PFAS in Soil: Promising, Realistic, and Affordable Solutions

Moderator: Kevin Olness, PG, WSP

Speakers:

- Stewart Abrams, Principal/Vice President, Langan
- Gorm Heron, Chief Technology Officer, TRS Group
- Dora Chiang, Global Principal, Jacobs

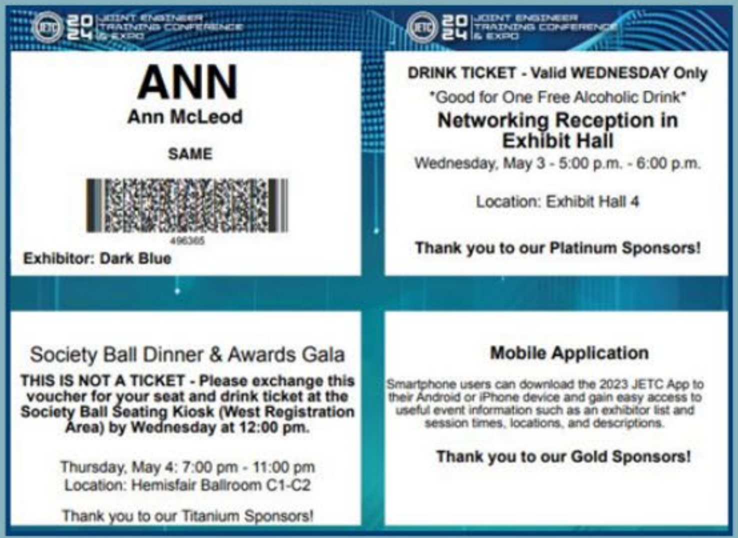
May 14, 2024, 10:30 a.m.

HOUSEKEEPING ITEMS

- Take Note of Exits
- Silence Your Mobile Devices
- Presentations and Audio Recordings will be available in the Attendee Service Center until August 30, 2024
- Download your PDH record in the Attendee Service Center before August 30, 2024

Opening Reception at Universal CityWalk

(Minimum age 18 - No Children)



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MODERATOR

Kevin Olness, PG

WSP

Vice President,
National Director of Emerging Contaminants/PFAS Program

Fun Facts

- Sports Teams: WVU Mountaineers, Steelers
- Vaca Spot: Wife's Family Farm
- Did you Know…Two Boys (3 and 5 years old)
- Hobbies: DGGG (Disc Golf, Guitar and Gardening)

Joint Engineer Training
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SPEAKER

Stewart Abrams, P.E.

Langan Engineering

Senior Consultant
Remediation Technology Director

Fun Facts

- NY Yankees, Philadelphia Eagles*
- House in the Poconos
- BS Civil Eng'g, BA Political Science*, MS Environmental Science
- Bicycling, Skiing

**Yes, I know these are odd combinations ☺*

JETC
Joint Engineer Training Conference & Expo

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SPEAKER

Gorm Heron

TRS Group

Chief Technology Officer

Fun Facts

- Arsenal, Arsenal, Arsenal!!!
- Italy, Hawaii
- 21-acre farm in New Hampshire

JETC
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SPEAKER

Dora Chiang Jacobs

Global Principal, PFAS and Emerging Contaminants

Fun Facts

- Ph.D. from Georgia Tech (Go Jackets!)
- World Traveler
- Grew up in Taiwan
- Love gardening but not good at it

Available and Conventional Soil Remediation Technologies for PFAS

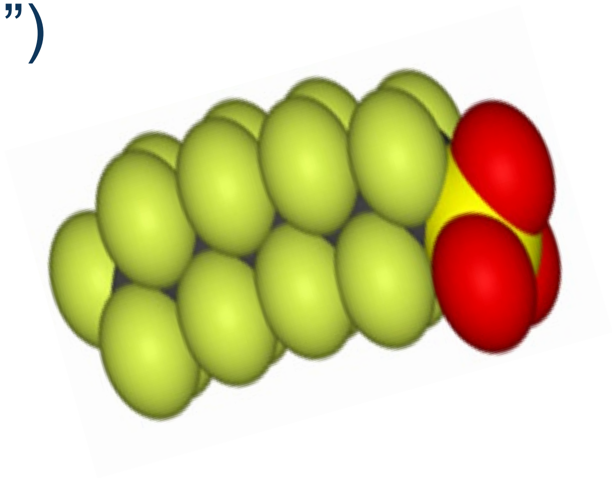
Stewart Abrams, P.E.
Langan Engineering

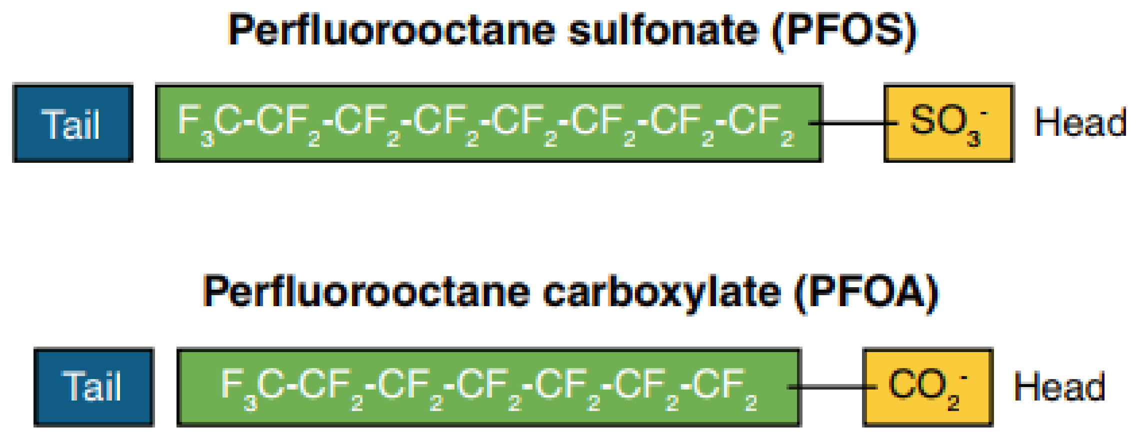
Outline

- PFAS Chemistry
- Emerging Regulatory Framework for Soils
- Excavation and Disposal
  - Landfilling
  - Incineration
- Capping and Institution Controls
- In-Situ Activated Carbon
- Solidification/Stabilization
  - Conventional and Enhanced
- Biosolids
  - Disposal
  - Land Application
- Thoughts

Basic PFAS Chemistry

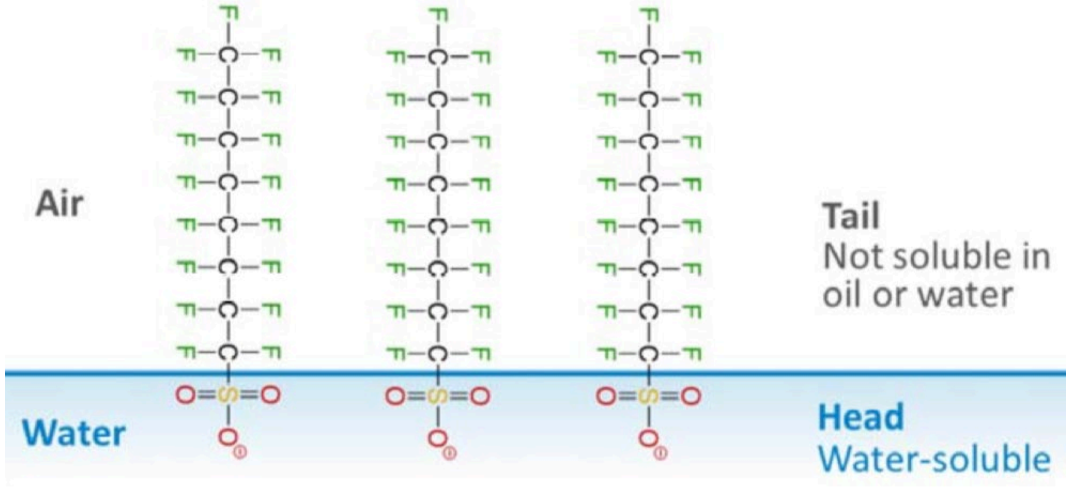
- Per- and Poly- Fluoroalkyl Substances (PFAS)
  - Fully ("per") fluorinated chain (2 or more carbon "tail")
  - Functional group ("head")
    - Sulfonate group (SO_3^-)
    - Carboxylate group (COO^-)

