

# Evolving PFAS Regulatory Landscape and Technology Readiness to Address the Challenges

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*Battelle*

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OSSERVATORIO PFAS ASSORECA  
RIFLESSIONI PER UN APPROCCIO  
METODOLOGICO

19.09.2024 | H 14.00

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**REMTECH EXPO 24**  
FERRARA FIERE



# Agenda

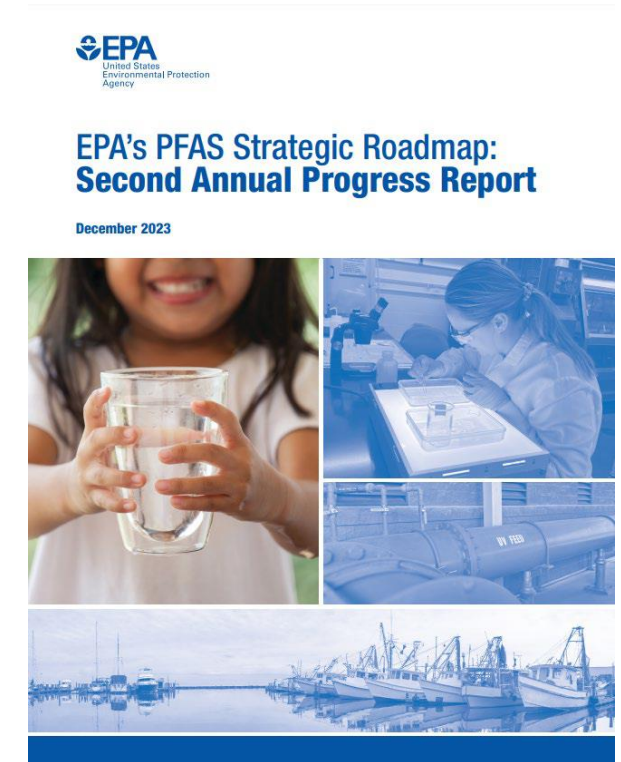
- Overview of PFAS Regulations in US
- Emerging Technologies
- Battelle PFAS Technology Tool Box

# EPA's PFAS Strategic Roadmap: Commitments to Action 2021-2024

PFAS Strategic Roadmap, released in October 2021 – a strategic, whole-of-EPA approach to protect public health and the environment from PFAS.

The Roadmap included:

- Timelines for concrete actions from 2021-2024
- Ensure science-based decision making
- Supports states' ongoing efforts
- Transparent, equitable, and inclusive engagement with all stakeholders



[www.epa.gov/pfas](http://www.epa.gov/pfas)

# USEPA's Strategic Roadmap Goals



Invest in research, development, and innovation to increase understanding of PFAS exposures and toxicities, human health and ecological effects interventions that incorporate the best available science



Pursue a comprehensive approach to proactively prevent PFAS from entering air, land, and water at levels that can adversely impact human health and the environment.

Broaden and accelerate the cleanup of PFAS contamination to protect human health and ecological systems.

# Key PFAS Roadmap Accomplishments - MCLs



REMTECH EXPO

**April 2024 Final Rule: First-ever nationwide, legally enforceable drinking water standards under Safe Drinking Water Act**

Chemical	Maximum Contaminant Level Goal (MCLG)	Maximum Contaminant Level (MCL)
PFOA	0	4.0 ppt
PFOS	0	4.0 ppt
PFNA	10 ppt	10 ppt
PFHxS	10 ppt	10 ppt
HFPO-DA (GenX chemicals)	10 ppt	10 ppt
Mixture of two or more: PFNA, PFHxS, HFPO-DA, and PFBS	Hazard Index of 1	Hazard Index of 1
<b>Maximum Contaminant Level Goal (MCLG):</b> The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.		

## The final rule requires:

- 3 years to complete initial monitoring (2027)
- 5 years (by 2029) to implement solutions that reduce these PFAS
- Beginning in 2029, violators must take action to reduce levels and must provide notification to the public of the violation.

EPA announced \$1 billion through the Bipartisan Infrastructure Law

# Key PFAS Roadmap Accomplishments – Hazardous Substance Designation



## April 2024 Final Rule: CERCLA hazardous substance designation for PFOA & PFOS

- Designation under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund.
- Allow EPA to:
  - address more contaminated sites,
  - take earlier action and expedite cleanups
  - ensure polluters pay for the costs to clean up pollution threatening the health of communities.
- Allow Department of Transportation to list and regulate these substances
- Likely result in increased litigation

[Designation of Perfluorooctanoic Acid \(PFOA\) and Perfluorooctanesulfonic Acid \(PFOS\) as CERCLA Hazardous Substances | US EPA](#)

# Other Key PFAS Roadmap Initiatives

- Finalized a new reporting requirements under Toxic Substances Control Act (TSCA)
- Proposed Resource Conservation and Recovery Act (RCRA) PFAS-Related Rules
- Addressing on-going uses of PFAS
- Released three new methods for measuring PFAS in the environment
  - Final EPA Method 1633 for 40 PFAS in aqueous and solid environmental matrices, and fish tissue
  - Final EPA Method 1621 for Total organofluorine in wastewater
  - Other Test Method (OTM) 45 for target PFAS and OTM 50 for 30 volatile fluorinated compounds in air

[Biden-Harris Administration Announces New Steps to Protect Communities from PFAS and Other Emerging Chemicals of Concern | US EPA](#)  
[EPA's PFAS Strategic Roadmap: Second Annual Progress Report](#)

# Other Key PFAS Roadmap Initiatives

- National Pollutant Discharge Elimination System (NPDES) Permit Applications – A proposed rule would include PFAS in the list of pollutants considered during NPDES permit applications by sewage treatment facilities.
- Effluent Limitation Guidelines (ELGs) to restrict PFAS discharges – No actionable guidelines released
- Industrial Discharges – Point Source Category:
  - PFAS Manufacturing plants
  - Electrical and electronics
  - Textile Industry
  - Pulp, paper industry
  - Concentrated animal Feeding operations
  - Landfills

[View Rule \(reginfo.gov\)](https://www.reginfo.gov)



# Updated Interim Guidance on PFAS Destruction and Disposal from U.S. EPA (2024)



- Updated interim guidance on the destruction or disposal including six specific PFAS containing materials including their manufacture and use:
  - aqueous film-forming foam;
  - soil and biosolids;
  - textiles, other than consumer goods, treated with PFAS;
  - spent filters, membranes, resins, granular carbon, and other waste from water treatment;
  - landfill leachate containing PFAS; and
  - solid, liquid, or gas waste streams containing PFAS from facilities manufacturing or using PFAS.

[Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances--2024 \(epa.gov\)](https://www.epa.gov/interim-guidance-on-the-destruction-and-disposal-of-perfluoroalkyl-and-polyfluoroalkyl-substances-and-materials-containing-perfluoroalkyl-and-polyfluoroalkyl-substances-2024)

# Updated Interim Guidance on PFAS Destruction and Disposal from U.S. EPA (2024)



- Destruction and Disposal Technologies Identified:
  - Thermal treatment
  - Landfills
  - Underground injection
- Ability to destroy/contain PFAS and control measures for PFAS if not destroyed
  - Potential for releases
  - Testing and monitoring
  - Uncertainties/unknowns and prioritized research needs
  - Technology and infrastructure considerations
- Interim storage may be an option when immediate destruction or disposal is not imperative; On-site capacity is readily available

[Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances--2024 \(epa.gov\)](https://www.epa.gov/interim-guidance-on-the-destruction-and-disposal-of-perfluoroalkyl-and-polyfluoroalkyl-substances-and-materials-containing-perfluoroalkyl-and-polyfluoroalkyl-substances-2024)

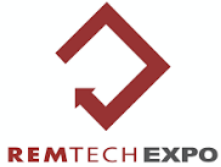
# Research Needs on PFAS Destruction and Disposal



- DoD has identified 4 commercially available options to destroy or dispose of DoD PFAS-containing materials, in order of consideration:
  - Carbon reactivation units with environmental permits
  - Hazardous waste landfills with environmental permits
  - Solid waste landfills with environmental permits
  - Hazardous waste incinerators with environmental permits
- DoD may also consider other 'existing and developing' PFAS treatment or destruction technologies that are accepted/permitted by the appropriate State or Federal Regulator, instead of utilizing incinerators on a site-specific basis
- Decision tree allows for alternative technology evaluation but needs to be economically viable liquid-contaminated PFAS/AFFF destruction

[Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances--2024 \(epa.gov\)](#)

# Emerging Technologies for PFAS Destruction and Disposal



- EPA's ORD initiated the PFAS Innovative Treatment Team (PITT) in 2020 as a short-term dedicated, cross-ORD effort to identify, review, and conduct preliminary research on potential treatment technologies.
- PITT focused on the effectiveness of select technologies using pilot scale testing:
  - mechanochemical degradation (Gobindlal et al.2023)
  - electrochemical oxidation
  - gasification and pyrolysis (Thoma et al., 2022)
  - supercritical water oxidation (Krause et al 2022; Sahle-Demessie et al., 2022)
- PITT studies generally indicated potential for PFAS destruction, further work using newly available methods is needed to more fully characterize the outputs of these processes and to evaluate their performance for PFAS-containing materials beyond AFFF

[Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances--2024 \(epa.gov\)](#)  
PFAS Innovative Treatment Team (PITT) | US EPA

# EPA Case Studies on SCWO

EPA/600/R-22/257 | September 2022 | www.epa.gov/research

**EPA**  
United States Environmental Protection Agency

## Industrial SCWO for the Treatment of PFAS/AFFF Within a Water Matrix



**EPA**  
www.epa.gov/research

### Research BRIEF

INNOVATIVE RESEARCH FOR A SUSTAINABLE FUTURE

**POTENTIAL PFAS DESTRUCTION TECHNOLOGY: SUPERCRITICAL WATER OXIDATION**

In Spring 2020, the EPA established the PFAS Innovative Treatment Team (PITT). The PITT was a multi-disciplinary research team that worked full-time for 6 months on applying their scientific efforts and expertise to a single problem: disposal and/or destruction of PFAS-contaminated media and waste. While the PITT formally concluded in Fall 2020, the research efforts initiated under the PITT continue.

As part of the PITT's efforts, EPA researchers considered whether existing destruction technologies could be applied to PFAS-contaminated media and waste. This series of Research Briefs provides an overview of four technologies for destroying PFAS and the research underway by the EPA's Office of Research and Development to further explore these technologies. Because research is still needed to evaluate these technologies for PFAS destruction, this Research Brief should not be considered an endorsement or recommendation to use this technology to destroy PFAS.

**Background**

Various industries have produced and used per- and polyfluoroalkyl substances (PFAS) since the mid-20th century. PFAS are found in consumer and industrial products, including non-stick coatings, waterproofing materials, and manufacturing additives. PFAS are stable and resistant to natural destruction in the environment, leading to their pervasive presence in groundwater, surface water, drinking water, and other environmental media (e.g., soil) in some localities. Certain PFAS also contain bioaccumulative and the blood of most US citizens toxicity of PFAS is a subject of current study and research known to motivate efforts to limit environmental release and human exposure (EPA, 2020).

To protect human health and the environment, EPA researchers are identifying technologies that can destroy PFAS in liquid and solid waste streams, including concentrated and spent (used) fire-fighting foam, biosolids, and landfill leachate. These technologies should be readily available, cost effective, and produce little to no

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## SCWO Case Studies

- Case studies performed with four separate SCWO operators
  - Aquarden (Denmark)
  - 374Water (Durham, NC)
  - Battelle (Columbus, OH)
  - General Atomics (San Jose, CA)
- Tested SCWO on dilute AFFF
- Analyzed for PFAS, TOF, fluoride, and COD
  - Some gas-phase PFAS sampled w/General Atomics



Source: <https://aquarden.com>



Source: <https://www.battelle.org/government-offerings/energy-environment/environmental-services/pfas-assessment-mitigation/pfas-annihilator-destruction-technology>

Office of Research and Development

## ASCE

### Supercritical Water Oxidation as an Innovative Technology for PFAS Destruction

Max J. Krause<sup>1</sup>; Eben Thoma<sup>2</sup>; Endakachew Sahle-Damesse<sup>3</sup>; Brian Crona<sup>4</sup>; Andrew Whitehill<sup>5</sup>; Erin Shields<sup>6</sup>; and Brian Gullett<sup>7</sup>

**Abstract:** Water above 374°C and 22.1 MPa becomes supercritical, a special state where organic solubility increases and oxidation processes are accelerated. Supercritical water oxidation (SCWO) has been previously shown to destroy hazardous substances such as halogenated compounds. Three separate providers of SCWO technology were contracted to test the efficacy of SCWO systems to reduce per- and poly-fluoroalkyl substances (PFAS) concentrations from solutions of dilute aqueous film-forming foam (AFFF). The findings of all three demonstration studies showed a greater than 99% reduction of the total PFAS identified in a targeted compound analysis, including perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). PFOS was reduced from 26.2 mg/L to 240 µg/L, 30.4 mg/L to 0.10 µg/L, and 190 mg/L to 8.57 µg/L from the Aquarden, Battelle, and 374Water demonstrations, respectively. Similarly, PFOA was reduced from 93.0 to 0.14 µg/L, 88.0 to 0.02 µg/L, and 3,100 µg/L to nondetect in the three evaluations. Additionally, the chemical oxygen demand of the dilute AFFF was shown to reduce from 4,750 to 5.17 mg/L after treatment, indicating significant organic compound destruction. In one demonstration, a mass balance of the influent and effluent found that the targeted compounds accounted for only 27% of the generated fluoride, suggesting that more PFAS were destroyed than measured and emphasizing the limitations of targeted analysis alone. As a destructive technology, SCWO may be an alternative to incineration and could be a permanent solution for PFAS-laden wastewater rather than disposal by injection into a deep well or landfilling. Additional investigation of reaction byproducts remains to be conducted for a complete assessment of SCWO's potential as a safe and effective PFAS treatment technology. DOI: 10.1061/(ASCE)E.1943-7870.0001987. © 2021. Published by American Society of Civil Engineers.

**Author keywords:** Supercritical water oxidation (SCWO); Aqueous film-forming foam (AFFF); Per- and poly-fluoroalkyl substances (PFAS); perfluorooctanesulfonic acid (PFOS); Fluoride.

**Introduction**

Water above 374°C and 22.1 MPa becomes supercritical, a special phase of water with both liquid-like and gas-like properties. Above the critical point of water, most organic compounds are soluble, oxygen is fully miscible, and salts are insoluble (Hoslen et al. 2004; Visin et al. 2017). In the presence of an oxidizing agent, such as oxygen, supercritical water's unique properties accelerate the oxidation of a broad range of organic pollutants. Since the 1980s, supercritical water oxidation (SCWO) has been used successfully to treat a variety of hazardous wastes, such as chemical warfare agents and halogenated compounds (Abeln et al. 2001; Cohen et al. 1998; Kim et al. 2010). Technical challenges have limited implementation of SCWO at scale, including the buildup of corrosive species during the oxidation reaction and salts' precipitation on the reactor body, leading to high maintenance and operation costs (Marone 2013; Milton et al. 2001). These factors have historically constrained SCWO's utility to hazardous or otherwise high-cost wastes.

