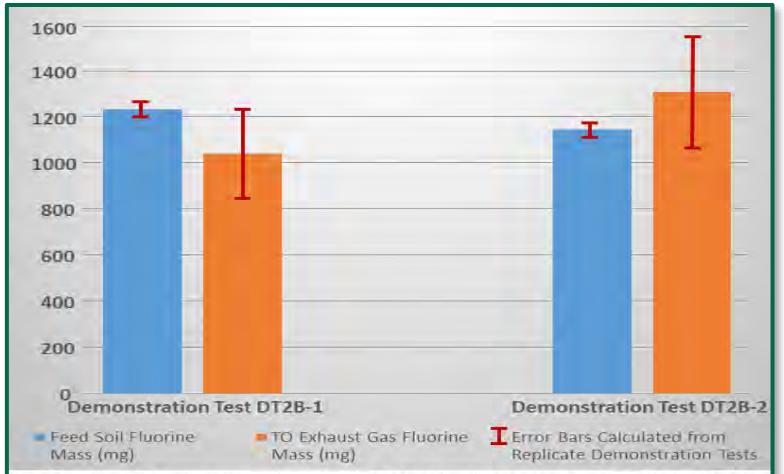
Indirect Thermal Desorption (ITD)/Thermal Oxidation (TO) of PFAS-Impacted Soil IDW



Controlled Intermediate Scale Experiments

- Test Condition 1 – AFFF-Spiked Feed Testing
- Test Condition 2 – PFAS Spiked Feed Testing





Note: Cumulative PFAS in exhaust gas was detected at less that 60 ng/sample in Demonstration Tests DT2A-1 and DT2A-2; therefore, all fluorine in exhaust gas was attributed to HF.

ER23: 8439 - Technical Objectives

Objective:

Employ a small-scale (processing range from tens to hundreds of cubic yards) prototype mobile ITD/TO system that requires minimal onsite infrastructure development and is capable of quick setup and operation to perform onsite destruction of PFAS in contaminated solids.

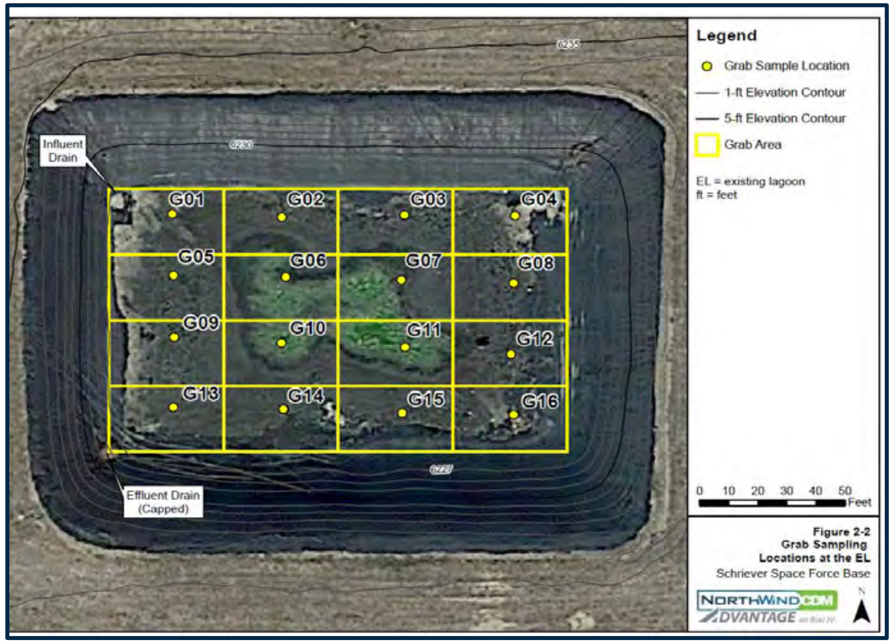
Aims:

- Is the on-site mobile system capable of achieving a destruction removal efficiency (DRE) of 99.99% for the suite of PFAS present in Schriever Space Force Base (SSFB) solids during ITD/TO treatment?
- Can a fluorine mass balance be closed with this mobile treatment system to within +/- 30% (current industry uncertainty) based on accuracy/precision of Hydrogen Fluoride (HF) analyses by EPA Method 026A confirming destruction of PFAS?
- Is the mobile prototype capable of treating PFAS to levels that would potentially allow for unrestricted on-site reuse of treated solids?

Performance Objectives

Performance Objective	Data Requirements	Success Criteria
Mobile ITD/TO treatment of SSFB sediments to low ppb levels of PFAS	**SSFB Solids - Pre & Post-Treatment:** EPA Method 1633	Treated solids with PFAS concentrations below EPA RSLs
Achieve >99.99% DRE for the suite of PFAS	**SSFB Solids - Pre & Post-Treatment:** EPA Method 1633, EOF-CIC, and TOPA **TO Exhaust:** OTM 45, OTM 50, and M 26A	Achievement of >99.99% targeted PFAS DRE for SSFB solids
Achieve fluorine mass balance within ±30% to confirm complete destruction of PFAS	**SSFB Solids - Pre & Post-Treatment:** EPA Method 1633, EOF-CIC, and TOPA **TO Exhaust:** OTM 45, M0010 (OTM 55), OTM 50, and M26A	Achievement of fluorine mass balance between 70% and 130% per SSFB solids batch runs
Achieve industry standard for batch reactors operational robustness criteria	Calculate Mean Time to Failure (MTTF) by tracking Mean Time to Repair (MTTR) and Mean Time Between Failure (MTBF) to assess operational robustness during testing.	Operational robustness goal of 86% or greater