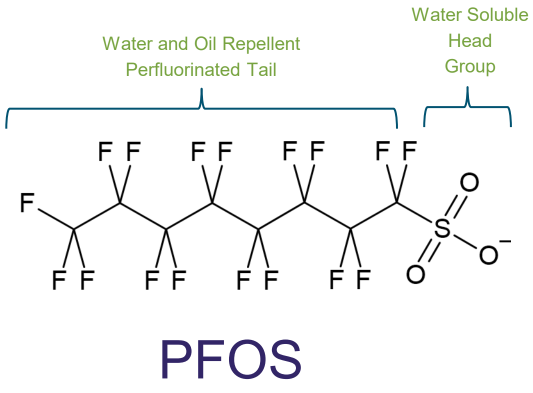


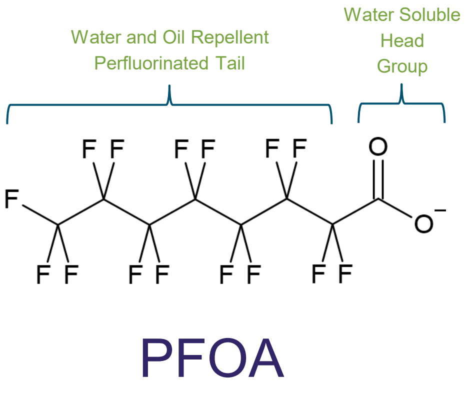


Source: ITRC Naming Conventions and Physical Chemical Properties fact sheet

Chemical Characteristics



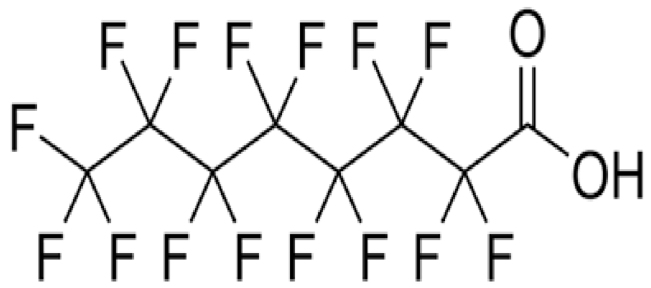




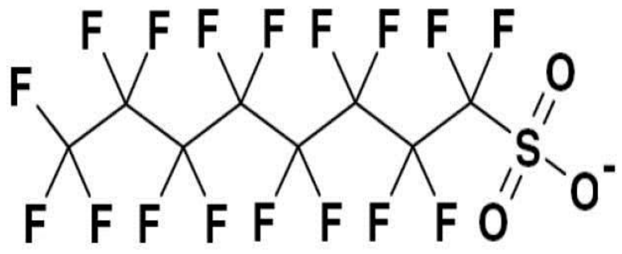
- PFAS are surfactants
- Behavior at water/air interface due to electrostatic forces
- Diffusion, co-contaminants and naturally occurring organics complicate fate and transport.
- Perfluorinated compounds are recalcitrant (do not readily breakdown). Often called "*Forever Chemicals*" in the media.

Key Issues for PFAS Remediation

- There is no “magic bullet”
- C-F bond exceptionally difficult to break
- Bioremediation may be impossible
- Focus of presently available technologies is immobilization and separation



PFOA



PFOS

Public Policy Actions

- On April 10, 2024 EPA announces new drinking water MCLs on six PFAS.
- These final MCLs are lower than any state or foreign country has enacted to date.
- MCLs will drive other standards, notably groundwater and soil.

Compound	MCL (ppt)
PFOA	4
PFOS	4
PFHxS	10
PFNA	10
"GenX"	10
Mixtures: PFHxS, PFNA, HFPO-DA, PFBS	Hazard Index ≤ 1.0

Public Policy Actions

April 19, 2024, EPA designated PFOA and PFOS as Hazardous Substances under CERCLA. Triggers the following :

- Notification for releases
- Phase 1 Site Assessments to include PFOA and PFOS

April 9, 2024 EPA Interim Guidance on PFAS Disposal and Destruction issued:

- Underground injection
- Landfilling and disposal
- Incineration
- Research and Data Needs

Specific PFAS proposed RCRA hazardous listing:

- Expected to be finalized in 2024
- Corrective action requirements at hazardous waste facilities

PFAS Remediation Considerations

- A new understanding may be necessary, based upon:
  - Risk – Is there an impact?
  - Pathway elimination – Can the impact be controlled?
  - Technology limitations – Can current technology meet the requirements?
  - Cost – Is the remedy affordable?
- Current remediation technologies may not fully address the issues.

Excavation, Landfilling and Incineration

- Landfilling is more expensive for PFAS-impacted soils
  - RCRA Landfills with leachate treatment only
  - Specialized landfill with composite liner and gas/leachate collection and treatment
- Incineration
  - Must be capable of > 2000° F
  - Limited number of facilities
- Excavation and Disposal (the simple solution) may be expensive.

Soil Stabilization/Solidification

- Contaminated soil is mixed with solid additives, including adsorbents, which reduce or eliminate PFAS leaching to groundwater.
- Portland cement is added for additional mechanical stability or hydrological control.
- Several commercially available additives are available. (e.g. RemBind®, Fluoro-sorb® Adsorbent).
- Typical weight percent is 2% to 5%.
- Batch leaching tests are required to determine the additive dosages.

RemBind® Additive

Biosolids

- State limits on land application:
  - MA, MI, MN, NY, SC, WI (others pending)
- Cost and technology crisis for wastewater treatment plants and communities
  - Beneficial reuse was sustainable and cost-effective
  - Agricultural users must replace nutrients
  - Affected lands now have liability and loss of productivity
- Agricultural crisis
  - Maine: Farmer land buy-backs
  - Search for viable technology for land remediation

Land application of Biosolids

Soil Remediation Thoughts

- Soil standards still evolving but expected to be very low.
- Landfill and incineration capacity limited
- Solidification/stabilization can play a significant role
  - Industry experience on the upswing
  - Technical improvements still needed
- Emerging issues in biosolids will complicate the soil issues.

Existing Remediation Technology:
Promising, Realistic and Affordable?
You Be The Judge!

