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# INTRODUCTION TO PFAS (PFAS-1)

ITRC Technical Resources For Addressing Environmental  
Releases Of Per- And Polyfluoroalkyl Substances



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# ITRC – Shaping the Future of Regulatory Acceptance

Host Organization



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# Today's PFAS Trainers



Kristi Herzer, Vermont  
Department of Environmental  
Conservation



Mitch Olson, Ph.D.,  
P.E., Trihydro



Sandra Goodrow,  
Ph.D. New Jersey  
Department of  
Environmental  
Protection



Shalene  
Thomas,  
Battelle



Andy  
Safulko,  
Brown and  
Caldwell



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# Introduction to ITRC and PFAS Team

Kristi Herzer

Vermont Department of Environmental Conservation (VT DEC)



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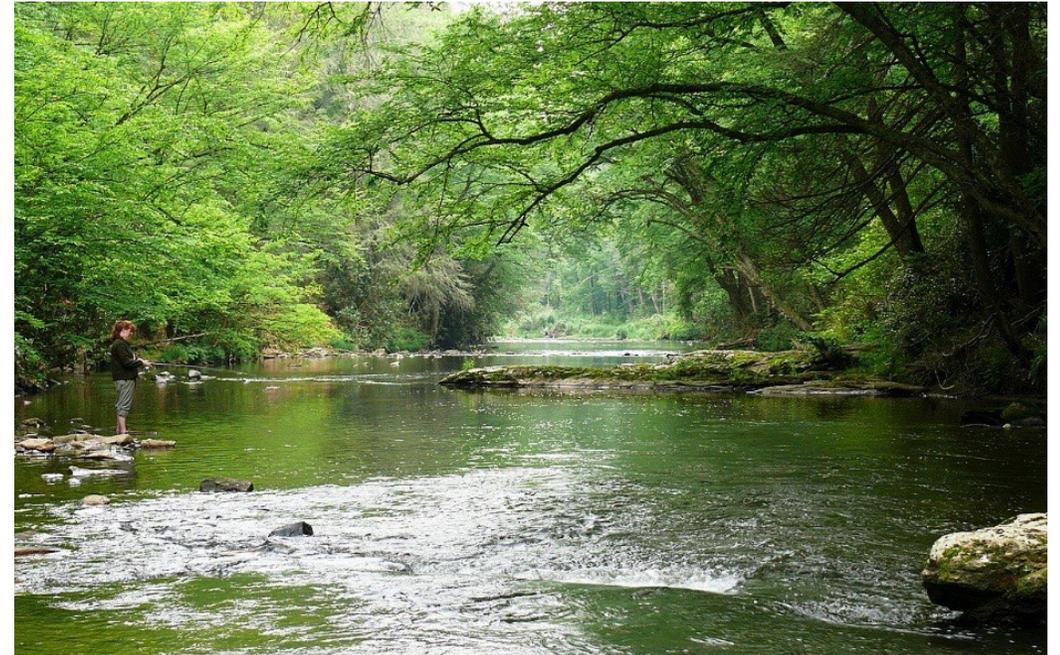
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# Topics for Today

Topic	Speaker
Introduction to ITRC and PFAS Team	Kristi Herzer
Naming Conventions and Sources	Mitch Olson
AFFF	Shalene Thomas
Fate and Transport and Site Characterization	Sandra Goodrow
Q&A Break	
Sampling and Analysis	Kristi Herzer
Treatment Technologies	Andy Safulko
Q&A Break	

# Who We Are

- State-led coalition (est. 1994) working to advance the use of innovative environmental technologies & approaches
- State, Federal, Stakeholder, Industry Members
- Funded through Federal Grants/ Industry Membership Fees



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# PFAS Experience Poll

- ▶ Which of the following best characterizes your experience with PFAS at environmental sites?
  - ▶ None
  - ▶ <1 year, 1-2 sites
  - ▶ 2-5 years, 10-20 sites
  - ▶ > 5 years, 20+ sites

# ITRC PFAS Team

- Producing concise technical resources for project managers – regulators, consultants, responsible parties, and stakeholders
- Why: State and federal environmental regulators and others need easily accessible information to aid them in evaluating risks and selecting appropriate response actions at PFAS release sites



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# Technical Resources

- ITRC PFAS: <https://pfas-1.itrcweb.org/>
- Guidance Document
  - First published April 2020
  - Updated December 2021
  - Full Update September 2023
  - Small edits & reference additions November 2023
- 13 Fact Sheets
- Training Sessions
  - Video Modules
- Outreach

**PFAS – Per- and Polyfluoroalkyl Substances** ENHANCED BY Google

**1 Introduction**

**2 Naming Conventions and Use** >

**3 Firefighting Foams** >

**4 Physical and Chemical Properties** >

**5 Fate and Transport** >

**6 Occurrence** >

**7 Health Effects** >

**8 Basis of Regulations** >

**9 Site Risk Assessment** >

**10 Site Characterization** >

**11 Sampling and Analysis** >

**12 Treatment Technologies** >

# Welcome

Technical Resources for Addressing Environmental Releases of Per- and Polyfluoroalkyl Substances (PFAS)

## PFAS HOME

This Interstate Technology and Regulatory Council (ITRC) online document includes the resources that the ITRC PFAS Team has developed since it began work in 2017.

- [PFAS Fact Sheets](#)
- [PFAS Technical and Regulatory Guidance Document](#)
  - [External Data Tables](#)
- Training Resources
  - [Quick Explainer Videos](#)
  - [Longer PFAS Training Module Videos](#)
  - [Archived Roundtable Sessions](#)
  - [PFAS Training Page](#)

You can reach this PFAS Home page from any of the pages on this web site with the Home button at the top of screen.

## PFAS Technical and Regulatory Guidance Document

# External Tables and Information

- [Fact Sheets: PFAS Water and Soil Regulatory and Guidance Values Table Excel File](#)
- [Fact Sheets: PFAS Air Criteria Table Excel File](#)
- [Section 2: Figure 2-5 PFAS Family Tree PDF](#)
- [Section 2: USEPA Analytes List – PFAS Classifications PDF](#)
- [Section 3: AFFF Characteristics Excel File](#)
- [Section 3: AFFF Transition to F3 Case Studies Excel File](#)
- [Section 4: Physical and Chemical Properties Table 4-1 Excel File](#)
- [Section 5: Aquatic Organisms BCF-BAF Table 5-1 Excel File](#)
- [Section 5: Plants BCF-BAF Table 5-2 Excel File](#)
- [Section 8: PFAS Regulatory Programs Summary Excel File](#)
- [Section 11: Analytical Methods Excel File](#)
- [Section 11: PFAS Data Usability Table PDF](#)
- [Section 12: Treatment Technologies Table Excel File](#)
- [Section 12: Integrated Water Treatment Flow Chart PDF](#)
- [Section 14: Risk Communication Social Factors Vision Board PDF](#)
- [Section 15: Water Treatment Case Studies Excel File](#)
- [Section 17.1: Table 17-1 A-C for Air PDF](#)
- [Section 17.1: Table 17-2 A-C for Soil, Sediments, and Biosolids PDF](#)
- [Section 17.2: Table 17-8 Toxicological Effects Excel File](#)

# 13 PFAS Fact Sheets

Naming Conventions

Regulations

History and Use

Fate and Transport and Physical and Chemical Properties

Sampling Precautions and Laboratory Analytical Methods

Site Characterization and Media-Specific Occurrence

Treatment Technologies and Methods

Aqueous Film-Forming Foam

Human and Ecological Health Effects and Risk Assessment

Risk Communication

Stakeholder Perspectives

Surface Water Quality

Biosolids

All updated September 2023



## 1 Introduction

This fact sheet provides a summary of the discovery of PFAS, emergence of known health effects, production/use, and environmental impacts. PFAS are thousands of chemicals that vary widely in their physical properties, as well as their potential in the environment. The unique physical and chemical properties of PFAS impart oil, water, stain, and soil repellent properties. PFAS have application in many industries, including aerospace, medical, automotive, electronics, and aviation industries, as well as in consumer products such as carpets, clothing, furniture, outdoor gear, and firefighting applications (e.g., firefighting foams). PFAS have followed a similar pattern of emergence and awareness that includes commercial production, environmental detection, and concerns.

	1930s	1940s	1950s
Production	Synthesis / Development		
Health & Environment			

Figure 1.4

Graphic provides general indication of more detail within the Guidance Document.

Source: J. F.

## 2 Discovery and Manufacture

PFAS chemistry was discovered in the 1930s and 1940s. PFAS have been manufactured and used in a wide variety of applications, including in the production of fluoropolymer coatings, fluoropolymer resins, and fluoropolymer elastomers. PFAS are used in a wide variety of applications, including in the production of fluoropolymer coatings, fluoropolymer resins, and fluoropolymer elastomers.



## Surface Water Quality Considerations for Per- and Polyfluoroalkyl Substances (PFAS)

### 1 Introduction

This fact sheet summarizes the emerging technical information available to support the development of regulatory criteria or guidance values to protect the beneficial uses of surface water (including as a drinking water source). This fact sheet also highlights considerations for sampling and analysis for surface water quality assessments for PFAS. The information in this fact sheet is based on Section 16 of the Guidance Document.

### 2 Regulatory Criteria and Beneficial Uses

Regulatory agencies may choose to develop and implement numeric surface water quality criteria (or guidance values) to protect the beneficial uses of surface water that may be negatively impacted by PFAS. The regulatory criteria selected for a water body are generally the most stringent of all of the values identified for each beneficial use for a water body. Surface water criteria do not consider analytical or treatment removal factors.

The Guidance Document focuses on the following beneficial use groupings that might be impacted by the presence of PFAS (see Section 16.1.1):

- drinking water source
- habitat for aquatic life and wildlife
- human consumption of aquatic organisms
- human contact with water during recreation, considering exposure due to incidental ingestion and dermal contact with surface water, sediments, and potentially PFAS-containing foam
- agricultural supply, considering farming, horticulture, dairy operations, ranching, watering of livestock, and use for irrigation of crops for consumption by humans or livestock (i.e., crop uptake), with potential human exposures through skin contact and inhalation of PFAS in irrigation water, as well as consumption of PFAS in livestock or crops contaminated by irrigation water
- natural and artificial groundwater recharge, with considerations similar to those for drinking water and agricultural supply beneficial uses

In general, for PFAS, the two most relevant beneficial uses are drinking water use and consumption of aquatic organisms that may take up and bioaccumulate PFAS from the surface water into their tissue.

To date, the U.S. Environmental Protection Agency (USEPA) has published draft surface water and biota tissue criteria for perfluorooctanoic acid (PFOA) (USEPA 2022 Ref#2300) and perfluorooctane sulfonic acid (PFOS) (USEPA 2022 Ref#2302). Currently, only a few states have formally established surface water criteria for PFAS that are protective of surface water uses. Available standards or criteria, where established by states, are presented in the Water and Soil Values Table posted on the fact sheets page (<https://pfas-1.itrcweb.org/fact-sheets>).

After the regulatory criteria are established for PFAS, existing regulatory mechanisms to maintain or reduce the concentrations in the water body to below the protective values can be implemented. These mechanisms include National Pollutant Discharge Elimination System (NPDES) discharge permit effluent limits for point sources, non-NPDES permits and best management practices for nonpoint sources, and assigned loadings from all sources to a water body through total maximum daily loads (TMDLs).

ITRC has developed a series of fact sheets that summarize recent science and emerging technologies regarding PFAS. The information in this and other PFAS fact sheets is more fully described in the *ITRC PFAS Technical and Regulatory Guidance Document (Guidance Document)* (<https://pfas-1.itrcweb.org/>).

- This fact sheet describes considerations for managing PFAS impacts to surface water, including:
- Beneficial uses of surface water impacted by PFAS
  - Regulatory approaches for developing surface water quality criteria and guidance values
  - Sampling and analysis considerations for surface water quality assessments, including surface water foam



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# Introduction to PFAS Naming Conventions and Sources

Mitch Olson, Ph.D., P.E., Trihydro



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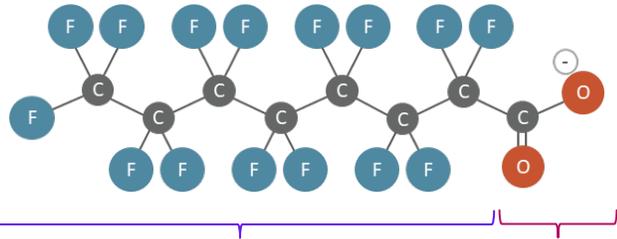
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# PFAS Technical and Regulatory Guidance Document Published

- Final web document PFAS-1: <https://pfas-1.itrcweb.org>
- PFAS Chemistry and Naming Conventions, History and Use of PFAS, and Sources of PFAS Releases to the Environment
  - Section 2.1 – Environmental Significance
  - Section 2.2 – Chemistry, Terminology, and Acronyms
  - Section 2.3 – Emerging Health and Environmental Concerns
  - Section 2.4 – PFAS Reductions and Alternative PFAS formulations
  - Section 2.5 – PFAS Uses and Products
  - Section 2.6 – PFAS Releases to the Environment

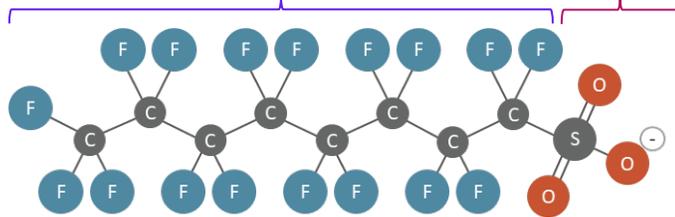
# General Classification of Per- and Polyfluoroalkyl Substances (PFAS)

Perfluorooctanoic acid (PFOA)

