Evolving PFAS Regulatory Landscape and Technology Readiness to Address the Challenges

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Agenda

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

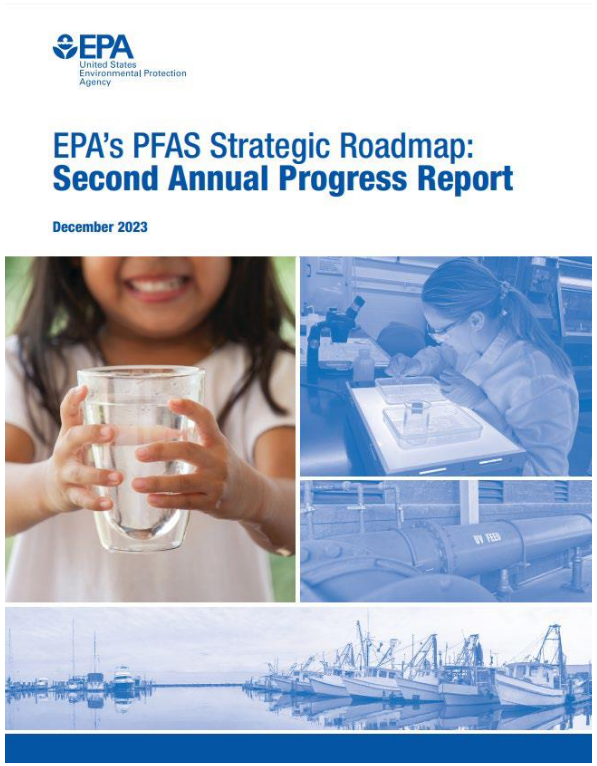
EPA’s PFAS Strategic Roadmap: Commitments to Action 2021-2024

REMTECH EXPO

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

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

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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
Maximum Contaminant Level Goal (MCLG): 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

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- 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

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- 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)

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

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- 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)

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)

Research Needs on PFAS Destruction and Disposal

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- 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

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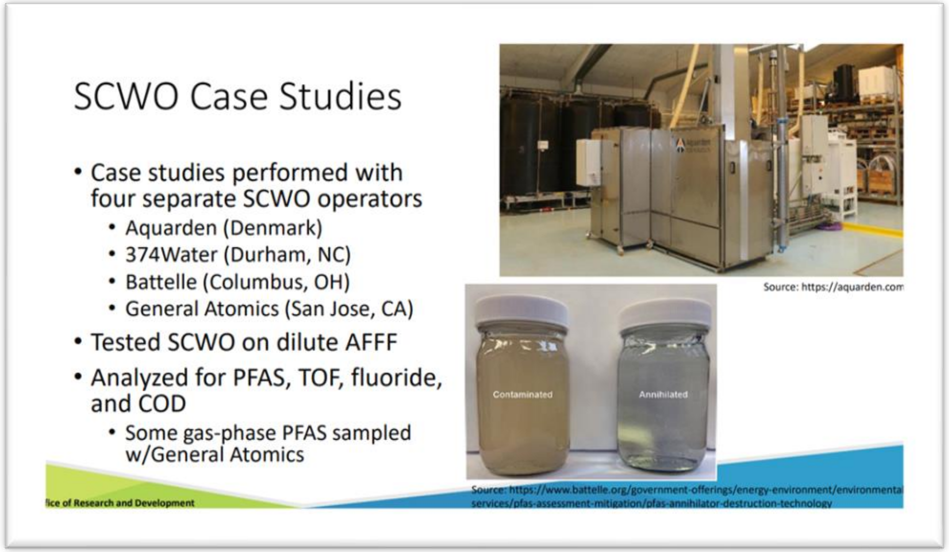
- EPA's ORD initiated the PFAS Innovative Treatment Team (PITT) in 2020 as a short-term dedicated, cross-ORD effort to identify, review, and conduct preliminary research on potential treatment technologies.
- PITT focused on the effectiveness of select technologies using pilot scale testing:
  - mechanochemical 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



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.

Our Solutions

Technology – Technology solutions to support national security, public health, and environmental challenges

Laboratory – Full service analytical lab capabilities, forensics, method development, management of nine national laboratories

Consulting – Services to support key clients with technical program management, strategy, and project execution.