Thermal Treatment of PFAS Impacted Soil

Gorm Heron, Lauren Soos, Emily Crownover, Patrick Joyce

TRS Accelerating Value

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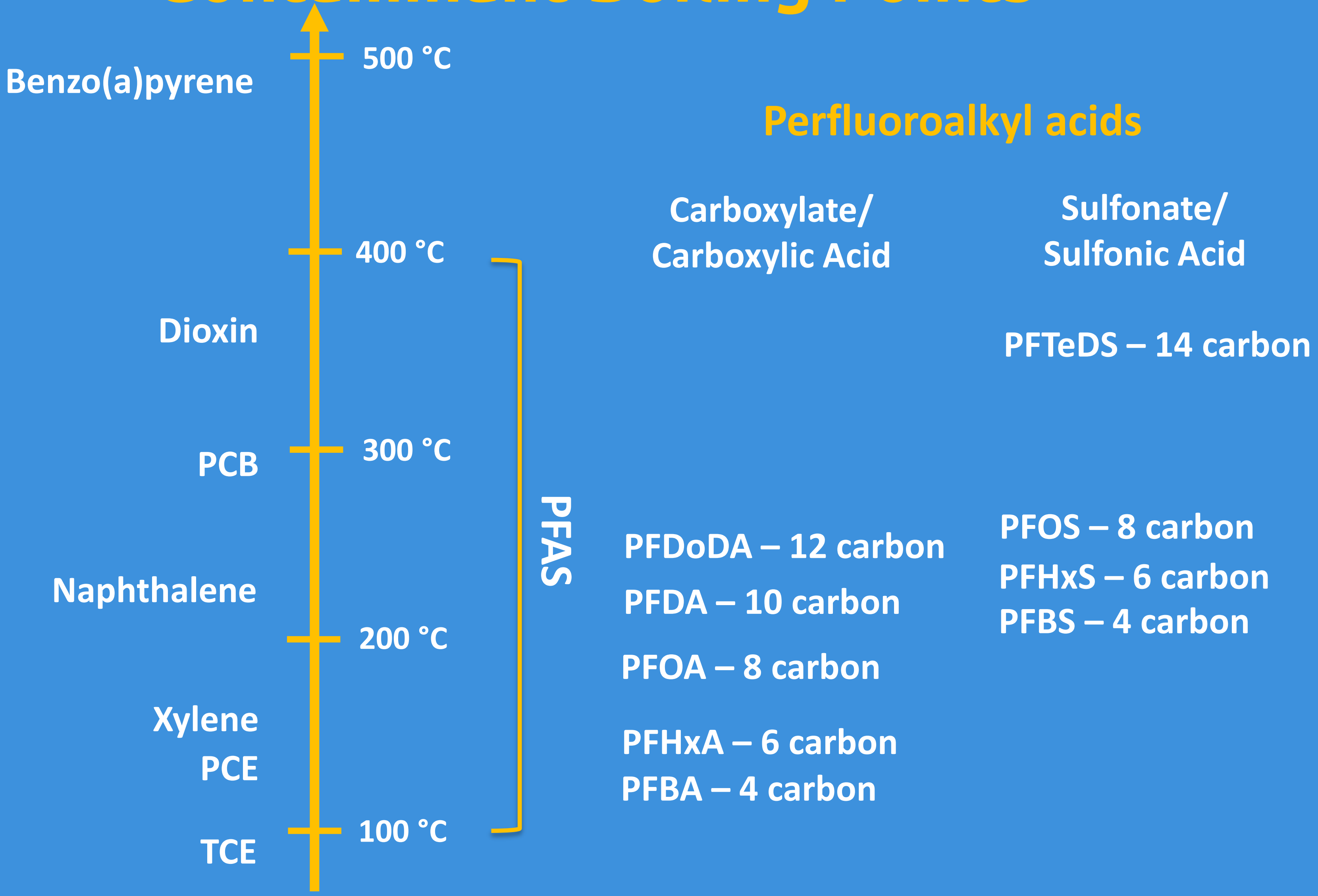
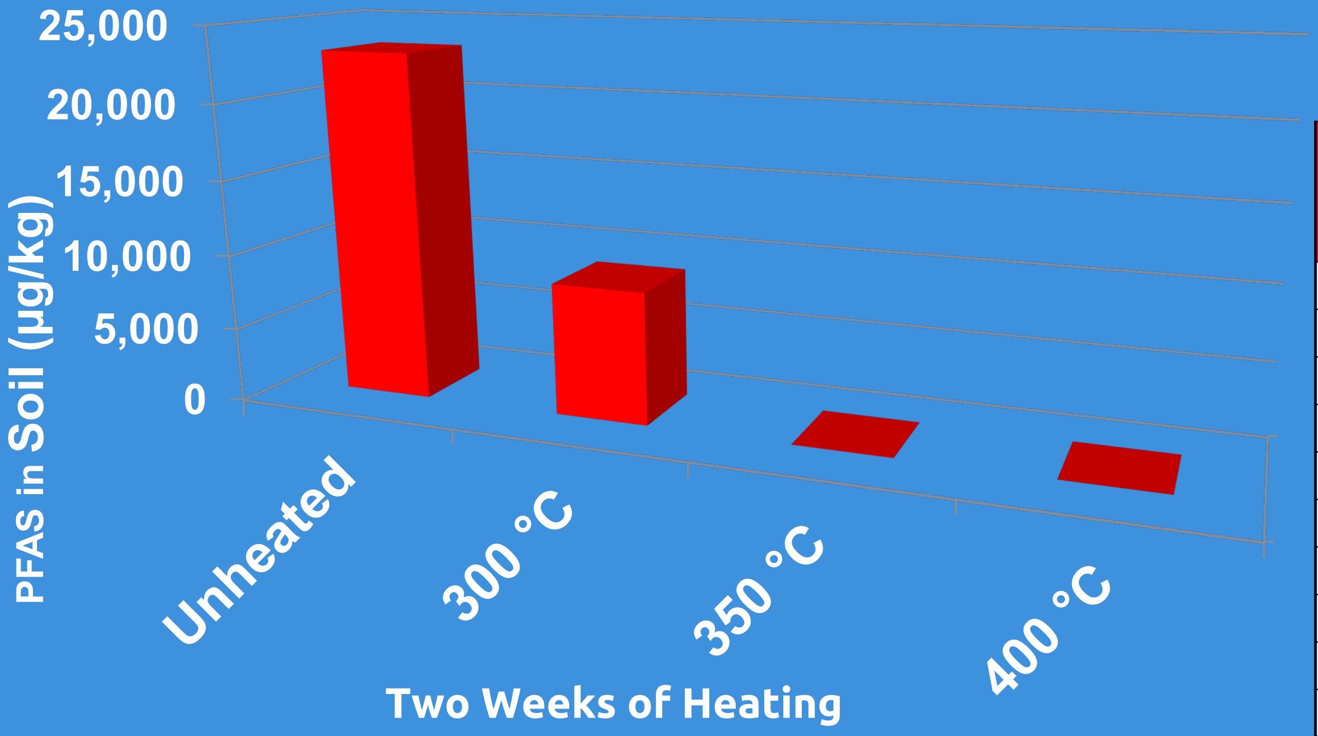
Contaminant Boiling Points



Laboratory testing



PFAS	Starting Concentration (ug/kg)	300 °C % reduction	350 °C % reduction	400 °C % reduction
PFOS	21000	61.90%	99.92%	>99.999%
PFBA	91	93.85%	99.82%	>99.999%
PFPeA	100	92.60%	<99.8%	>99.999%
PFBS	41	58.54%	99.80%	>99.999%
PFHxA	200	95.30%	99.96%	>99.999%
PFHpA	27	86.67%	98.63%	>99.998%
PFHxS	1600	51.88%	99.84%	>99.999%
PFNA	16	96.81%	<98.75%	>99.997%
PFDS	48	75.00%	<99.58%	>99.999%
PFOA	64	92.97%	99.22%	>99.865%