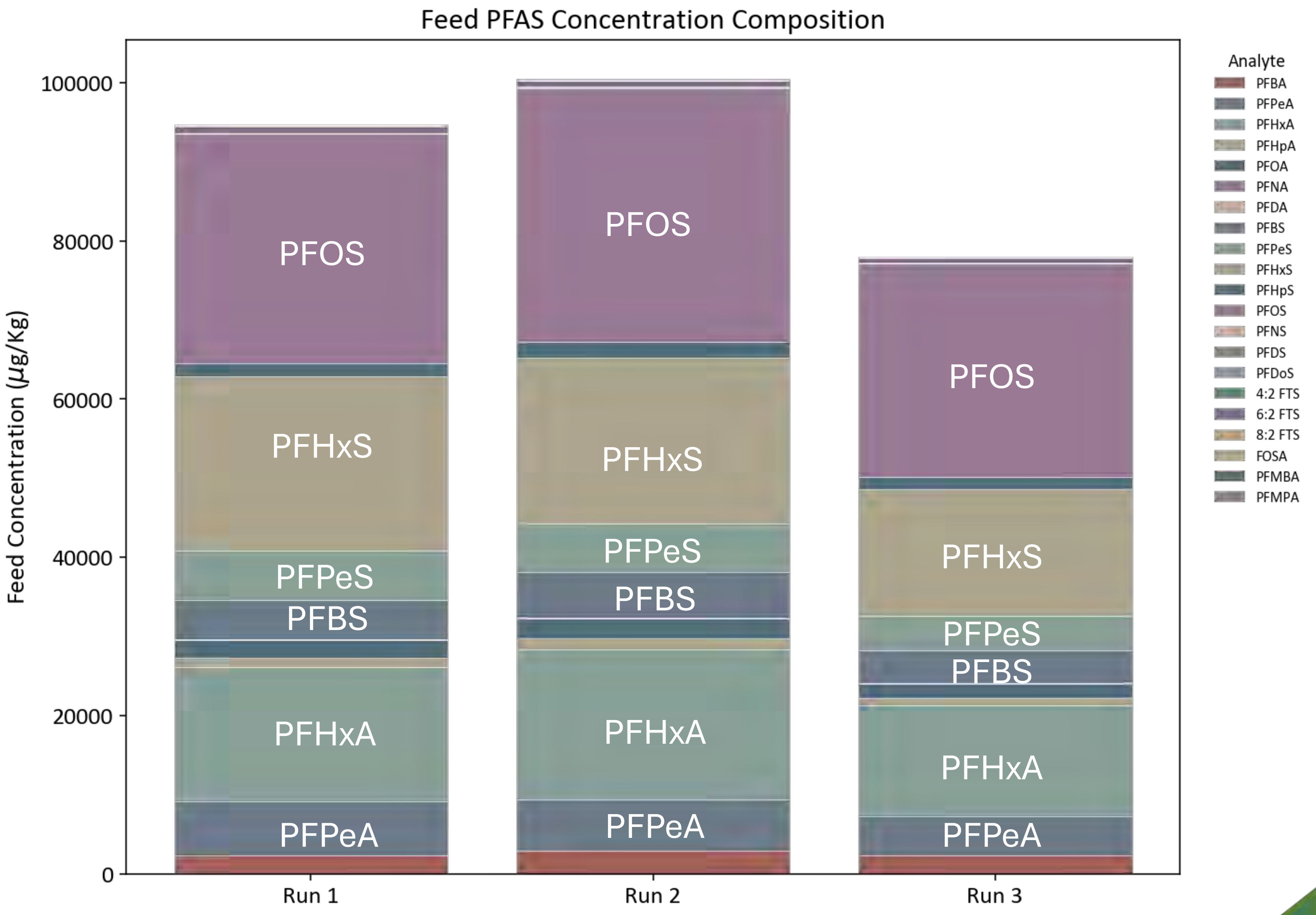
Site Description



- **Location**: Schriever Space Force Base, Colorado Springs, CO
- **Tested Media**: Unconsolidated solids excavated from an existing lagoon which received AFFF (nozzle/spray testing), sludge (sewage overflow), and stormwater (shallow ponding)
- **Media Makeup**: Significantly elevated PFAS (up to 265 mg/kg), TOC (up to 95%), and calcium and sodium (up to 26,000 mg/kg and 19,000 mg/kg, respectively)