Societal Benefits

Nonprofit, charitable trust formed in 1925

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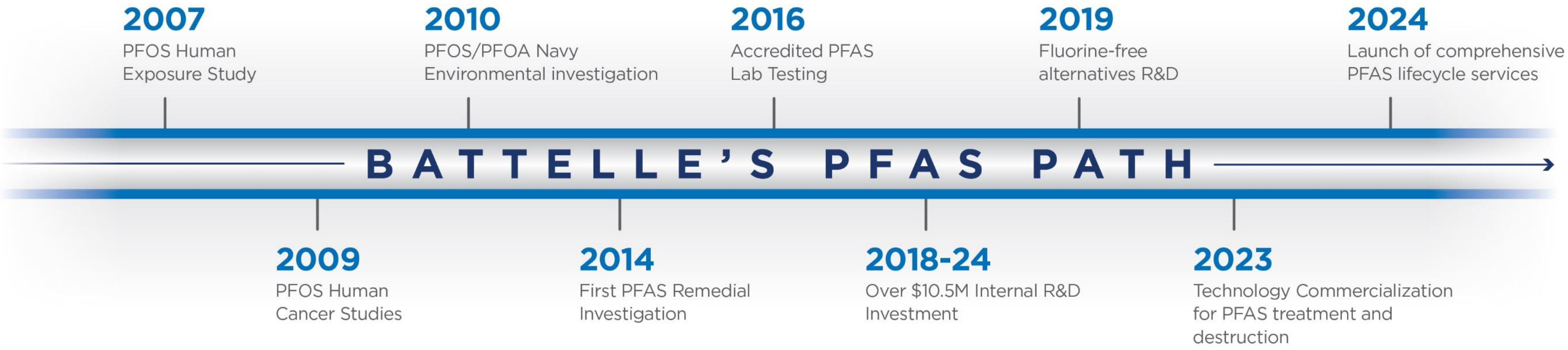
Battelle's Pathway to PFAS Technologies



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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

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Battelle PFAS Technology Toolbox

ANALYTICAL CHEMISTRY

PFAS Accredited Laboratory
EPA Methods 537.1, 533, 1633
EPA UCMR5

PFAS Signature®
Identifying the distinct patterns of PFAS chemicals for source discrimination and establishing background

Optimized Total Oxidizable Precursor (TOP) Assay
Improve results from published assay to account for co-contaminants

SITE ASSESSMENT

PFAS Predict®
PFAS groundwater transport simulator

PFAS Insight®
Simple to operate passive sampler for monitoring aquatic systems

PFAS Air Insight™
Methodology for ambient air monitoring

TREATMENT AND DESTRUCTION

PFAS Annihilator®
Achieve complete PFAS destruction with inert end-products
Revive environmental

GAC RENEW™
Non-thermal method for removing PFAS from granular activated carbon (GAC)
Revive environmental

In-Situ Soil Treatment
Removal and concentration of PFAS using electroosmosis

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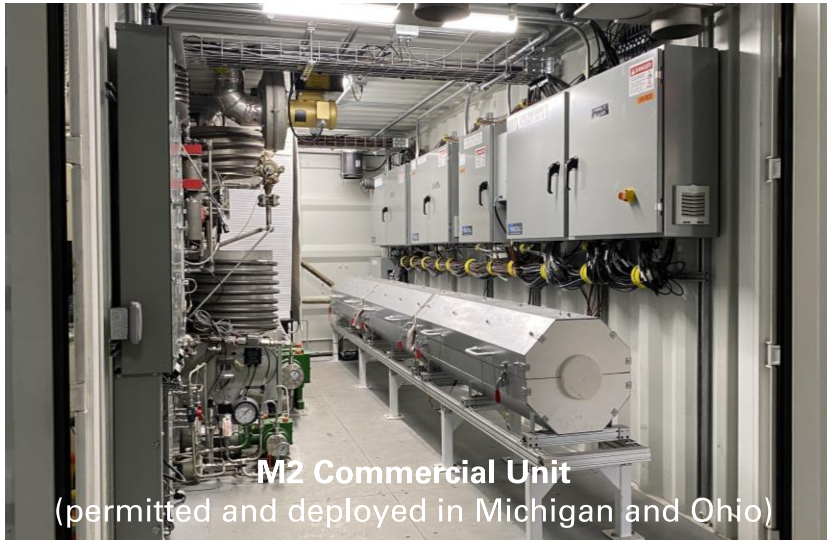
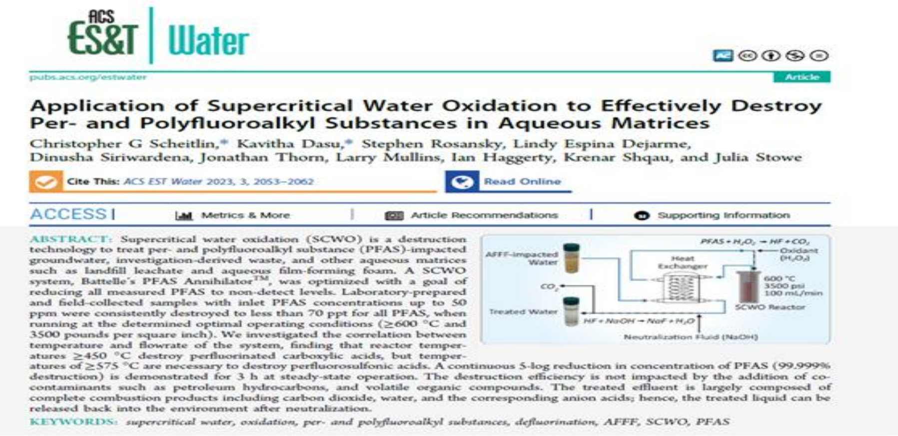
Technology + Commercial Destruction Results