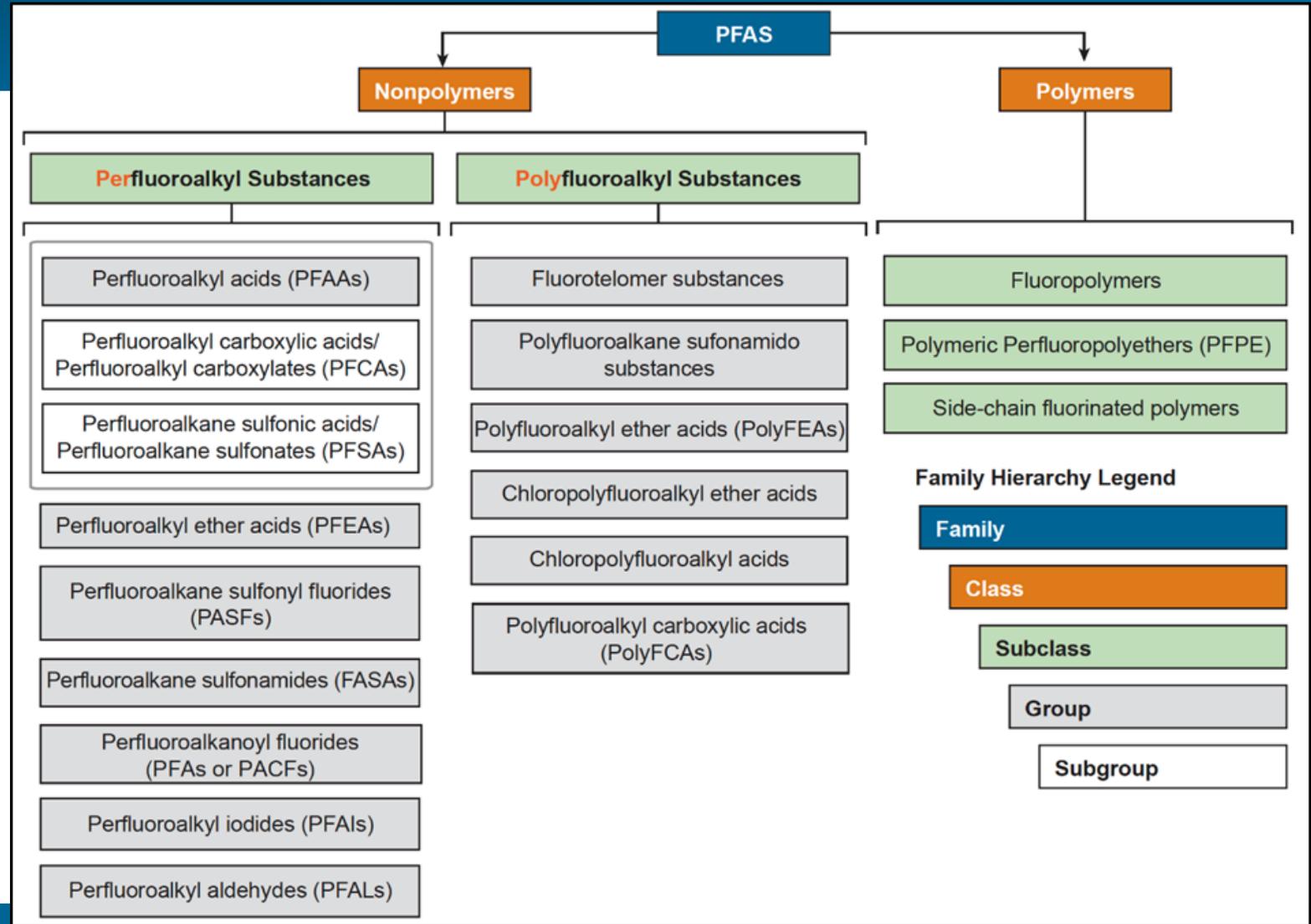


Tail

Head



Perfluorooctane sulfonate (PFOS)



Family Hierarchy Legend

Family

Class

Subclass

Group

Subgroup

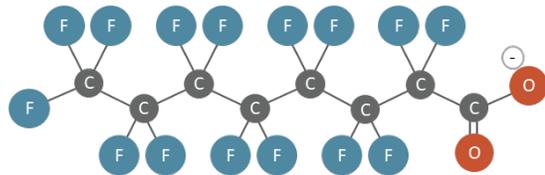
PFAS-1, Section 2.2. Figure 2-4 PFAS Family Tree and Figure 2-7 The tail and head structure of PFOS and PFOA molecules. Molecule Figures Source: M. Olson, Trihydro. Used with permission.

# Key Terms and Acronyms

- PFAS (per- and polyfluoroalkyl substances)
- Perfluoroalkyl substances

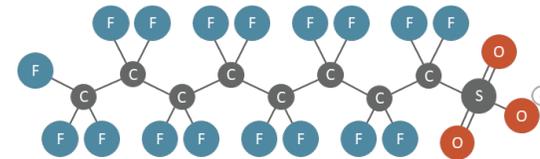
## Perfluoroalkyl acids, or PFAAs

PFCAs (perfluoroalkyl carboxylates)



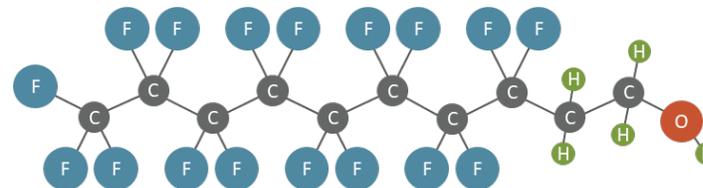
PFOA (perfluorooctane carboxylate)

PFSA (perfluoroalkane sulfonates)



PFOS (perfluorooctane sulfonate)

- Polyfluoroalkyl substances
  - “Precursors”



8:2 Fluorotelomer alcohol (8:2 FTOH)

# PFAA Naming System

- **PFXY**
  - PF = perfluoro
  - **X** = number of carbons
    - Same convention as hydrocarbons
    - Includes C in the carboxylate group
  - **Y** = functional group
    - S = sulfonate (R-SO<sub>3</sub><sup>-</sup>)
    - A = carboxylate (R-COO<sup>-</sup>)

4	B	(buta-)
5	Pe	(penta-)
6	Hx	(hexa-)
7	Hp	(hepta-)
8	O	(octa-)
9	N	(nona-).....

# PFAA Naming System

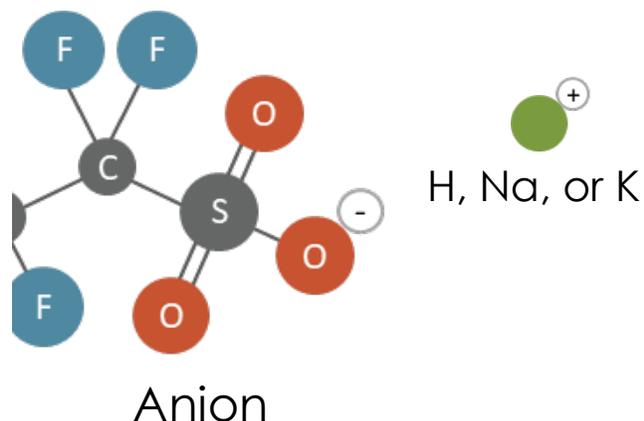
- **PFXY**
  - PF = perfluoro
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    - S = sulfonate (R-SO<sub>3</sub><sup>-</sup>)
    - A = carboxylate (R-COO<sup>-</sup>)

Table 2-2 Basic naming structure and shorthand for PFAAs

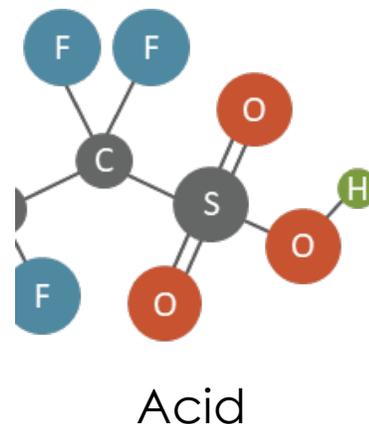
X	Y	Acronym	Name	Formula	CAS No.
B = buta (4 carbon)	A = Carboxylate or carboxylic acid	PFBA	Perfluorobutanoate	C <sub>3</sub> F <sub>7</sub> CO <sub>2</sub> <sup>-</sup>	45048-62-2
			Perfluorobutanoic acid	C <sub>3</sub> F <sub>7</sub> COOH	375-22-4
	S = Sulfonate or sulfonic acid	PFBS	Perfluorobutane sulfonate	C <sub>4</sub> F <sub>9</sub> SO <sub>3</sub> <sup>-</sup>	45187-15-3
			Perfluorobutane sulfonic acid	C <sub>4</sub> F <sub>9</sub> SO <sub>3</sub> H	375-73-5
Pe = penta (5 carbon)	A = Carboxylate or carboxylic acid	PFPeA	Perfluoropentanoate	C <sub>4</sub> F <sub>9</sub> CO <sub>2</sub> <sup>-</sup>	45167-47-3
			Perfluoropentanoic acid	C <sub>4</sub> F <sub>9</sub> COOH	2706-90-3
	S = Sulfonate or sulfonic acid	PFPeS	Perfluoropentane sulfonate	C <sub>5</sub> F <sub>11</sub> SO <sub>3</sub> <sup>-</sup>	NA
			Perfluoropentane sulfonic acid	C <sub>5</sub> F <sub>11</sub> SO <sub>3</sub> H	2706-91-4
Hx = hexa (6 carbon)	A = Carboxylate or carboxylic acid	PFHxA	Perfluorohexanoate	C <sub>5</sub> F <sub>11</sub> CO <sub>2</sub> <sup>-</sup>	92612-52-7
			Perfluorohexanoic acid	C <sub>5</sub> F <sub>11</sub> COOH	307-24-4
	S = Sulfonate or sulfonic acid	PFHxS	Perfluorohexane sulfonate	C <sub>6</sub> F <sub>13</sub> SO <sub>3</sub> <sup>-</sup>	108427-53-8
			Perfluorohexane sulfonic acid	C <sub>6</sub> F <sub>13</sub> SO <sub>3</sub> H	355-46-4
Hp = hepta (7 carbon)	A = Carboxylate or carboxylic acid	PFHpA	Perfluoroheptanoate	C <sub>6</sub> F <sub>13</sub> CO <sub>2</sub> <sup>-</sup>	120885-29-2
			Perfluoroheptanoic acid	C <sub>6</sub> F <sub>13</sub> COOH	375-85-9
	S = Sulfonate or sulfonic acid	PFHpS	Perfluoroheptane sulfonate	C <sub>7</sub> F <sub>15</sub> SO <sub>3</sub> <sup>-</sup>	NA
			Perfluoroheptane sulfonic acid	C <sub>7</sub> F <sub>15</sub> SO <sub>3</sub> H	375-92-8
O = octa (8 carbon)	A = Carboxylate or carboxylic acid	PFOA	Perfluorooctanoate	C <sub>7</sub> F <sub>15</sub> CO <sub>2</sub> <sup>-</sup>	45285-51-6
			Perfluorooctanoic acid	C <sub>7</sub> F <sub>15</sub> COOH	335-67-1
	S = Sulfonate or sulfonic acid	PFOS	Perfluorooctane sulfonate	C <sub>8</sub> F <sub>17</sub> SO <sub>3</sub> <sup>-</sup>	45298-90-6
			Perfluorooctane sulfonic acid	C <sub>8</sub> F <sub>17</sub> SO <sub>3</sub> H	1763-23-1
N = nona (9 carbon)	A = Carboxylate or carboxylic acid	PFNA	Perfluorononanoate	C <sub>8</sub> F <sub>17</sub> CO <sub>2</sub> <sup>-</sup>	72007-68-2
			Perfluorononanoic acid	C <sub>8</sub> F <sub>17</sub> COOH	375-95-1
	S = Sulfonate or sulfonic acid	PFNS	Perfluorononane sulfonate	C <sub>9</sub> F <sub>19</sub> SO <sub>3</sub> <sup>-</sup>	NA
			Perfluorononane sulfonic acid	C <sub>9</sub> F <sub>19</sub> SO <sub>3</sub> H	474511-07-4
D = deca (10 carbon)	A = Carboxylate or carboxylic acid	PFDA	Perfluorodecanoate	C <sub>9</sub> F <sub>19</sub> CO <sub>2</sub> <sup>-</sup>	73829-36-4
			Perfluorodecanoic acid	C <sub>9</sub> F <sub>19</sub> COOH	335-76-2
	S = Sulfonate or sulfonic acid	PFDS	Perfluorodecane sulfonate	C <sub>10</sub> F <sub>21</sub> SO <sub>3</sub> <sup>-</sup>	126105-34-8
			Perfluorodecane sulfonic acid	C <sub>10</sub> F <sub>21</sub> SO <sub>3</sub> H	335-77-3

# Which PFAA Are We Talking About?

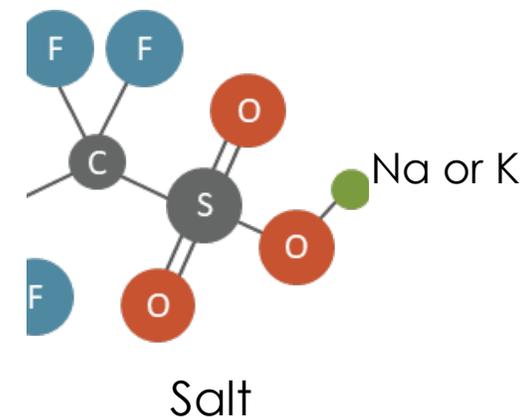
- Anion, Acid, or Salt?
  - PFAAs may exist in various states



In the environment, most PFAS exist in the anionic state (sulfonate/carboxylate)



Acid form of the name often used interchangeably (sulfonic acid/carboxylic acid)

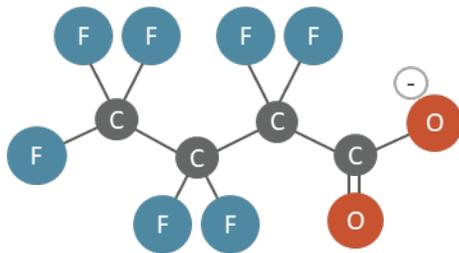


Different CAS numbers & physical/chemical properties

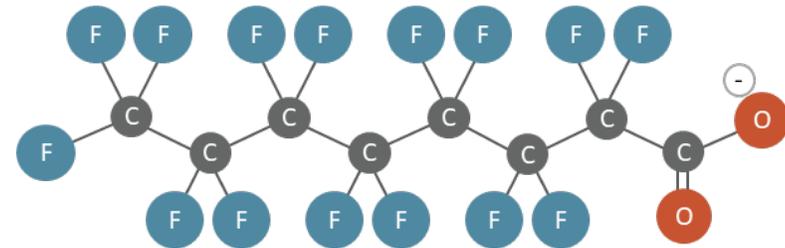
# Long-Chain vs Short-Chain PFAAs

Short-chain PFCAs				Long-chain PFCAs				
PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA
PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFUnS	PFDoS
Short-chain PFSA		Long-chain PFSA						

