



Understanding PFASs within the MSW Management Industry

New Mexico Recycling Solid Waste Conference: Circularity in Action
Santa Fe Community Convention Center: 201 W. Marcy Street September 30-October 1, 2025

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What Makes PFASs Hard to Manage?

Oleophobic/
Hydrophobic

1,000,000s of
compounds

Wide Range
Molecular
Weight

Thermally
resistant

Polar/
Soluble

Surfactant
characteristics
f(chain length)

Strong
Electronegativity

Biologically
recalcitrant

Properties
f(chain length)

Parts per trillion
criteria

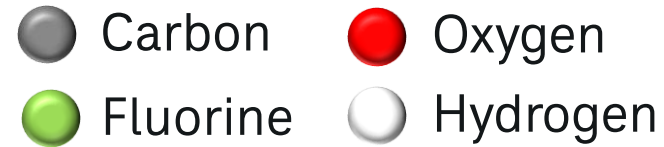
Negligible
relevant
volatility

Supramolecular
Structures

Ubiquitous

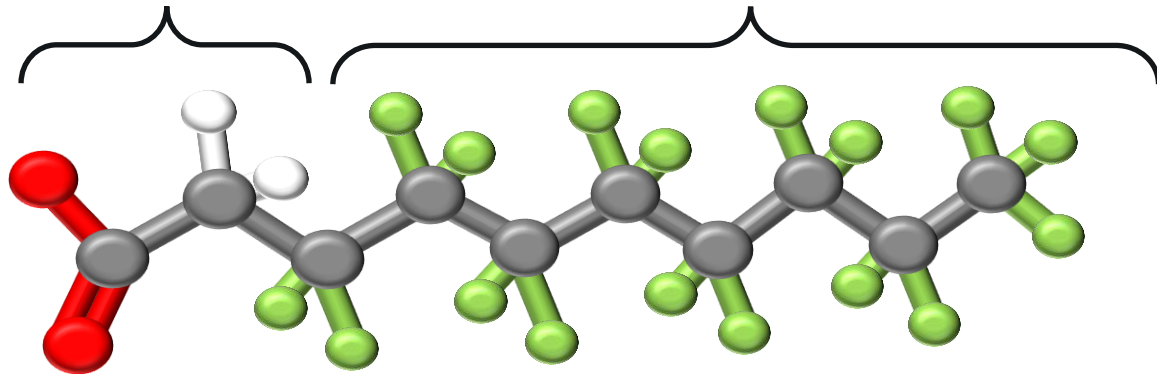
Persistent, Bioaccumulative, Toxic...and Mobile

Polyfluoroalkyl Compounds can be Precursors to Perfluoroalkyl Acids (PFAAs)

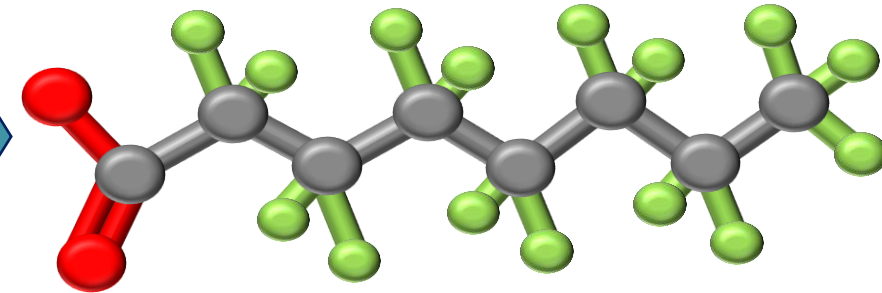
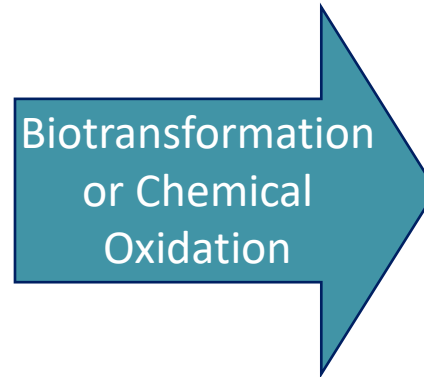


Non- or partially fluorinated

Persistent perfluorinated



8:2 FTCA



PFOA



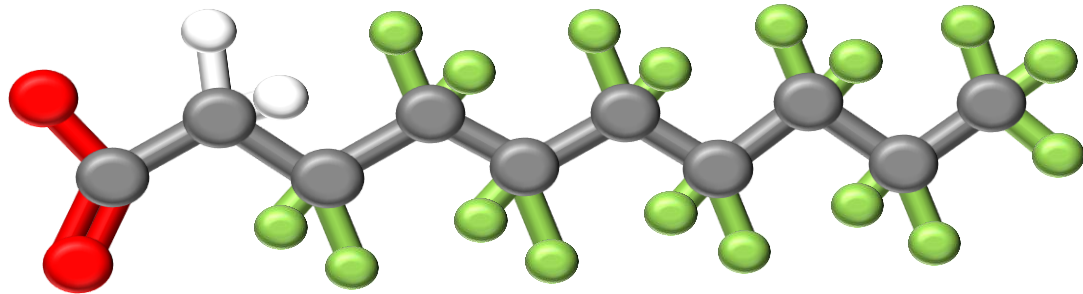
Wooden shaft (non-fluorinated part) **degrades in situ / in vivo**

Stone arrowhead (perfluorinated part) **persists indefinitely**

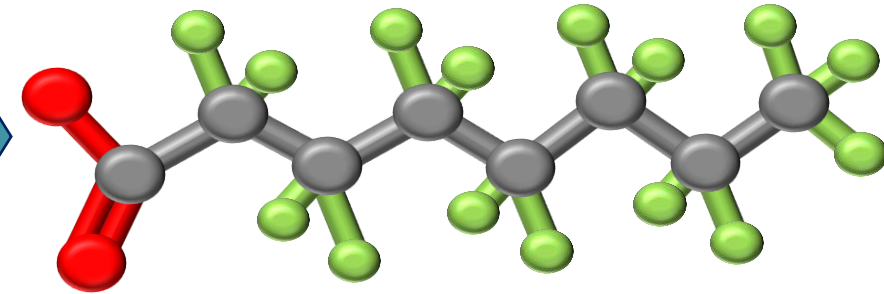
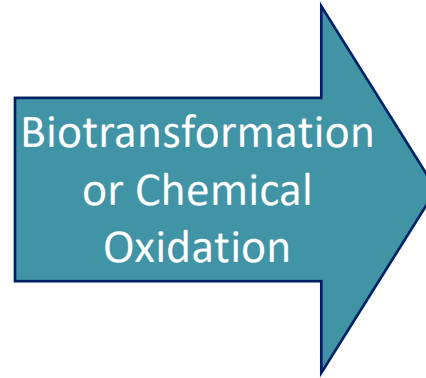
Resultant PFAA persists indefinitely (“chemical rock”)

Important and Dynamic Physical and Chemical Properties

● Carbon ● Oxygen
● Fluorine ● Hydrogen



8:2 FTCA



PFOA



Extreme Persistence

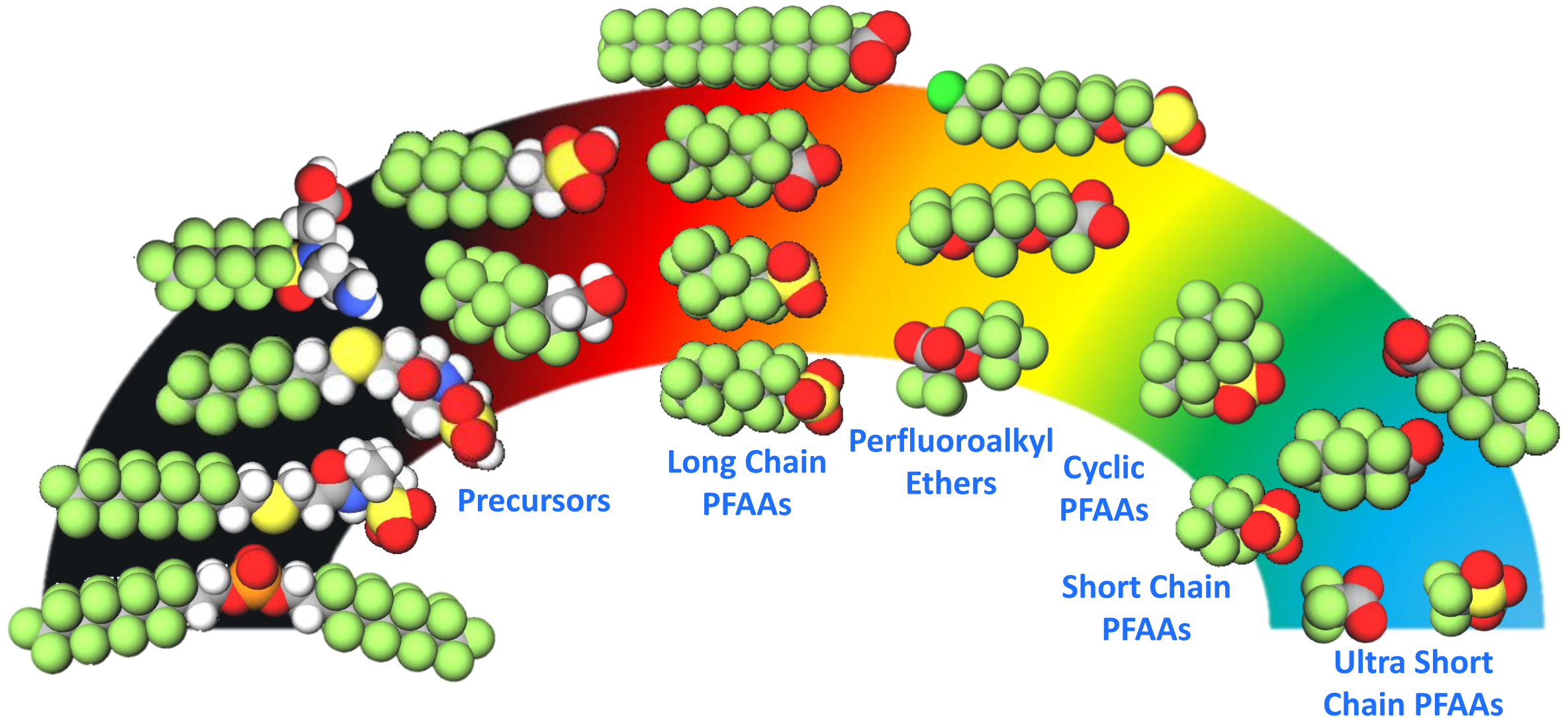
Mobility

Bioaccumulation

Toxicity

Surfactancy

Broad Spectrum of PFASs



PFASs Manufacture: Forensic Line of Evidence

Electrochemical Fluorination (ECF)

- Branched & Linear (~30% / 70%)
- Mostly PFSA's with some PFCAs
- Perfluoroalkylsulfonamides (e.g., PFSaAm & PFSaAmA)

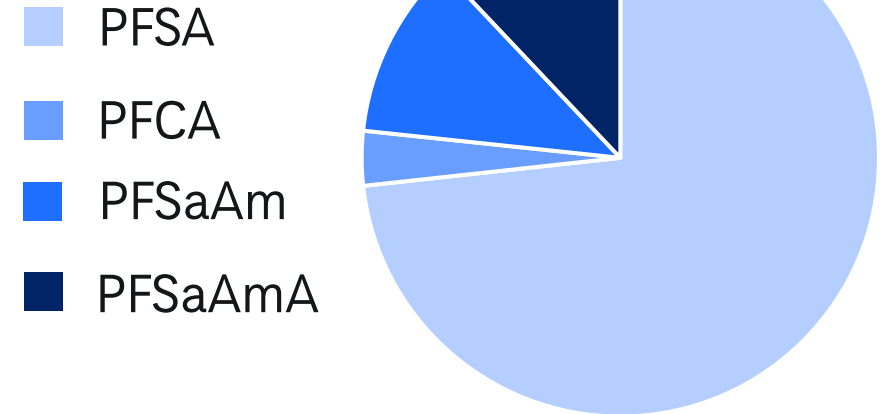
Fluorotelomerization (FT)

- Mostly linear; even numbered carbon chains
- Many polyfluoroalkyl compounds (PFAA precursors)