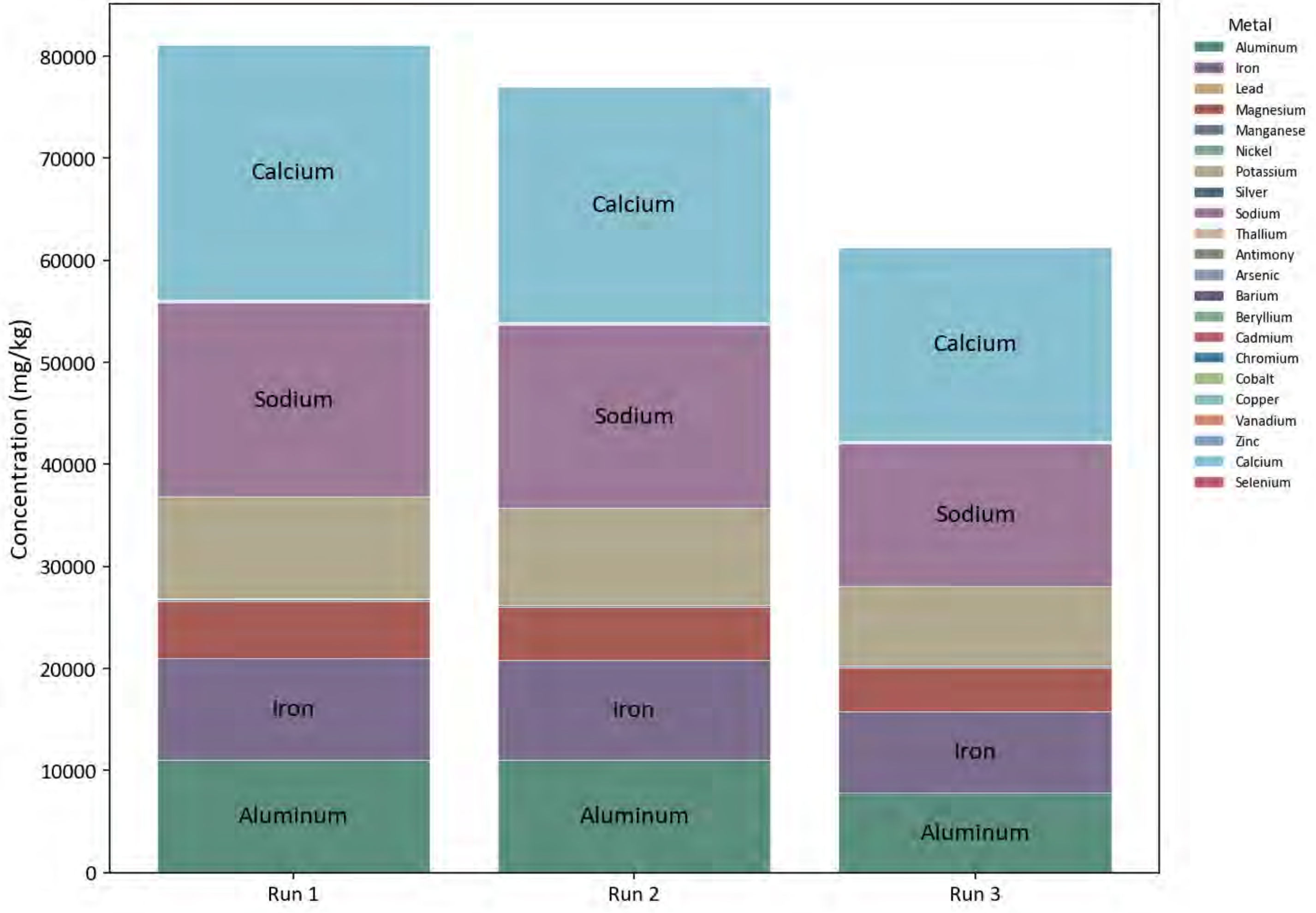
Feed PFAS Concentrations

EPA Method 1633

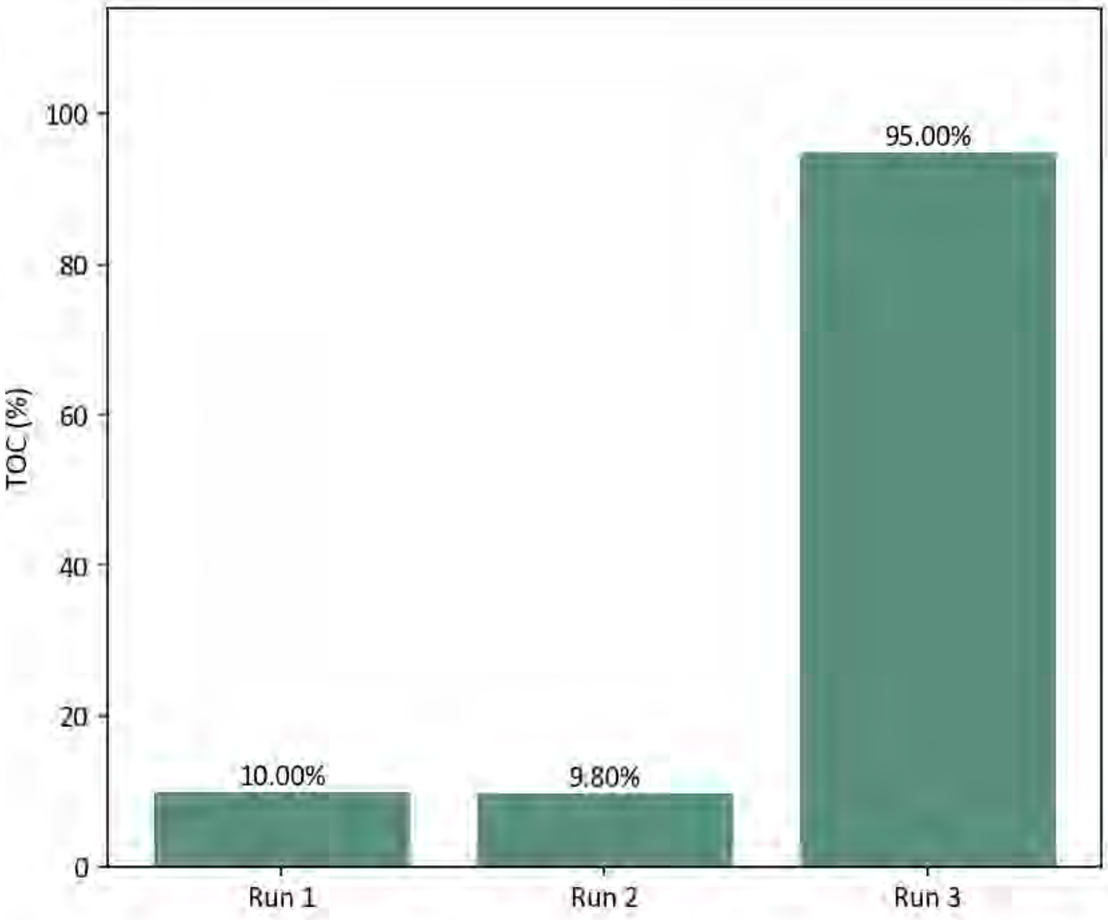


Metals and TOC Feed Concentrations

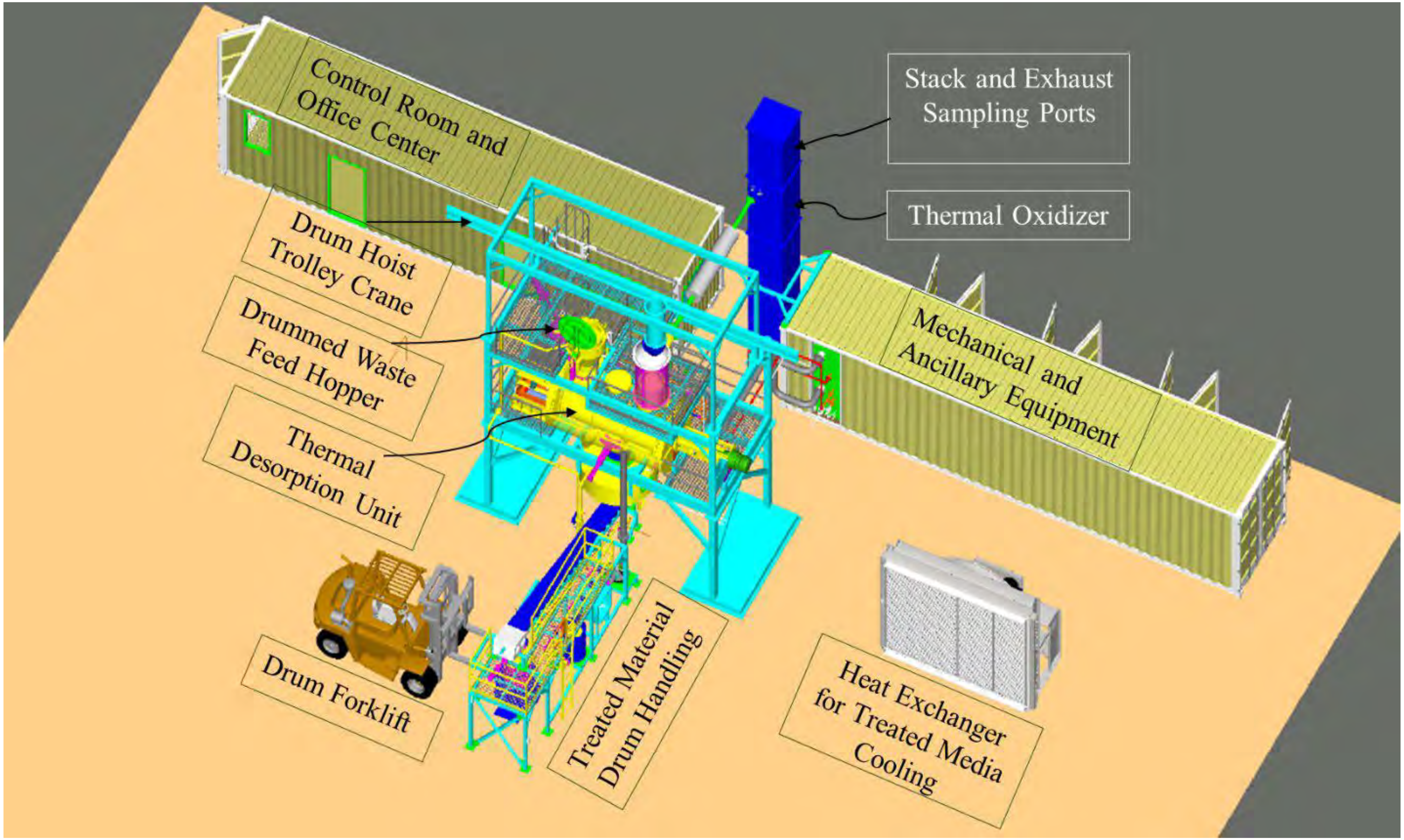
Metals



TOC



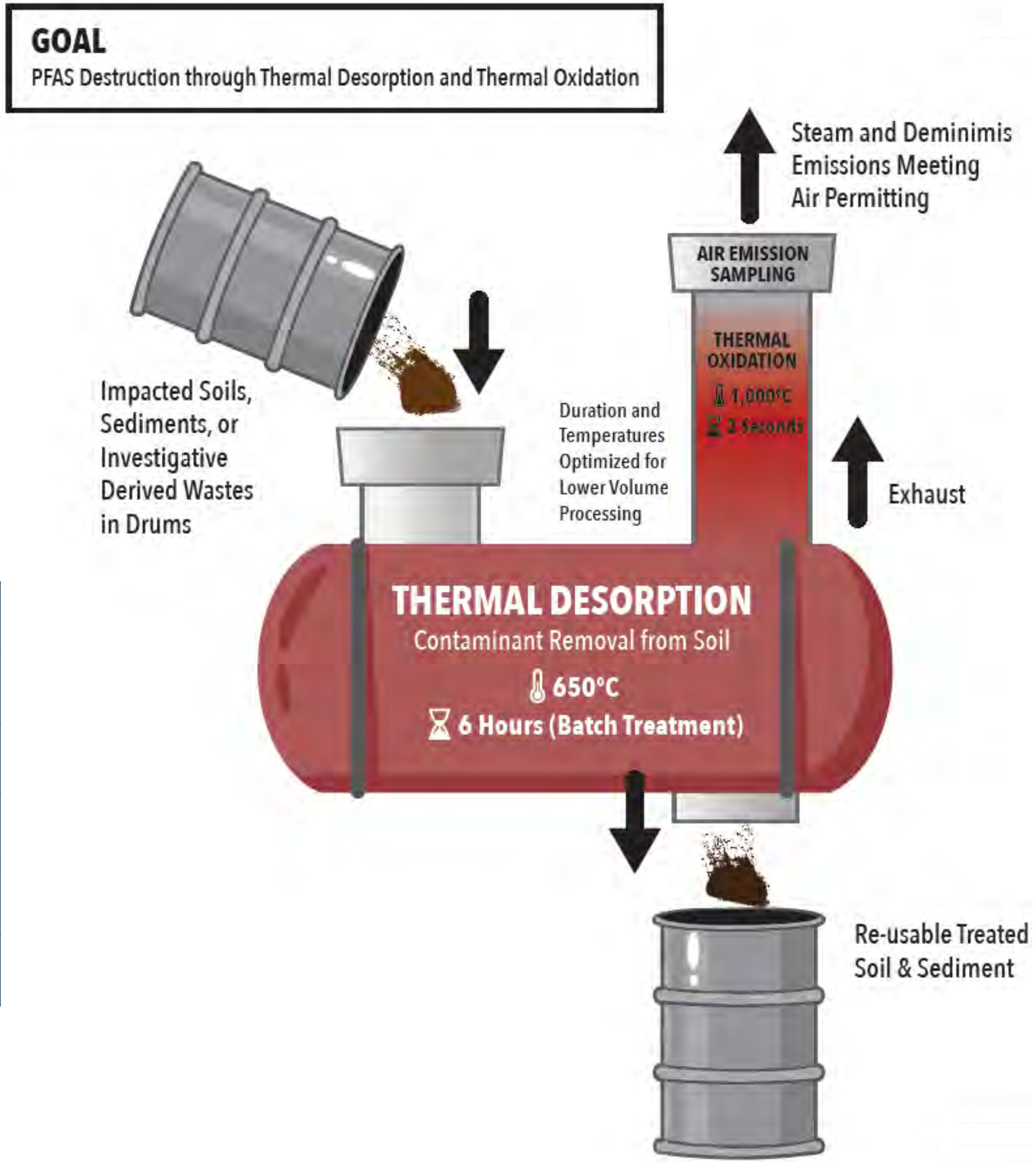
Demonstration Site Setup Schematic



Technology/Equipment Overview

Maximum Freight Weight:	**44,000 pounds**
Maximum Freight Dimensions:	Length 37 feet
	Width 8.5 feet (102”)
	Height 9.5 feet (114”)