PFAS Annihilator

Supercritical Water Oxidation (SCWO)





ACS ES&T Water
pubs.acs.org/estwater
Article

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

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

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

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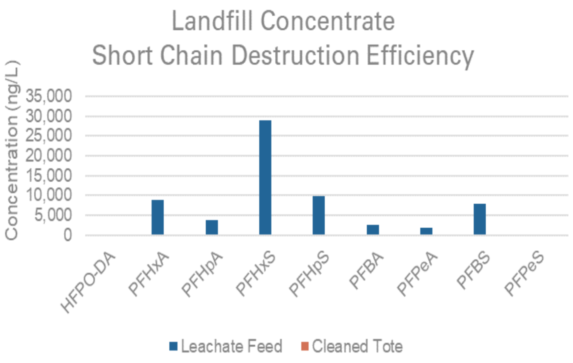
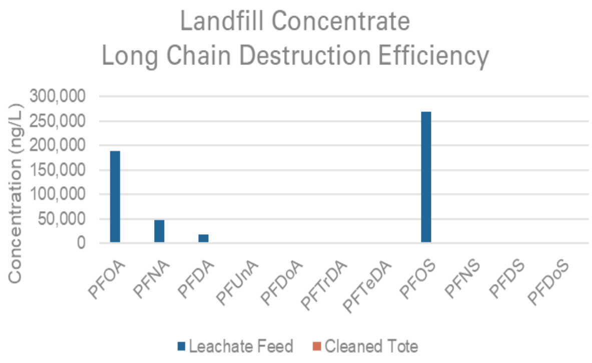
ABSTRACT: Supercritical water oxidation (SCWO) is a destruction technology to treat per- and polyfluoroalkyl substance (PFAS)-impacted groundwater, investigation-derived waste, and other aqueous matrices such as landfill leachate and aqueous film-forming foam. A SCWO system, Battelle's PFAS Annihilator™, 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 ≥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*

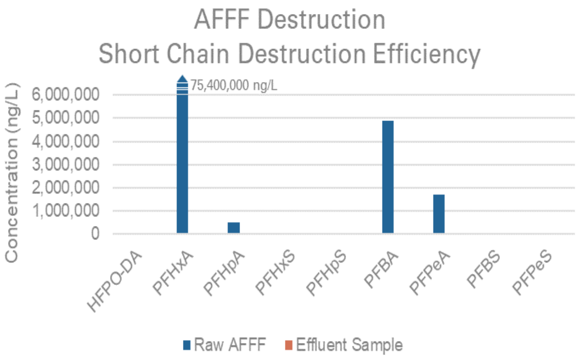
Landfill Concentrate from Foam Fractionation

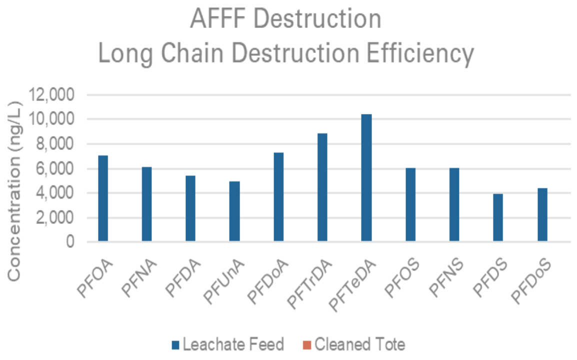




Destruction Efficiency >99.99% when starting value above 2000 ng/L

AFFF Concentrate (ANSULITE 6% AR-AFFF)





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

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Overview of PFAS Signature® Tool for Source Tracking and Background Evaluations

September 19, 2024

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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