In the United States, aqueous film-forming foam (AFFF) has been used for over 50 years for certain firefighting applications and associated training exercises. The vast majority of AFFF in use or stockpiled contains fluorosurfactants, which are made up of per- and poly-fluoroalkyl substances (PFAS) (Baron-Hanson et al. 2017; Place and Field 2012). It is estimated that there are millions of liters of AFFF in private, public, and military custody (Darwin 2011). Many PFAS are stable and resistant to natural destruction in the environment, leading to their pervasive presence in groundwater, surface waters, and drinking water in some localities (Boone et al. 2019; Heitz et al. 2013, 2016; He et al. 2016; Mauer et al. 2017). The US Environmental Protection Agency (EPA) and Department of Defense (DoD) identified PFAS destruction as a priority research area, and several states have promulgated or drafted individual PFAS limits for drinking water and soils (Coyle et al. 2021; FIRC 2021). Due to the bioaccumulative nature and adverse health effects of some PFAS, many states have restricted or prohibited the use of firefighting foam containing PFAS. Millions of liters of highly concentrated material now must be disposed of or destroyed in a manner that protects human health and the environment

<sup>1</sup>Engineer, US Environmental Protection Agency, Office of Research and Development, 26 Martin Luther King Dr., W. Cincinnati, OH 45268 (corresponding author). ORCID: <https://orcid.org/0000-0001-8383-8026>. Email: [krmae@epa.gov](mailto:krmae@epa.gov)

<sup>2</sup>Scientist, US Environmental Protection Agency, Office of Research and Development, 109 TW Alexander Dr., Durham, NC 27709. ORCID: <https://orcid.org/0000-0003-1172-4569>

<sup>3</sup>Engineer, US Environmental Protection Agency, Office of Research and Development, 26 Martin Luther King Dr., W. Cincinnati, OH 45268.

<sup>4</sup>Engineer, US Environmental Protection Agency, Office of Research and Development, 109 TW Alexander Dr., Durham, NC 27709.

<sup>5</sup>Scientist, US Environmental Protection Agency, Office of Research and Development, 109 TW Alexander Dr., Durham, NC 27709.

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Note. This manuscript was submitted on July 6, 2021; approved on September 18, 2021; published online on November 23, 2021. Discussion period open until April 23, 2022; separate discussions must be submitted for individual papers. This paper is part of the *Journal of Environmental Engineering*, © ASCE, ISSN 0733-9792.

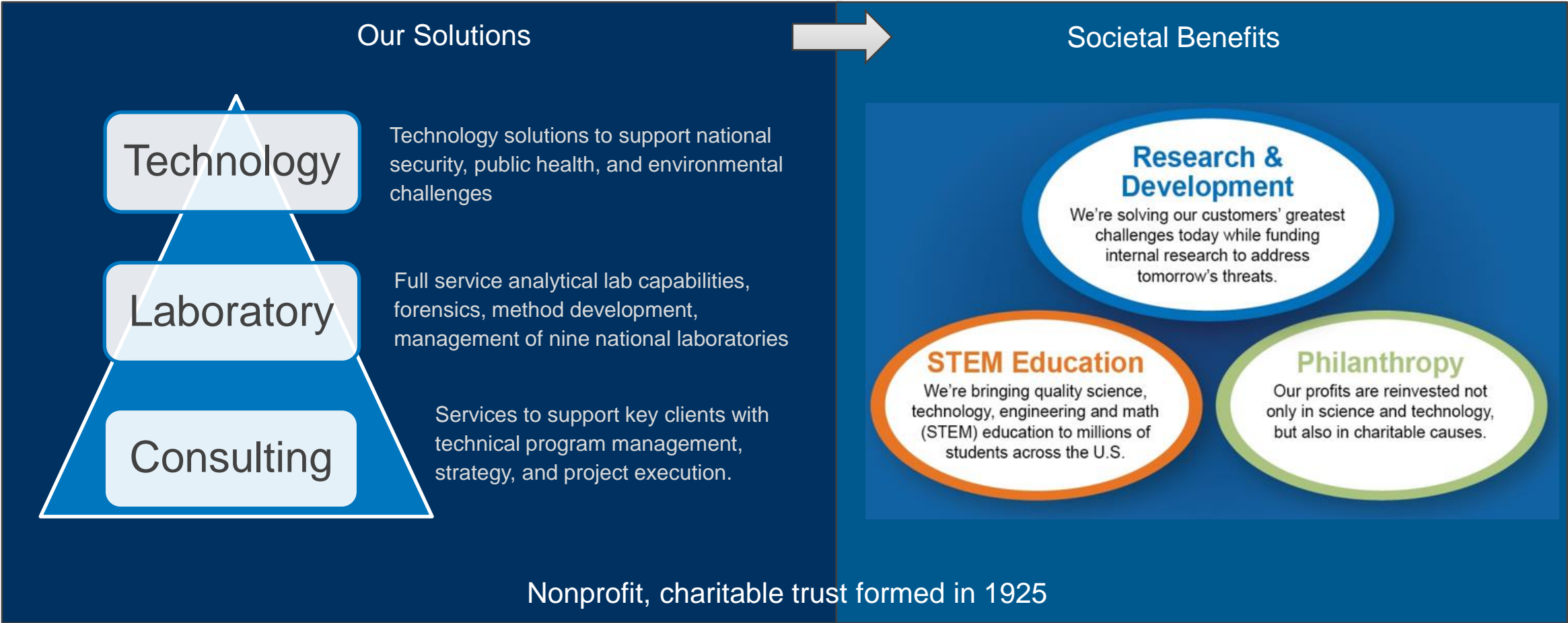
© ASCE 05021006-1 J. Environ. Eng.

The tests achieved 99.99% destruction and removal efficacies of targeted PFAS and total organic carbon. The tests show that hydrothermal flame as an internal heat source reduces residence time, with minimum corrosion, by controlling the wall temperature and construction materials. SCWO process shows limited partial and incomplete oxidation products that are entrained in the solution, and no fluorinated compounds were detected in the stack gas emission. The effluent from SCWO is easily collected, analyzed, and can be recycled. Gaseous effluents from SCWO were carbon dioxide and oxygen with traces of carbon monoxide and trace quantities of hydrothermal heat source oxidized products. The hydrogen fluoride formed within the reactor was neutralized, precipitated from the SCWO reactor water solution, and removed from the SCWO reaction vessel. The study provided additional data on the effectiveness of SCWO as an alternative technology for treating high PFAS-concentrated aqueous waste.