Utility	Consumption
Water	8.5 gal/min
No. 2 Fuel Oil	50 gal/hr
Nitrogen (Dryer Carrier Gas)	20 scfm
Electricity – 3 phase 480V/460A	100 kW
Compressed Air	10 scfm, 80 psig

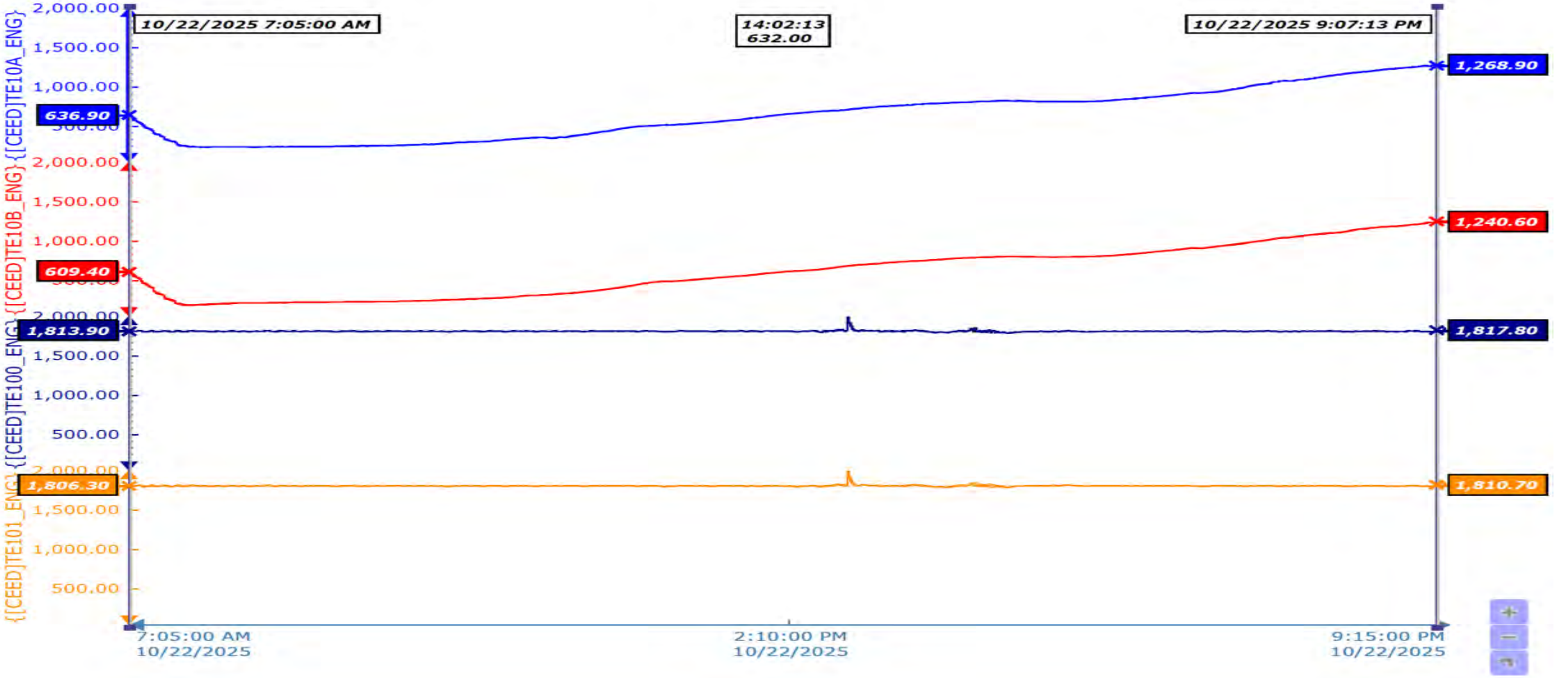


Demonstration Test Design – Operational Parameters

Test Run	Volume (Drums)	TD Temperature (°C)	TD Duration (hours)	TO Temperature (°C)	TO Duration (seconds)
1*	5	650	14.0	1000	2
2*	5	650	12.0	1000	2
3*	5	650	11.5	1000	2
ADD	5	650	11.0	1000	2

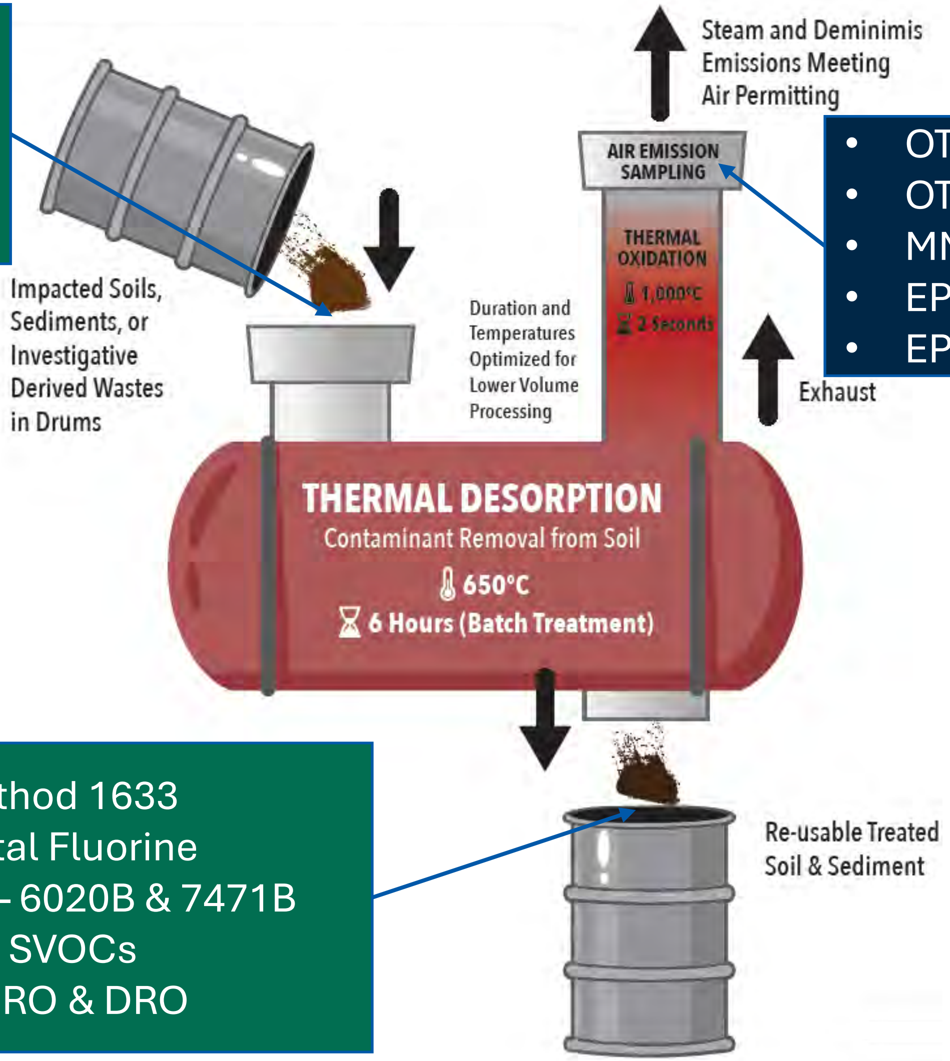
* Exhaust sampling conducted

Test Run 2: TD and TO Temperature Profiles (degrees F)



Test Design - Analytical

- EPA Method 1633
- EOF, Total Fluorine
- Metals – 6020B & 7471B
- VOCs & SVOCs
- TPH – ORO & DRO



- OTM 45
- OTM 50
- MM0010 (OTM 55)
- EPA Method 26A
- EPA Method 0060

- EPA Method 1633
- EOF, Total Fluorine
- Metals – 6020B & 7471B
- VOCs & SVOCs
- TPH – ORO & DRO

Demonstration Test – Feed Solids Sampling

- Drums were segregated by individual test run. Composite samples were collected from the drums associated with each test run. A hand auger was used to collect material across the full depth of each drum, after which the material was homogenized and composited.
- Laboratory sample containers were filled using the composite material from each test run, packed in coolers, and shipped overnight to the laboratory.