Crownover et al. 2029. Remediation; 29:77-81

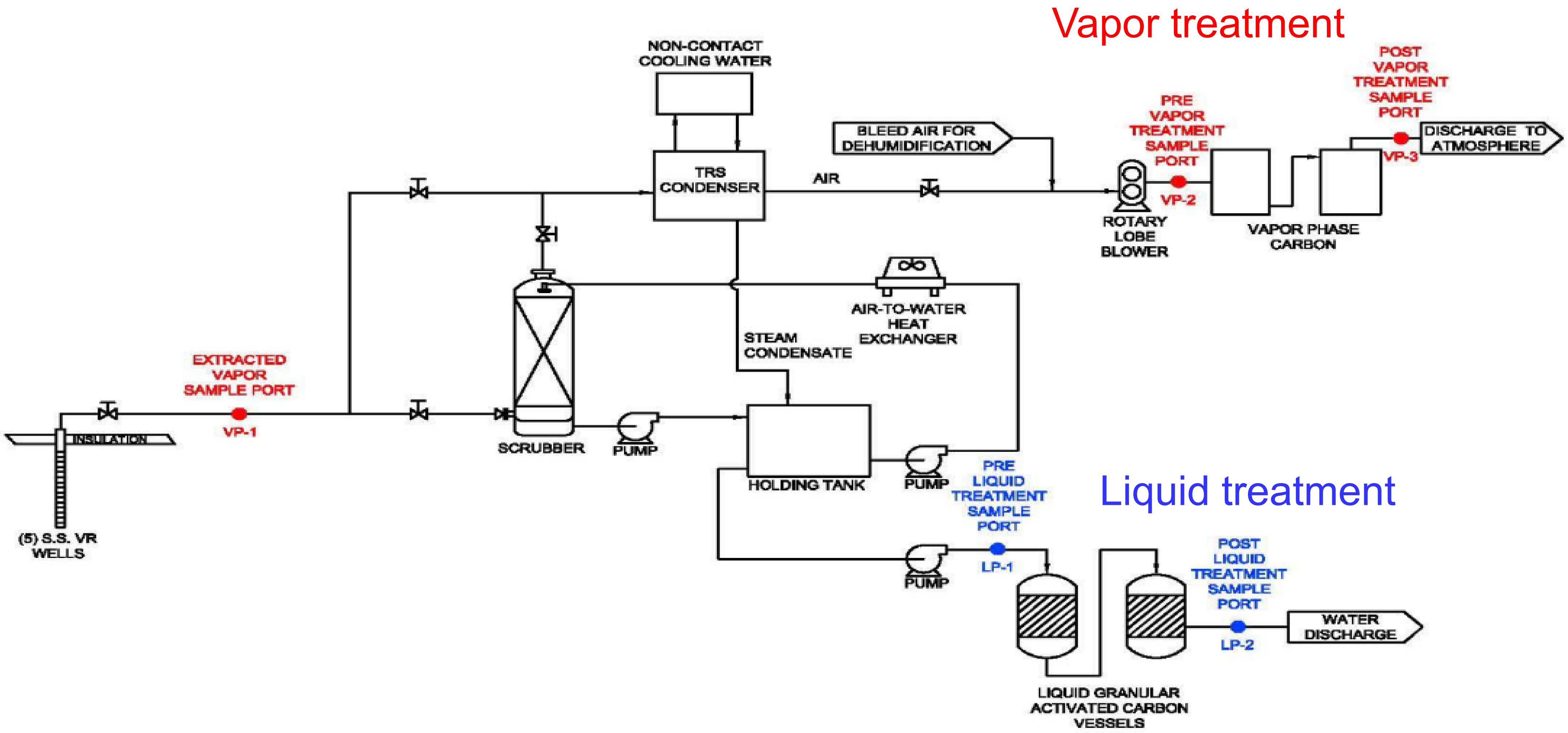
Stockpile Construction

PARAGON

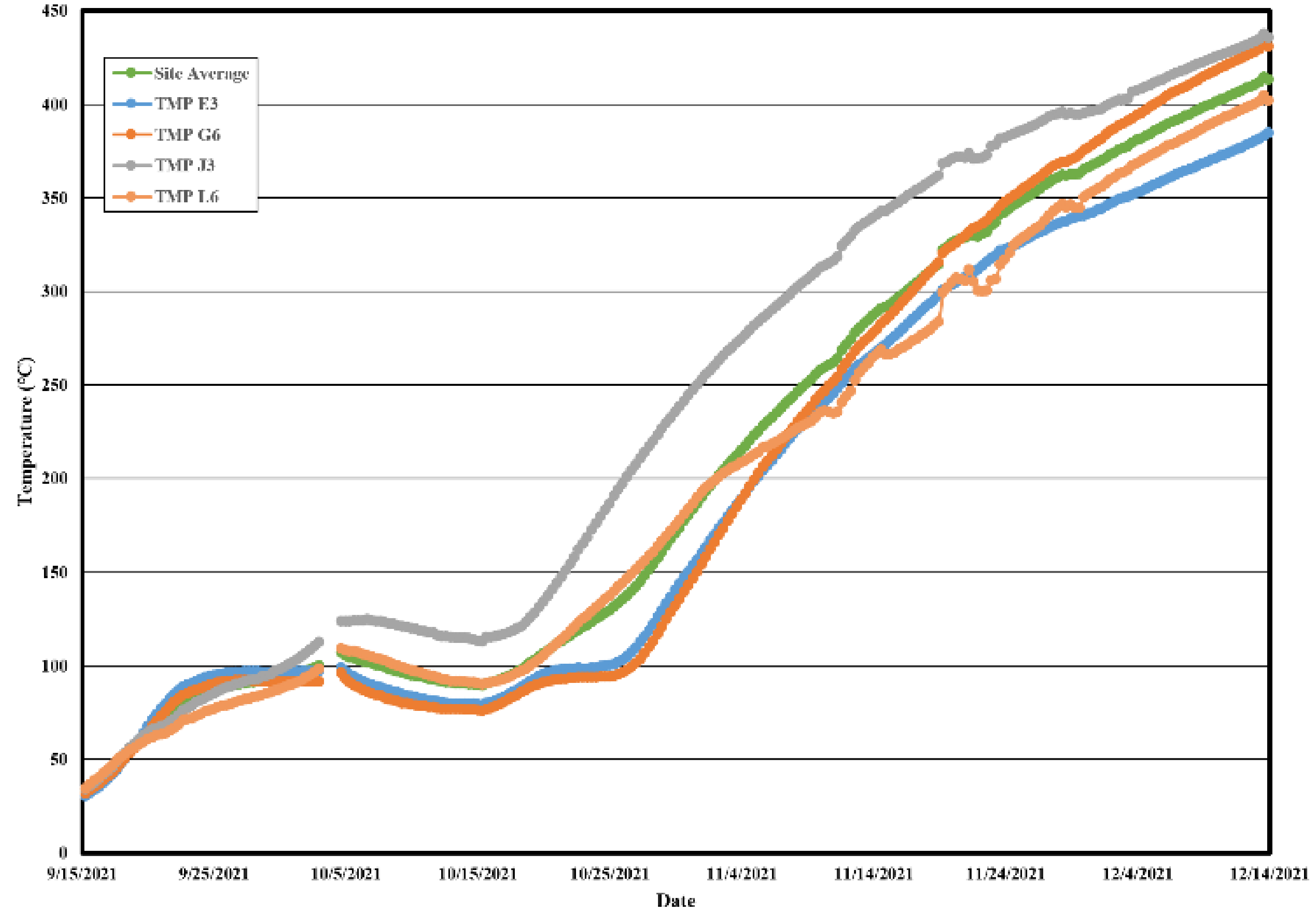
Winter Operation

TRS
Accelerating Value

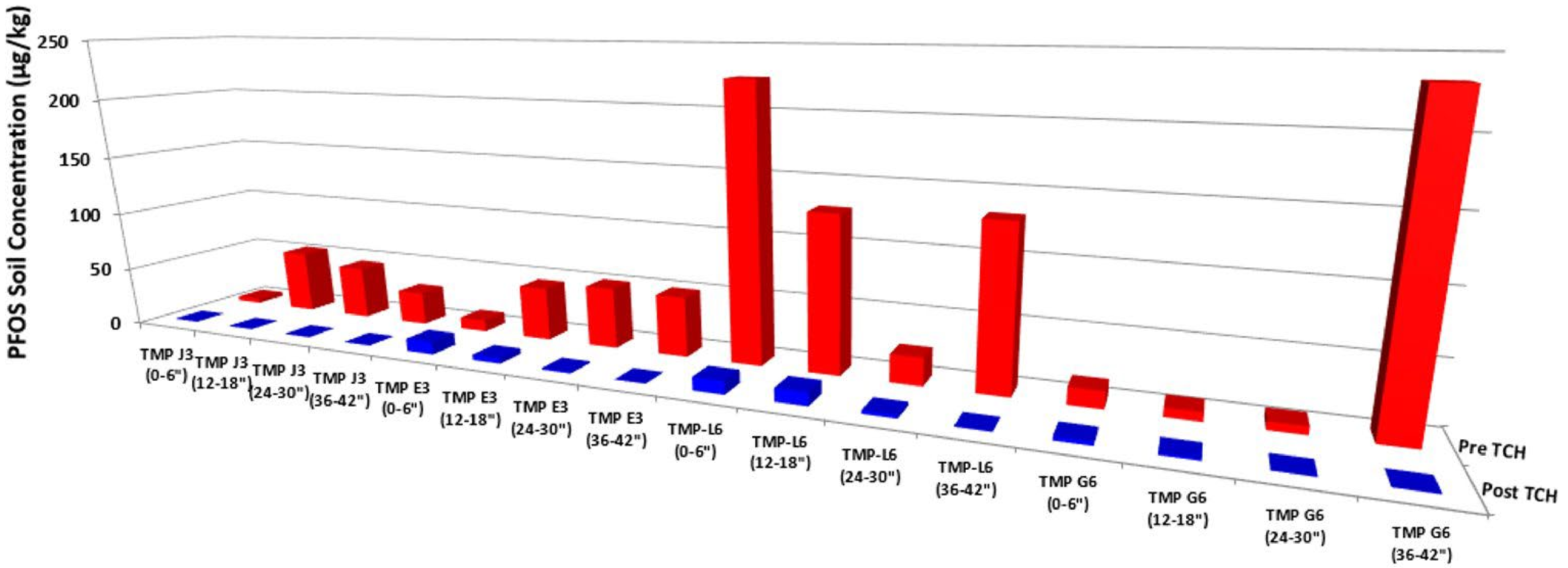
Treatment System



Soil Pile Temperatures



PFOS and PFOA Results



**all post treatment samples below PFOA detection limits*

Beale Air Force Base

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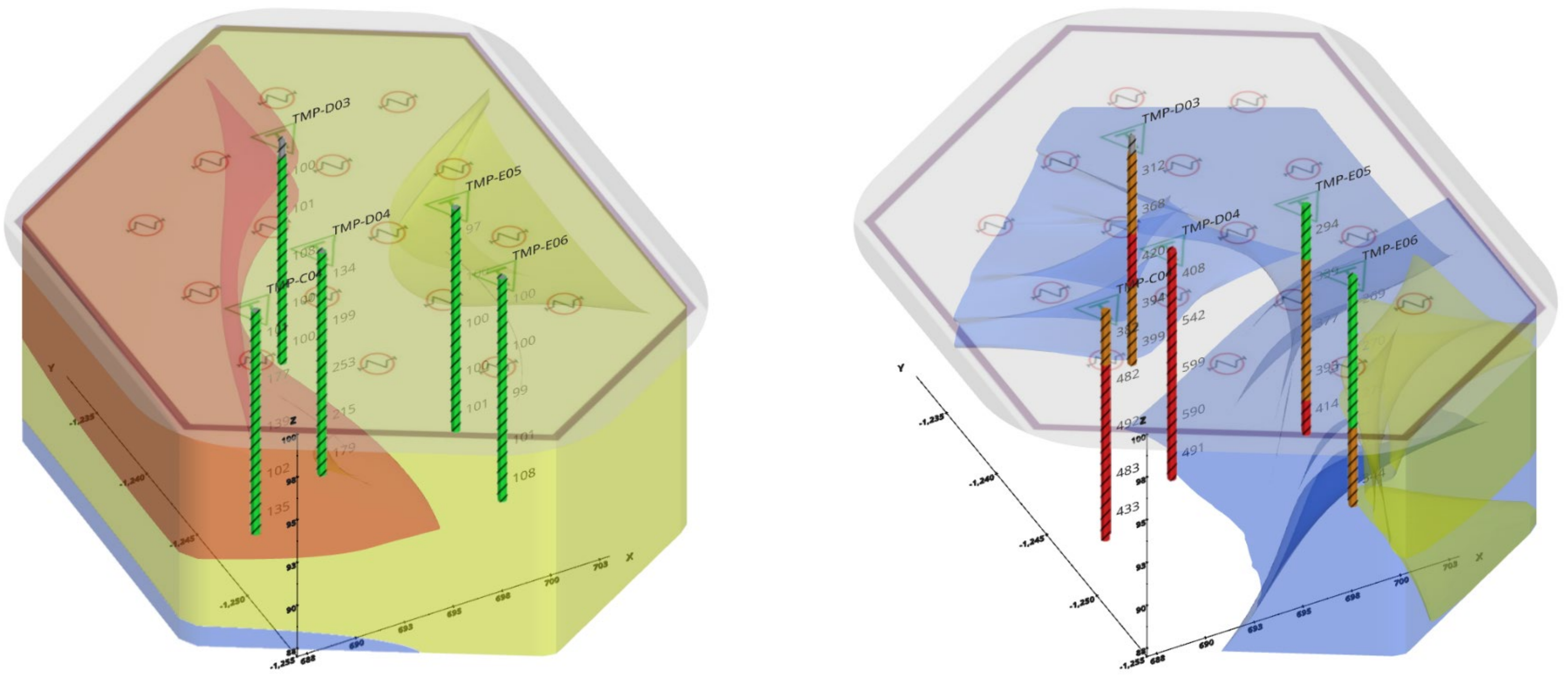
Soil Concentration Reductions



Total PFAS :: >1,900 ng/g
Total PFAS :: 126 - 1,900 ng/g
Total PFAS :: 13 - 126 ng/g

Temperature :: >500 °C
Temperature :: 300 - 500 °C
Temperature :: 100 - 300 °C

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400ºC
500-800 kWh/m3
Working on sustainability improvements

Perspective

Thermal used for higher concentration soils

- Fines from soil washing treated thermally
- Spent GAC can be used for STAR or reactivated with PFAS destruction