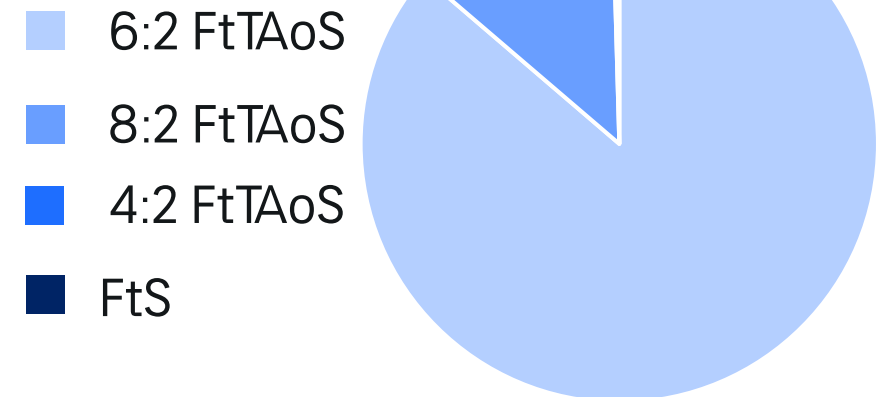
Oligomerization

- Perfluoroalkylethers & Perfluoroalkyl ether sulfonates
- Oxygen-linked perfluoroalkyl groups (e.g., HFPO-DA)

ECF Example: Aqueous Film-Forming Firefighting (AFFF) Foam (1993-2001; 3M)



FT Example: Ansul AFFF (2005)



Managing PFASs Analysis

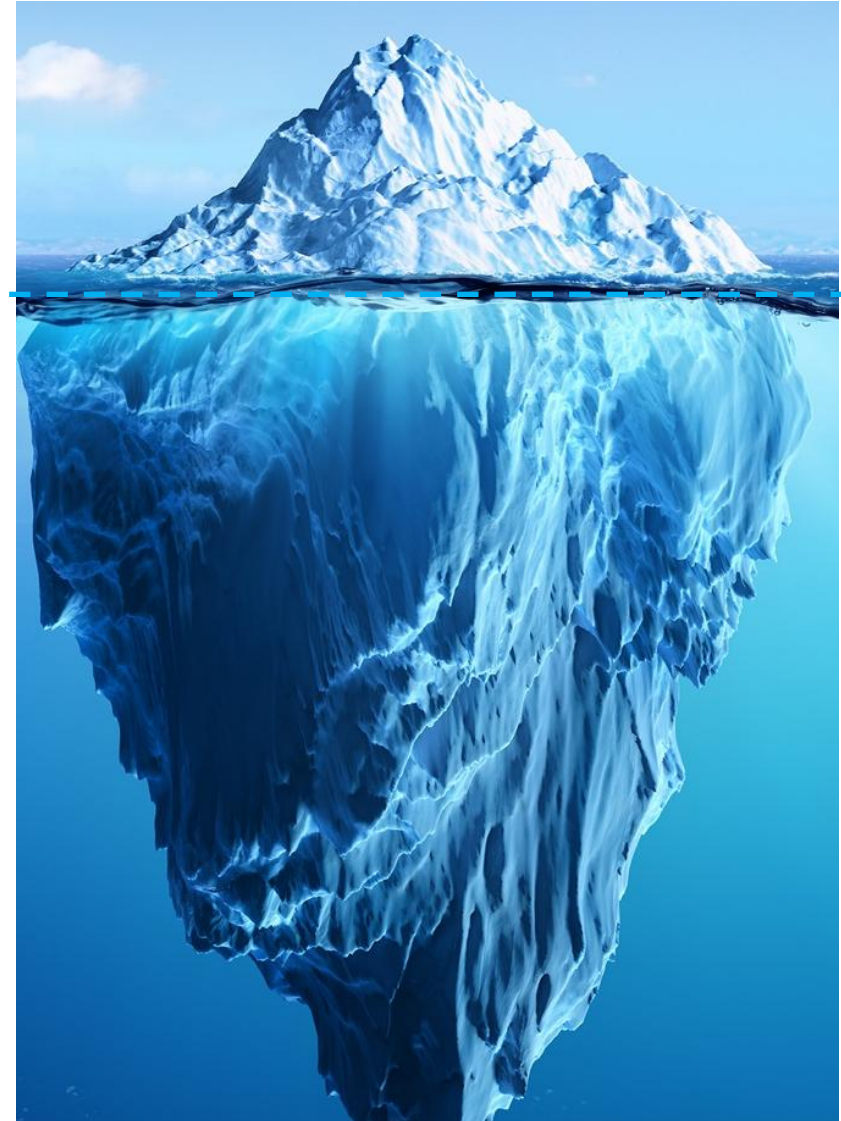
Targeted Analysis

- USEPA Methods 533, 537.1, 1633A, 8327
- ASTMs D7979, 7968, D8421, D8535
- DWI 47 PFAS
- OTM-45, -50, -55 (under development)

Nontargeted Analysis

- Combustion ion chromatography
 - TOF, AOF, EOF
- High-Resolution Mass Spectrometry
- Total Oxidizable Precursor Assay
- ¹⁹Fluorine Nuclear Magnetic Resonance
- Chemical Ionization Mass Spectrometry
- Fourier Transform Infrared Spectroscopy
- Thermal desorption-pyrolysis-direct analysis in real time – mass spectrometry

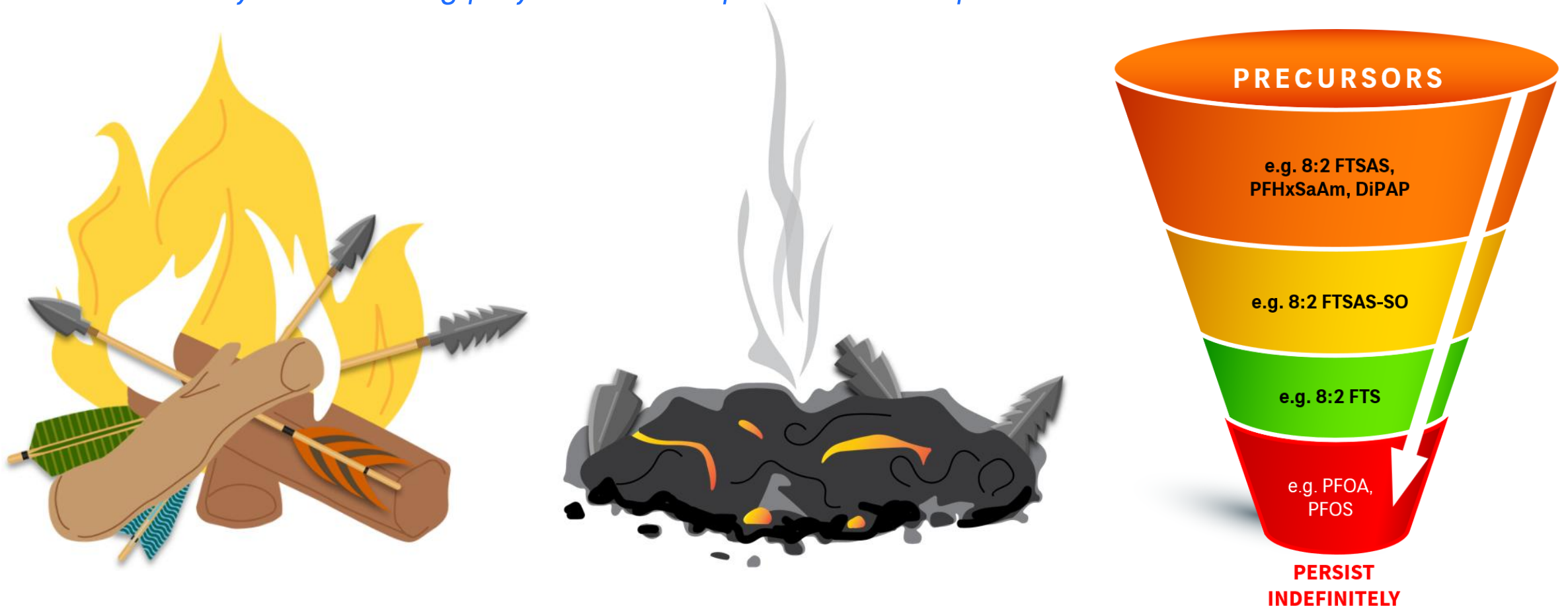
Gaseous
Emissions



[Merrill et al., 2021](#) [Mattila et al., 2024](#) [West et al., 2023](#)
[Riedel et al., 2019](#) [Merrill et al., 2024](#)

Managing PFAs Analysis – Total Oxidizable Precursor Assay

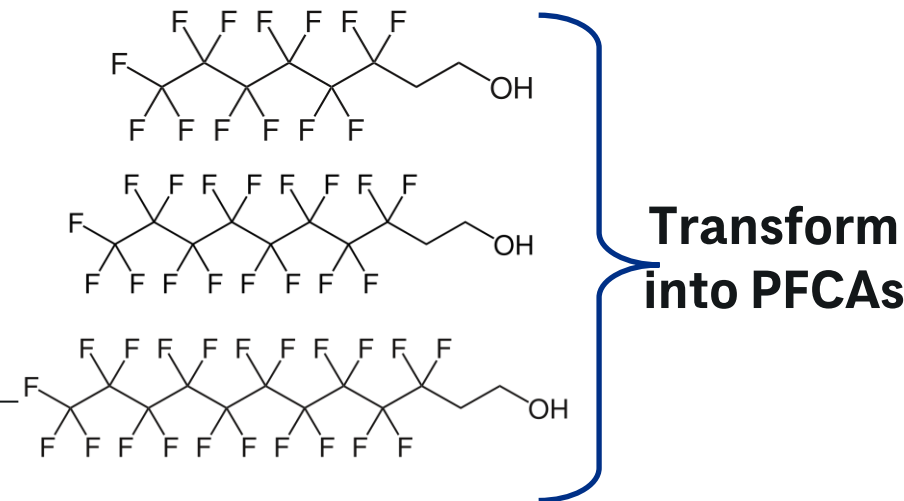
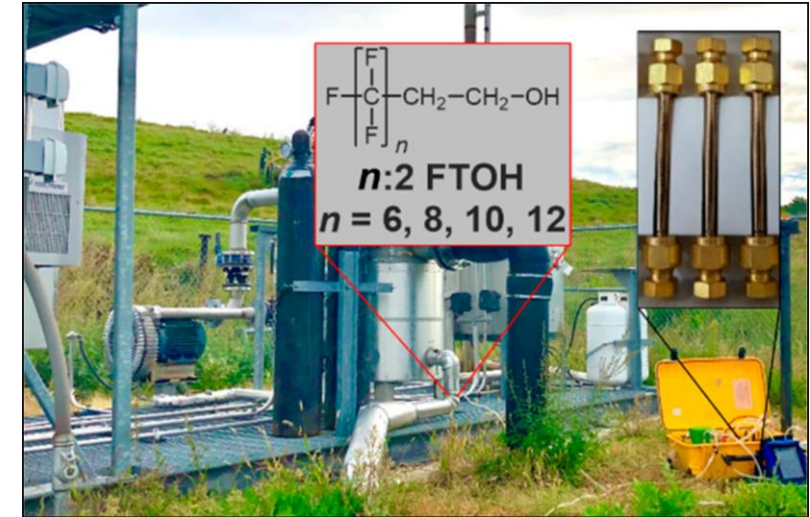
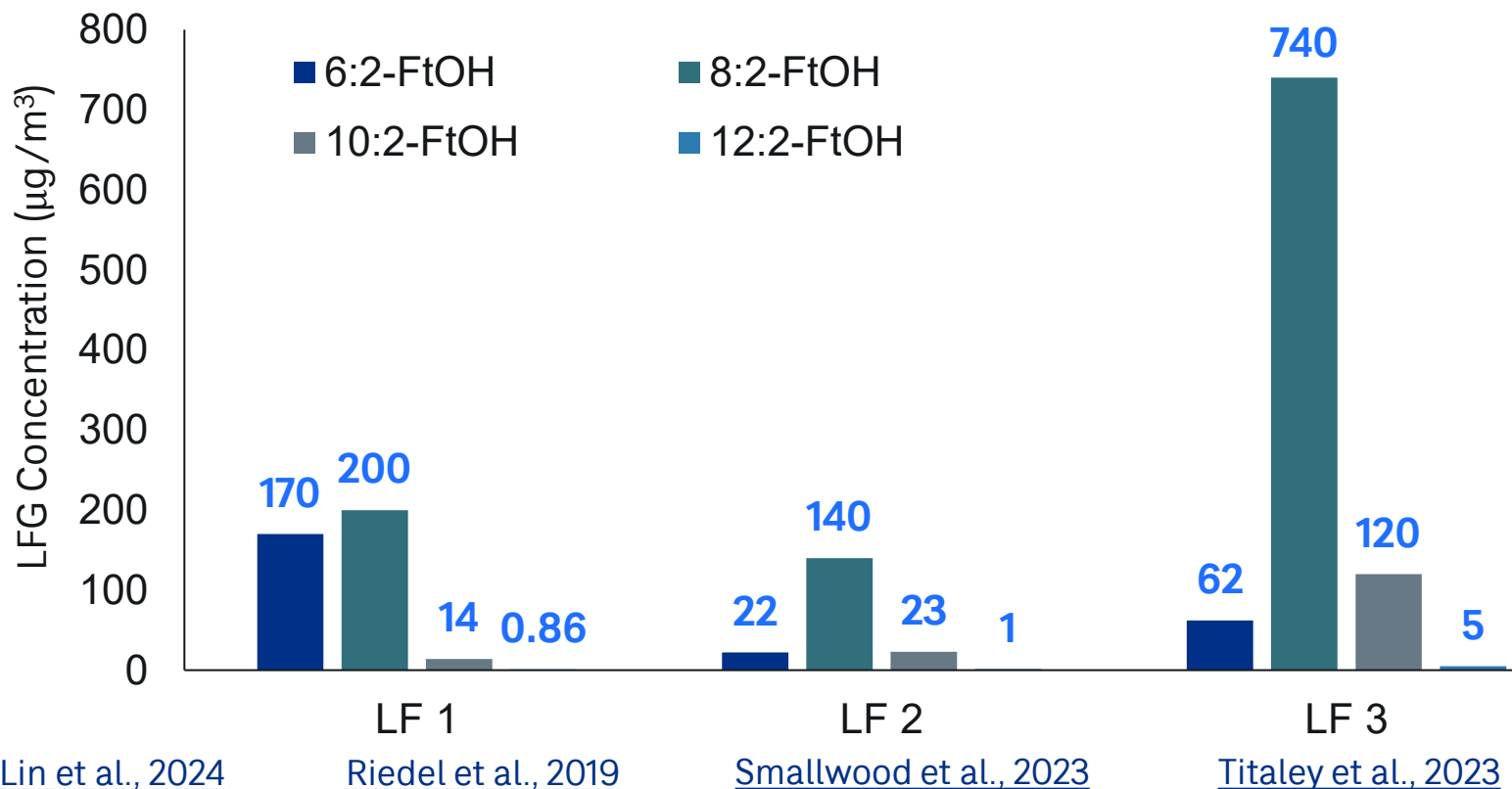
Chemically transforming polyfluorinated “precursor” compounds into detectable PFAs