Demonstration Test –Treated Solids Sampling

- Due to elevated temperatures, treated solids were sampled by the TDX team using stainless steel containers and allowed to cool overnight prior to compositing (solids were visibly glowing red at the time of collection).
- The following morning, cooled materials were composited into laboratory sample containers, packed in coolers, and shipped overnight to the laboratory.

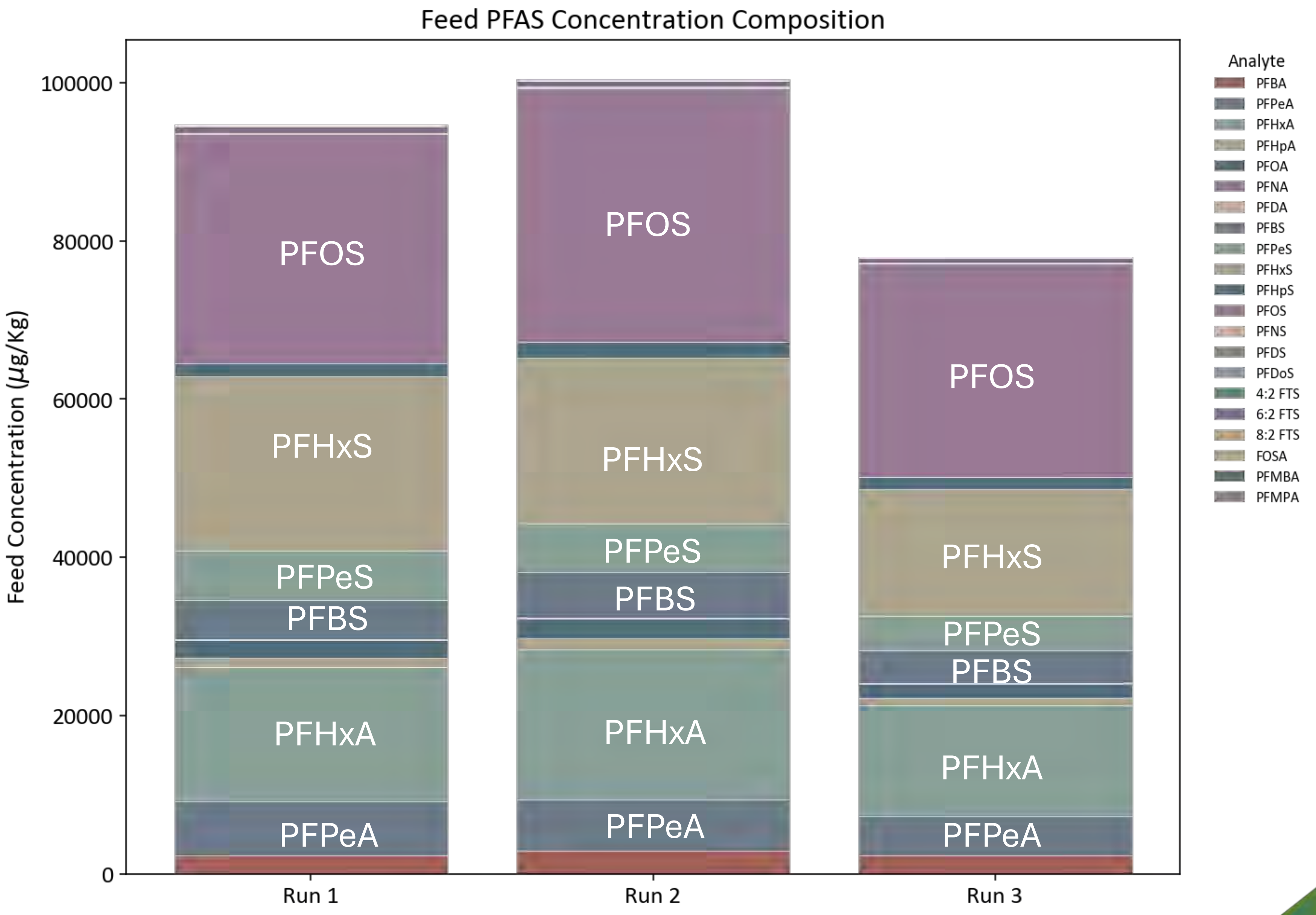
Feed vs Treated Solids

QA/QC

- <u>Solids QA/QC</u>: Included field duplicates, trip blanks, equipment blanks, and matrix spike/matrix spike duplicates (MS/MSDs) for both feed and treated solids.
- <u>Exhaust QA/QC</u>: Each air method incorporated required QA/QC elements, including proof blank trains, field blank trains, and method-specific blank checks in accordance with protocol requirements.