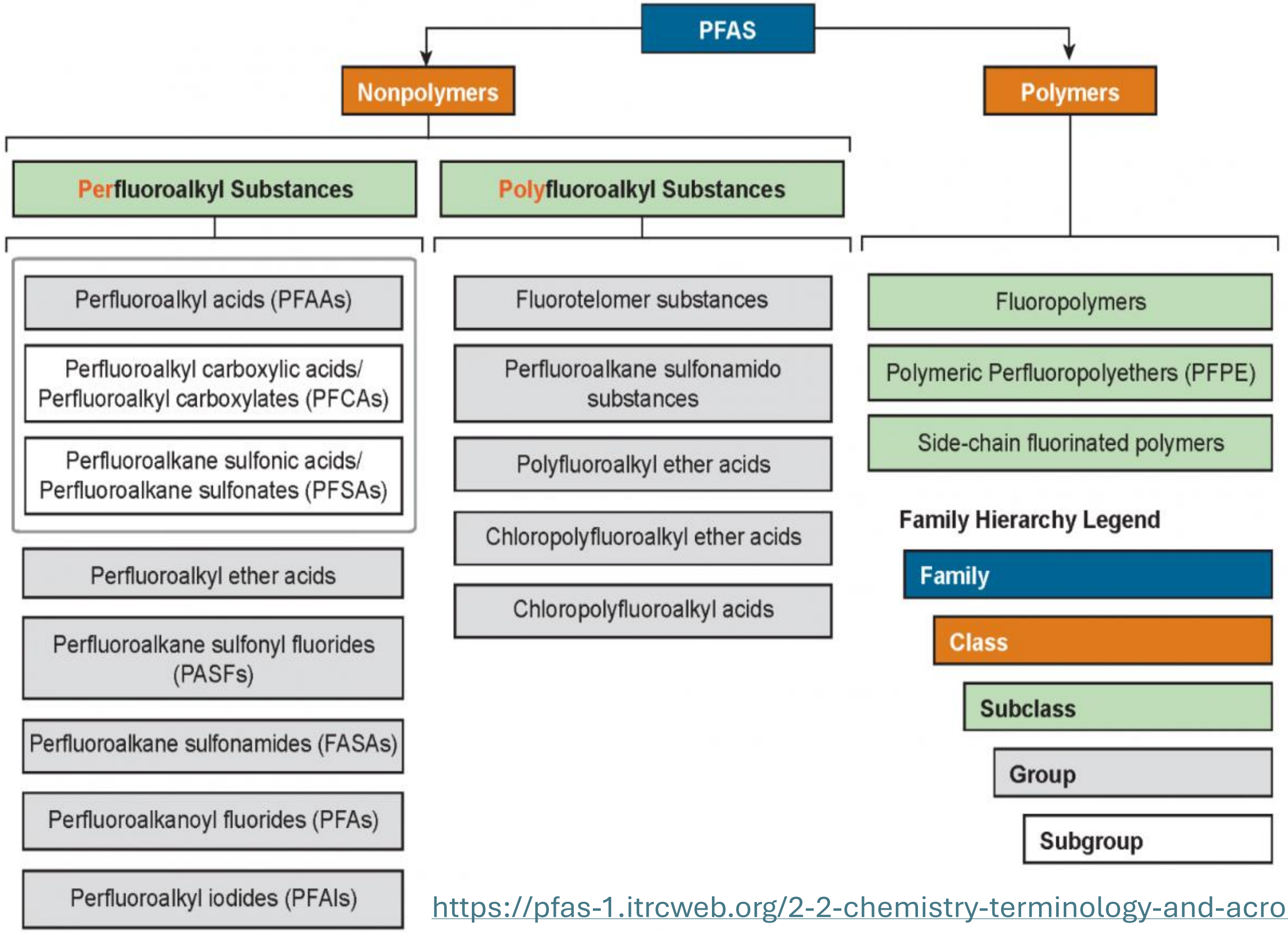
- **Landfills**
  - Leachates
  - Landfill gases
- **Wastewater treatment plants**
  - Effluents
  - Land application of biosolids
- **Waste Incineration**
  - Sewage sludge
  - Industrial waste

Indirect Sources

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

Prevedouros et al. 2006

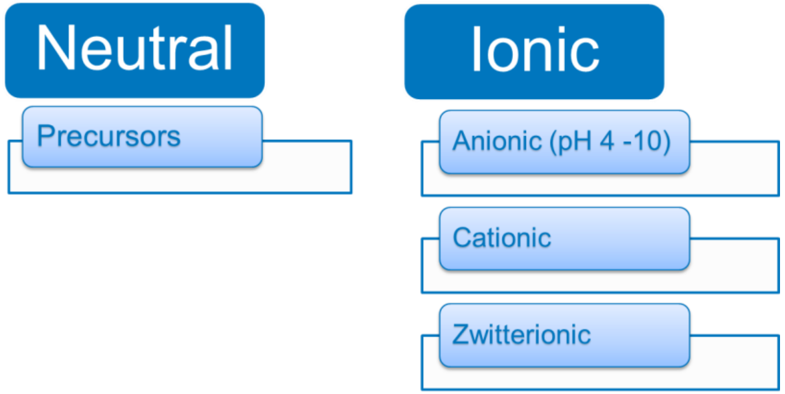
Applications of PFAS are Driven by Differences in Chemistry