Arrows in a fire metaphor: *Wooden shafts burn leaving behind stone arrow heads like undetectable polyfluorinated compounds are oxidized in detectable PFAs*

Volatile Polyfluoroalkyl Substances as Associated with Landfill Gas (LFG); Future Perfluoroalkyl Carboxylic Acids

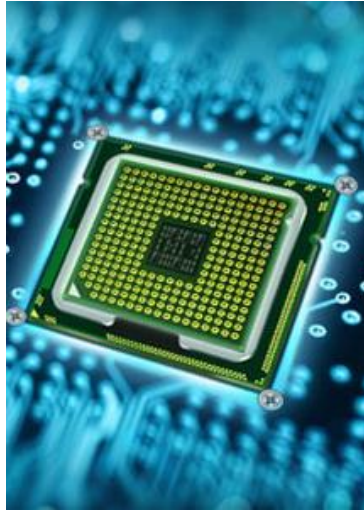
- Neutral polyfluoroalkyl substances quantified in LFG.
- Polyfluoroalkyl substances transform into detectable PFAAs in the environment.



Noteworthy Commercial & Industrial Uses of PFASs



Fire Suppression



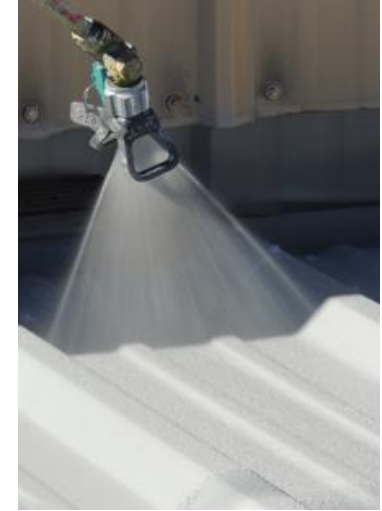
Electronics



Cosmetics



Household Products



Coatings



Electroplating



Textiles



Paper & Packaging

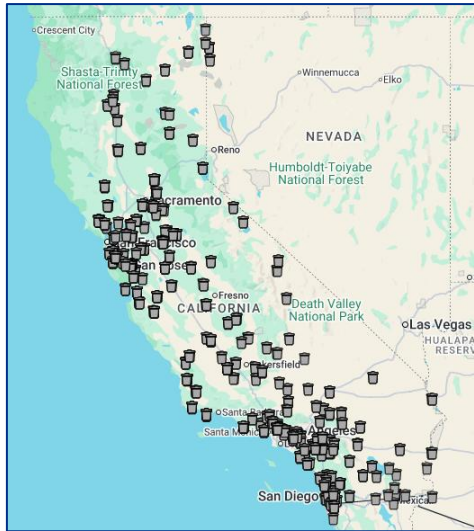


Aviation & Aerospace

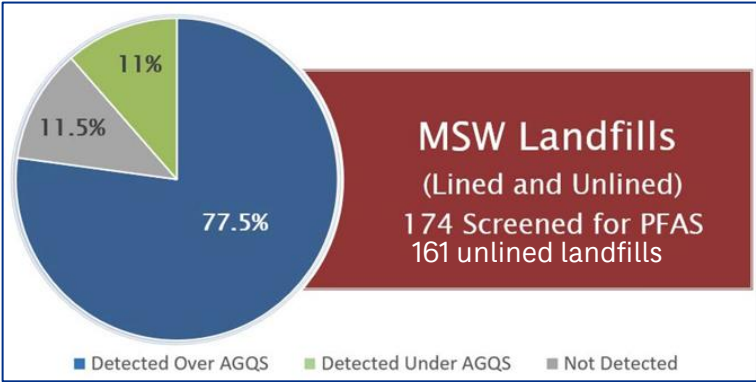
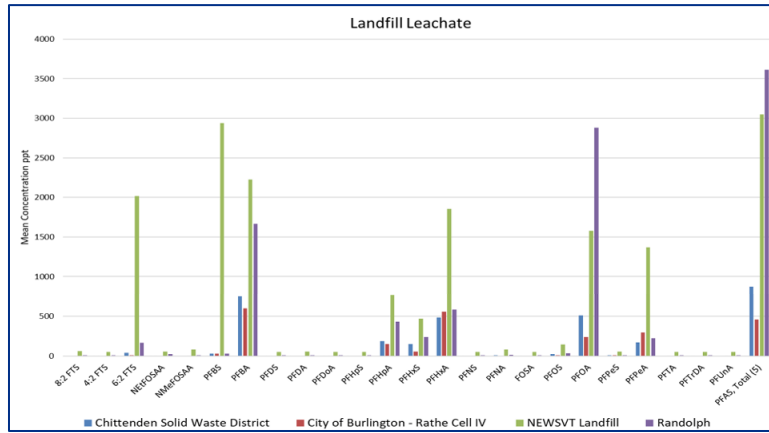


Manufacturing

PFASs in Landfills: States



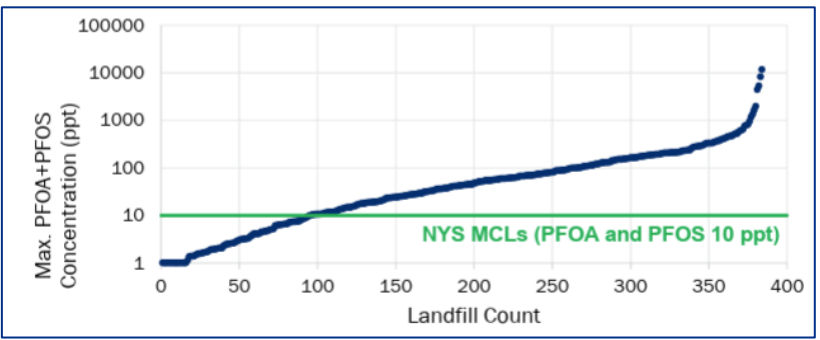
VTDEC 2019
Elevated levels of several different PFASs in all landfill leachate tested



GEOTRACKER
Accessed 2025

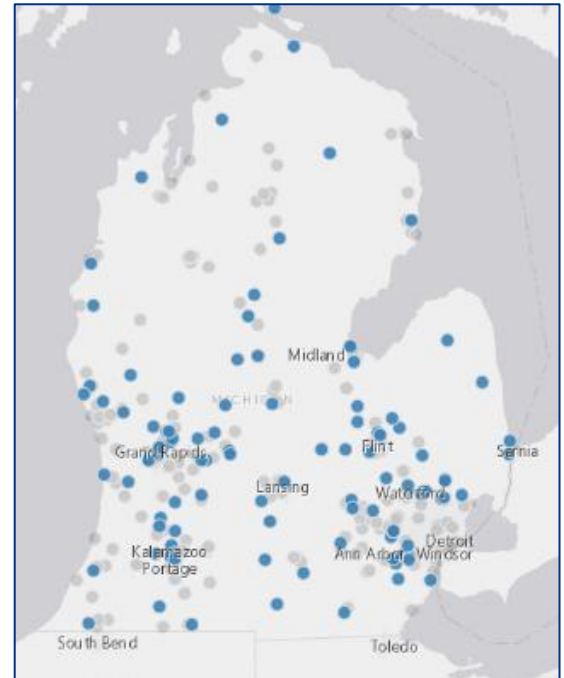
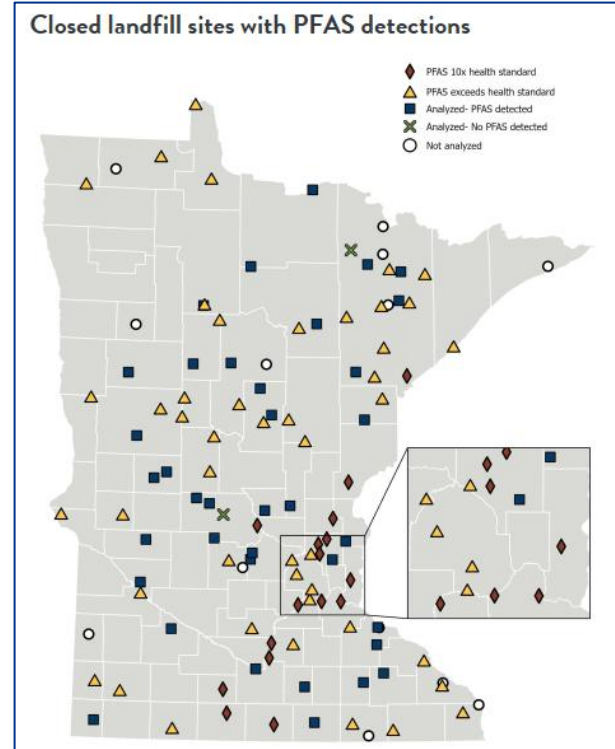
84 sampled leachates contained PFASs (some as high as 10,000 ppt)

NHDES 2022



NYSDEC 2022

PFAS found in >70% of landfills > standards



EGL E Accessed 2025
PFASs detected at 93 landfills

MN Pollution Control Agency, accessed 2025
100 closed landfills, 16 locations were 10X above state drinking water standards

Influential Federal PFASs Regulations

NPDWR for 2 PFASs
(MCLs: PFOA & PFOS)

PFOS & PFOA as CERCLA
hazardous substances

Final Recommended Aquatic Life
Criteria & Benchmarks



Updated interim Destruction
and Disposal Guidance

Related/ Proposed/ Pending/ On-
hold: Effluent Limitation Guidelines;
biosolids risk assessment; updated
PFHxS/PFDA toxicity data; draft
human health water quality criteria;
HFPO-DA, PFBA, PFHxA, PFOA, PFNA,
PFDA, PFBS, PFHxS, PFOS as **RCRA**
hazardous constituents

TSCA & TRI (final, proposed) PFASs
reporting improvements

Influential New Mexico PFASs Regulations

[Governor Grisham's 2021 letter to EPA Administrator](#)

[House Bill 212](#) (phases out products with intentionally added PFASs 2032)



[House Bill 140](#) (PFAS-containing AFFF = hazardous waste)