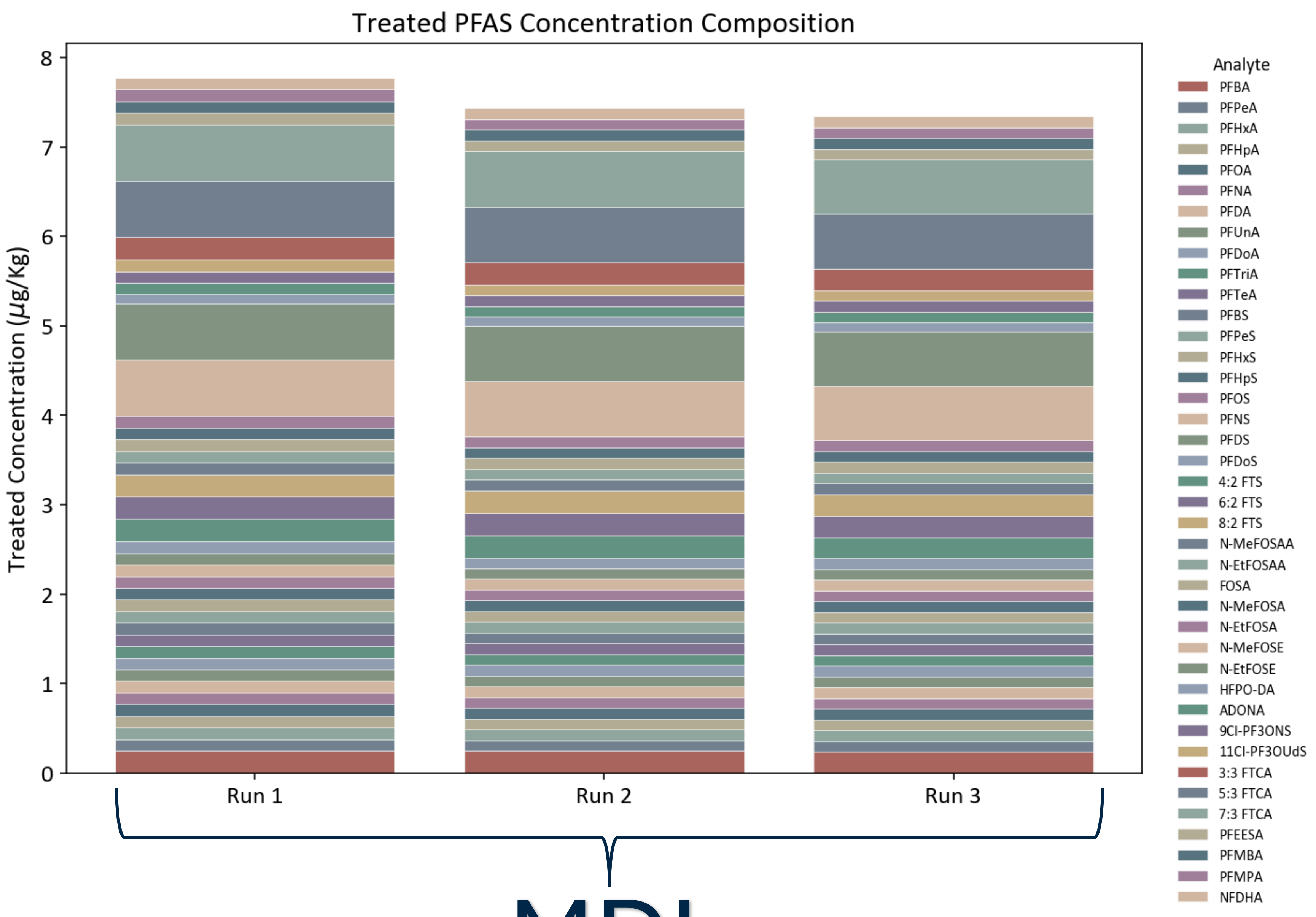
Feed PFAS Concentrations

EPA Method 1633



Treated PFAS Concentrations

EPA Method 1633



MDLs

How does this compare to RSLs?

Comparison of Treated Solids Concentration to DoW-Recognized Soil RSLs

Chemical	Chemical Abbreviation	CAS RN	DoW Screening Levels – Residential Soil (µg/Kg)*	Treated Solids – EPA 1633 (µg/Kg)
Hexafluoropropylene Oxide Dimer Acid	HFPO-DA (GenX)	13252-13-6	23	<0.1
Perfluorobutanoic Acid	PFBA	375-22-4	7,800	<0.25
Perfluoropropanoic Acid	PFPrA	422-64-0	3,900	-
Perfluorohexanoic Acid	PFHxA	307-24-4	3,200	<0.13
Perfluorooctanoic Acid	PFOA	335-67-1	0.070[a]	<0.13
Perfluorononanoic Acid	PFNA	375-95-1	19	<0.13
Perfluorodecanoic Acid	PFDA	335-76-2	0.06[a]	<0.13
Perfluorobutanesulfonic Acid	PFBS	375-73-5	1,900	<0.13
Perfluorohexanesulfonic Acid	PFHxS	355-46-4	130	<0.13
Perfluoroocatanesulfonic Acid	PFOS	1763-23-1	0.63[b]	<0.13
Bis(trifluoromethylsulfonyl)amine	TFSI	82113-65-3	2,300	-

* – https://www.acq.osd.mil/eie/eer/ecc/pfas/docs/policies/Memo-for-Investigating-DoD-PFAS-Cleanup.pdf

a – Certain PFAS RSLs have EPA-approved analytical methods, but with values that are below the method detection limit (MDL) . For PFAS with RSLs below the MDL that do not have an MCL, DoW uses the method's pooled MDL to establish consistent and measurable values.

b – Certain PFAS RSLs have EPA-approved analytical methods and with RSLs higher than the established MCL. For PFAS with RSLs above the MCL, DoW uses the MCL as the screening level.

Stack PFAS Concentrations

- OTM 45
- OTM 50
- OTM 55 (MM0010)

- OTM 45 – Targets 49 semi-volatile PFAS
  - ≤ MDLs for all test runs
- OTM 50 and OTM 55
  - ≤ MDLs for all test runs

Destruction Efficiency (DE) Vs Destruction Removal Efficiency (DRE)

$$DE = \frac{W_{in} - Wout}{W_{in}}$$

W_{in} – Mass Feed Rate of a particular POHC

W_{out} – Mass rate of the same POHC in *residuals and emission*

POHC – Principal Organic Hazardous Contaminant

$$DRE = \frac{W_{in} - Wout}{W_{in}}$$

W_{in} – Mass Feed Rate of a particular POHC

W_{out} – Mass *emission* rate of the same POHC

Destruction Removal Efficiency (DRE) and Destruction Efficiency (DE)

Highest Feed Concentrations (ug/kg)

Analyte	Run 1	Run 2	Run 3
PFHxA	17000	19000	14000
PFOA	2200	2500	1800
PFHxS	22000	21000	16000
PFOS	29000	32000	27000

Destruction and Removal Efficiency

	Run 1	Run 2	Run 3
PFBA	99.99757	99.99827	99.99757
PFPeA	99.99986	99.99987	99.99981
PFHxA	99.99994	99.99995	99.99993
PFHpA	99.99778	99.99829	99.99713
PFOA	99.99956	99.99965	99.99946
PFNA	99.98831	99.98949	99.98613
PFDA	99.92538	99.93290	99.89987
PFBS	99.99981	99.99985	99.99976
PFPeS	99.99985	99.99986	99.99978
PFHxS	99.99996	99.99996	99.99994
PFHpS	99.99939	99.99956	99.99935
PFOS	99.99997	99.99997	99.99996
PFNS	99.94894	99.96035	99.94604
PFDS	99.97147	99.97642	99.97057
PFDoS	99.97147	99.97763	99.97143
4:2 FTS	99.98885	99.99273	99.98458
6:2 FTS	99.99867	99.99864	99.99812
8:2 FTS	99.98802	99.98736	99.98506
FOSA	99.98910	99.99072	99.98755
PFMBA	99.94611	99.95154	99.91906
PFMPA	99.94611	99.95409	99.93063

Destruction Efficiency

	Run 1	Run 2	Run 3
PFBA	99.99049	99.99206	99.98998
PFPeA	99.99861	99.99854	99.99806
PFHxA	99.99944	99.99950	99.99931
PFHpA	99.99072	99.99211	99.98774
PFOA	99.99571	99.99619	99.99461
PFNA	99.88622	99.88535	99.86146
PFDA	99.27354	99.26803	99.00024
PFBS	99.99811	99.99833	99.99763
PFPeS	99.99850	99.99847	99.99780
PFHxS	99.99957	99.99955	99.99939
PFHpS	99.99410	99.99524	99.99353
PFOS	99.99967	99.99970	99.99964
PFNS	99.50295	99.56747	99.46124
PFDS	99.72224	99.74282	99.70613
PFDoS	99.72224	99.75601	99.71477
4:2 FTS	99.80154	99.84267	99.70755
6:2 FTS	99.97880	99.97363	99.96802
8:2 FTS	99.78684	99.72639	99.71655
FOSA	99.89389	99.89877	99.87567
PFMBA	99.47534	99.47136	99.19186
PFMPA	99.47534	99.49918	99.30731