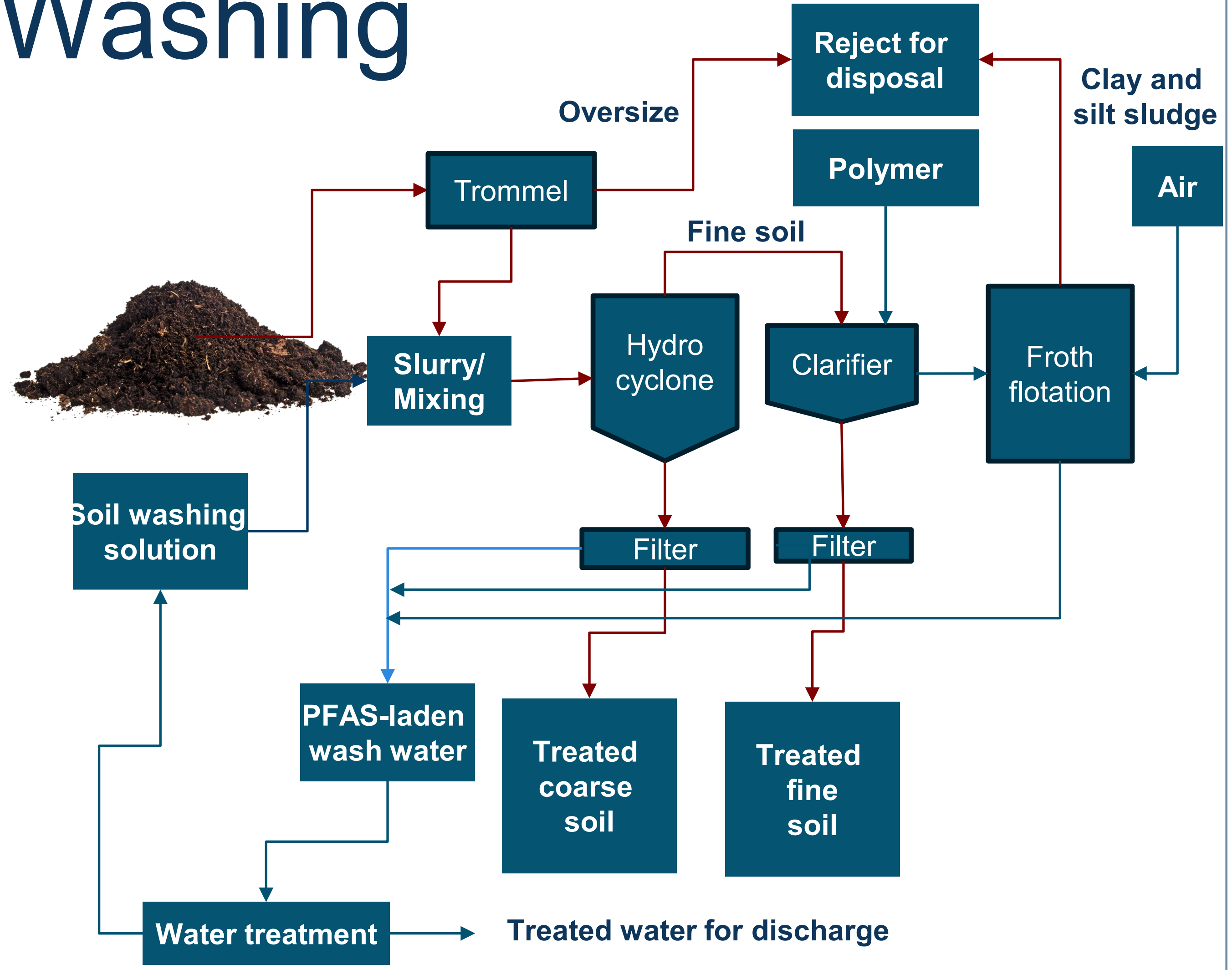
Minimal solid waste produced

Advanced PFAS Treatment Technologies in Soil

Dora Chiang, Ph.D., P.E.
Jacobs
Global Principal, PFAS and Emerging Contaminants

Soil Washing

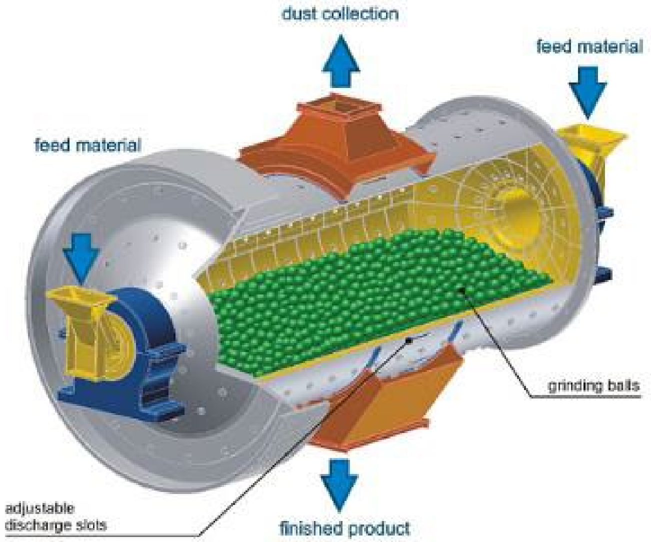
- Use of washing agent to separate PFAS from soil
- Fines (typically most of the PFAS) separated from coarse fraction
- Washing agent (e.g., water) subsequently treated/recycled or disposed
- Minimal waste residuals
- Full-scale system operating in Australia and Canada, some US pilot testing



PFAS Destruction

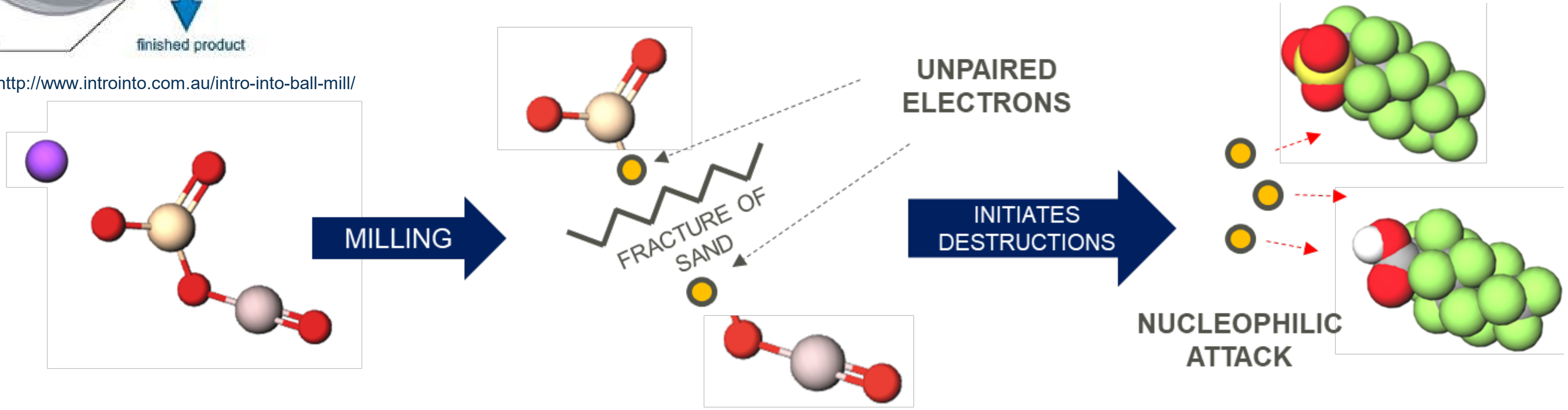
- Ball milling for PFAS-contaminated soil
- Supercritical water oxidation or gasification for spent media (GAC, AIX) generated from treating soil vapor condensate, soil wash water
- Multiple technologies for liquid wastes
  - Electrochemical oxidation
  - Plasma
  - Hydrothermal Alkaline Treatment (HALT)
  - Reductive UV/Sulfite, etc.