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

More than 4700 chemicals in the family

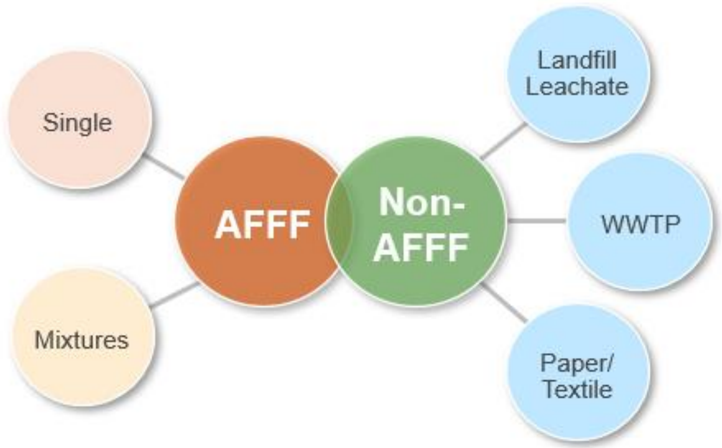
AFFF Chemistry



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

Understanding precursors chemistry is key for source identification

PFAS Signature® - 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

Sample Preparation
- SPE Extraction
- Direct Injection

Sample Analysis
- Targeted Analysis
- High Resolution

Data Processing
- Data Filtering
- Machine Learning Tool

Data Interpretation
- Other Lines of Evidence

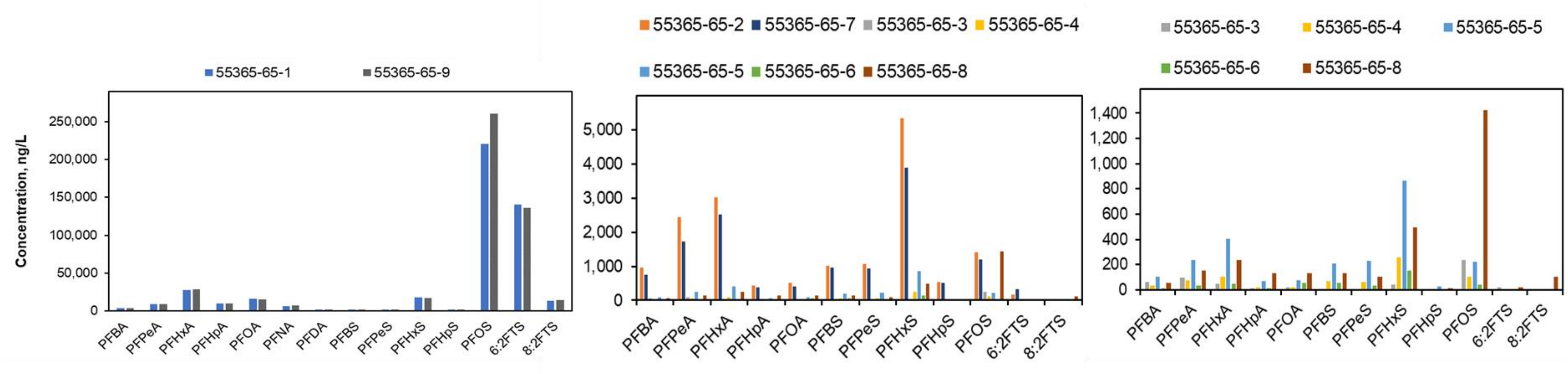
AI/ML Trained Library Allows for the Identification and Discrimination of PFAS Sources

- 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

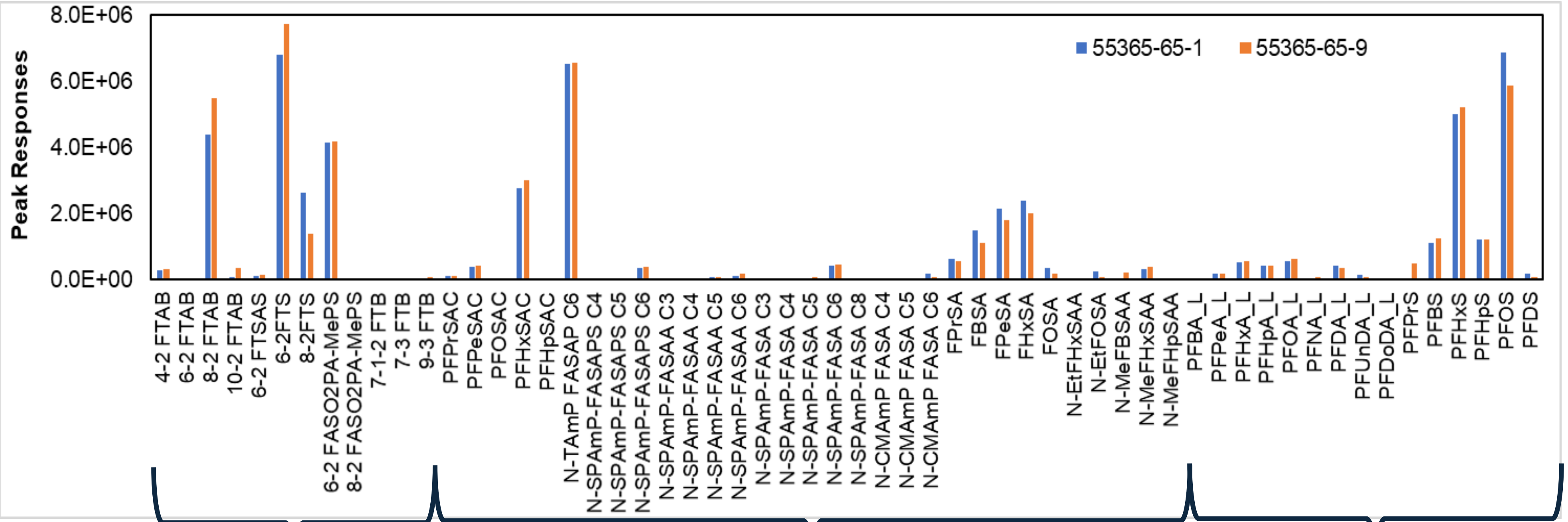
Library is continually populated as more source data is generated