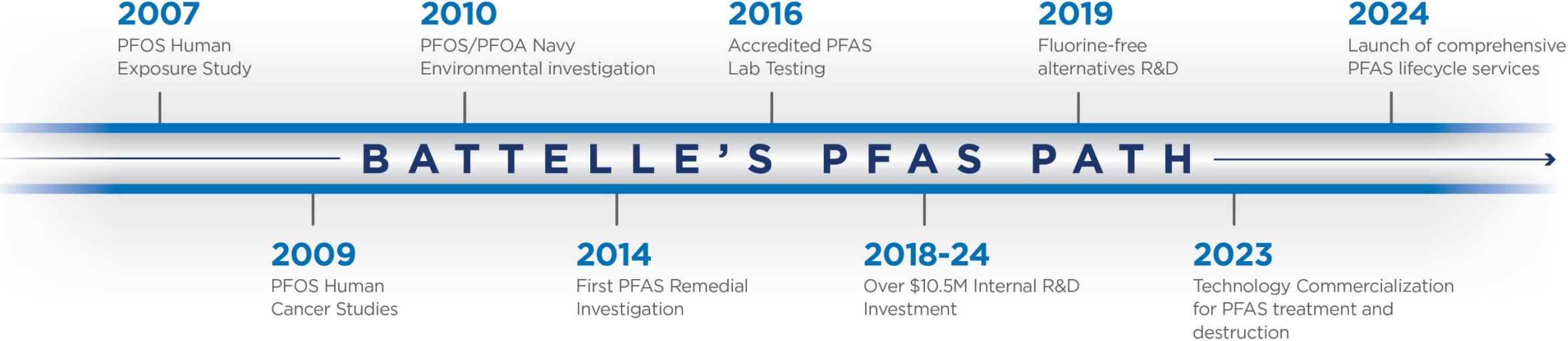
# Battelle PFAS Research

# Battelle: over 90 years of innovation

*Mission: To translate scientific discovery and technology advances into societal benefits.*



# Battelle's Pathway to PFAS Technologies





# Battelle's PFAS Applied R&D Efforts Resulting in Commercial-Ready Technologies

2022

▶ SERDP ER22-3384, Bench-Scale Demonstration of PFAS Destruction in Solids Using Supercritical Water Oxidation (SCWO)

▶ ESTCP ER22-7338, Bench-Scale Evaluation of SCWO to Destroy PFAS in Aqueous Investigation-Derived Waste and Complex Waste Streams

▶ NESDI, Bench-scale study of developing methods to confirm adsorption of PFAS on sorbent and to recover PFAS off the PFAS-laden sorbent to support the applications of passive flux meters (PFMs) for PFAS investigation at a Navy base (WSP)

2023

▶ ESTCP ER23-7939, Sustainable On-Site Removal and Destruction of PFAS using Surface Active Foam Fractionation and SCWO (Allonia)

▶ ESTCP ER23-8435, Application of SCWO to Destroy PFAS in Aqueous Media

2024

▶ NESDI, Application of SCWO to Destroy PFAS-Impacted Waste Streams

▶ DIU, SCWO (PFAS Annihilator®) field demonstration for treating PFAS concentrated waste streams

## Internal R&D



▶ \$10.5M+ invested in IRAD



▶ 23 PFAS projects focused on chemistry, investigation, toxicology, and destruction technologies

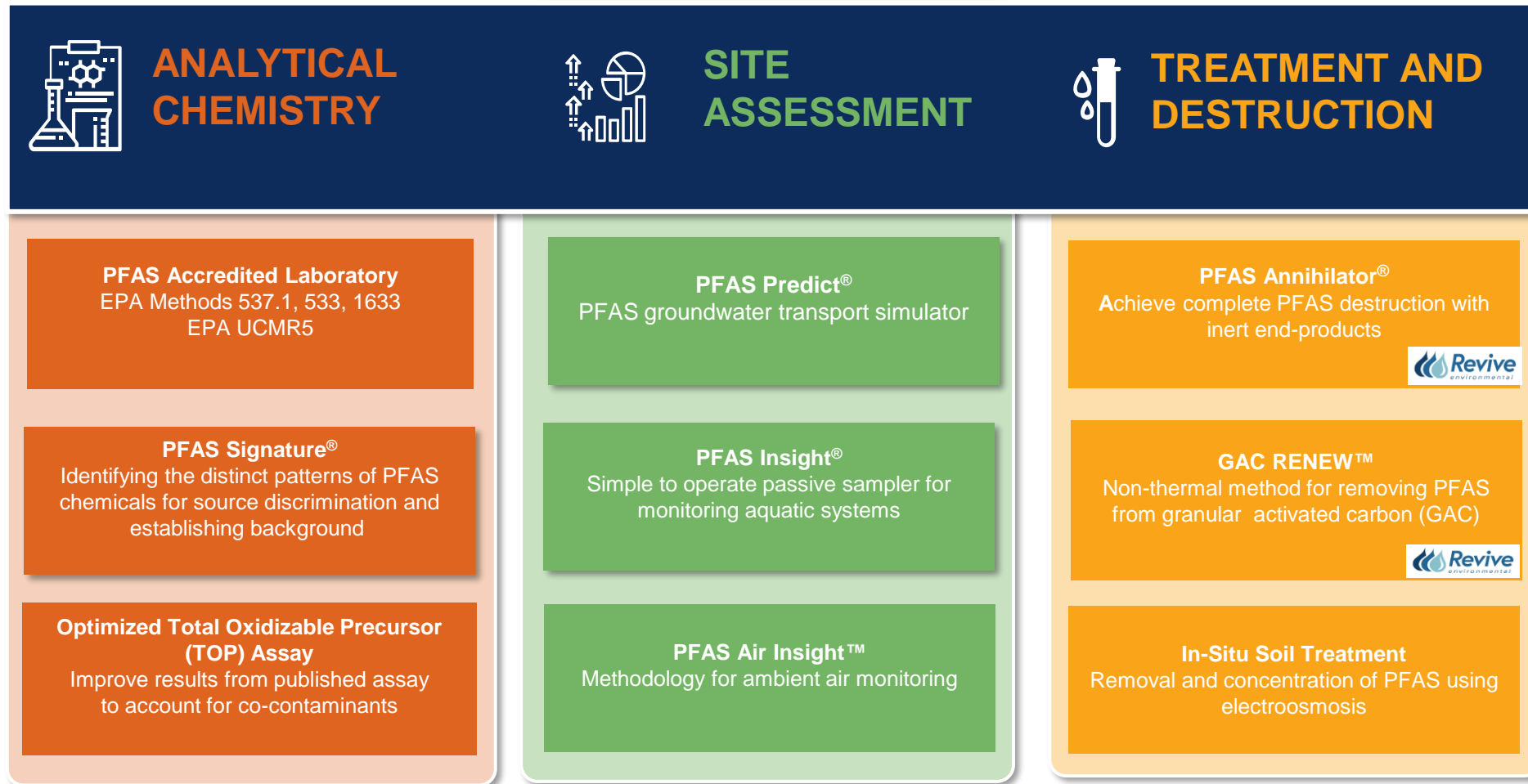


▶ Battelle PFAS Technology Toolbox



▶ 2023 commercialization of PFAS Annihilator® for destruction of aqueous matrices

# Battelle PFAS Technology Toolbox



# Technology + Commercial Destruction Results

## PFAS Annihilator Supercritical Water Oxidation (SCWO)



ACS  
ES&T | Water

pubs.acs.org/estwater

### Application of Supercritical Water Oxidation to Effectively Destroy Per- and Polyfluoroalkyl Substances in Aqueous Matrices

Christopher G Scheitlin,\* Kavitha Dasu,\* Stephen Rosansky, Lindy Espina Dejarne, Dinusha Siriwardena, Jonathan Thorn, Larry Mullins, Ian Haggerty, Krenar Sheqau, and Julia Stowe