Destruction of PFAS-Impacted Soil Using Ball Milling



http://www.introinto.com.au/intro-into-ball-mill/

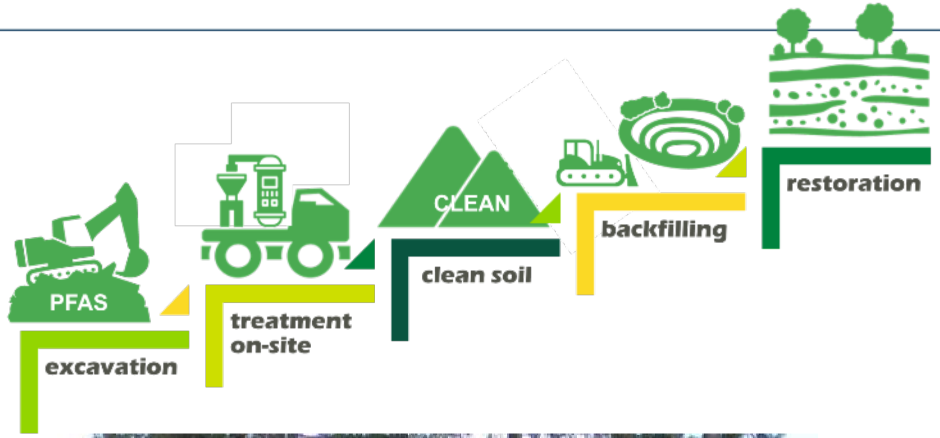
Mechanical action promotes reactivity and surface chemistry states that are not attainable in ambient conditions

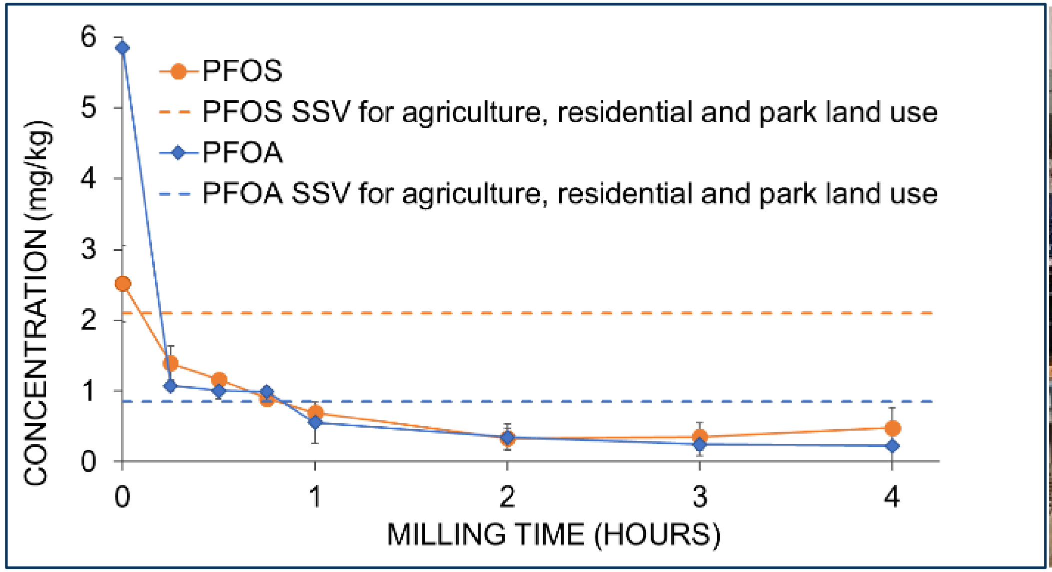


(WSP)

Figure modified from Cagnetta, Huang and Yu (2018)

Results

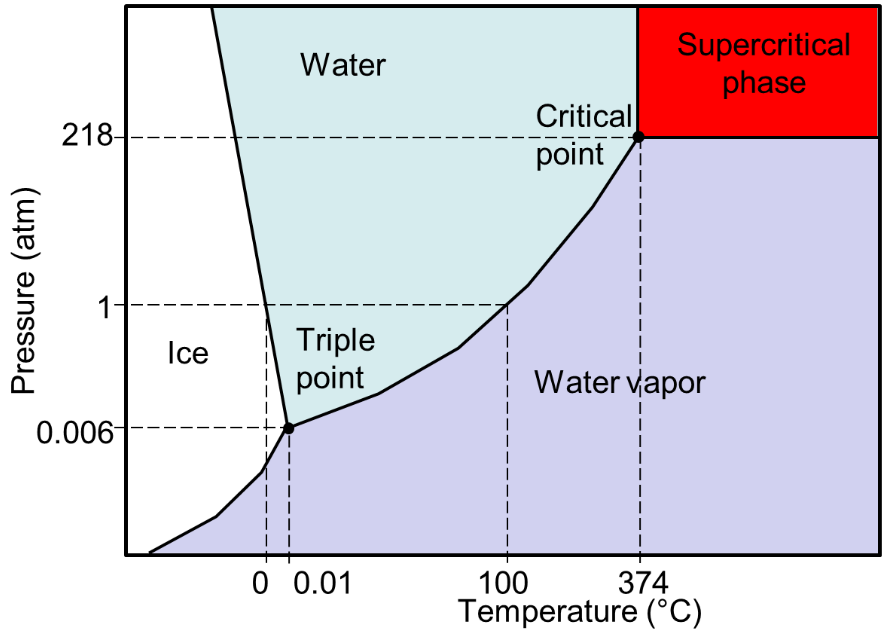




- PFAS destruction confirmed by free fluoride analysis, TOP assay, and high-res. mass spectrometry
- Currently optimizing operational parameters

(WSP)

Supercritical Water Oxidation (SCWO)



Technology

- Water >374°C and pressure of 221.1 bar is considered "supercritical"
- Under these conditions, certain chemical oxidation processes are accelerated
- SCWO Technology was developed for other recalcitrant organics back in 1980s and is mature

$$\textbf{PFAS} + O_2\ (\text{air}) \xrightarrow[\sim 240\ \text{bars}]{>374\ ^{\circ}\text{C}} CO_2 + \mathbf{F^-} + \mathbf{CaF_2} + \text{heat} + H_2O$$

PFAS-1, Section 12.5.4.12 Supercritical Water Oxidation.

Image from EPA: https://www.epa.gov/sites/production/files/2021-01/documents/pitt_research_brief_scwo_final_jan_25_2021_508.pdf

Supercritical Water Oxidation (Liquids and Solids)

Applications

- Liquid: AFFF, AFFF firetruck wash wastewater, leachate, foam concentration,
- Solids: biosolids, sludge
- spent IX, spent GAC (Today's presentation)
- SCWO station approach

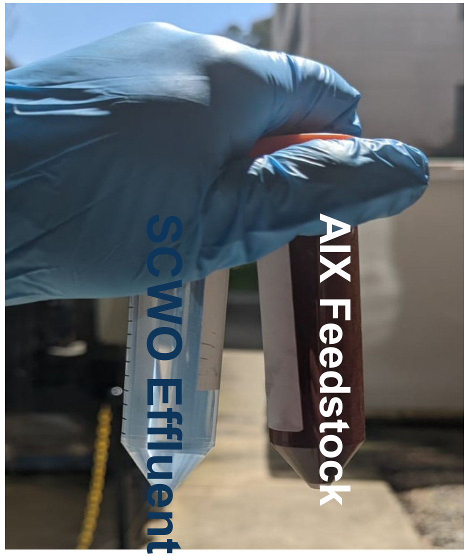
Market Ready

- 374Water AirSCWO™
- General Atomics iSCWO™
- Revive Annihilator™


Source: General Atomic

AirSCWO-1 Testing Results

FT-02 Spent GAC	Feedstock (Measured)	Effluent
	ng/kg	ng/L, ppt
PFBA	15,035.78	42.6
PFPEA	25,196.78	25.7
PFHXA	33,506.26	28.7
PFHPA	3,364.94	1.14
PFOA	**13,059.03**	**1.1**
PFNA	288.82	ND
PFBS	689.62	41.3
PFPES	514.4	5.09
PFHXS	17,737.03	50.9
PFHPS	928.44	4.62
PFOS	**83,935.60**	**243**
6:2 FTS	12,611.81	98.7
8:2 FTS	4,321.11	ND
PFOSA	3,164.58	5.07
Total PFCA	90,451.61	99.24
Total PFSA	103,805.09	344.91
Precursors	20,097.50	103.77
Short chain (C<6)	41,436.58	114.69
Total	214,354.20	547.92