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 <u>many</u> sources
- Identifies trends, not sources

PFAS Signature® Provides More Detailed PFAS Information



FT Based Precursors/Metabolites

ECF Based Precursors/Metabolites

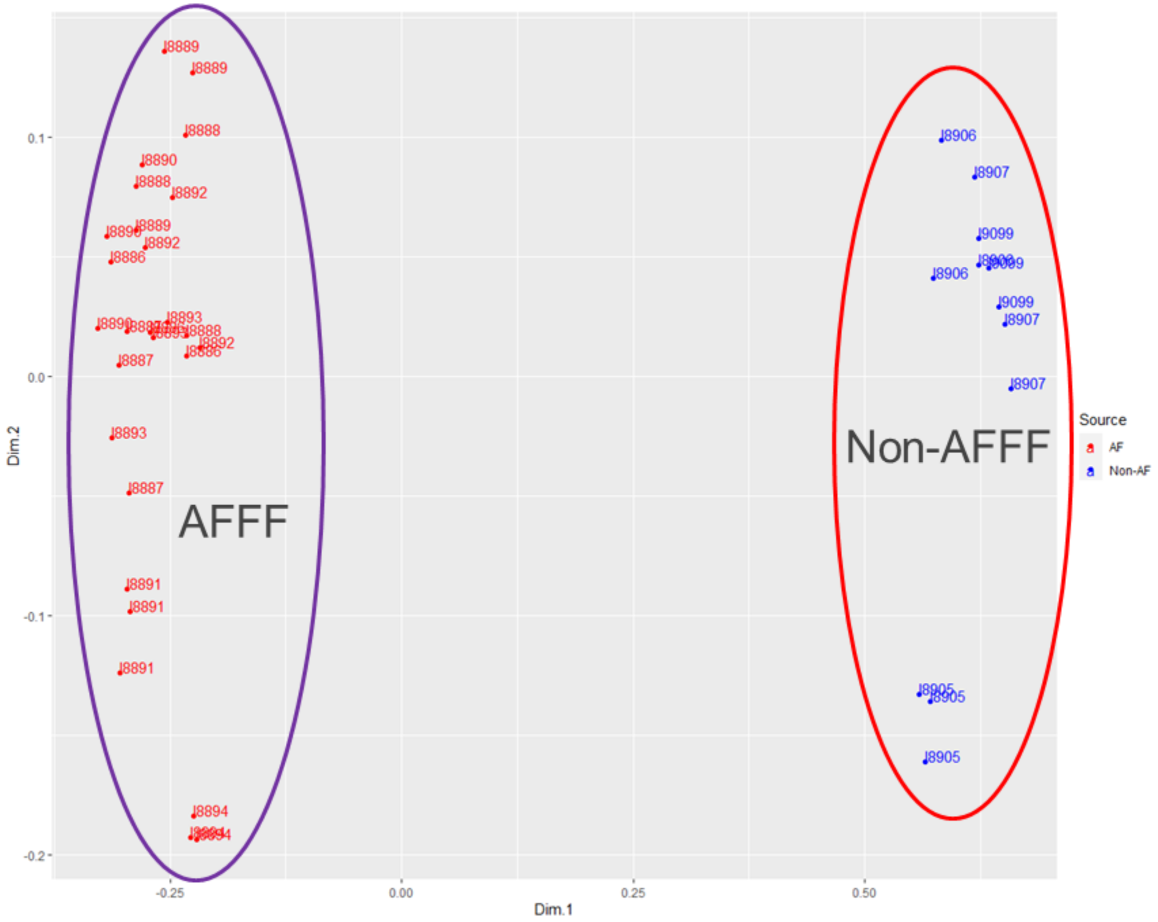
Perfluoroalkyl acids (PFAAs)