Cite This: ACS EST Water 2023, 3, 2053–2062

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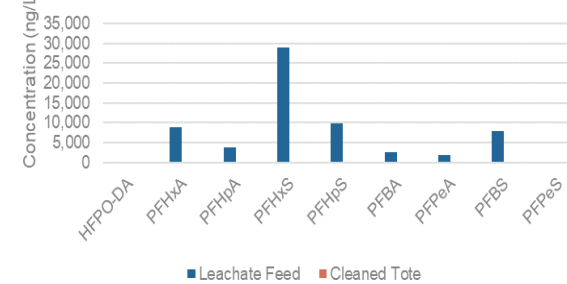
ACCESS | Metrics & More | Article Recommendations | Supporting Information

**ABSTRACT:** Supercritical water oxidation (SCWO) is a destruction technology to treat per- and polyfluoroalkyl substance (PFAS)-impacted groundwater, investigation-derived waste, and other aqueous matrices such as landfill leachate and aqueous film-forming foam. A SCWO system, Battelle's PFAS Annihilator™, was optimized with a goal of reducing all measured PFAS to non-detect levels. Laboratory-prepared and field-collected samples with inlet PFAS concentrations up to 50 ppm were consistently destroyed to less than 70 ppt for all PFAS, when running at the determined optimal operating conditions (≥600 °C and 3500 pounds per square inch). We investigated the correlation between temperature and flowrate of the system, finding that reactor temperatures of ≥450 °C destroy perfluorinated carboxylic acids, but temperatures of ≥575 °C are necessary to destroy perfluorosulfonic acids. A continuous 5-log reduction in concentration of PFAS (99.999% destruction) is demonstrated for 3 h at steady-state operation. The destruction efficiency is not impacted by the addition of co-contaminants such as petroleum hydrocarbons, and volatile organic compounds. The treated effluent is largely composed of complete combustion products including carbon dioxide, water, and the corresponding anion acids; hence, the treated liquid can be released back into the environment after neutralization.

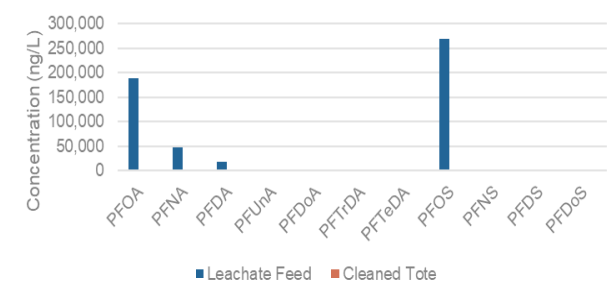
**KEYWORDS:** supercritical water, oxidation, per- and polyfluoroalkyl substances, defluorination, AFFF, SCWO, PFAS

## Landfill Concentrate from Foam Fractionation

Landfill Concentrate  
Short Chain Destruction Efficiency



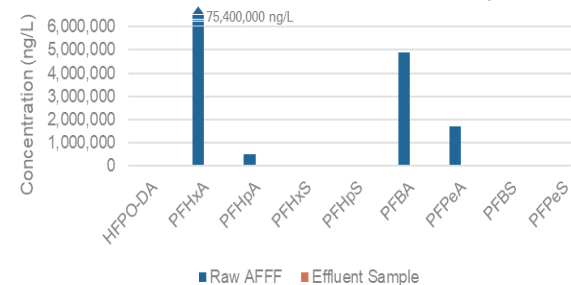
Landfill Concentrate  
Long Chain Destruction Efficiency



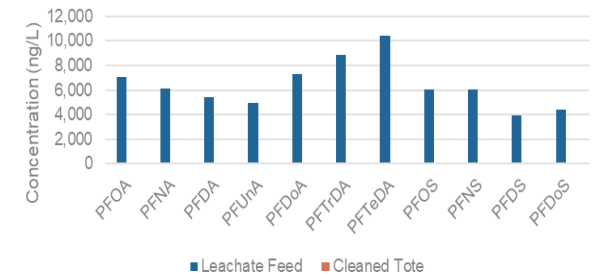
Destruction Efficiency >99.99% when starting value above 2000 ng/L

## AFFF Concentrate (ANSULITE 6% AR-AFFF)

AFFF Destruction  
Short Chain Destruction Efficiency



AFFF Destruction  
Long Chain Destruction Efficiency



AFFF Current Capacity: 3 GPH / unit; Working to 4+ GPH in 2024

# Overview of PFAS Signature<sup>®</sup> Tool for Source Tracking and Background Evaluations

September 19, 2024

Kavitha Dasu  
PFAS Technical Lead  
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# How PFAS Enters the Environment

- **Industrial**
  - Primary - manufacturing plants
  - Secondary - plastic, paper and textile coatings
  - Metal plating
- **AFFF Usage**
  - Fire training areas
  - Airports
  - Emergency response
  - Oil refineries

## Direct Sources



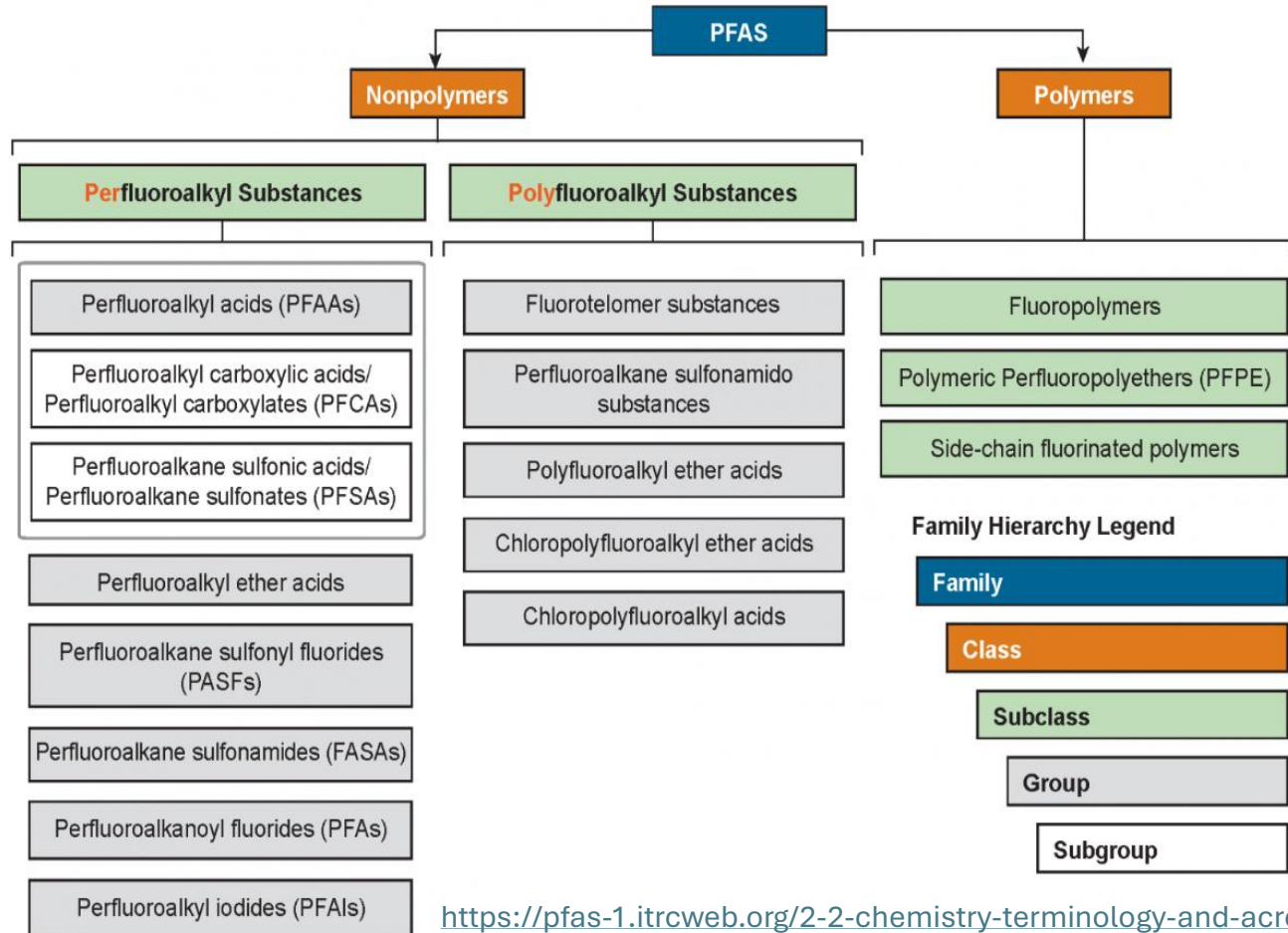
- **Landfills**
  - Leachates
  - Landfill gases
- **Wastewater treatment plants**
  - Effluents
  - Land application of biosolids
- **Waste Incineration**
  - Sewage sludge
  - Industrial waste