Perfluorobutane carboxylate (PFBA)

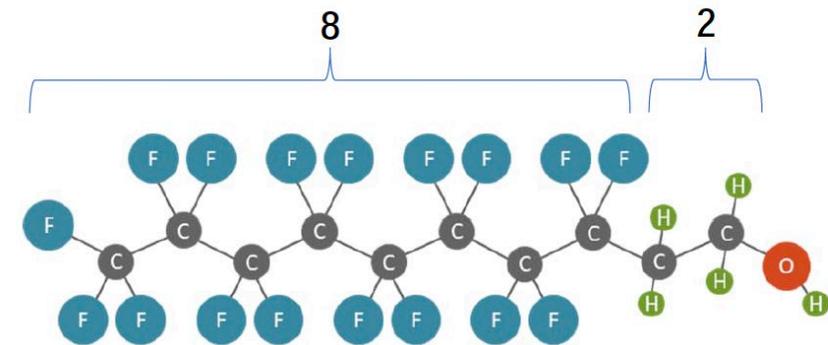


Perfluorooctane carboxylate (PFOA)



# Polyfluoroalkyl Substances

- Partially fluorinated
  - Non-fluorine atom (usually H or O) attached to at least one, but not all, of the carbons in the alkane chain
- May be susceptible to biotic or abiotic transformation (not degradation)



8:2 Fluorotelomer alcohol

Fluorotelomers are often named using a “n:x” prefix (8:2 fluorotelomer alcohol, 8:2 FTOH)

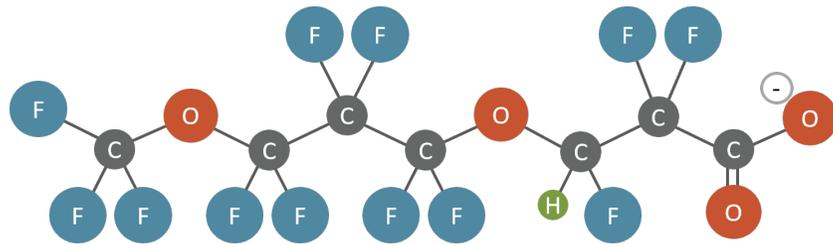
# PFAS Precursors (under environmental conditions)

- Some PFAS can transform to PFAAs under environmental conditions
  - Referred to as "PFAA precursors"
  - Resulting PFAAs sometimes referred to as "terminal PFAAs"
- Perfluoroalkane sulfonamides (FASAs)
  - May transform to PFSAs and PFCAs
- Polyfluoroalkyl Substances
  - Fluorotelomers
    - Fluorotelomer alcohols (FTOH)
    - Fluorotelomer sulfonates (FTS)
    - Fluorotelomer carboxylates (FTCA)
    - May transform to PFCAs
  - Perfluoroalkyl sulfonamido ethanols (FASE) & acetic acids (FASAA)
    - May transform to PFCAs or PFSAs

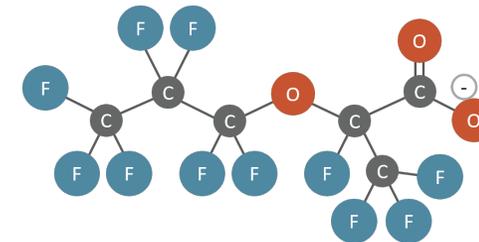
As we learn more about transformation pathways, we may be able to use that information for site characterization – to determine sources, age, history, etc.

# Replacement Chemistry

- ADONA and HFPO-DA (GenX) are replacement chemicals for PFOA
- Generally limited info on toxicities, physical/chemical properties
- HFPO-DA (Hexafluoropropylene oxide dimer acid)
  - Component of GenX processing aid technology used by one manufacturer (USEPA 2018)
  - U.S. EPA proposed MCL for HFPO-DA; Health-Based Water Concentration = 10 ppt



Chemical structure for ADONA



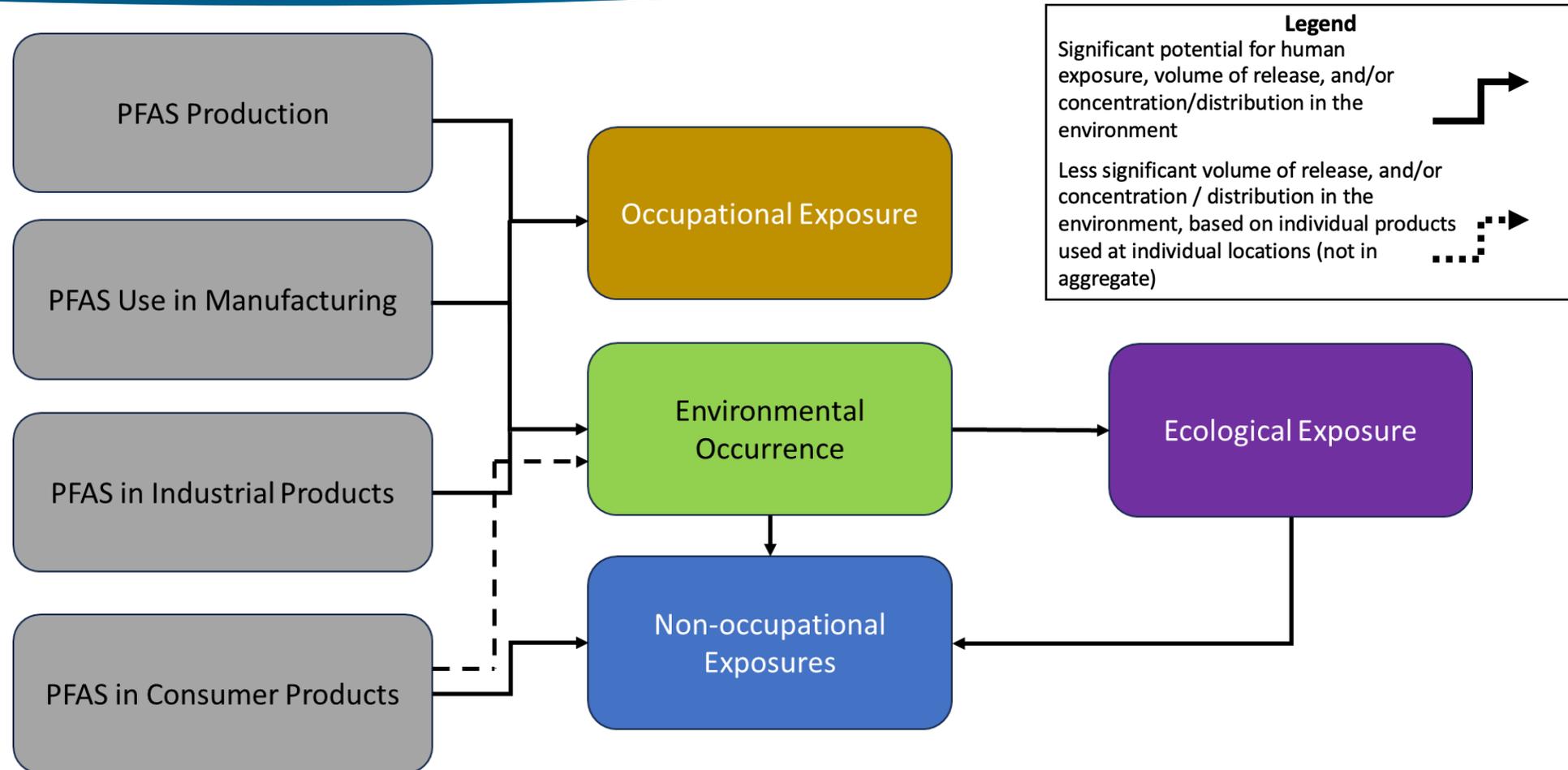
Chemical structure for HFPO-DA (GenX)  
(hexafluoropropylene oxide dimer acid)

# A Brief History of PFAS Discovery and Manufacture

**PFAS Emergence Timeline**

	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s	2020s
Production	Synthesis / Development									
			Manufacturing and Commercial Production							
									Phase-outs / Reductions / Alternatives	
Health & Environment					Health Concerns					
									Environmental Detection & Analytical Improvements	

# Relative exposure and environmental impact due to PFAS manufacture and use



# PFAS Use and Sources to the Environment

## Aqueous Film Forming Foam (AFFF)

- Military installations & civil airports
- Petroleum refineries, terminals, & chemical facilities
- Firefighting - training and response areas

## Industrial

- Primary manufacturing
- Surfactants, resins, molds, plastics
- Chrome plating and etching
- Photolithography/Semiconductor
- Textiles, coatings, leather, paper, carpet, etc.



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## Landfills

- Consumer products, industrial waste, biosolids from WWTP applied as cover
- Potential release via leachate or landfill gas

## Wastewater Treatment Plants

- PFAS in influent (from industrial & domestic sources) may not be treated and end up in effluent
- Potential release via Liquid effluent or biosolids



Iain Thompson / Cathkin Landfill Site, CC  
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# Recent Claims of PFAS Use and Occurrence

- ▶ Cosmetics and Personal Care Products
- ▶ Fluorinated HDPE Containers
- ▶ Food Packaging
- ▶ Synthetic Turf

# PFAS Certification in Products

Institution	Products	Criteria
USEPA Sustainable Marketplace	Comprehensive web site of multiple product categories	Links to multiple Standards and Ecolabel
USEPA – Safer Choice	Industrial and consumer products	PFAS not specifically prohibited but EPA has determined that PFAS no longer meet the Safer Choice standard; Exceptions allowed; will be specifically called out as not meeting the standard in March of 2023 Other labels also listed
FDA	Food-contact equipment & packaging	Authorized limited PFAS use for certain categories of food contact products
Green Screen	PFAS-free AFFF, cleaners and degreasers, furniture and fabrics, food service ware, and textiles	Separate limits for intentionally added PFAS (0-100 ppm) versus contamination as Total Organic Fluorine (1-100 ppm), which vary by product category.
Biodegradable Products Institute (BPI)	Compostable products and packaging	No intentionally added PFAS; Limit of 100 ppm total fluorine; SDS review; BPI-approved lab testing
EWG	EWG-Verified Program for consumer products	Products cannot contain the PFAS that are on “Unacceptable” list of ingredients; Right to perform random testing
PFAS-Central	Referrals to PFAS-free products	Based on declared company policy, no independent verification



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# Aqueous Film Forming Foam (AFFF) and the Current Best Management Practices

Shalene Thomas, Battelle



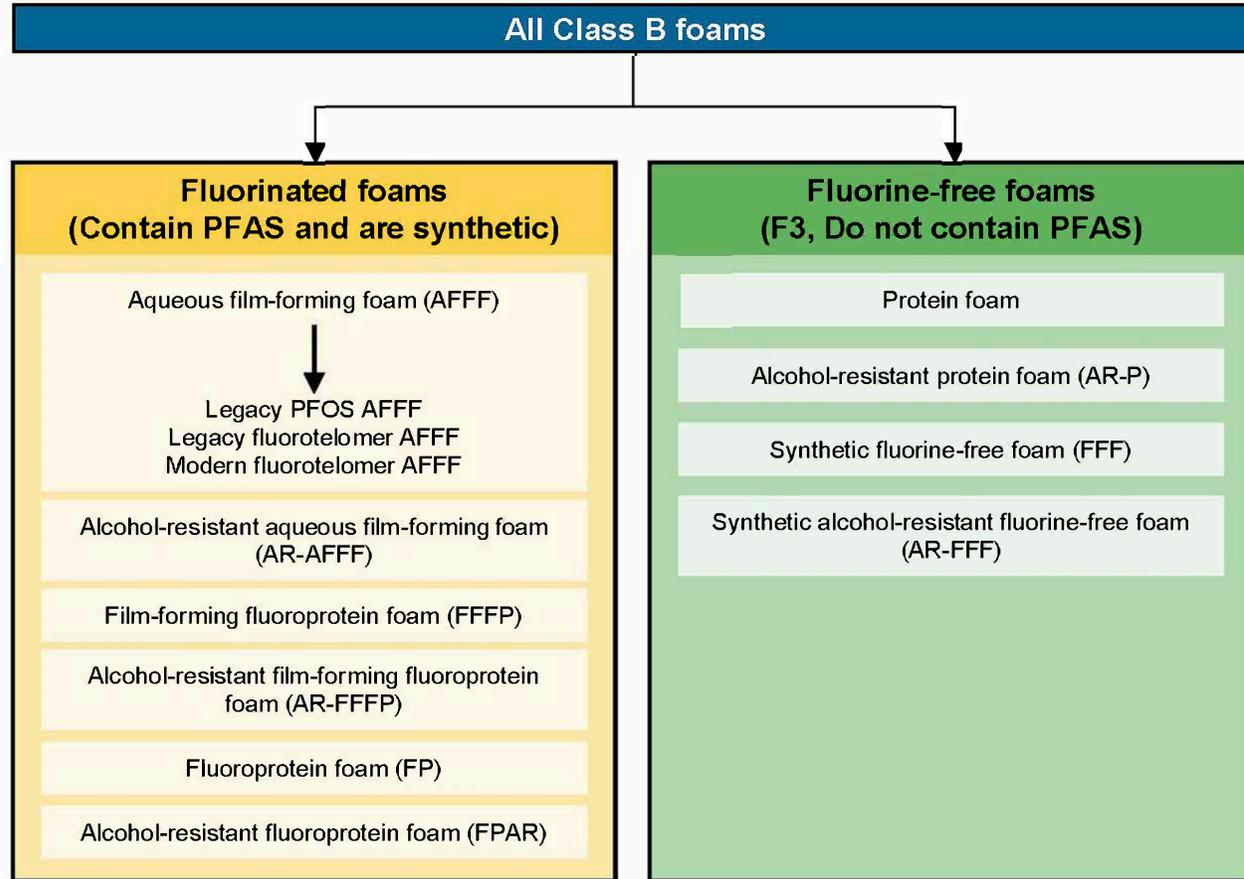
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# PFAS Technical and Regulatory Guidance Document Published

- Final web document PFAS-1: <https://pfas-1.itrcweb.org>
- Firefighting Foams, Section 3
- External Tables
  - AFFF Characteristics Excel File
  - AFFF Transition to fluorine-free foams (F3) Case Studies Excel File

# Classes of Firefighting Foams



- **CLASS A Foams-** Developed in the 1980s for fighting wildfires and used in structure fires. Do not contain PFAS
- **CLASS B Foams-** Used to fight fires involving flammable and combustible liquids and gases; petroleum greases, tars, oils and gasoline; and solvents and alcohols

Many Class B foams contain PFAS  
(due to Mil-Spec)

AFFF are the primary Class B foams  
that contain fluorosurfactants

# AFFF Classifications

- **Legacy PFOS AFFF<sup>1,2</sup>**

- ECF chemistry, (C2-C13), Branched & linear isomers (~1:4), PFAS composition (Mostly PFSAs, 89% (e.g., PFOS) in 3M Lightwater)

- **Legacy Fluorotelomer AFFFs<sup>3, 4</sup>**

- Contain polyfluorinated PFAS which can transform to PFCAs, Contain no PFOS and cannot transform to PFOS, Fluorotelomers not listed on UCMR or Method 537 lists

- **Modern Fluorotelomer AFFFs**

- Developed in response to PFOA/PFOS phaseout, contains short chain PFAS (C6), may have trace amounts (ppb) PFOA, may transform to PFCAs

Note: PFAS composition of AFFF has changed over time



Photo courtesy of J. Field.