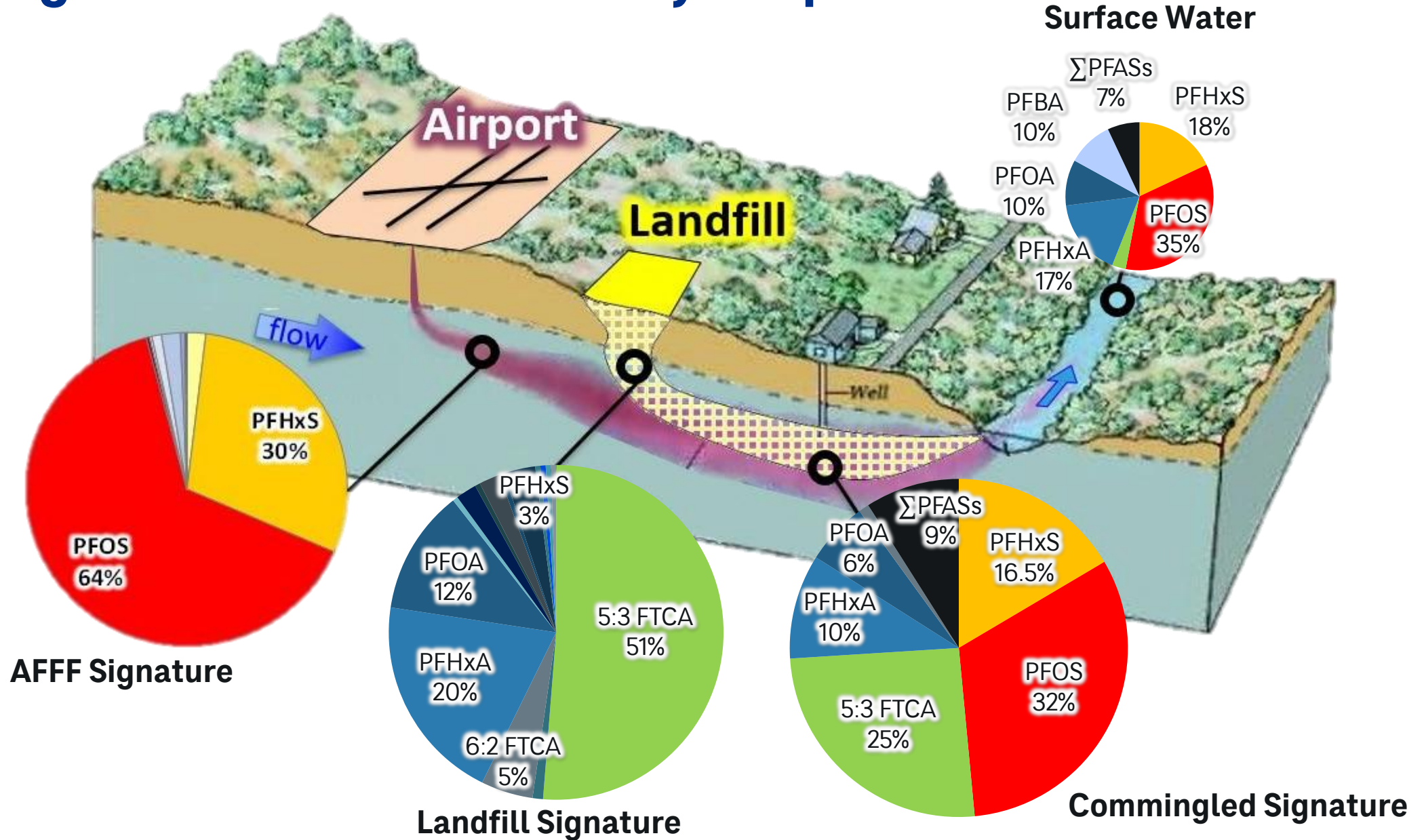
2022 Preliminary Screening Levels for Drinking Water (PFOA, PFNA, PFBS, PFHxS, PFOS/K-PFOS) superseded by adoption of MCLs

[PFAS in New Mexico webpage](#) & Emerging Contaminants Program

Managing PFASs in Landfill Leachate



Strategic Characterization May Help



Case Study Example: Nantucket, MA

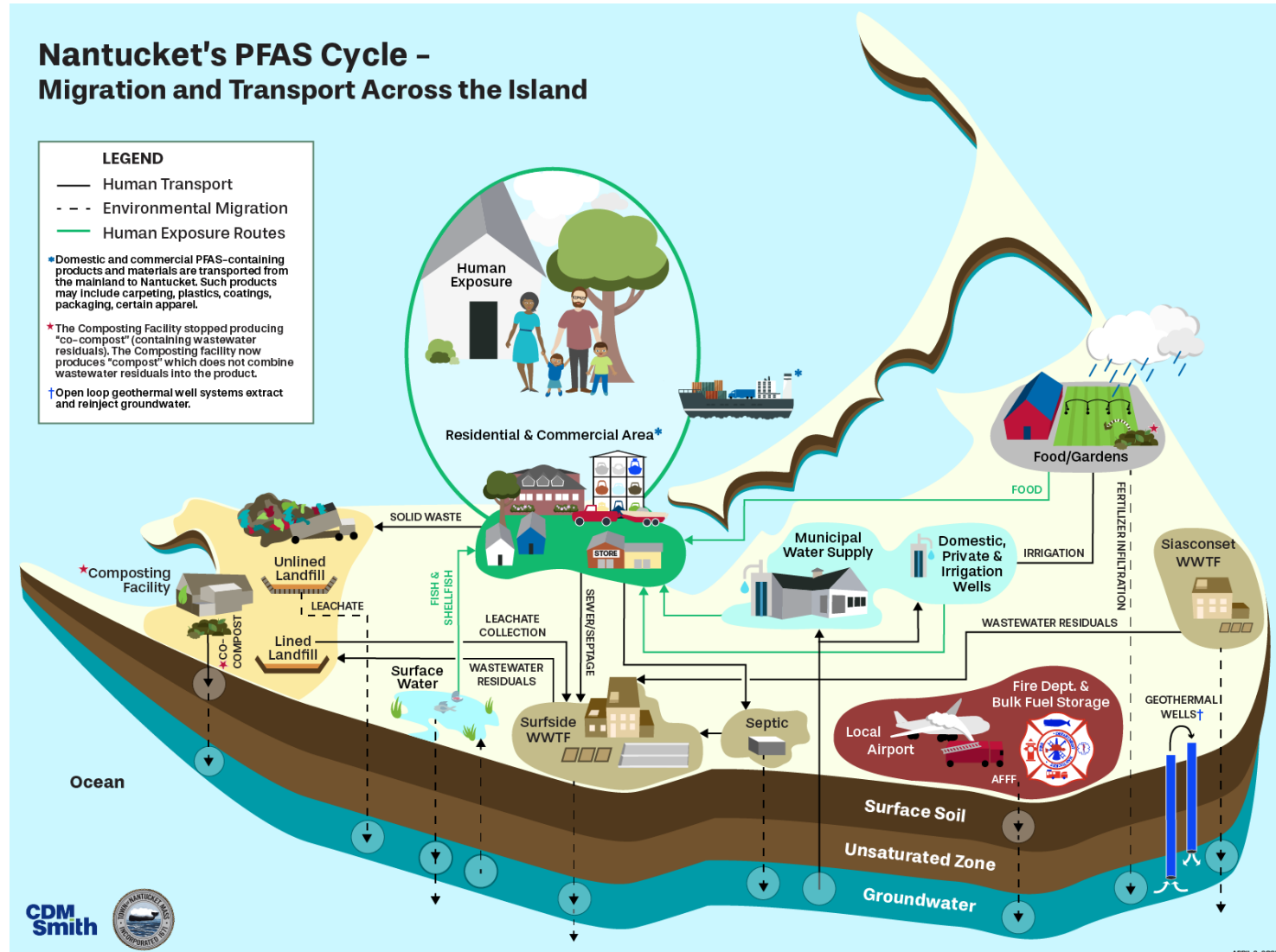
- PFAS Cycle
- Public Outreach
- Sampling (PFASs in co-compost)
- Pilot Testing (Options for WWTF residuals)
 - Cease public distribution
 - Bench-scale testing



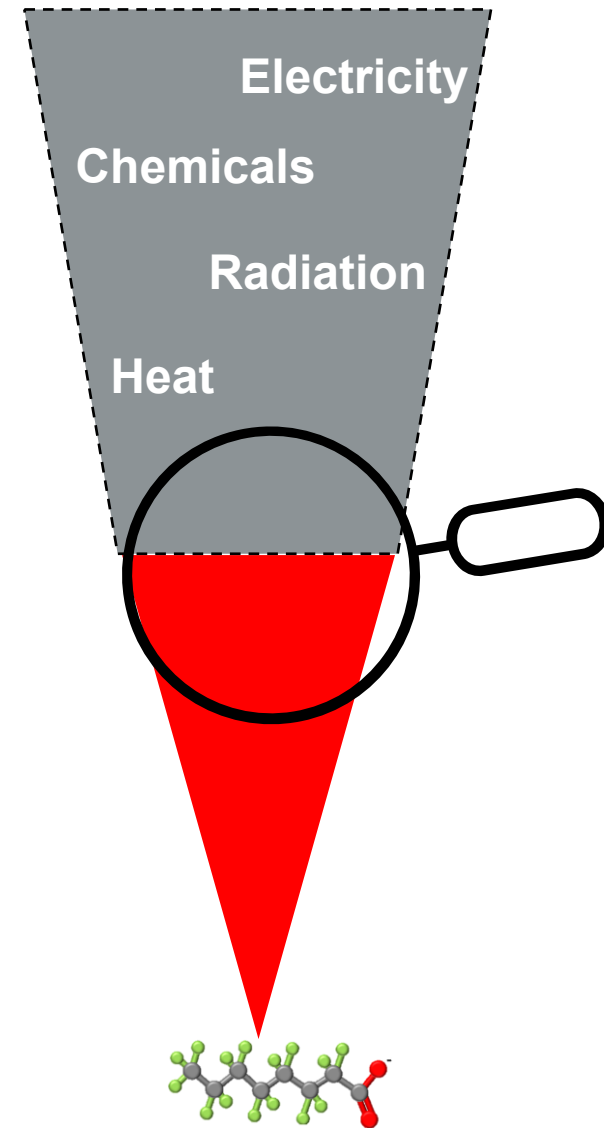
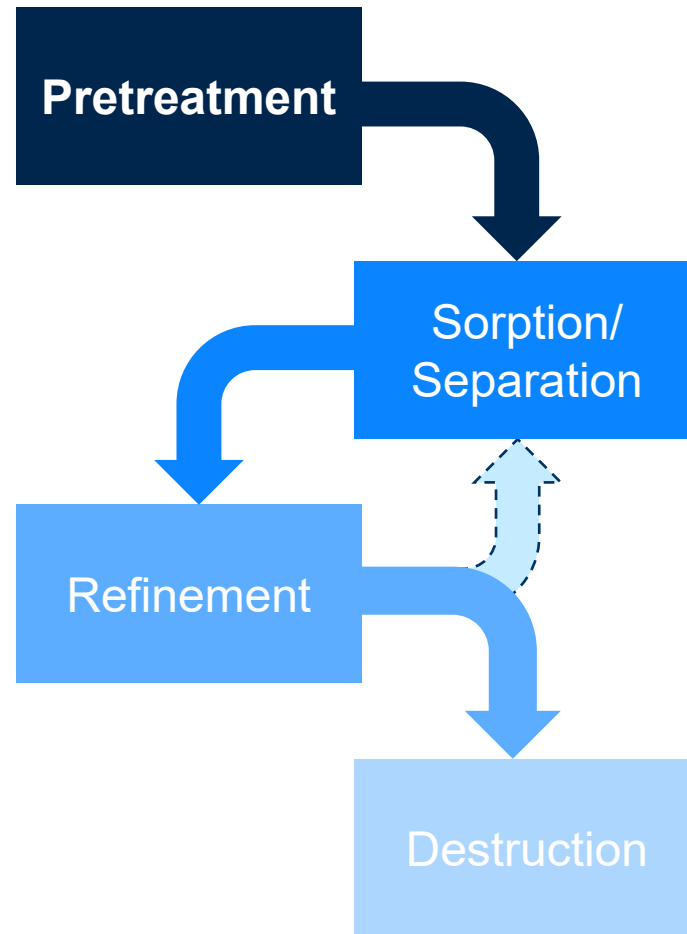
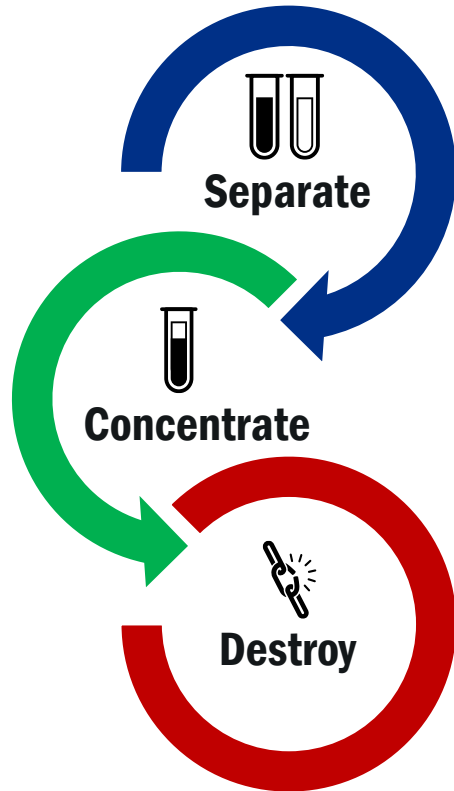
What is co-compost?