DRE and DE %

>99.99

99.9–99.99

99–99.9

<99

Fluorine Balance Analysis

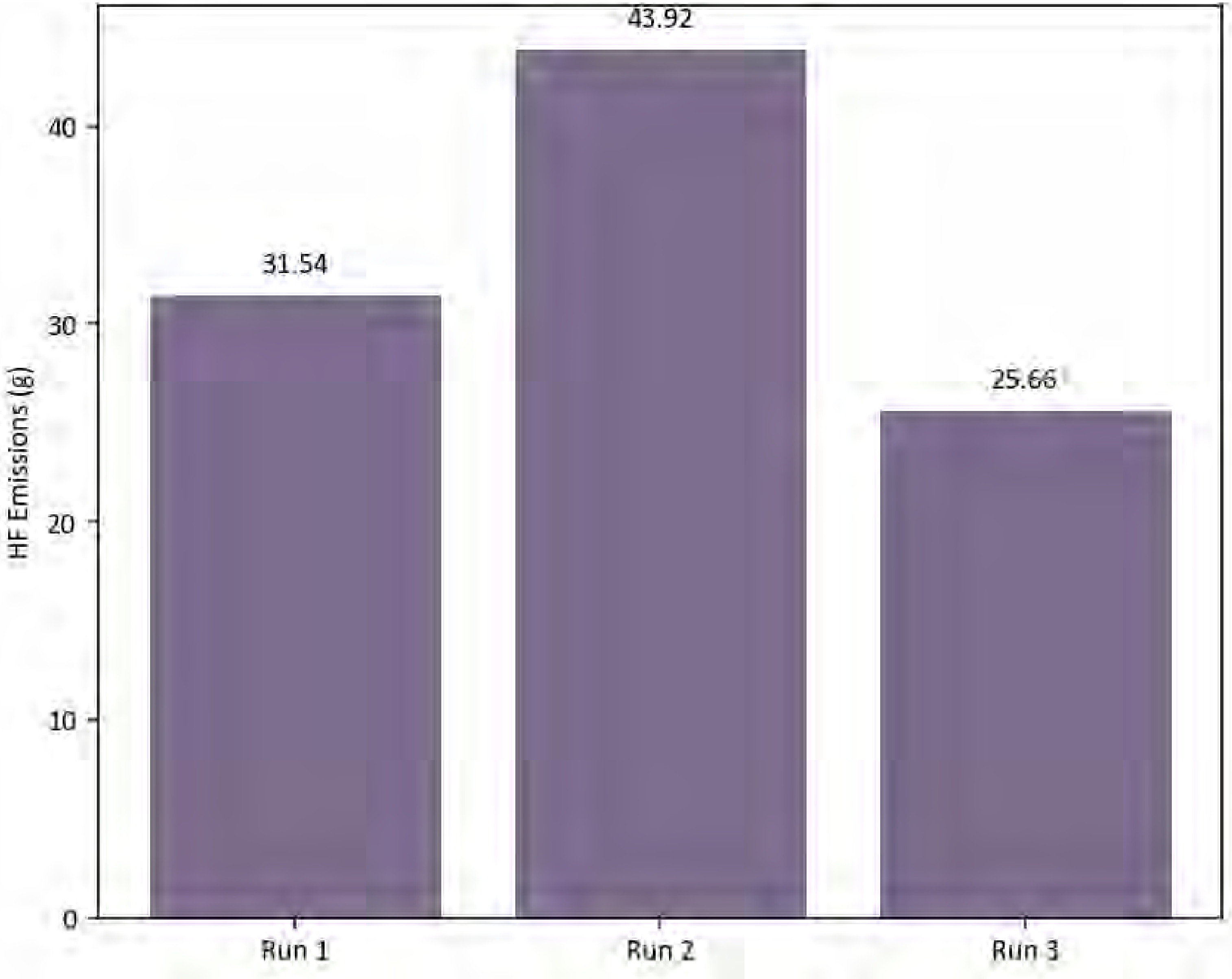
Fluorine Mass In vs Fluorine Mass Out

Why Perform a Fluorine Mass Balance?

- PFAS thermal treatment systems transform fluorinated compounds into multiple fluorine-containing species.
- Conventional targeted PFAS analysis alone does not fully account for fluorine fate during treatment.
- A fluorine mass balance provides a more complete understanding of:
  - PFAS destruction,
  - fluorine transformation pathways,
  - atmospheric emissions,
  - and residual fluorine partitioning.