## Indirect Sources



Some of these indirect sources might also contribute to background concentrations.

# Applications of PFAS are Driven by Differences in Chemistry



<https://pfas-1.itrcweb.org/2-2-chemistry-terminology-and-acronyms/>

More than 4700 chemicals in the family

## AFFF Chemistry

Neutral

Precursors

Ionic

Anionic (pH 4 -10)

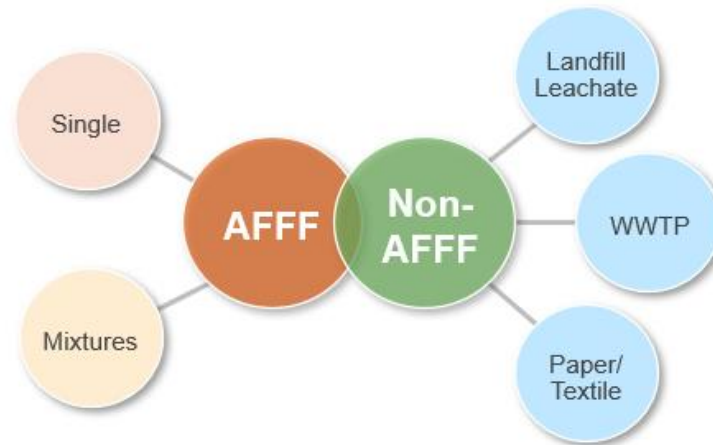
Cationic

Zwitterionic

- Complex chemistry
- Changes in formulations
- Mixtures - partitioning behavior

Understanding precursors chemistry is key for source identification

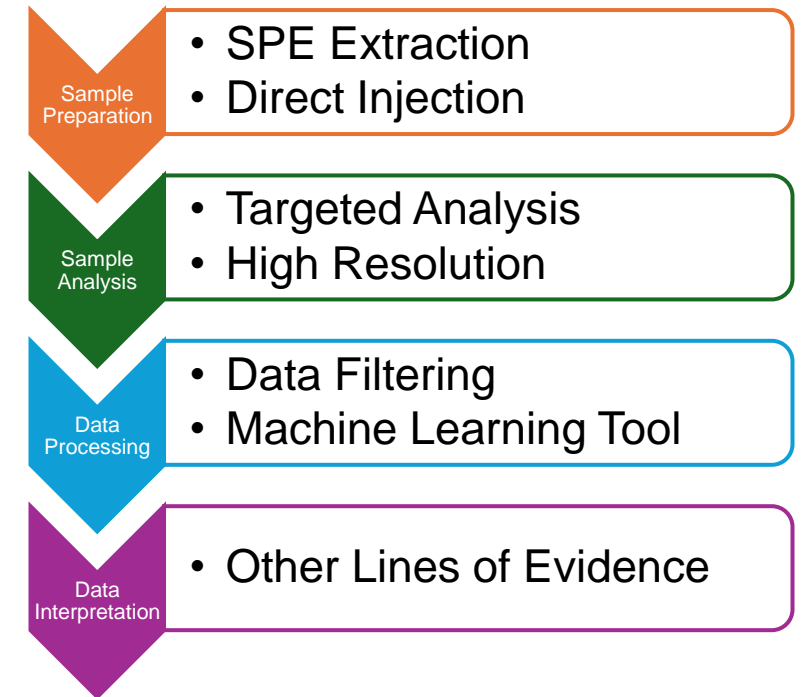
# PFAS Signature<sup>®</sup> - Tool for Background Evaluations and Source Tracking



# PFAS Signature®

- Source discrimination through the combination of analytical chemistry and data analytics
- HRMS extends the list from 40 to 600 PFAS analytes
- Acquired data can be screened using NIST PFAS library
- Also screens for other indicator chemicals – pharmaceutical and personal care products, pesticides, etc. useful to identify non-AFFF sources
- Trained artificial intelligence/machine learning (AI/ML) tools allows for the identification and discrimination of PFAS sources
- Identifies data gaps that would not have been revealed by targeted analysis alone
- Available commercially since 2021

## Workflow





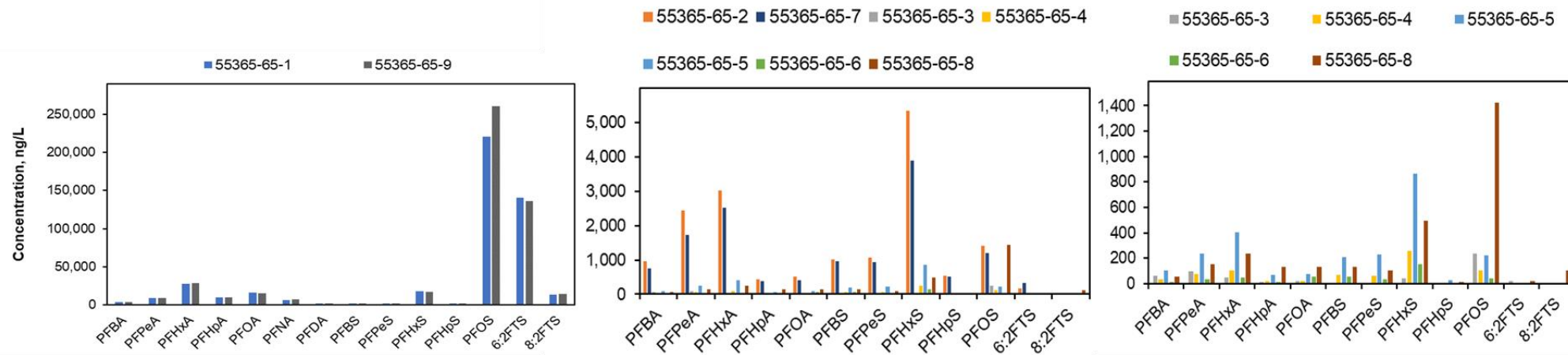
# AI/ML Trained Library Allows for the Identification and Discrimination of PFAS Sources

- AFFF Formulations
  - ECF based
  - FT based
- AFFF-Impacted matrices
  - AFFF impacted Groundwater
  - WWTP located within AFFF impacted site
  - AFFF impacted biosolids applied soil
  - AFFF used for emergency response
- Industrial Processes
  - Metal Plating
  - Chrome Plating
  - Paper Mill