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

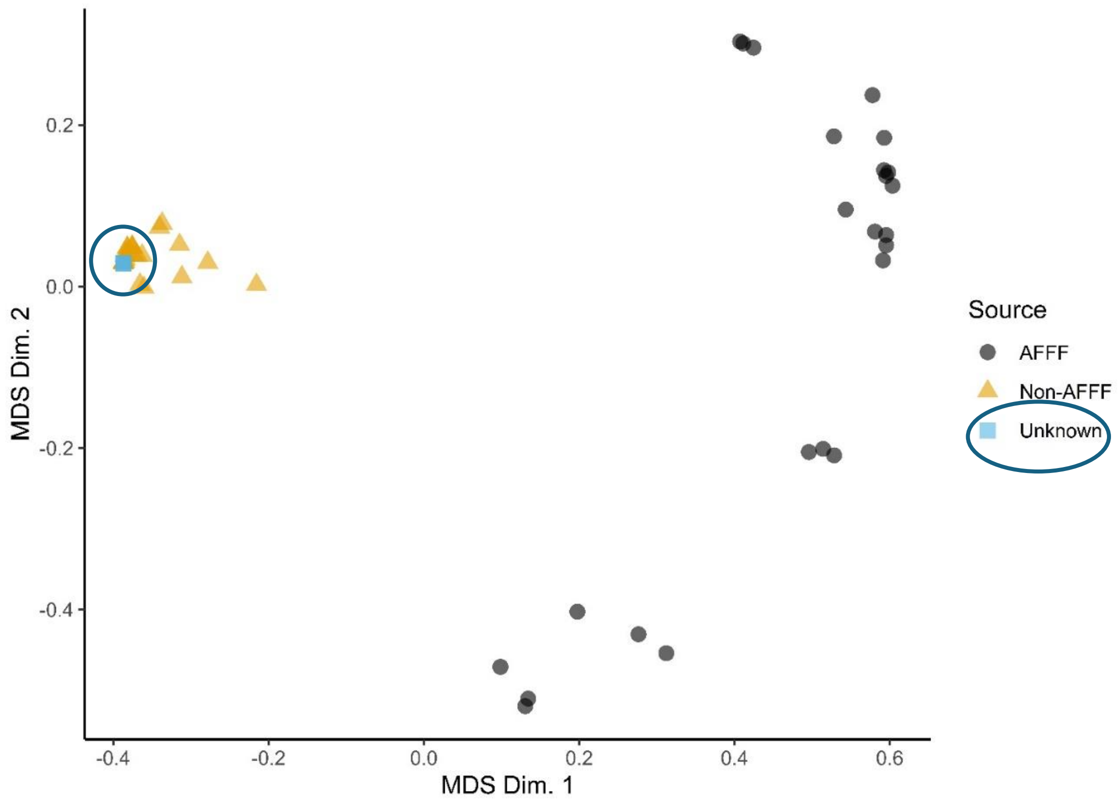
AI/ML is Used to Train the PFAS Source Library