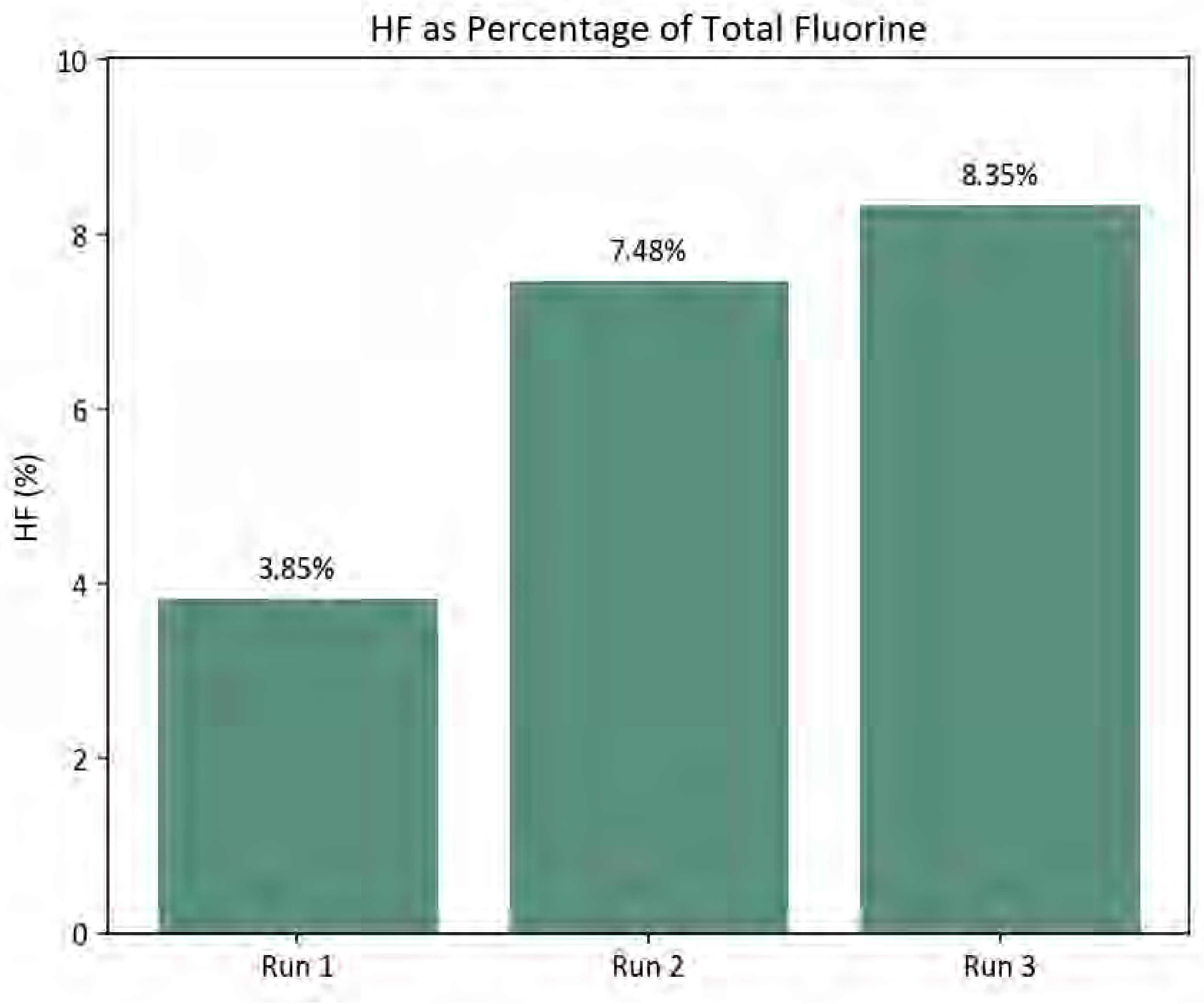
Hydrogen Fluoride (HF) Emissions

Method 26A



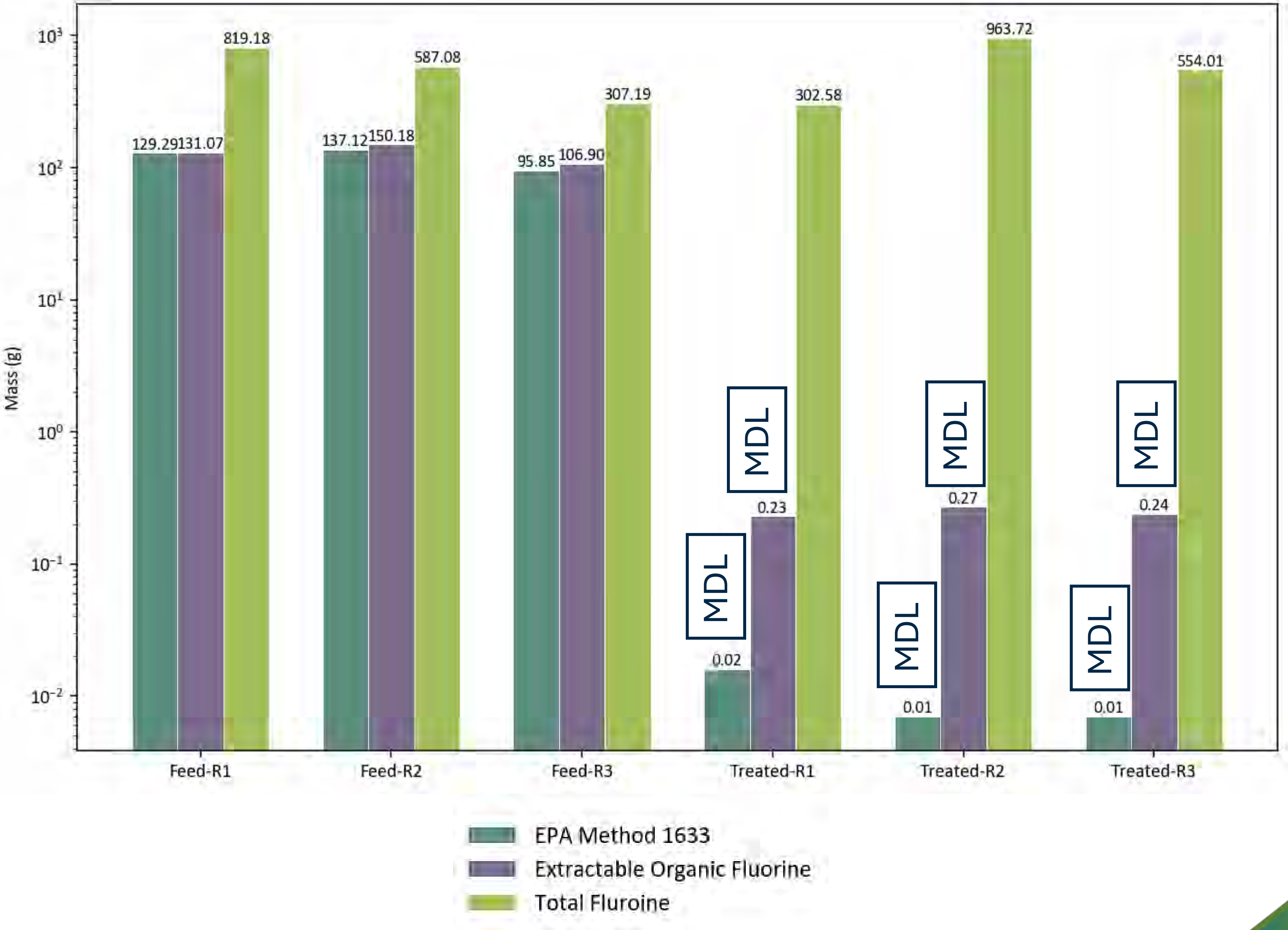
Hydrogen Fluoride (HF) Emissions

As a percent of Total Fluorine in Feed Solids



Feed vs Treated – EPA 1633, EOF, and TF

Mass Trends



Key Points

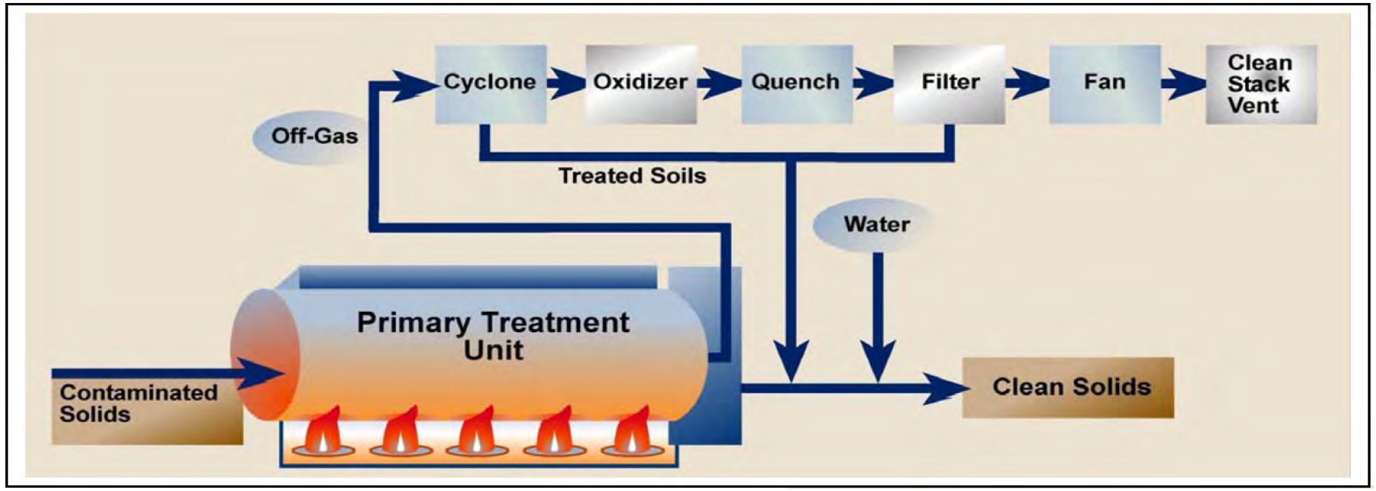
- Demonstration test completed successfully with minimal operational interruptions.
- Results indicate complete destruction of PFAS in SSFB solids.
- Stack data show limited Hydrogen Fluoride, no targeted Potentially Incomplete Destruction Organofluorine Byproducts (OTM 50 and 55) in exhaust.
- Due to elevated calcium content in feed, strong likelihood of Inorganic Fluorine capture in treated solids as calcium fluoride.
- Additional analytical testing (e.g., NMR) to be conducted to confirm Inorganic Fluorine fate.
- Data validation and fluorine mass balance evaluations are ongoing.

Next Steps

- Additional analysis of samples to assess how fluorine is bound on the treated solids.
- Cost analysis based on detailed cost and performance data collected during construction, shakedown, and execution of the demonstration test.
- **Cost Elements:** Mobilization and site setup, fuel and utility consumption, system operation and labor, average throughput rates, teardown, and demobilization.
- Demonstration data will be normalized to develop unit treatment costs (e.g., **$/yd^3 treated**) representative of prototype system performance.
- Measured throughput, cycle times, and operating conditions will be used to extrapolate costs to larger-scale batch or continuous treatment systems.
- **Economies of Scale:** Additional full-scale tests and **c**ost modeling will evaluate how increased treatment volumes reduce unit costs and identify conditions where larger deployments become more cost-effective.

Future Work: ER21-5119 Onsite Demonstration of TD-TO for Destruction of PFAS-impacted Soils

- Soil treatment performed in Primary Treatment Unit, or Thermal Desorption Unit (TDU), where contaminants aggressively desorbed, vaporized, and transferred via off-gas to a Secondary Treatment Unit (STU), comprised of a high-temperature TO.
- TO just one feature of a robust Air Pollution Control (APC) train consisting of a cyclone separator (for initial particulate control), TO (for contaminant destruction), a quench chamber (for exhaust gas cooling), and baghouse for final particulate filtration (dust removal).
- For the soil treatment, a direct-fired TDU will be operated at a target temperature of 600ºC - 650ºC and TDU residence time ranging from 8 to 15 mins.



Process Flow for a Typical TD/TO System

Similar TDU Setup

QUESTIONS

Project Website

Frank Barranco, Ph.D.
Principal Investigator
Phone: (410) 584-7000

Pavan Challa, Ph.D.
Co-Principal Investigator
Phone: (443) 646-8060

Your Success is Our Mission!