- Waste Sector
  - Landfill Leachates
  - Municipal WWTP related samples and additives
  - Compost
- Commercial Products
  - Fast Food wrappers
  - Stain resistant carpets
  - Cleaning products
  - Surface protectants

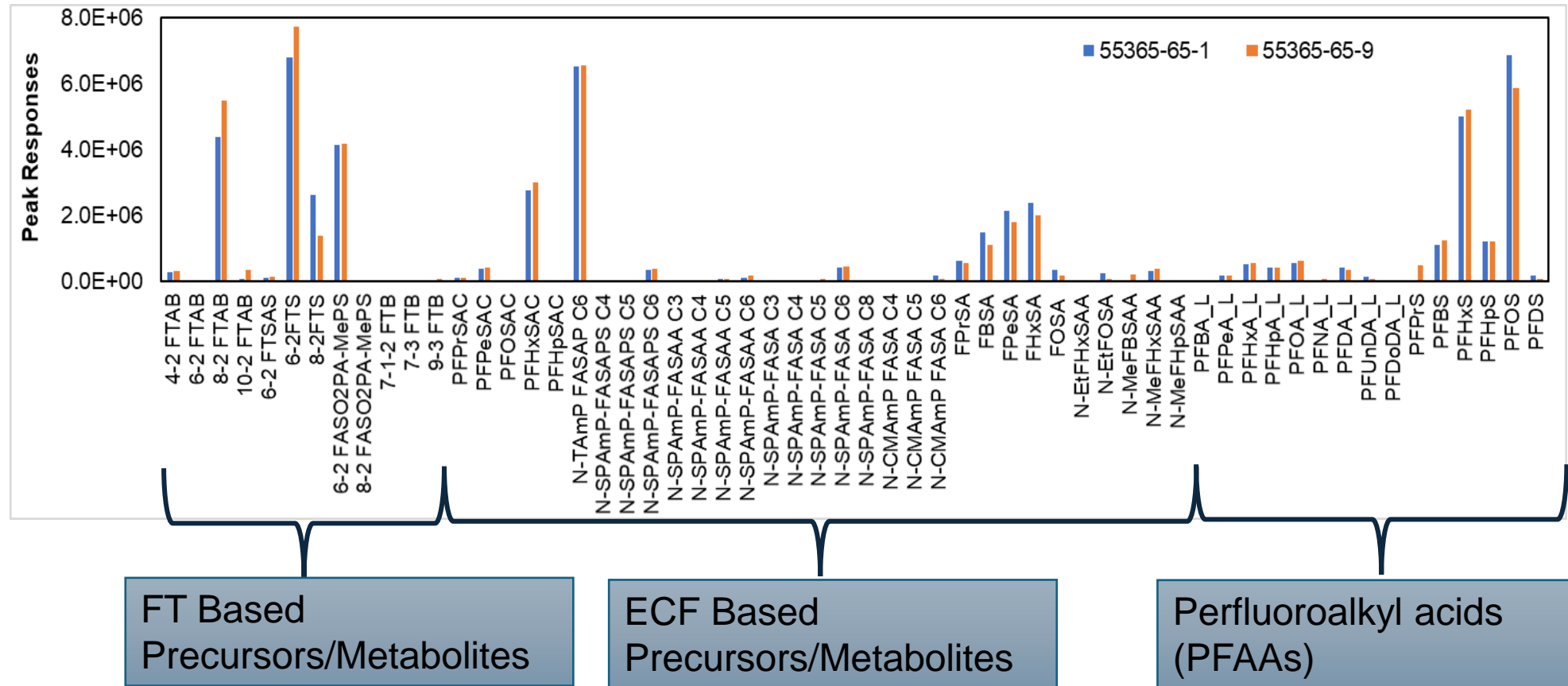
Library is continually populated as more source data is generated

# Method 1633 Does Not Provide Enough Information to Identify or Discriminate PFAS Sources



- Targeted analysis provides very limited information
- Only information on PFAAs which are commonly found associated with many sources
- Identifies trends, not sources

# PFAS Signature® Provides More Detailed PFAS Information



More than 100 analytes detected. Branched and linear isomers detected. Mix of both FT and ECF chemistries.

PFAS HRMS analysis can identify up to 600 PFAS analytes including source specific precursors and transformation products

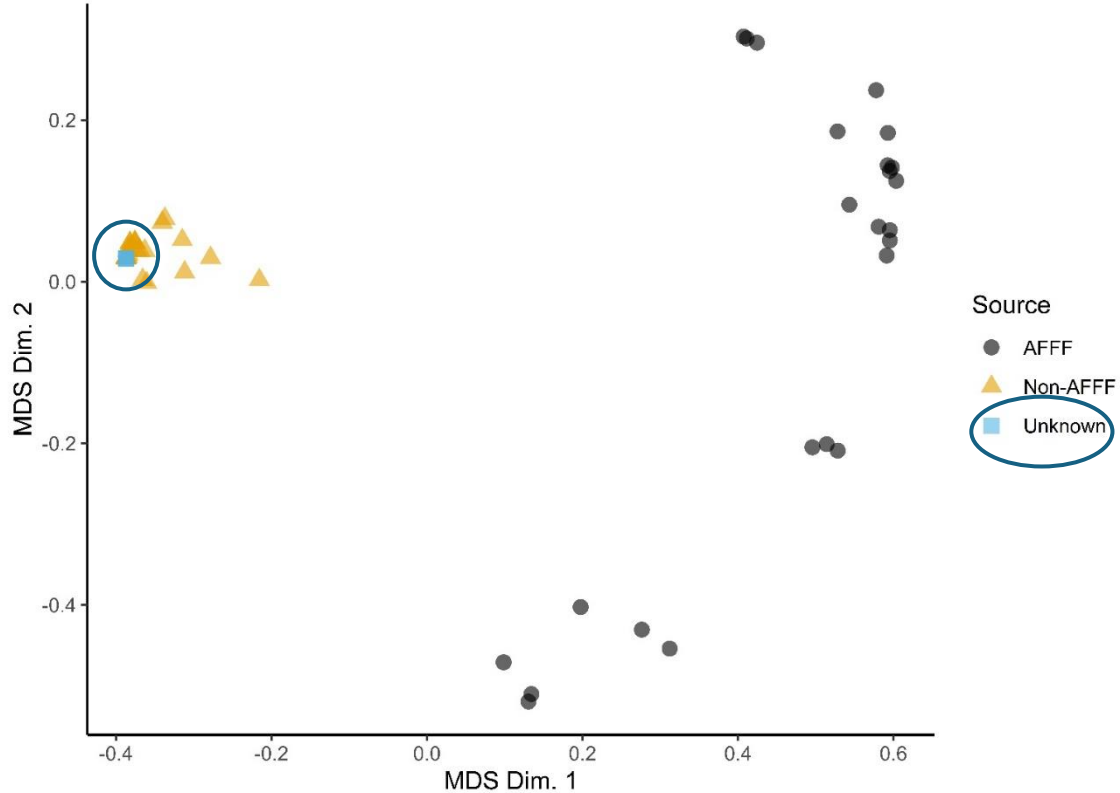
# AI/ML is Used to Train the PFAS Source Library

- Discriminates AFFF chemistry and formulations through development of source library with known samples
- Source discrimination of AFFF vs non-AFFF in environmental (unknown) samples
- Provides delineation of distinct PFAS sources and co-occurrence



Trained AI/ML tools allow for the identification and discrimination of PFAS Sources