Leaf/yard waste & WWTF residuals

Spargimino et al., 2025

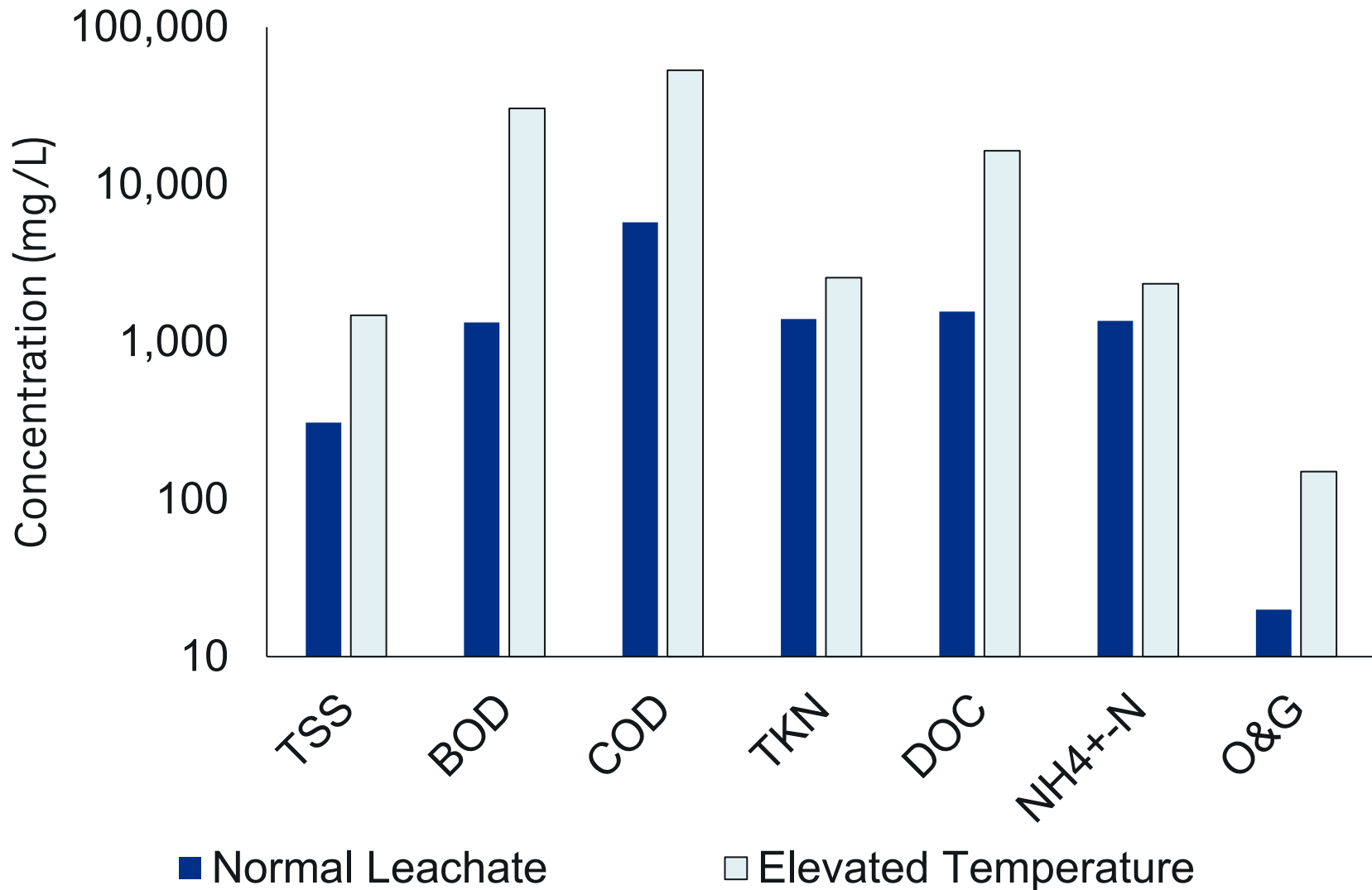


Treating Landfill Leachate to Remove PFASs



State of the Practice: Serial treatment to concentrate PFAS and reduce the volume requiring energy intensive destruction ([Concentration Factor \[CF\]](#))

Geochemistry of Landfill Leachate can Influence Technology Selection

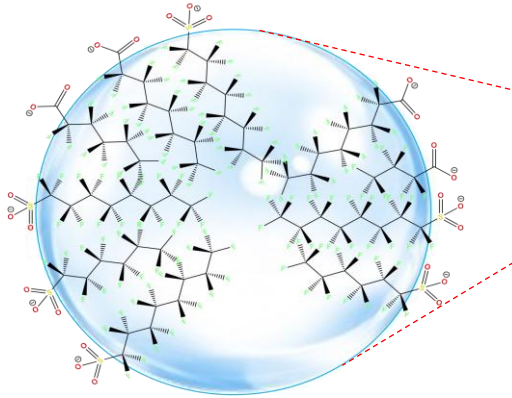


Sorbent strategies targeting $\mu\text{g/L}$ concentrations of PFAS can be overwhelmed by mg/L organics and inorganics in LL

PFAS CF also increases geochemical parameters that can challenge some forms of destruction technologies

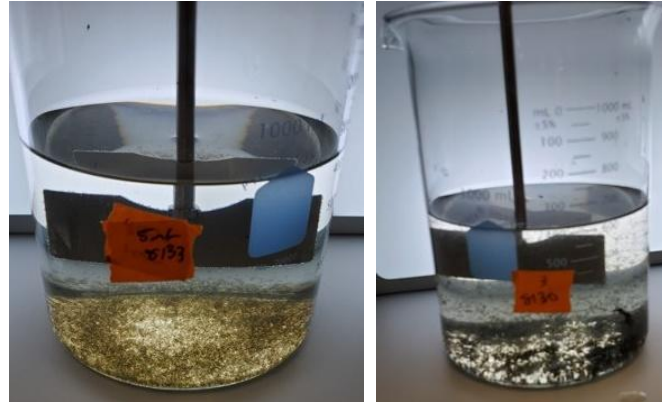
Non-Sorbent Treatment Options

Foam Fractionation



Foam fractionate
(EPOC, 2023)

Flocculation



Cationic Coagulants
(Menkhaus 2020)



Magnetic
Flocculation

Tan et al., 2023

Membrane Separation



Municipal-Scale RO
(Bellona, 2023)

Evaporators

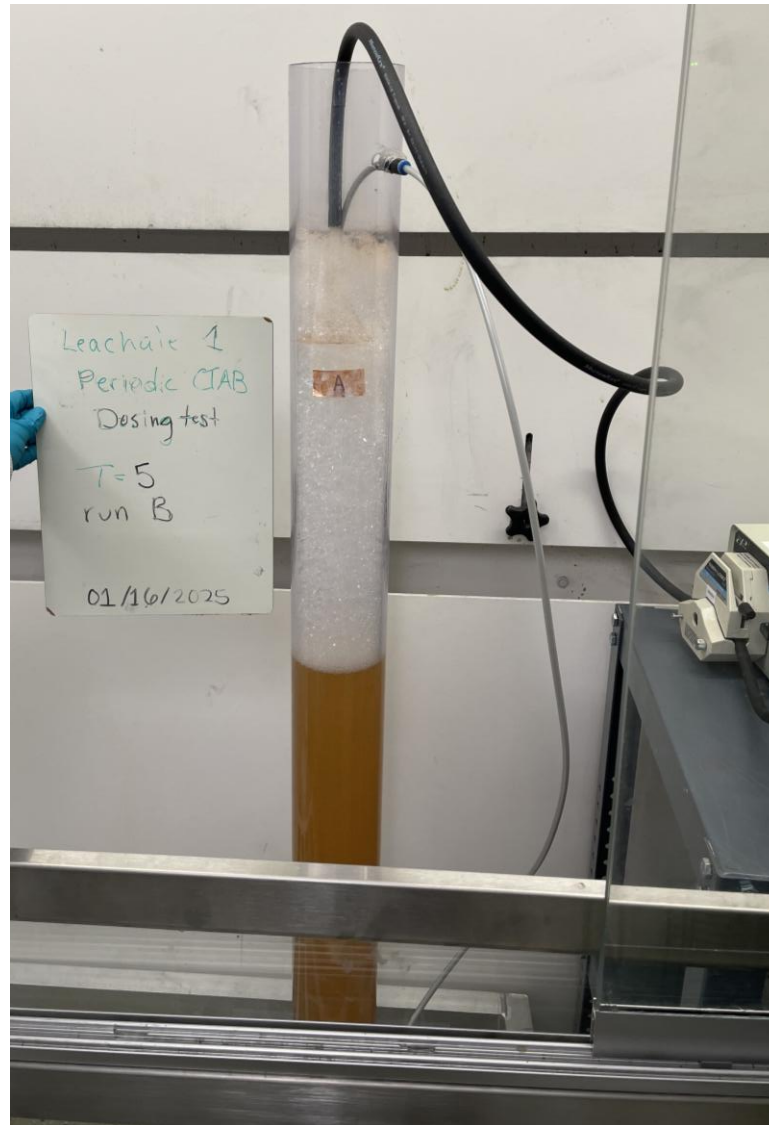


30,000 gpd
(Skagen 2025)