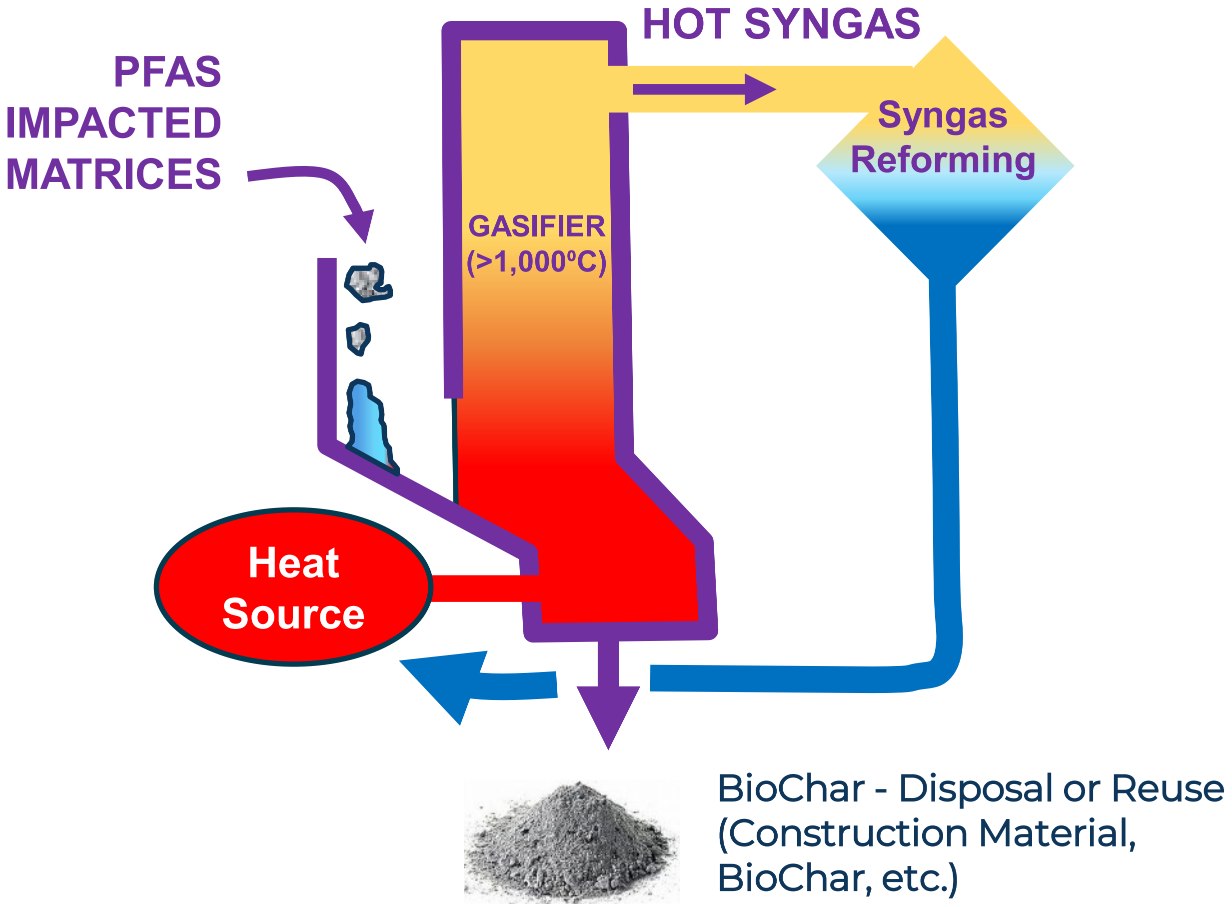
Mission Street Spent AIX	Feedstock	Effluent
	ng/kg	ng/L, ppt
PFBA	2,645.65	ND
PFPeA	17,841.45	ND
PFHxA	87,831.90	1.04
PFHpA	31,155.68	ND
PFOA	**120,057.31**	**ND**
PFNA	686.53	ND
PFBS	27,153.77	0.47
PFPeS	36,743.08	0.5
PFHxS	555,873.93	6.45
PFHpS	50,687.68	0.71
PFOS	**421,776.50**	**62.7**
6:2 FTS	33,256.92	1.39
PFOSA*	182.426	3.74
Total PFCA	260,218.52	1.04
Total PFSA	1,092,234.96	70.83
Precursors	33,256.92	5.13
Short chain (C<6)	84,383.95	0.97
Total	1,385,892.83	77

(Chiang et al., 2023)

R&D on Treatment of PFAS-Impacted Matrices Using Gasification

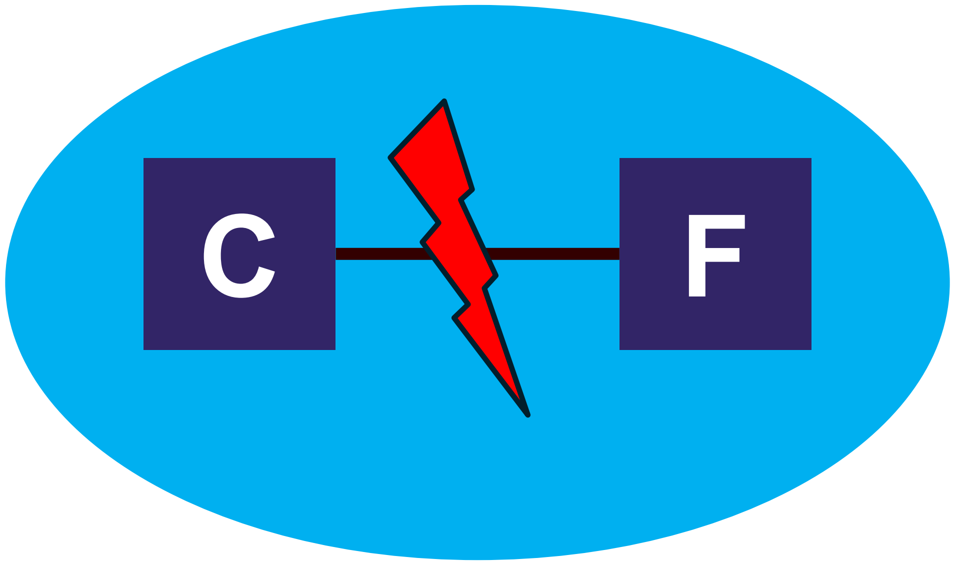
- Evaluate the feasibility and effectiveness of gasification thermal treatment and complete destruction of PFAS in spent treatment system media (GAC, organoclay, and/or AER) and AFFF concentrate.

(WSP)



Multiple Technologies for Liquid Wastes

- Electrochemical oxidation
- Plasma
- Hydrothermal Alkaline Treatment (HALT)
- Reductive UV/Sulfite, etc.



Takeaways

- Treatment train approach is needed for on-site advanced treatment of PFAS in soil
- On-site ex-situ destruction of PFAS requires high energy and can be cost prohibitive. However, if successfully applied, it is permanent solution
- In-situ options are very limited to blending sorbent with PFAS-laden soil in place, no in-situ destructive technologies claims effective yet
- More research is still needed

THANK YOU

Please take a few minutes to complete a short survey about this session. Your feedback will help us improve future programming for JETC.

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PFAS in Soil: Promising, Realistic, and Affordable Solutions

Q&A

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- Dora Chiang, dora.chiang@jacobs.com