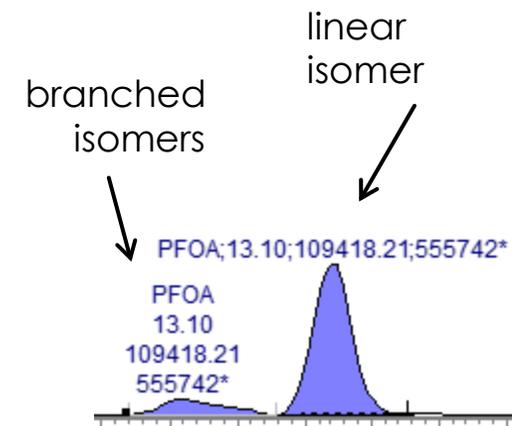


Figure courtesy C. Higgins, Colorado School of Mines.

PFAS-1, Section 3.1 Foam Formulations.

<sup>1</sup>Barzen-Hansen et al., 2015. *ES&T Letters* 2: 95-99; <sup>2</sup>Benskin, 2010. *Rev Environ Contam Toxicol*.

<sup>3</sup>Place and Field, 2012. *ES&T* 46: 7120-7127; <sup>4</sup>Weiner et al., 2013. *Environ Chem* 10:486-493;

# Typical Composition of AFFF

AFFF products contain other surfactants, solvents, additives

- 3% AFFF concentrate contains:
  - More than 60% water/diluent
  - Up to 20% is solvents
  - As much as 18% is surfactants *of which less than 2% is fluorosurfactants.*



# AFFF Contains Highly Diverse Mixtures

## AFFF product chemistry has changed over time

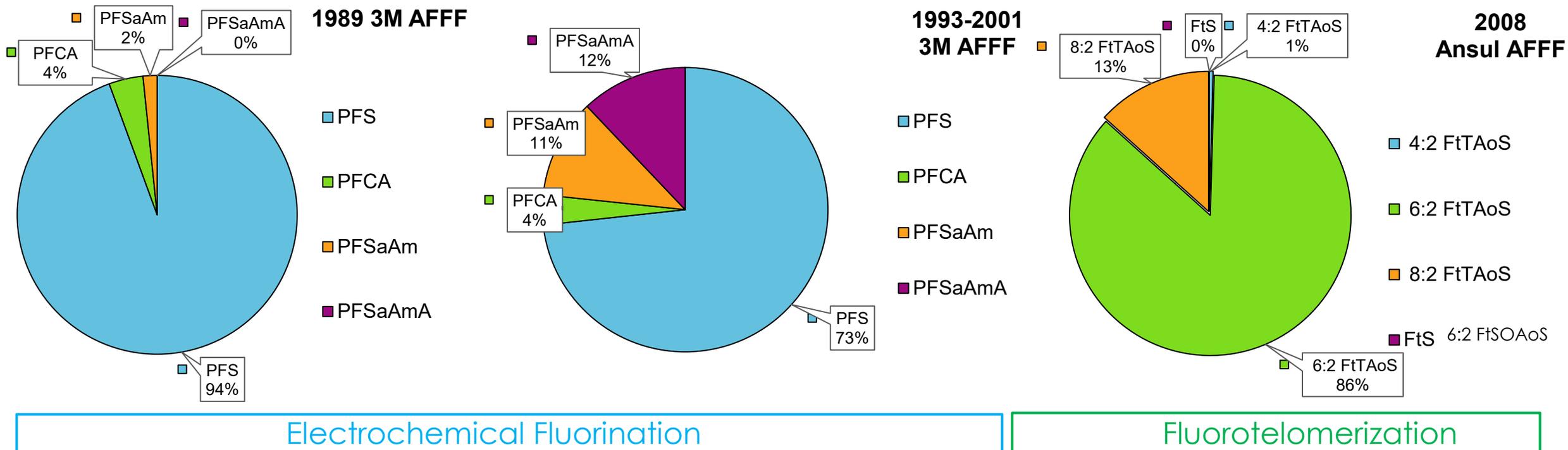
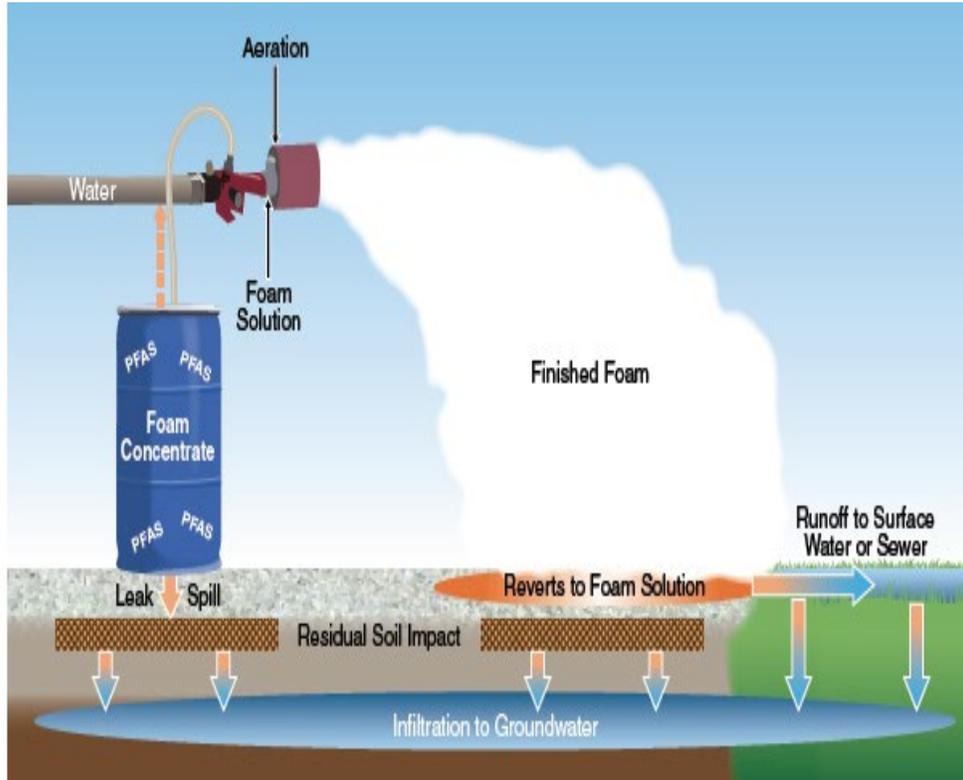


Table 3-1 of the ITRC PFAS Technical Regulatory Guidance document presents types of foam and composition.

# Mechanisms for Application and Release to Environment



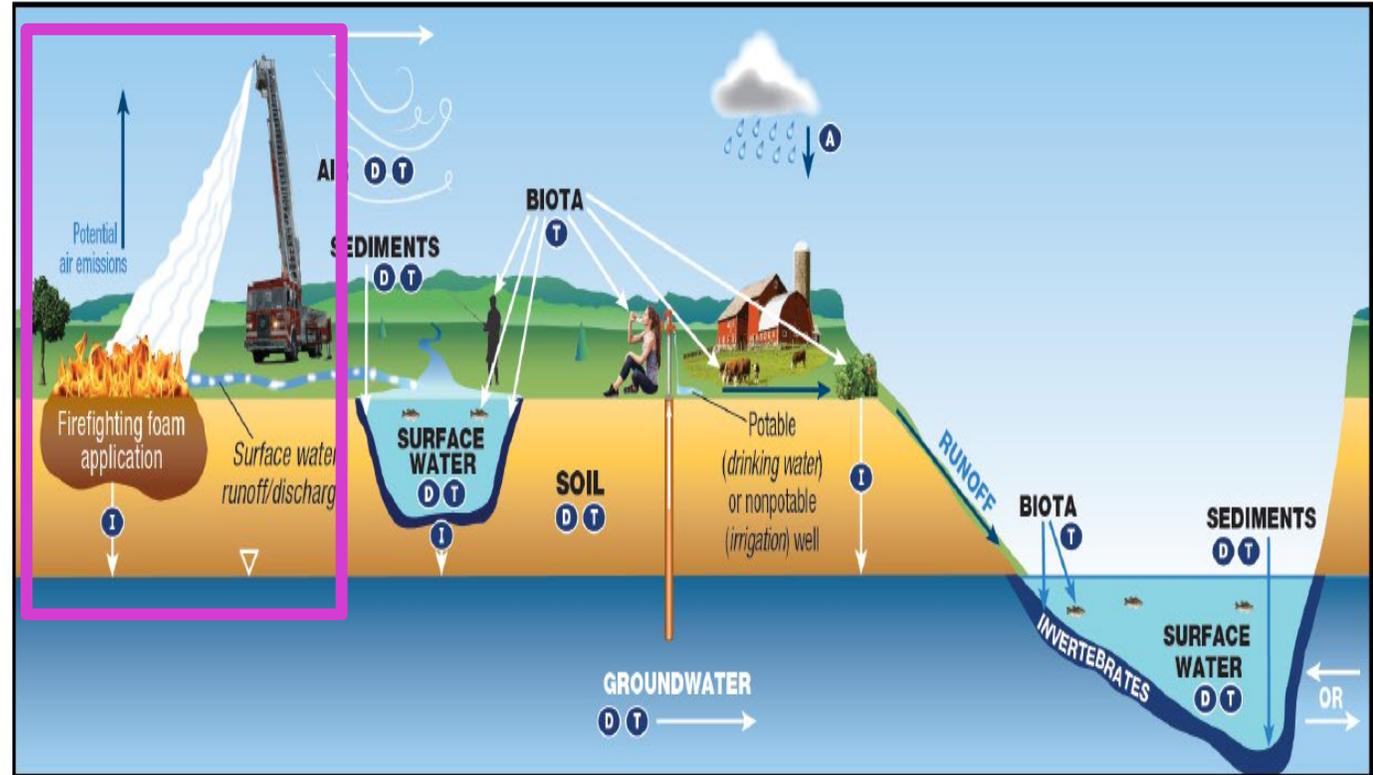
PFAS-1, Figure 3-4 Release of firefighting foam.  
Source: Adapted from figure by J. Hale, Kleinfelder, used with permission.

Foam is released via various practices and mechanisms:

- Low volume releases of foam concentrate (Spills)
- Accidental leaks
- Moderate volume discharge of foam solution (Firefighting operations)
- Infrequent high-volume, broadcast discharge (Firefighting operations)
- Periodic, high volume, broadcast discharge (historic training operations, equipment checks)

# AFFF Fate and Transport

- Used to address potential risk, development of CSM, and identification of treatment options.
- Affected by several physical and chemical properties.
- Abiotic transformation of precursors by hydrolysis, photolysis, and oxidation can produce PFCAs and PFSA.
- Biotransformation of precursors to PFAA over time can produce PFAAs such as PFOA.



KEY A Atmospheric Deposition D Diffusion/Dispersion/Advection I Infiltration T Transformation of precursors (abiotic/biotic)

PFAS-1, Figure 2-21 CSM for fire training areas. Figure Adapted from figure by L. Trozzolo, TRC, used with permission.

# AFFF Procurement and Inventory-BMP

**HAZARD X EXPOSURE = RISK**

## Foam Selection and Requirements

- Document all procurement and inventory
- Understand performance specification requirements
- (e.g., Mil-Spec MIL-PRF-24385, MIL-PRF-32725; UL Standard 162)
- Concentrate mixtures of 1,3, or 6 percent solution in water

## Foam Storage and Handling

- Stored in 5-gallon bucket, 55-gallon drum to 256-gallon tote container, 5000-gallon tanker truck, or suppression system
- Ensure proper secondary containment to avoid spills/mishaps

# Treatment and Disposal

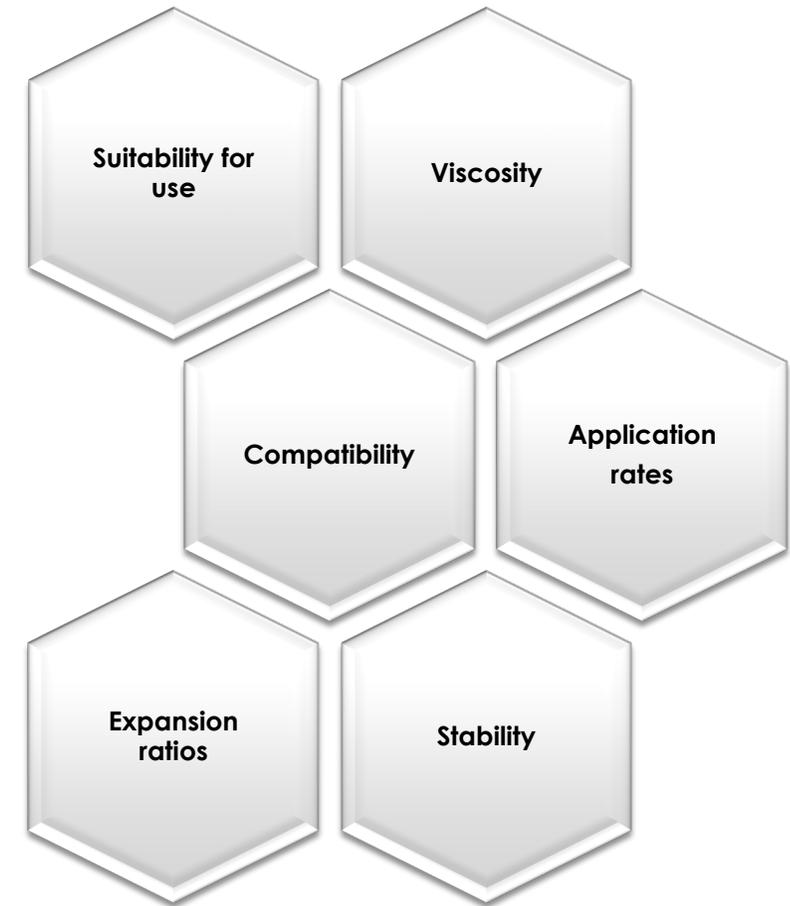
- Consider USEPA Interim Guidance on Destroying and Disposing of Certain PFAS and PFAS-Containing Materials (Dec 2020)<sup>1</sup>
- Fire and flush water containing AFFF should be disposed of as a generated waste, when possible
  - PFAS in water can be processed to concentrate PFAS prior to disposal to reduce treatment costs
  - Concentrated waste can be stored, incinerated, landfilled, or stabilized <sup>1</sup>
  - Incineration of AFFF concentrate should be performed at certified facilities
- Best management practices include accounting for all volumes of AFFF and weights of system components for disposal certificates.