Foam Fractionation with Landfill Leachate in Action



Leachate with Additive

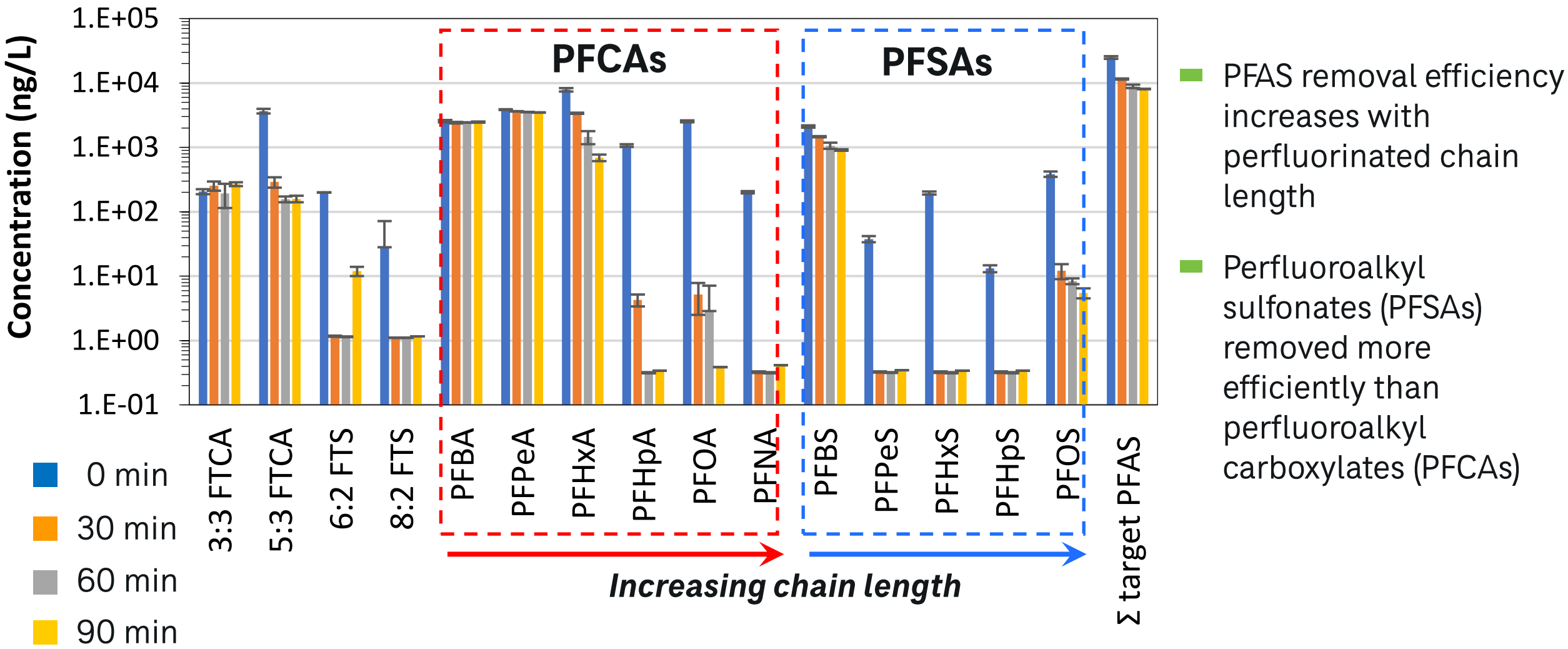


Leachate with Additive



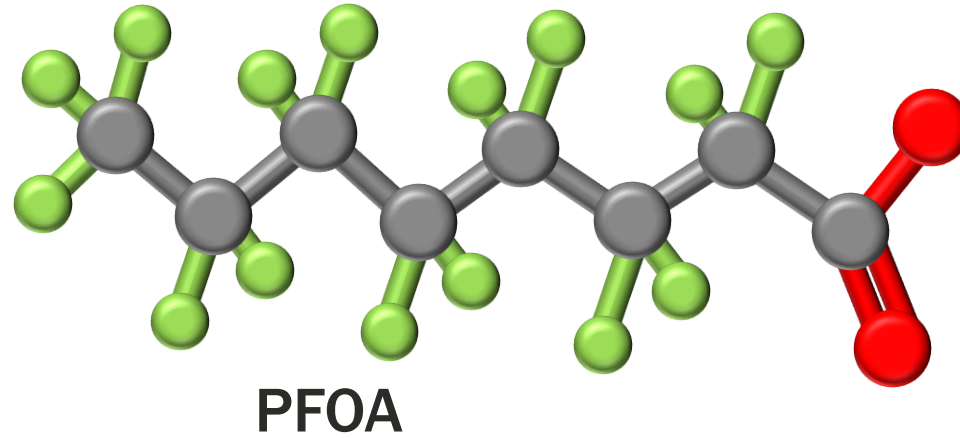
Leachate without Additive

Landfill Leachate Foam Fractionation Bench Study



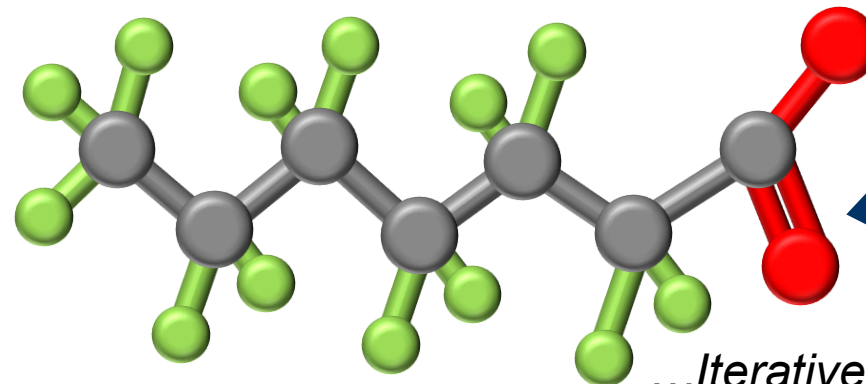
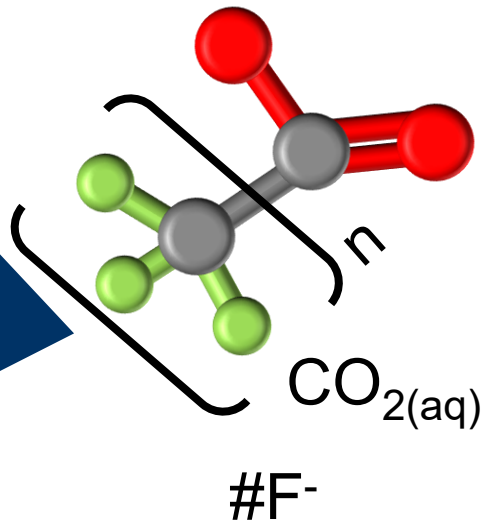
PFAS-Relevant Destruction: Currently Known Mechanisms

- Carbon
- Oxygen
- Fluorine
- Hydrogen



Intense Heat

Heat
Advanced Oxidizing Processes (AOP)
Advanced Reducing Processes (ARP)



Main Hazardous Waste Incineration Takeaways

Approaching industry consensus:
>1,000°C for >2 s gas phase residence
time with **proper mixing** and excess
hydrogen for adequate destruction
(atmospheric pressure)



**Complete
Mineralization**

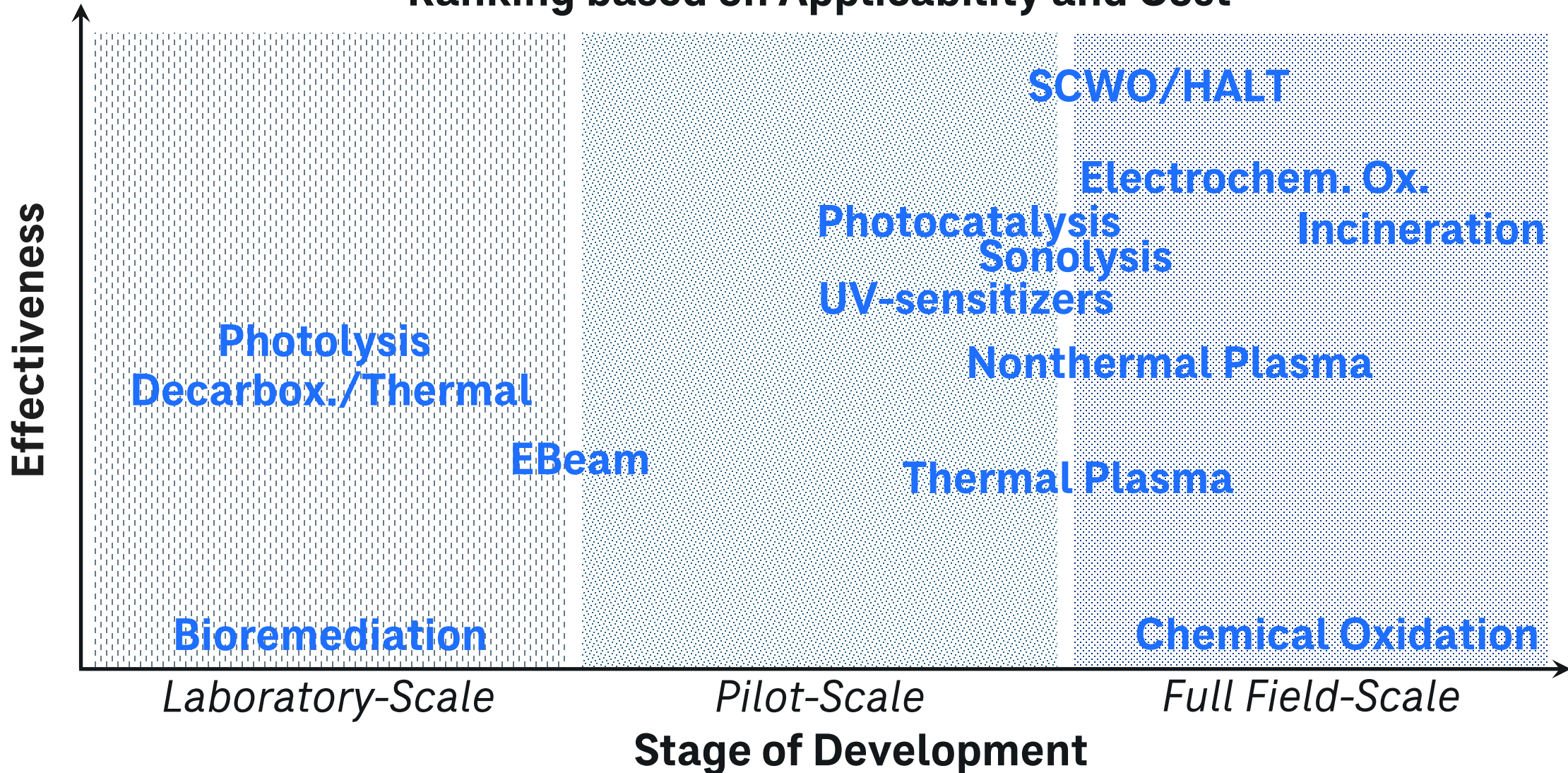
Method Limitations

**Adequate
Destruction**

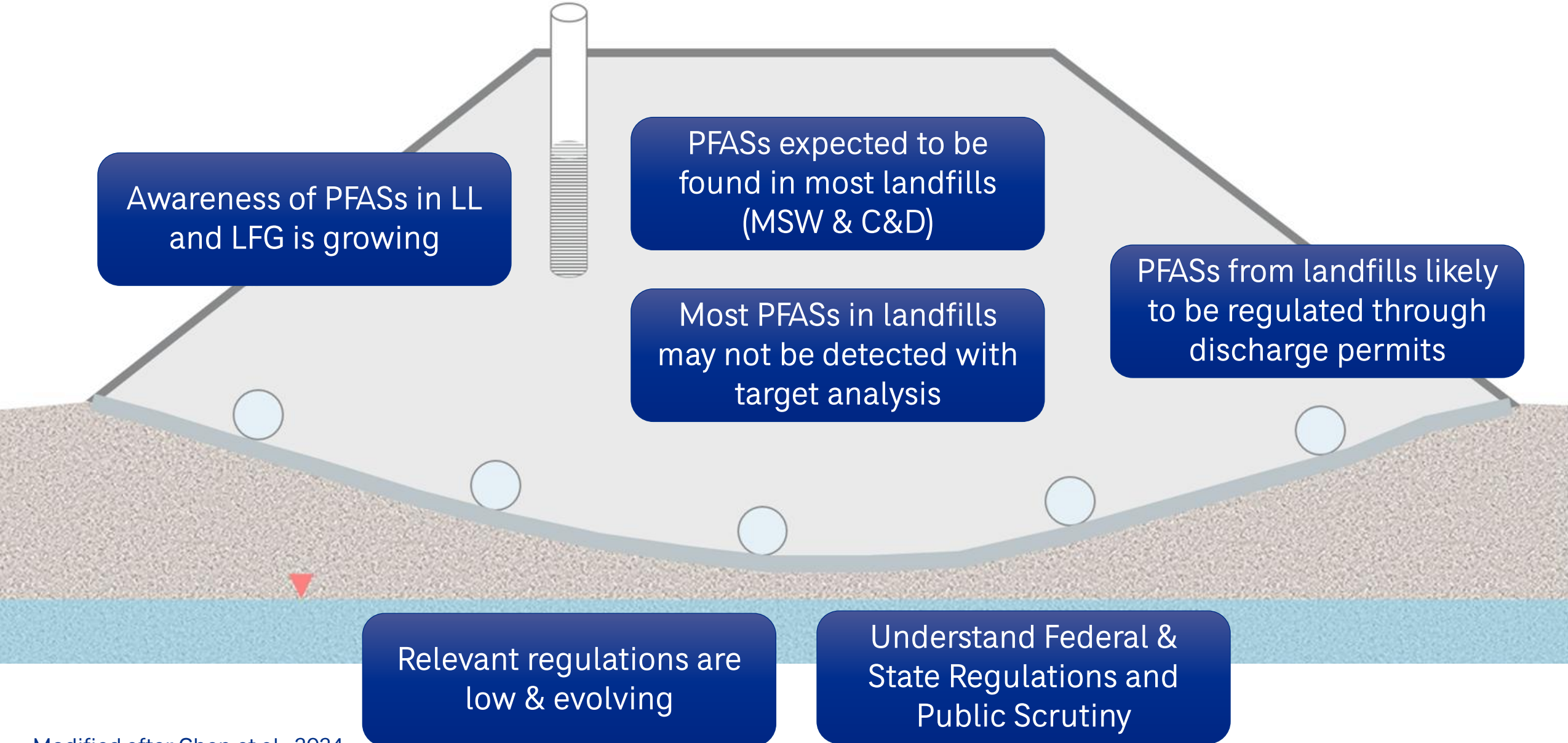
[USEPA 2024 \(Section 3a, pg 44\)](#)