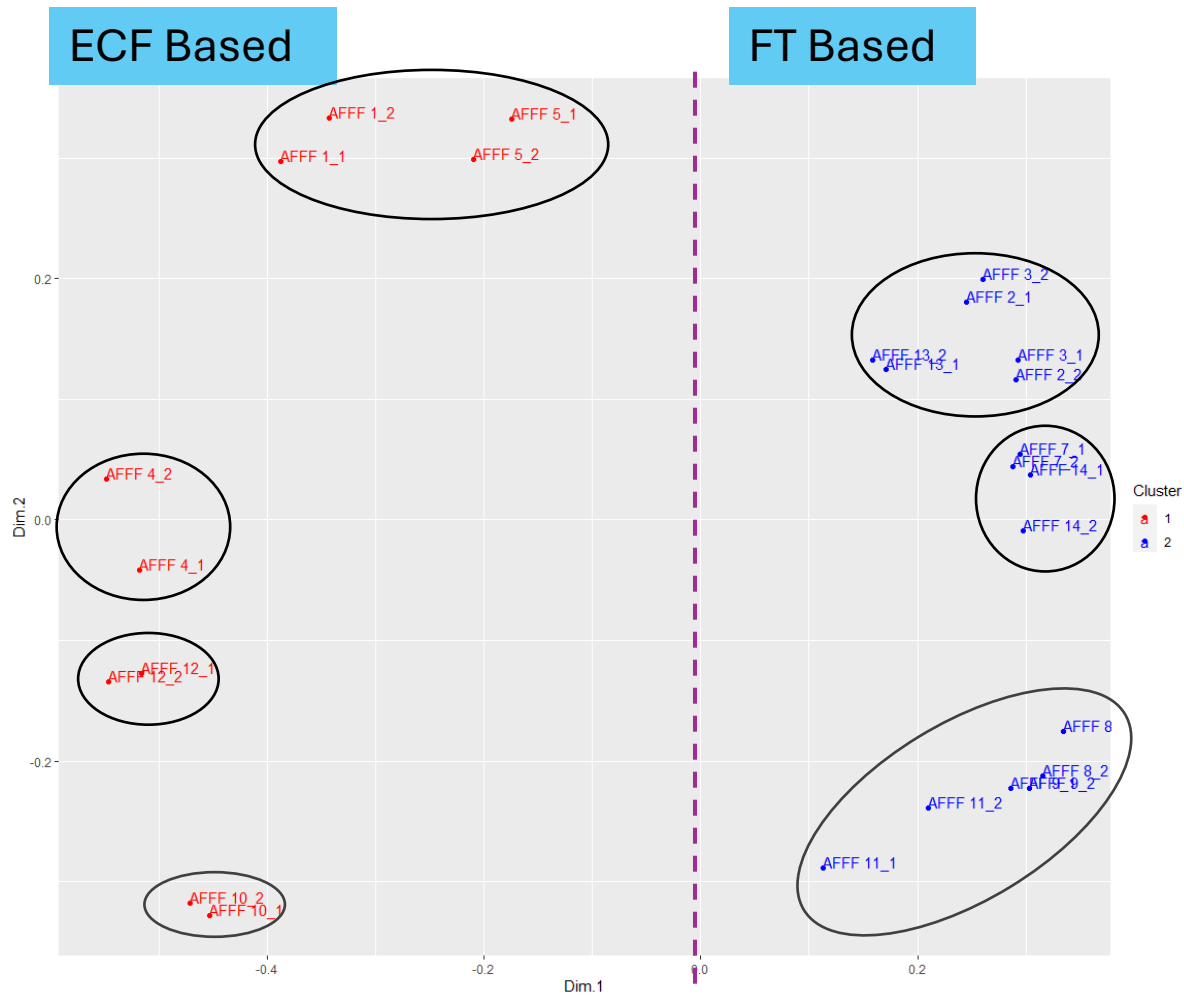
# Visualizing a new, unknown sample



PFAS Signature<sup>®</sup> assesses how the unknown sample compares to the trained library to understand the similarities and differences between the unknown and known sources

PFAS Signature<sup>®</sup> AI/ML compares the signature of unknown samples with the known source library to understand unknown sample sources

# PFAS Signature<sup>®</sup> - Differentiates between AFFF sources



- Discriminates AFFF chemistry and formulations
- Identification of unknown manufacturing source

# PFAS Signature Provides Analytically Robust Data To be Considered with Multiple Lines of Evidence

**PFAS  
Signature®**



## Multiple Lines of Evidence

- Site history
- Source knowledge
- Understanding the F&T
- Database and patent searches
- Conceptual site models
- Data gap analysis
- Due diligence investigations

# Approaches for PFAS Background Evaluations





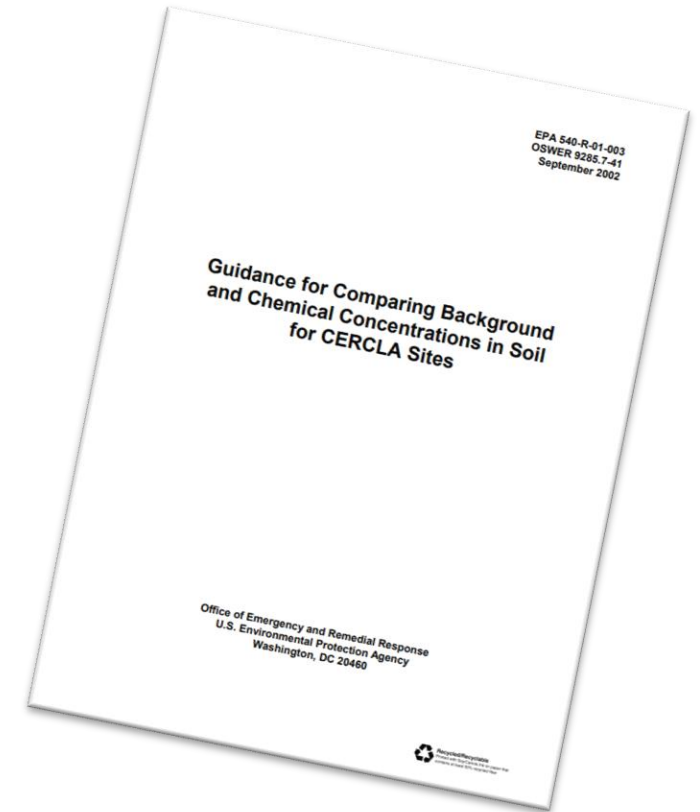
# Use of Suspect Screening Analysis with Statistics to Establish Background

- From EPA Guidance EPA 540-R-01-003, background samples are needed....
  - “Gaps in the available data (certain chemicals were excluded from the sample analyses, or certain soil types were not collected)”

Suspect screening library for up to 600 PFAS

- Identifies chemicals that would not have been identified by the targeted analysis
- Supports development of the conceptual site model to validate assumptions
- Identifies contributing sources that are not the ‘known’ or expected source(s) using multivariate statistics

HRMS analysis helps identify chemicals that would not have been identified by targeted analysis  
hence can assist in background analysis



[Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites \(epa.gov\)](https://www.epa.gov/erdc/guidance-comparing-background-and-chemical-concentrations-soil-cercla-sites)

# PFAS Signature® Applications



Targeted and Suspect  
Screening Analysis data of  
PFAS Signature®

Background  
Mass Balance  
Due Diligence



PFAS Signature® (including  
Machine Learning trained  
database)

Source Discrimination  
On/offsite Migration and  
Transport  
Data Gap Investigations

# ***BATTELLE***

**It can be done**

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