Photo from: <http://clui.org/ludb/site/east-liverpool-hazardous-waste-incinerator>.

# Firefighting Foam and Foam System Replacement

- Consider performance specifications, system modifications, decontamination and disposal
- Consider clean-out vs replacement options
- Consider alternatives to using fire foam for specific hazards such as: Water Mist; Dry Chemical; Containment flooring systems; separation and exposure protection
- Factors to consider:
  - What are the current performance requirements for the foam?
  - What application techniques are anticipated?
  - How Clean does the System need to be for future use?



# Foam Research and Development

- Research is being conducted on fluorine-free alternatives
- SERDP-ESTCP Research can be accessed online
  - <https://serdp-estcp.org/>
  - Table 3-8 includes a summary of some of these studies



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# Fate and Transport and Site Characterization

Sandra Goodrow, Ph.D., NJDEP



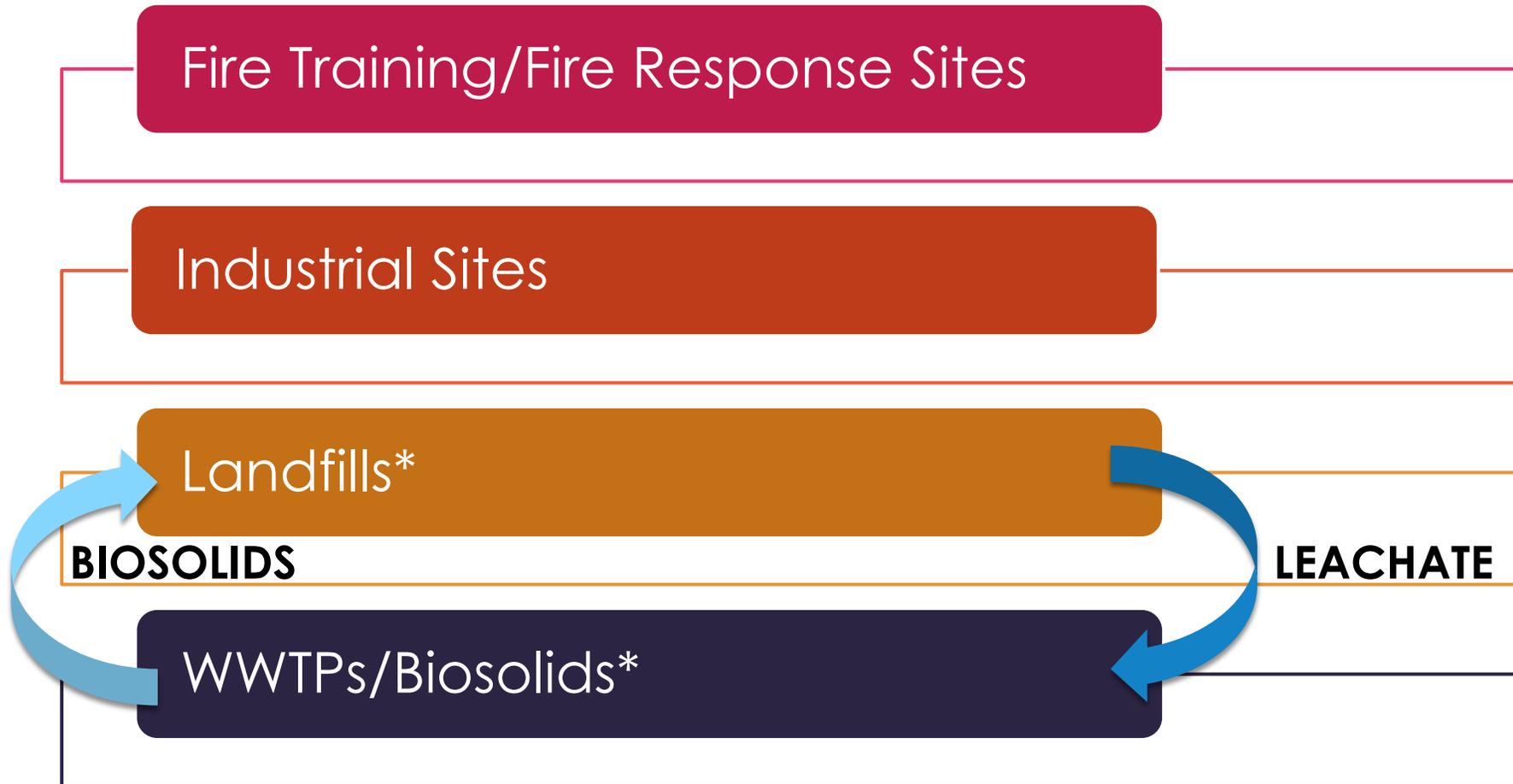
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# PFAS Technical and Regulatory Guidance Document Published

- Final web document PFAS-1: <https://pfas-1.itrcweb.org>
- PFAS Releases to the Environment, Section 2.6
- Physical and Chemical Properties, Section 4
  - Physical and Chemical Properties Table 4-1
- Fate and Transport, Section 5
- Media-Specific Occurrence, Section 6
  - Additional Information for Media-Specific Occurrence, Section 17.1
- Site Characterization, Section 10

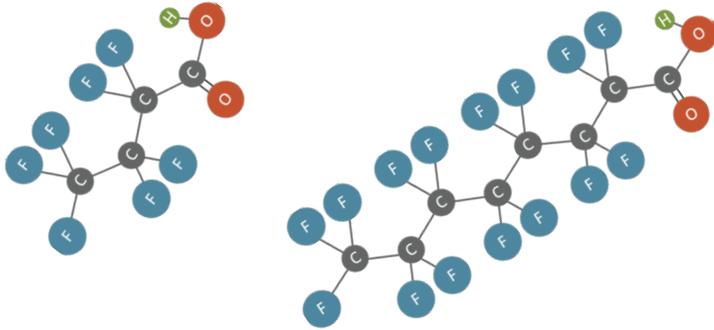
# Sources of PFAS Release to the Environment



\*Landfills and WWTPs are receivers of PFAS materials from domestic and industrial sources. PFAS concentrations vary widely depending on the waste stream accepted by facilities.

# What is Fate and Transport?

## PFAS Characteristics

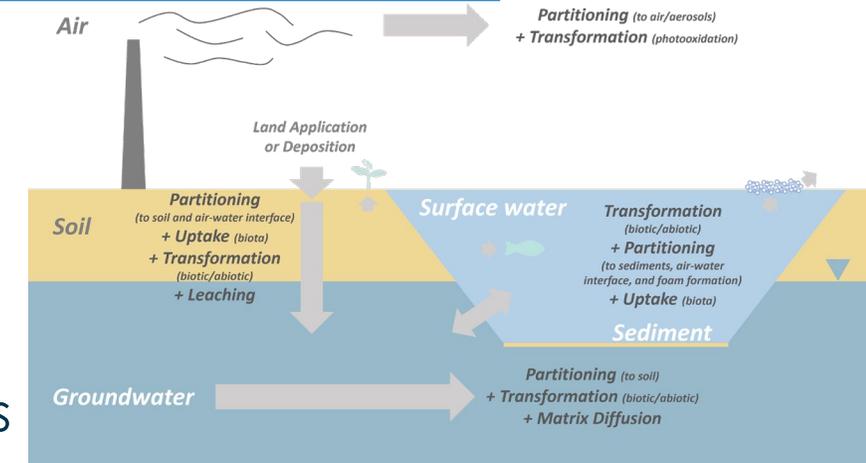


- *Perfluorinated* vs. *polyfluorinated*
- *Fluorinated tail*: chain length
- *Non-fluorinated head*: functional group and charge state

## PFAS

### Fate & Transport Nature of release

## Site Characteristics



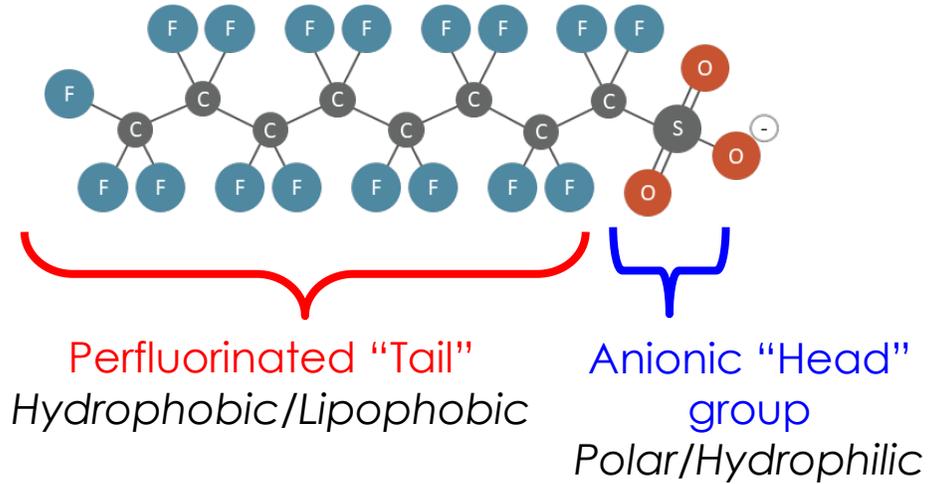
- Soil properties
- Groundwater depth/velocity
- Groundwater geochemistry
- Prevailing atmospheric conditions
- Co-contaminants

PFAS figure source: M. Olson, Trihydro. Used with permission.

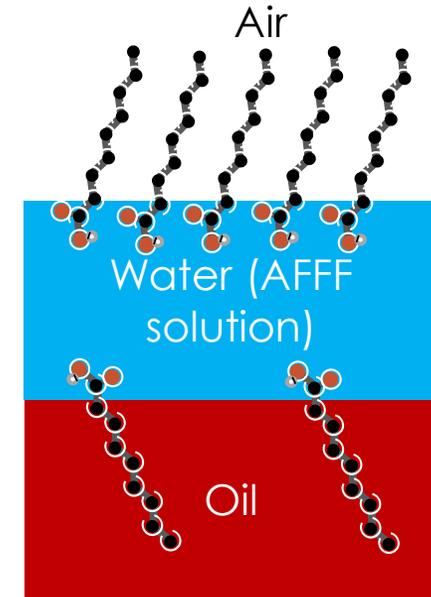
PFAS-1, Section 5.1. Figure 5-1 Fate and transport processes relevant for PFAS. Source: D. Adamson, GSI. used with permission.

# The Heads and Tails of PFAS

Perfluorooctane sulfonate (PFOS)



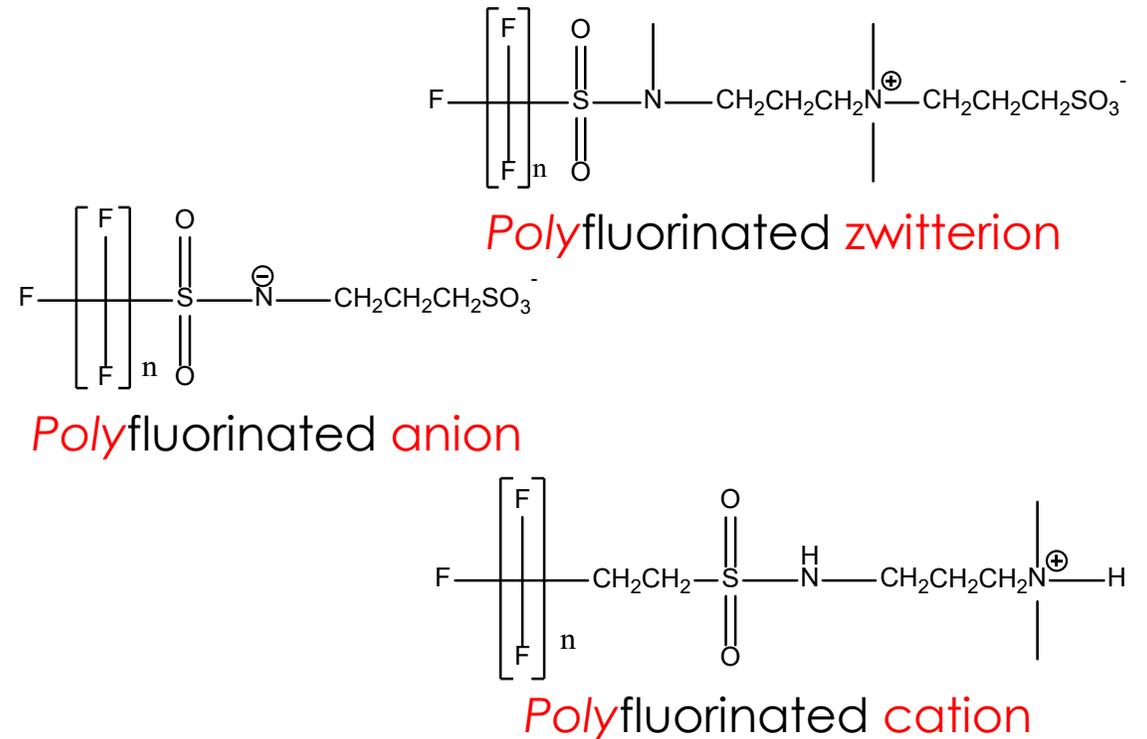
Perfluoroalkyl acids (PFAAs) are extremely persistent in the environment