Liquid Phase PFASs-Relevant Destruction Technologies

Ranking based on Applicability and Cost



Summary of PFASs Associated with Municipal Solid Waste



Questions and Discussion



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Extra Slides

PFASs Studies/Reviews in Landfill Leachate

Pre 2022

2022

2023

2024

2025

[Busch et al., 2010](#)
[Eggen et al., 2010](#)
[Huset et al., 2011](#)
[Li et al., 2012](#)
[Benskin et al., 2012](#)
[McKay Allred et al., 2014](#)
[Clarke et al., 2015](#)
[Kim et al., 2015](#)
[Yan et al., 2015](#)
[Gallen et al., 2016](#)
[Gallen et al., 2017](#)
[Lang et al., 2017](#)
[Fuertes et al., 2017](#)
[Yin et al., 2017](#)
[Qi et al., 2018](#)
[Hepburn et al., 2019](#)
[Harrad et al., 2019](#)
[Wei et al., 2019](#)
[Hamid et al., 2020a](#)
[Hamid et al., 2020b](#)

[Liu et al., 2020](#)
[Solo-Gabriele et al., 2020](#)
[Feng et al., 2021](#)
[Maldonado et al., 2021](#)
[Masoner et al., 2021](#)
[McCleaf et al., 2021](#)
[Mojiri et al., 2021](#)
[Singh et al., 2021](#)
[SWANA 2021](#)
[Tian et al., 2021](#)

Indicates some form of non-target analysis (e.g., TOP Assay)

[Burns et al., 2022](#)
[Golwala et al., 2022](#)
[Huang et al., 2022](#)
[Karatas et al., 2022](#)
[Liu et al., 2022](#)
[McQueen et al., 2022](#)
[Smith et al., 2022](#)
[Urtiaga et al., 2022](#)
[Zhang et al., 2022a](#)
[Zhang et al., 2022b](#)

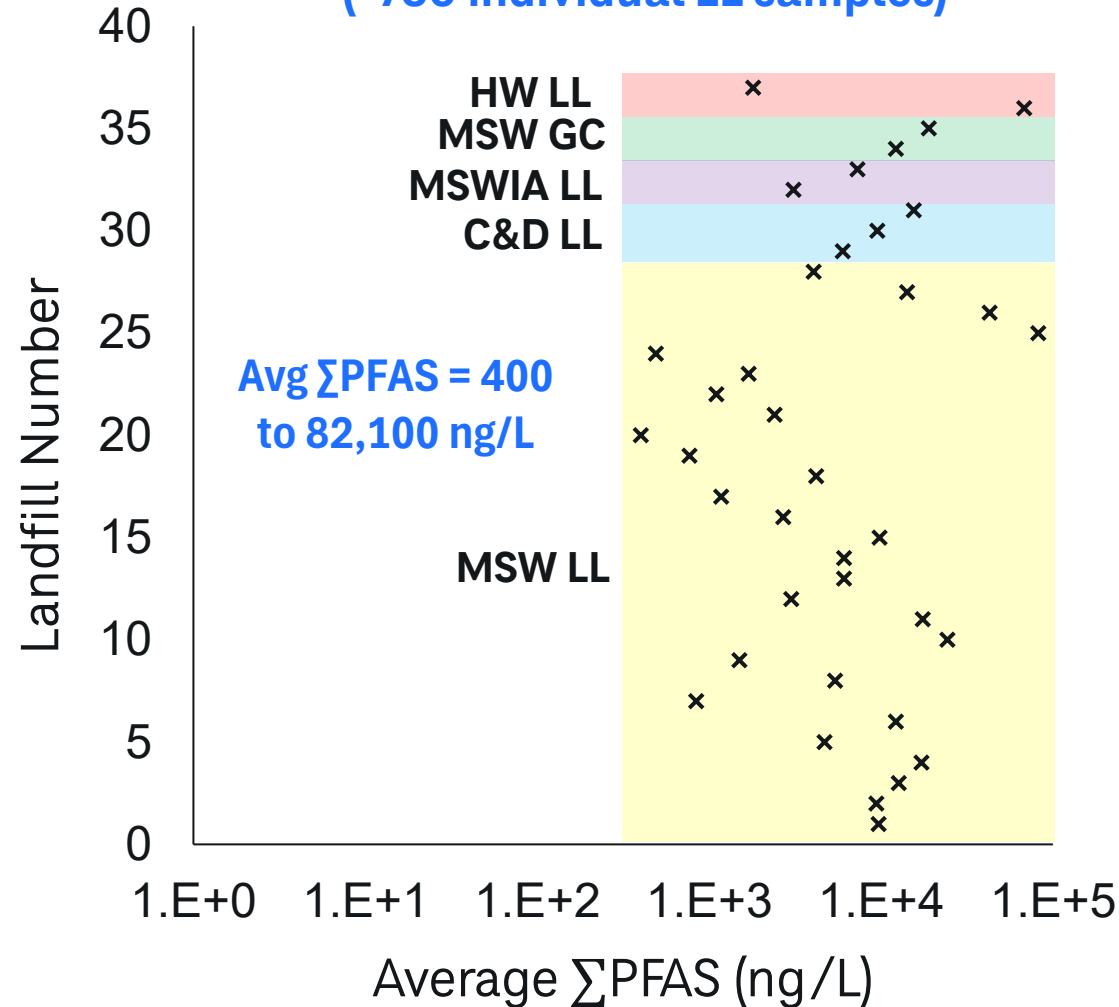
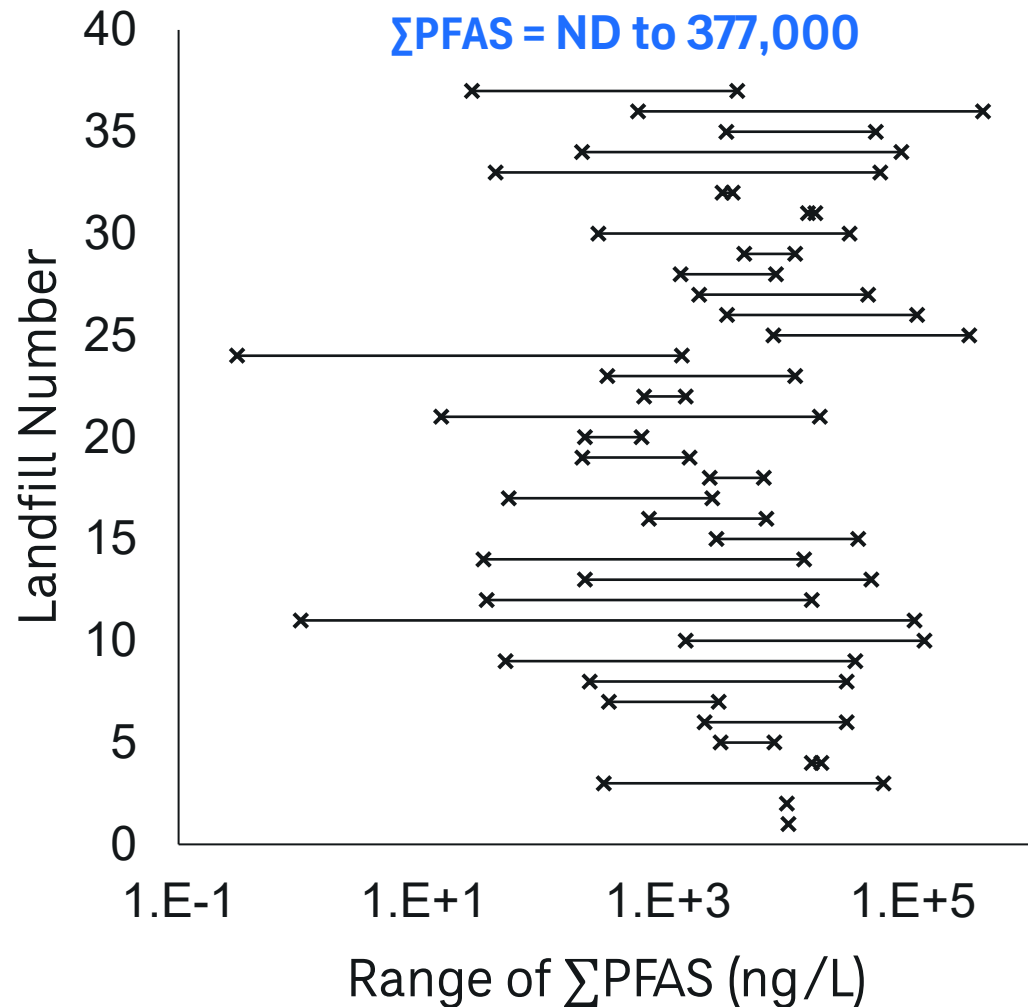
[Capozzi et al., 2023](#)
[Chen et al., 2023](#)
[Coffin et al., 2023](#)
[Johnson et al., 2023](#)
[Karatas et al., 2023](#)
[Li et al., 2023](#)
[Lott et al., 2023](#)
[Lu et al., 2023](#)
[Malovanyy et al., 2023](#)
[Qian et al., 2023](#)
[Rehnstam et al., 2023](#)
[Sun et al., 2023](#)
[Tolaymat et al., 2023](#)
[Vo et al., 2023](#)
[Zhang et al., 2023](#)

[Cerlanek et al., 2024a](#)
[Cerlanek et al., 2024b](#)
[Chen et al., 2024a](#)
[Chen et al., 2024b](#)
[European Union, 2024](#)
[Collins et al., 2024](#)
[Feng et al., 2024](#)
[Li et al., 2024](#)
[Neill and Megson 2024](#)
[Ogata et al., 2024](#)
[Prada et al., 2024](#)
[Robey et al., 2024](#)
[Rehnstam et al., 2024](#)
[Sabba et al., 2024](#)
[Singh et al., 2024](#)
[Vo et al., 2024](#)
[Wang et al., 2024](#)

[Chen et al., 2025a](#)
[Chen et al., 2025b](#)
[Chen et al., 2025c](#)
[Chen et al., 2025d](#)
[Goukeh et al., 2025](#)
[Kirilova et al., 2025](#)
[Khurana et al., 2025](#)
[Mustafa et al., 2025](#)
[Pierpaoli et al., 2025](#)
[Ramadan et al., 2025](#)
[Robey et al., 2025](#)
[Uwayezu et al., 2025](#)