- 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

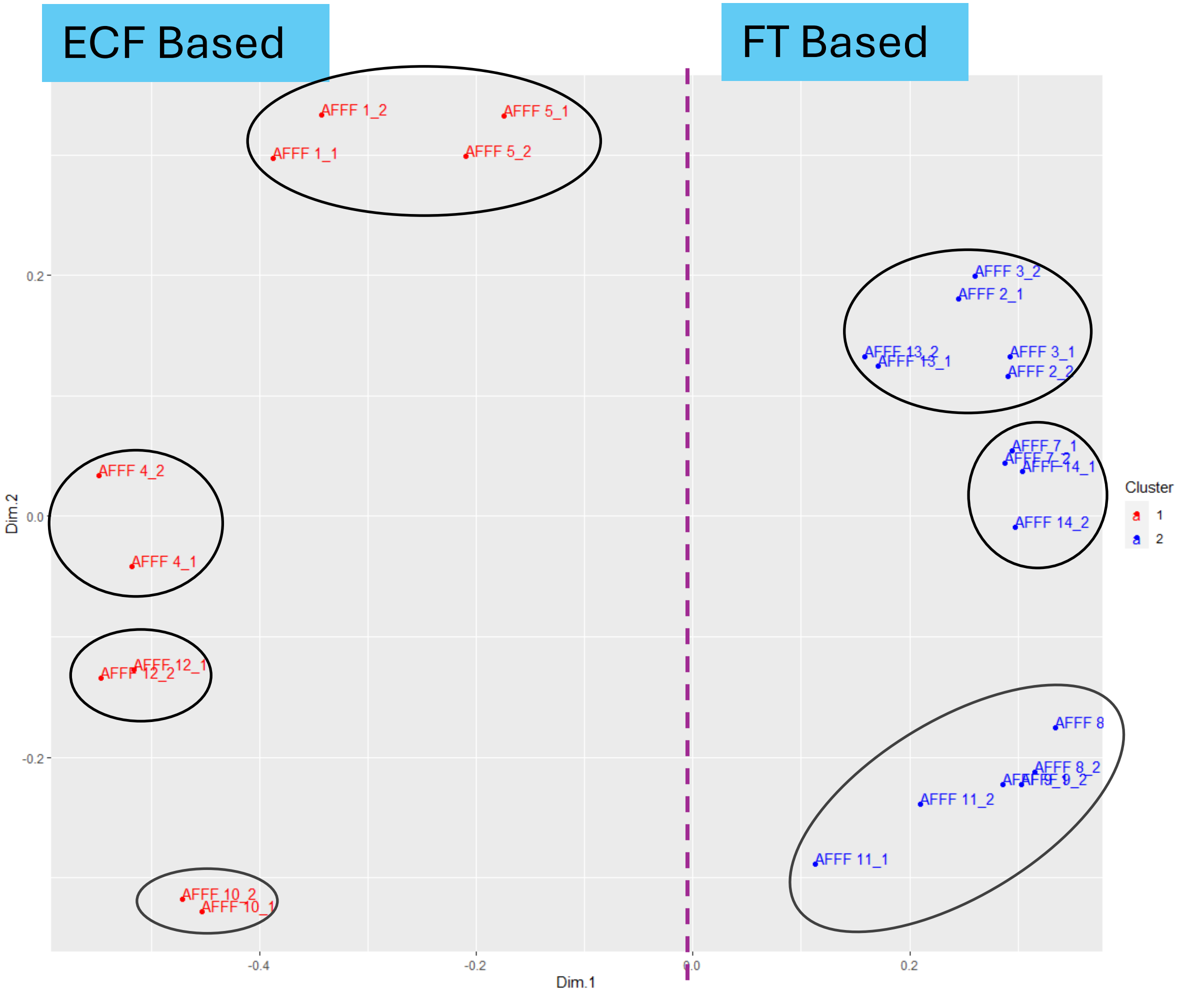
Visualizing a new, unknown sample



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

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

PFAS Signature® - Differentiates between AFFF sources



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

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

PFAS Signature®

+

Multiple Lines of Evidence

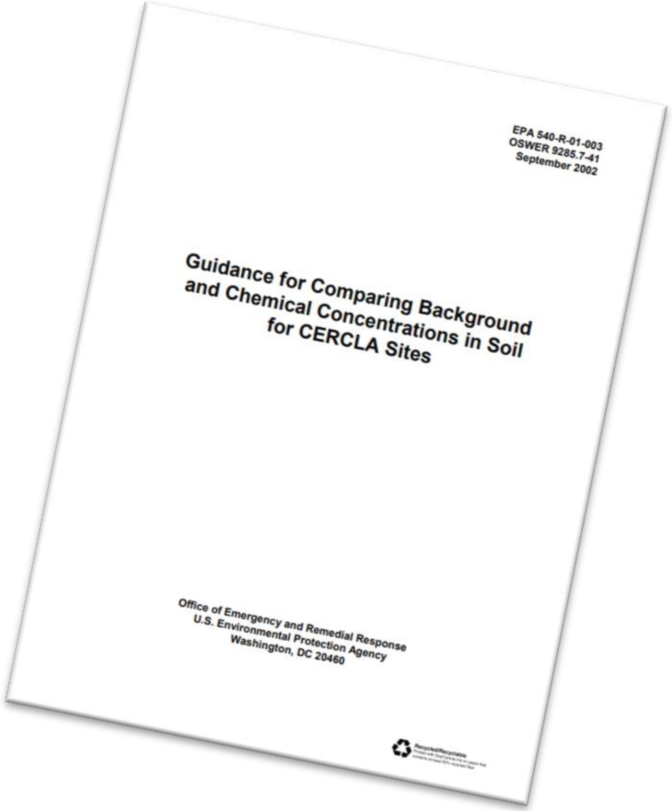
- Site history
- Source knowledge
- Understanding the F&T
- Database and patent searches
- Conceptual site models
- Data gap analysis
- Due diligence investigations

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


EPA 540-R-01-003
OSWER 9285.7-41
September 2002

Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites

Office of Emergency and Remedial Response
U.S. Environmental Protection Agency
Washington, DC 20460

Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites (epa.gov)

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

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

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It can be done

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www.battelle.org/pfas