PFAAs preferentially partition at interfaces

# Structural Implications

- Functional Groups
  - PFSAAs tend to sorb more strongly than PFCAs of equal chain length
- Fluorination
  - Polyfluorinated can be transform to perfluorinated (PFAAs)



# Properties of PFAAs

- Negatively charged at typical environmental and physiological pH (i.e., 4-10)
- Water soluble
- Surfactants
- Low vapor pressure and Henry's Law coefficients

Table 4-1 Physical and Chemical Properties Excel Table

# Anion Sorption and Transport

$K_{oc}$  data from Guelfo, J.L., Higgins

Analyte	# Carbons	$K_{oc}^1$	$R_f$
PFBA	4	76	2.6
PFPeA	5	23	1.5
PFHxA	6	20	1.4
PFHpA	7	43	1.9
PFOA	8	78	2.7
PFNA	9	229	5.9
PFDA	10	912	21
PFUnA	11	3,600	78
PFBS	4	62	2.3
PFHxS	6	112	3.4
PFOS	8	631	15

Note: these results represent one study of many summarized in the physical/chemical properties in Section 4

- Sorption ( $K_{oc}$  and  $K_d$ ) generally increases with number of carbons
- Retardation factor ( $R_f$ ) calculations illustrate potential variability

$$R_f = 1 + K_d \frac{\text{Bulk density}}{\text{Porosity}}$$

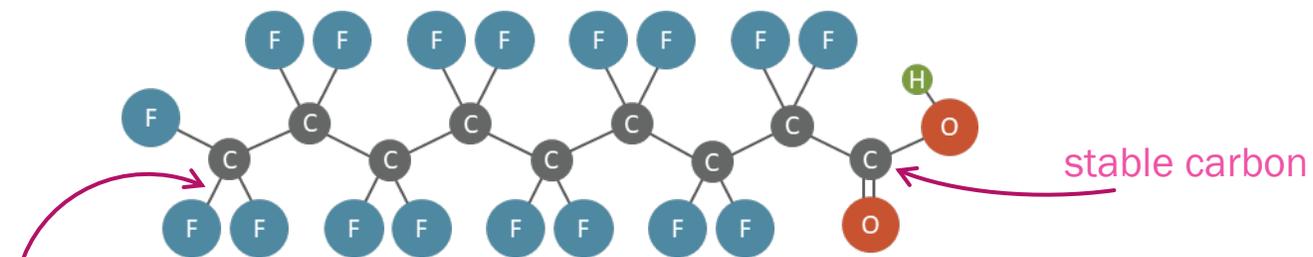
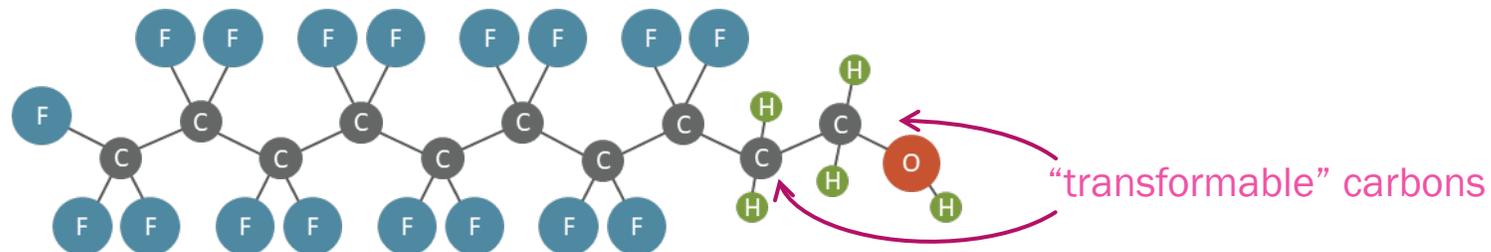
where  $K_d = K_{oc} * f_{oc}$

and  $f_{oc}$  = fraction of organic carbon (0.01)

- Partitioning at interfaces may further slow transport and contribute to retardation
- PFAS-NAPL interactions are complex

# Transformation of Precursors to PFAAs

8:2-fluorotelomer alcohol (8:2-FTOH) is biotransformable, not biodegradable

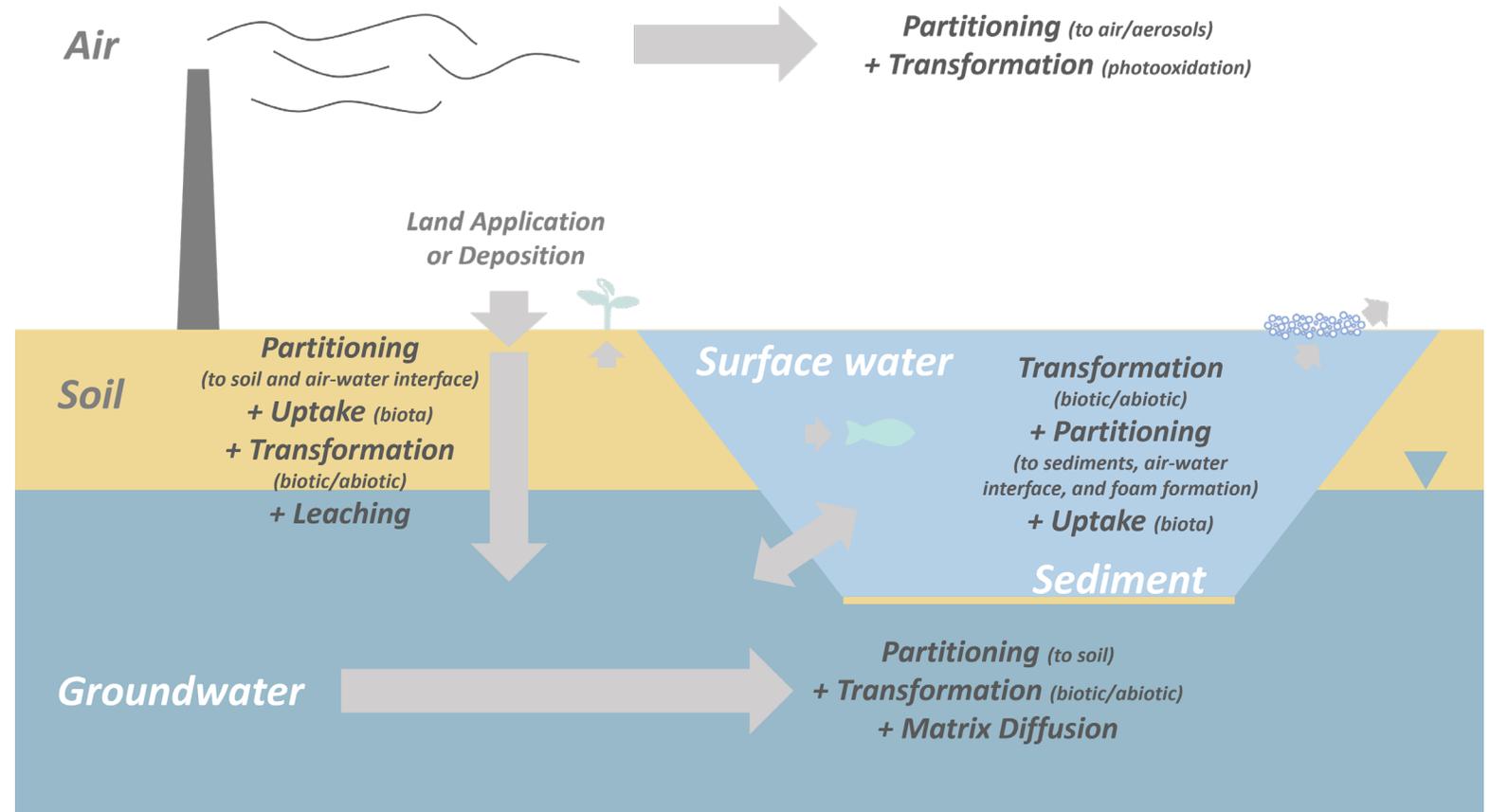


PFNA is neither biotransformable nor biodegradable

C-F bond is strongest covalent bond in organic chemistry

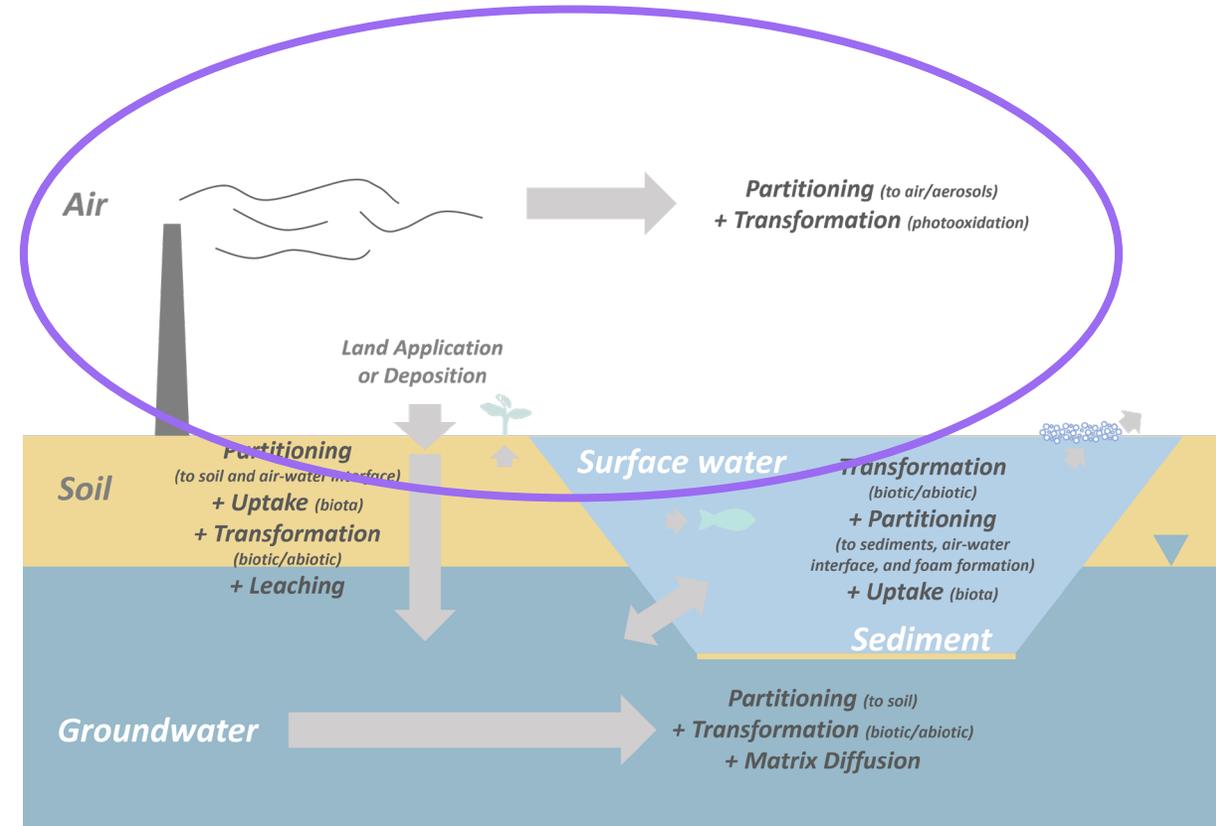
# PFAS Occurrence in Environmental Media

- Air
- Soil
- Groundwater
- Surface water
- Sediment
- Biota



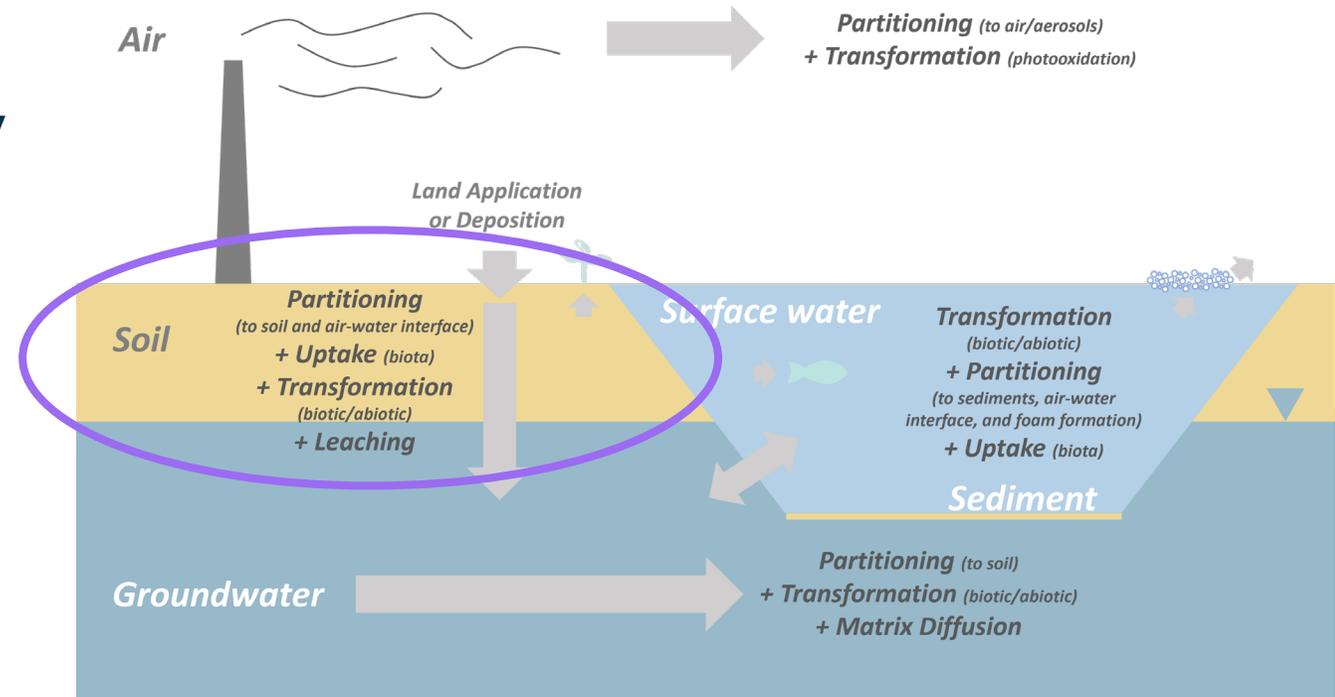
# Atmospheric Transport

- Regional/global scale
- Sources: stack emissions, incineration, fire suppression
- Some PFAA precursors are volatile: fluorotelomer alcohols (FTOHs)
  - Precursors may transform into PFAAs
  - PFAAs (PFOA, PFOS) may transport via aerosols/particulates
- Atmospheric deposition = large impacted areas around industrial sites