Landfill Studies Find PFASs

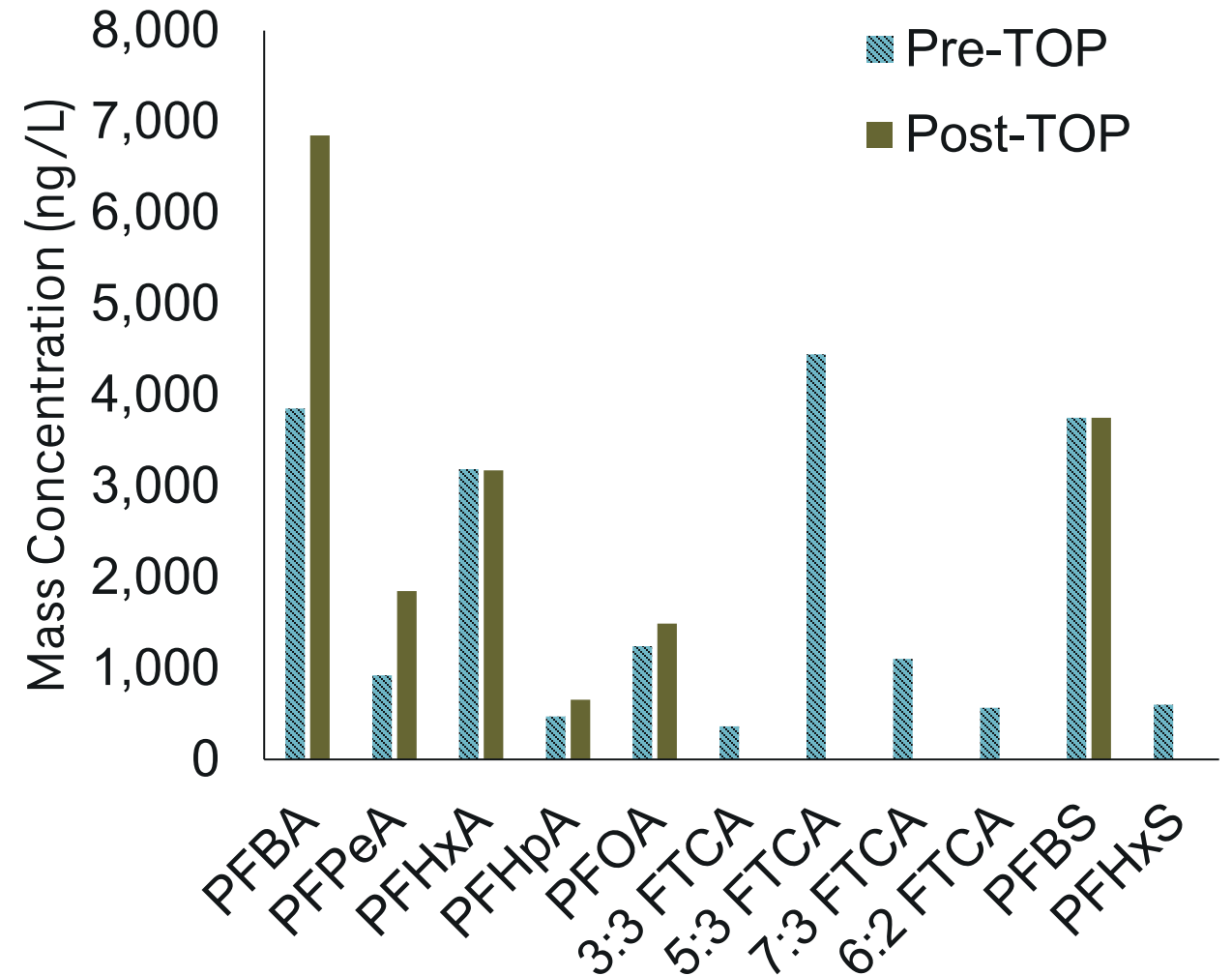
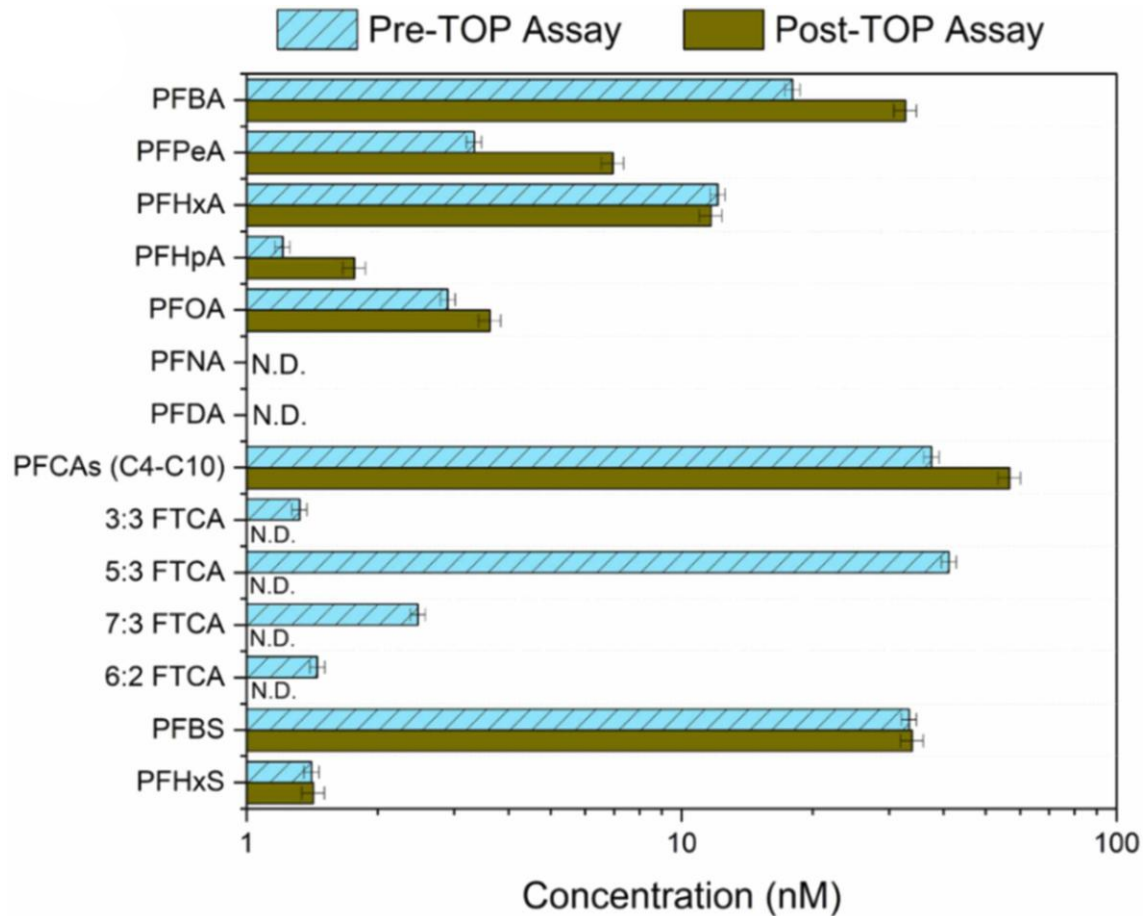
37 different landfills globally
(>750 individual LL samples)



LL = Landfill Leachate
MSW = Municipal Solid Waste
C&D = Construction and Debris

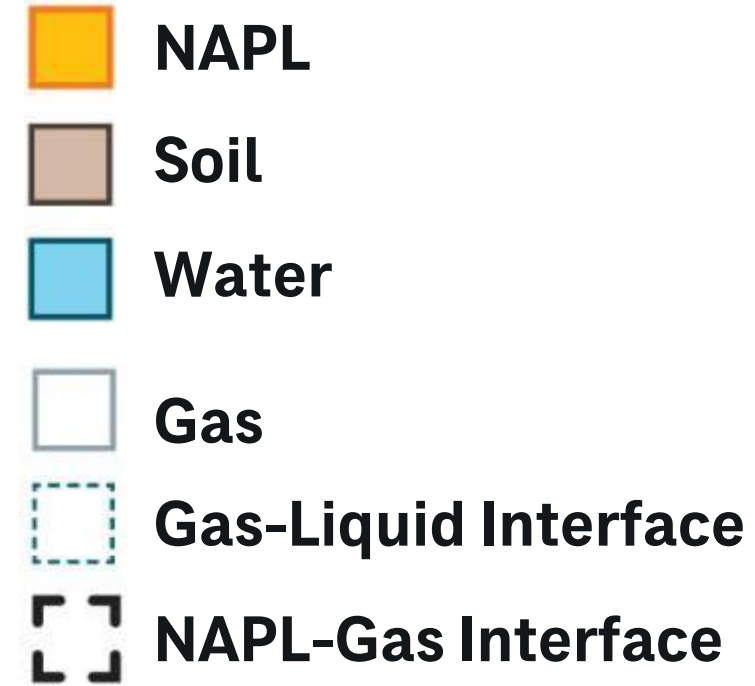
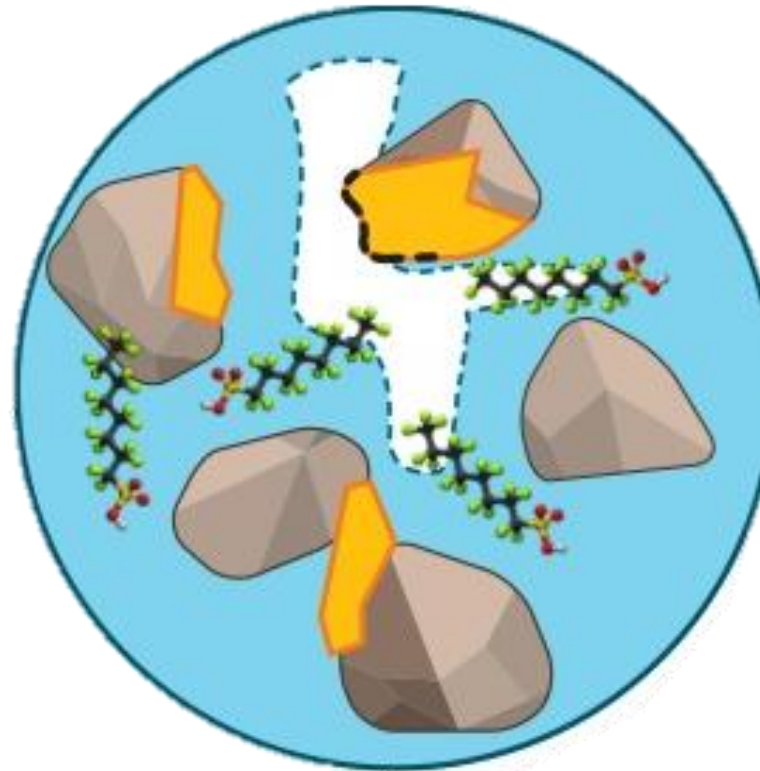
MSWIA = MSW Incineration Ash
GC = Gas Condensate
HW = Hazardous Waste

Landfill Studies Find PFASs – TOP Assay Example



Conceptual Site Model Fate and Transport Considerations

- Regulated PFAS are generally fluorosurfactants and amphiphiles
- Amphiphilic PFAS have unique fate and transport properties
- Surfactants accumulate on surfaces and at interfaces
- Some PFAS can form highly stable assemblies/films on surfaces or at interfaces



Extreme Persistence

Mobility

Bioaccumulation

Toxicity

Surfactancy

PFAS Concerns at a Waste Combustors

Pre-Combustion

Inconsistent and Diverse Source of Waste as Influent Fuel



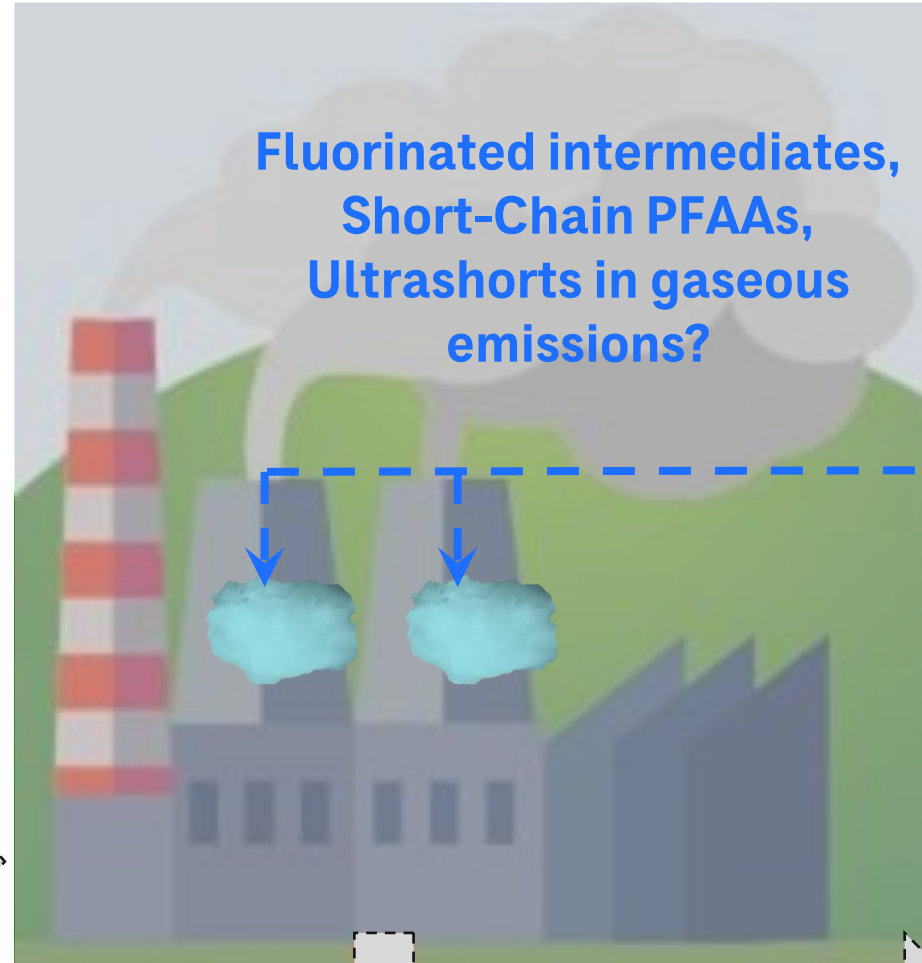
[Björklund et al., 2021](#)

[Liu et al., 2021](#)

[Wang et al., 2020](#)

Precursors, PFAAs, Ultrashorts in leachate

Post-Combustion



**Fluorinated intermediates,
Short-Chain PFAAs,
Ultrashorts in gaseous
emissions?**

[Mattila et al., 2024](#)

[Weitz et al., 2024](#)

[Wang et al., 2022](#)

[Shields et al., 2023](#)

[Blotevogel et al., 2023](#)

[Weber et al., 2025](#)

**PFAAs in
condensate from
scrubbers**

[Björklund et al., 2024](#)

[Carlund 2023](#)

[Johansson et al 2024](#)

**PFAS in
associated ash**

[Loganathan et al., 2007](#)

[Winchell et al., 2020](#)

[Liu et al., 2022](#)

[Hyks et al 2024](#)