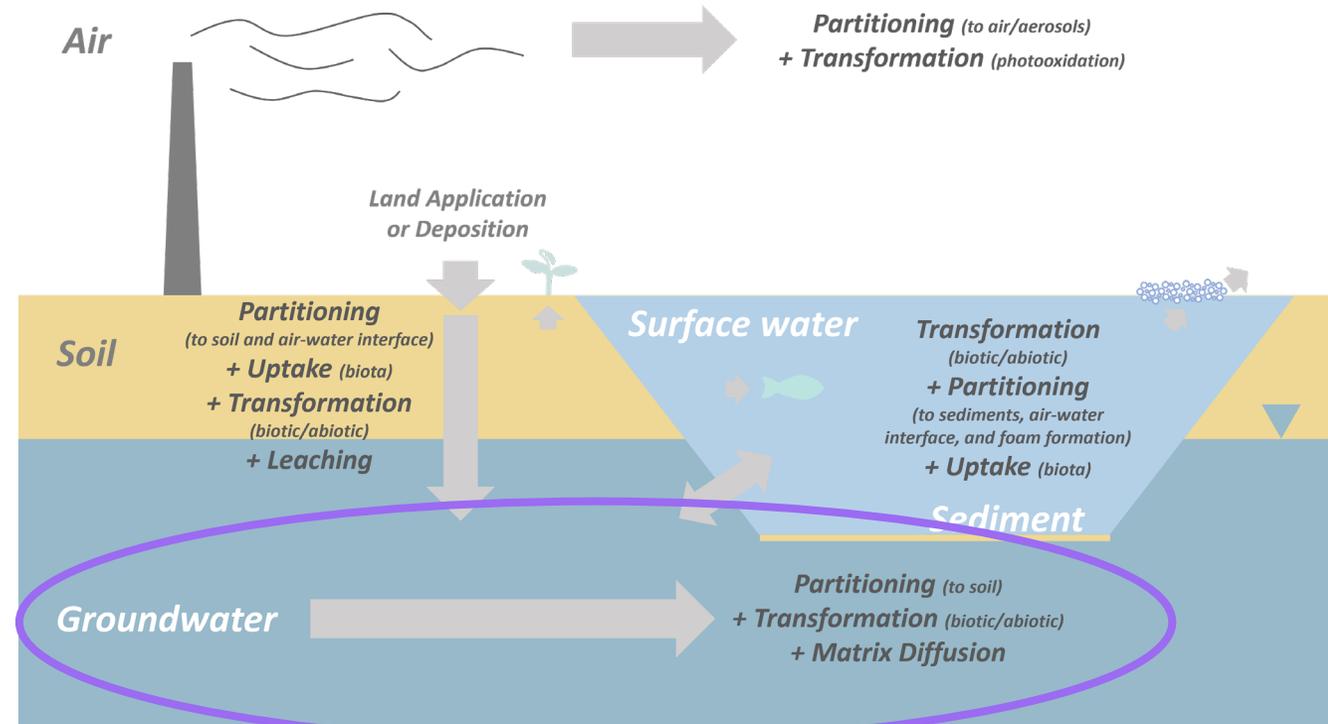
# Transport in the Vadose Zone

- PFAS source areas: vadose-zone retention may be significant
  - Cationic/zwitterionic precursors may strongly sorb
  - Long-chain PFAA sorption
  - PFAAs accumulate at air/water interfaces (may retard transport)
- Low volatility for most PFAS
- Leaching may provide long-term source to groundwater



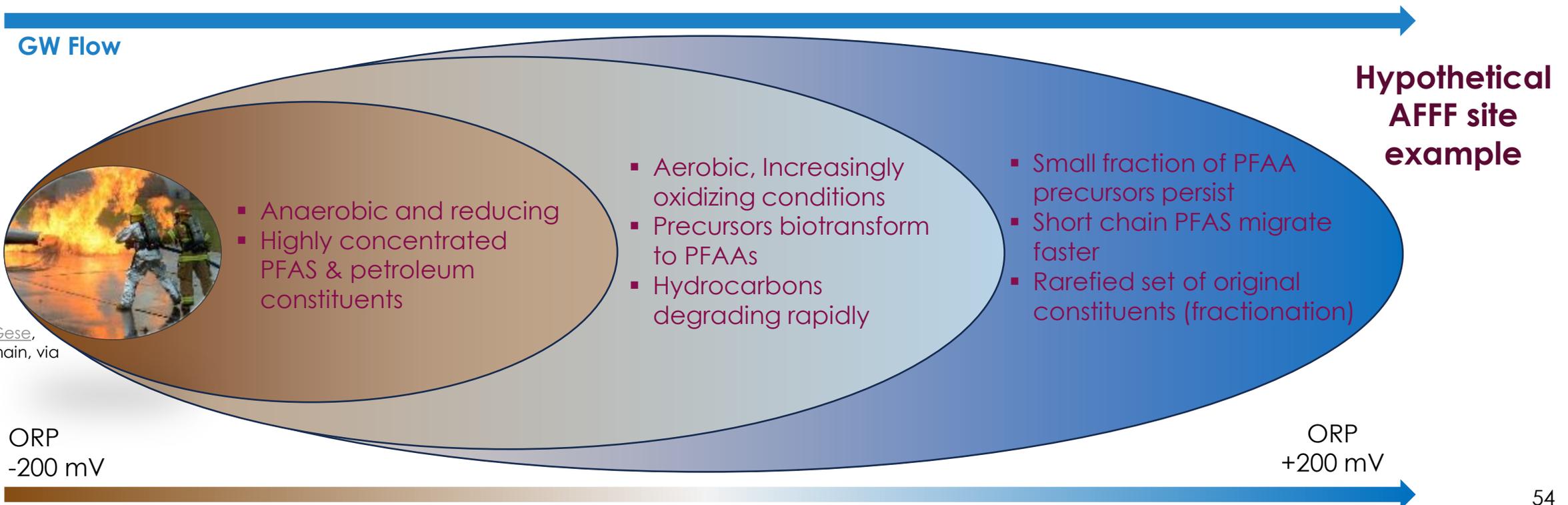
# Transport in Groundwater

- Readily transported once in groundwater
  - Chain-length dependent
  - $K_{oc}$  important, but not sufficient
  - Biotransformation vs. biodegradation
- Potential impacts of remedial activities/biotransformation
  - Precursor transformation may cause PFOA/PFOS (and other PFAAs) concentrations to increase



# Conceptual PFAS Fate and Transport at an AFFF site

- Differential transport and precursor transformation lead to environmental fractionation
- As PFAS move downgradient from source area, composition of PFAS changes
- Source type and hydrogeochemical parameters influence type and rates of change



# Site Characterization: Issues Relevant to PFAS

- Evolving science and regulations
  - State of the science
  - Analytical methodologies (detection and reporting limits, expanding parameter lists)
  - Sampling methodologies (potential for cross-contamination)
  - Regulatory environment (changing regulatory limits, sampling procedures, and compounds of interest)

# Site Characterization: Issues Relevant to PFAS

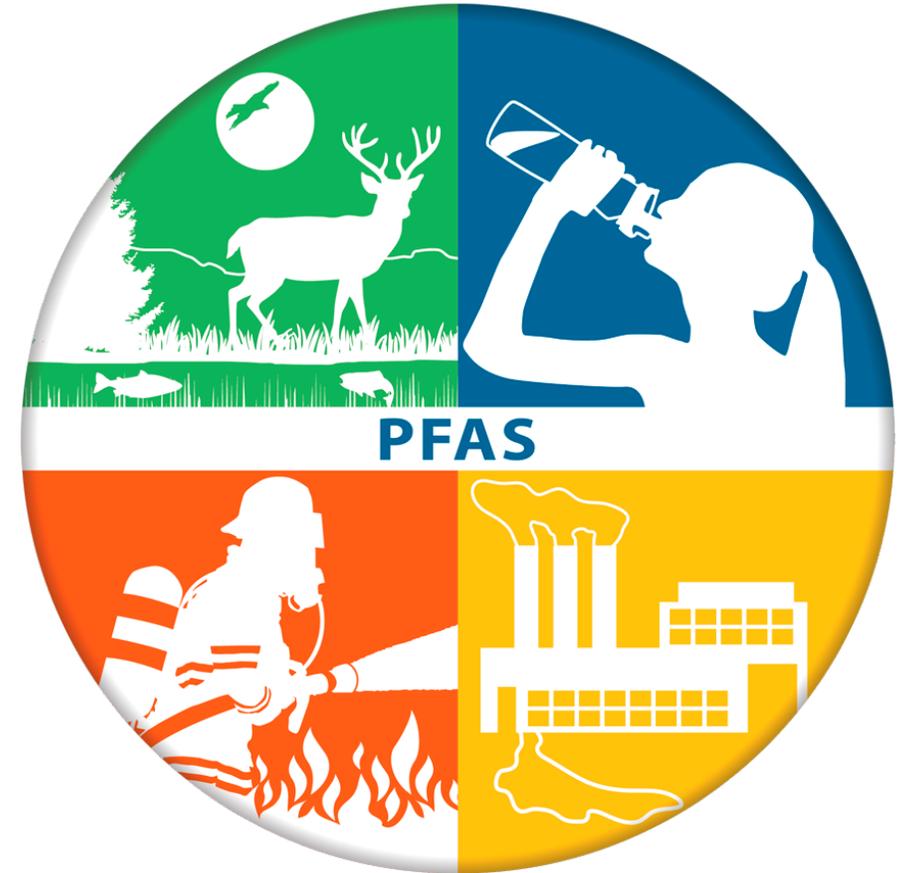
- Groundwater significant due to its source as drinking water
- Plumes may be quite extensive
- Compound suite and possible precursors
- Identification of PFAS-specific data analysis and interpretation approaches, models, and tools
- Need historical view to understand site
- Widespread use (potential for multiple releases in a given area, off-site contributions)

# Site Characterization: Issues Relevant to PFAS

- Site characterization concerns arise due to unique source, fate and transport properties
  - Atypical sources
    - Broad variety of unusual primary sources
    - Secondary sources created from movement of contaminated media into a previously uncontaminated area
    - Precursor transformation
  - Atypical pathways (e.g., air deposition resulting in groundwater impacts with no direct on-site release)
  - Complex transitions between media (e.g., vadose zone, groundwater and surface water interactions)
  - Partitioning (e.g., sorption through hydrophobic, electrostatic, and interphase partitioning mechanisms)

# Questions

Please use the Q&A Pod to ask questions.





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# PFAS Sampling and Analysis

Kristi Herzer

Vermont Department of Environmental Conservation  
(VT DEC)



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# PFAS Technical and Regulatory Guidance Document Published

- Final web document PFAS-1: <https://pfas-1.itrcweb.org>
- Sampling and Analytical Methods, Section 11
- Analytical methods Excel file
  - Table 11-2 Published methods basics
  - Table 11-3 Published methods specifics
  - Table 11-4 Analyte lists
  - Table 11-5 Draft published methods

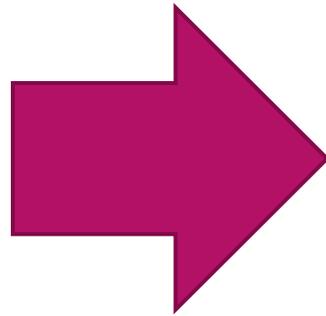
# General Sampling Guidelines

- Site-specific QAPP or work plan
- Refer to 11.1.2 for materials to avoid during sampling event
- Pretesting sampling equipment or materials
  - Equipment Rinse Blanks (ERBs/EBs)
  - Documentation during sampling event for any potential causes for bias

# Sampling Event Preparation

The overarching objectives of the project and conceptual site model will influence the fundamentals of any sampling and analysis program

- Site history (e.g., potential sources, quantities used) as an indicator of potential level of PFAS
- Project Action Levels



Develop a project-specific sampling and analysis plan (SAP) which addresses the increased risk of contamination and project-specific considerations

# Planning Laboratory Analysis

- Project team discusses with the laboratory:
  - the PFAS to be analyzed and project reporting levels
  - the volume of sample required to achieve the lab reporting levels
  - project sample preparation requirements
  - the number of bottles needed, including QC samples
- Provide laboratory information on high concentration samples
- For USEPA 1633, request laboratory screen all samples prior to sample preparation (additional containers for aqueous samples needed)

# What To Do If You Are Unsure If Item Contains PFAS Or Not?

- Review the Safety Data Sheets and consult with the manufacturer of the item
- Consult:
  - PFAS sampling guidance documents
  - PFAS resources within your organization
  - An analytical chemist with PFAS experience
- Collect equipment blank(s) from a specific item in question or send a section or piece of the equipment (if practical) to the laboratory for a more vigorous leachate analysis
- Tiered approach
  - 1st: Restrictions on sampling materials in direct contact with samples
  - 2nd: Restrictions on materials allowed on personnel and staging area



**ERR ON THE SIDE OF BEING CAUTIOUS  
RATHER THAN BEING UNSURE AND RISK CROSS-CONTAMINATION**

# Sample Considerations

- USEPA Methods 537.1 and 533, and USEPA Method 1633 all require the laboratory to prepare the entire sample collected, including sample container rinsate(s)
- DOD AFFF01 requires the container holding the diluted AFFF concentrate be prepared in its entirety, including a rinse of the container

# Laboratory Supplied Sampling Materials

Sample containers (polypropylene or HDPE), solvents (such as methanol), and water used for blanks in the field and for final rinse of equipment should:

- be supplied by the lab performing the analysis, and
- be verified as being PFAS-free (as defined by the project) prior to use

If site water is used in the field for any blanks or final rinse, a sample of this water should be sent to the laboratory for analysis.

# Field Decontamination

- Reusable field equipment cleaned between samples
- The SDSs of detergents or soaps used in decontamination procedures should be reviewed to ensure fluorosurfactants are not listed as ingredients
- Heavy equipment best cleaned at decontamination facility or other containment method
- Use laboratory-verified PFAS-free water in final rinse of decontamination of sampling equipment

# Field Quality Control

- Table 11-1 lists typical field QC samples
- USEPA 537.1 and 533 have additional requirements
  - Minimum of one field reagent blank for each set of samples per site and field duplicates
  - Both methods specify the frequency of the field duplicate in terms of extraction batch (one per extraction batch, not to exceed 20 field samples), not collection frequency
- Additional quality control samples may be needed based on site-specific work plan and data quality objectives

# QA/QC Sample Collection

**Using blanks to evaluate composition or suitable nature of equipment/supplies for sampling, and to assess possibility of cross-contamination during sampling/transport/storage**

- **Pre-investigation equipment blanks** (decon water, methanol, new equipment, plastic bags as sample containers, anything you are unsure of)
- **Equipment blanks** to assess adequacy of decontamination process and/or evaluate potential contamination from equipment.
- **Field blanks** to assess contamination from field conditions.
  - Recommended frequency: one blank/day/matrix or one blank/20 samples/matrix, whichever more frequent.
  - **Field reagent blanks** (USEPA Method 537.1, 533) should originate from the laboratory for all drinking-water programs (minimum of 1/event).

# Filtering of Water Samples

- Evidence that PFAS may sorb onto various filters (e.g., glass fiber filters)
- Data may be misinterpreted as PFAS sorbed to soil or sediment in the water sample when the reduction may actually reflect PFAS sorbed onto the glass fiber filter
- Consider use of low flow sampling
- Laboratory centrifugation is a good alternative



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# PFAS Analysis



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# USEPA 537.1 & 533 PFAS Drinking Water Methods

## Similarities

- Sample preparation via Solid Phase Extraction (SPE)
- Compound-Specific Analysis by LC-MS/MS
- Laboratories allowed some modifications, but not:
  - Sample collection/preservation
  - Extraction
  - Quality control
- Multi-laboratory validated method

## Differences

- Sample collection - chemical preservation
- Analysis
  - Quantification scheme
  - Analyte Lists
  - Holding time

# USEPA PFAS DW Analytical Methods

Method 537.1 Only		Both Methods 537.1 and 533			Method 533 Only		
NEtFOSAA	NMeFOSAA	PFOA	PFOS	11CI-PF3OUdS	4:2 FTS	6:2 FTS	8:2 FTS
PFTA	PFTTrDA	PFDA	PFDoA	9CI-PF3ONS	PFBA	PFHpS	PFPeS
		PFHxA	PFUnA	ADONA	PFPeA	PFMBA	PFMPA
		PFBS	PFHpA	HFPO-DA	PFEESA	NFDHA	
		PFHxS	PFNA				

Table 2-5, separate PDF, categorizes the PFAS analytes according to the family tree hierarchy

# USEPA Method 1633

- USEPA Method 1633 (January 2024)
- Isotope dilution method
  - Compound-Specific Analyses (targeting 40 PFAS)
  - GW, SW, WW, Leachate, Biosolid, Tissue, Sediment, Soil

# Key Method Consistencies

- Use liquid chromatography tandem mass spectrometry (LC-MS/MS)
- Do not address neutral/volatile PFAS (i.e., fluorotelomer alcohols and derivatized PFCAs)
- Standards must be analyzed in order to identify and quantify individual PFAS
- Same equipment and supply concerns associated with field sampling apply to sample preparation and analysis

# Key Method Differences

- Method Scope
  - Media; Limit of Detection & Quantitation; Analytes (individual and isomeric profile)
- Sample preparation processes
  - Whole sample vs Aliquot; Solid Phase Extraction vs solvent dilution; Clean-up vs no clean-up
- Quantitation Scheme
  - External standard
    - Surrogates added prior to sample preparation; Quantitation does not account for bias associated with sample preparation or instrumentation; Data review must include evaluation of surrogate recoveries
  - Internal standard
    - Surrogates added before sample preparation and internal standards added to aliquot of extract prior to analysis; Quantitation does not account for bias associated with sample preparation but DOES account for instrumentation bias; Internal standard recoveries matter
  - Isotope standard quantitation
    - Isotopically labeled standards added before sample preparation; Quantitation accounts for bias associated with sample preparation AND instrumentation; Isotopically labeled standard recoveries matter



# Data Review and Validation

- Published Data Review and Validation Guidelines
  - Drinking Water Data Validation Guidance (*Data Review and Validation Guidelines for Perfluoroalkyl Substances (PFASs) Analyzed Using EPA Method 537* (EPA 910-R-18-001, November 2018))
  - Data Review Guidance (USEPA Technical Brief “Per-and Polyfluoroalkyl Substances (PFAS): Reviewing Analytical Methods Data for Environmental Samples.” April 2019)
  - DOD Validation Guidance (*Data Validation Guidelines Module 6: Data Validation Procedure for Per- and Polyfluoroalkyl Substances Analysis by QSM Table B-24*, 2022)

# Less-Standardized Analytical Techniques

- Particle-Induced Gamma Emission (PIGE) spectroscopy measures elemental fluorine from a sample isolated on a thin surface
- Precursor Analysis by Total Oxidizable Precursor (TOP) Assay measures PFAA precursors or polyfluorinated compounds that can be converted to PFAAs
- LC quadrupole time-of-flight mass spectrometry (LC-QToF-MS) tentatively identifies PFAS structures through library matches
- Extractable/Absorbable Organic Fluorine (EOF/AOF) measures fluorine in a sample as fluoride



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# Treatment Technologies

Andy Safulko, Brown and Caldwell



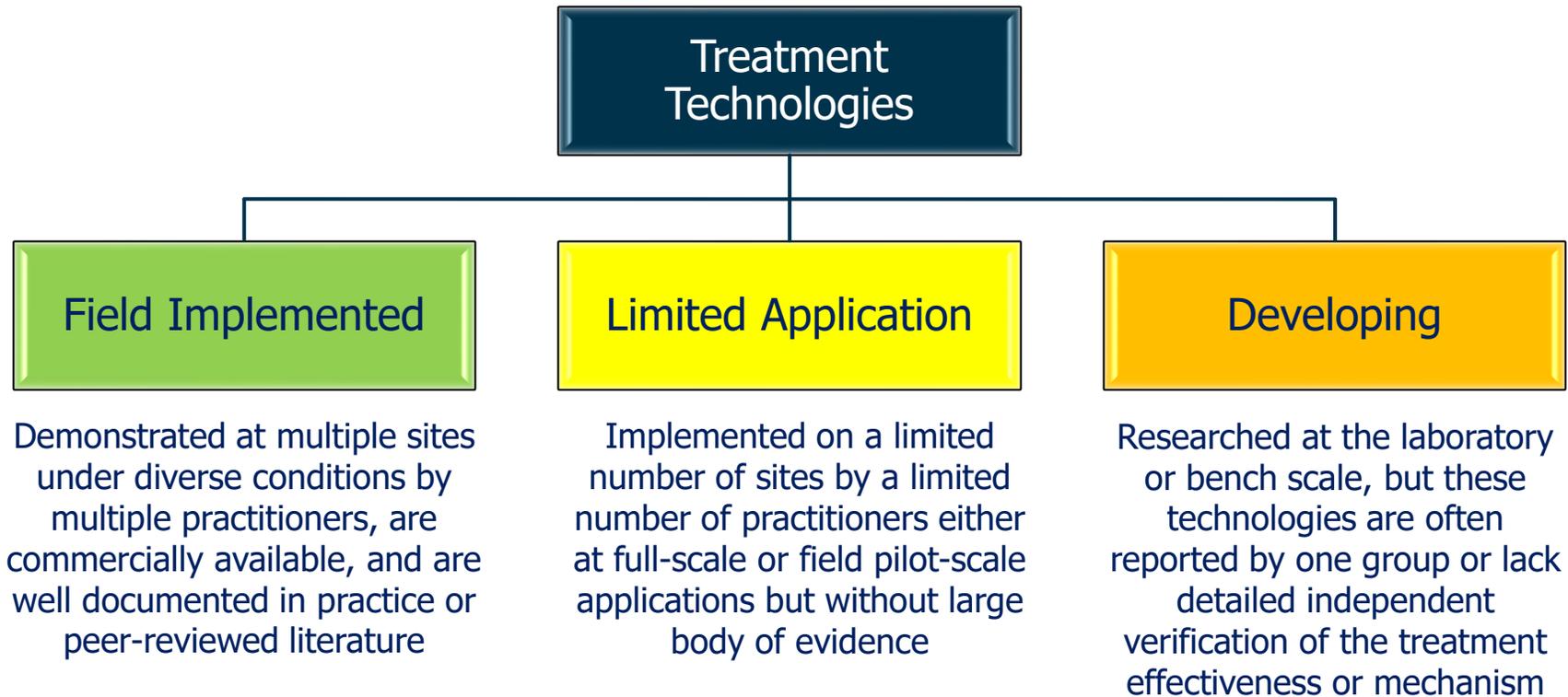
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# PFAS Technical and Regulatory Guidance Document Published

- Final web document PFAS-1: <https://pfas-1.itrcweb.org>
- Treatment Technologies, Section 12
- Table 12-1 Treatment Technologies Table
- Treatment Case Studies, Section 15.2

# Treatment Technology Maturity



# Treatment Technologies Table

Technology (Note 1)										
Technology Name	Treatment Technologies Section 12	Treatment Case Studies Section 15.2	Description (brief, include in/ex situ)	Stage of Development: Field Implemented (F); Limited Application (L); Developing (D)	Phase		Applicable Media			
	<a href="https://pfas-1.itrcweb.org/12-treatment-technologies/">https://pfas-1.itrcweb.org/12-treatment-technologies/</a>	<a href="https://pfas-1.itrcweb.org/15-case-studies/#15_2">https://pfas-1.itrcweb.org/15-case-studies/#15_2</a>			Liquid	Solid	water	soil/ sediment	liquid waste (Note 2)	solid waste (Note 3)
Name	Section	Case Study	Description	Stage	Liq	Sc	wa	soil/ sedi	liq <sup>l</sup> wa	soil <sup>l</sup> wa
Activated Persulfate	<a href="#">12.6.3.3</a>		Oxidation (ex situ, in situ)	D	Yes	No	x		x	
Alkaline Hydrothermal Reaction	<a href="#">12.6.5</a>		Chemical Treatment (ex situ)	D	Yes	No	x		x	
Alkaline Metal Reduction	<a href="#">12.6.3.10</a>		Reduction (ex situ)	D	Yes	No	x		x	
Biochar	<a href="#">12.6.13</a>		Adsorption (in situ, ex situ)	D	Yes	No	x		x	
Biodegradation	<a href="#">12.6.4</a>		Transformation (in situ)	D	Yes	No	x			
Catalyzed Hydrogen Peroxide	<a href="#">12.6.3.2</a>		Oxidation (ex situ, in situ)	D	Yes	No	x		x	
Coated Sand	<a href="#">12.6.11</a>		Adsorption (in situ, ex situ)	D	Yes	No	x		x	
Colloidal Activated Carbon	<a href="#">12.2.4</a>	<a href="#">15.2.3</a>	Adsorption (in situ)	L	Yes	No	x			



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# Liquids Treatment Technologies



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# Liquids Treatment

- **Field Implemented (Section 12.2)**
  - Granular activated carbon (GAC) adsorption
  - Ion exchange (IX) resin adsorption
  - High-pressure membrane filtration
  - Foam fractionation
  - In-situ colloidal activated carbon
- **Limited Applications (Section 12.6)**
  - Examples include - surface modified clay
- **Developing Technologies (Section 12.6)**
  - Examples include – alternative adsorbents, bioremediation, advanced chemical oxidation/reduction, plasma, others

Field Implemented

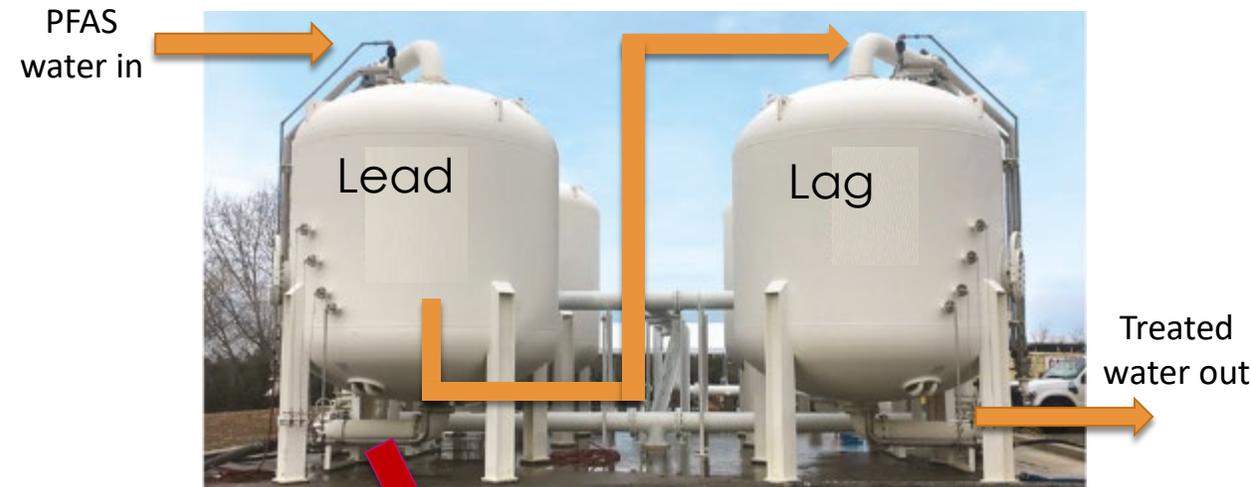
Limited Application

Developing

# Adsorption Systems

Field Implemented

- Technologies: granular activated carbon (GAC), single use ion exchange resin (IX), regenerable IX
- PFAS are not destroyed
- Pre-Treatment needed
- Monitoring - Influent, mid-point, effluent
- Media Change Out: Lag to lead, new to lag
- Post treatment/polish (optional)
- Spent Media Management
- Field implemented applications for Drinking water, Groundwater, Surface Water, Industrial Wastewater



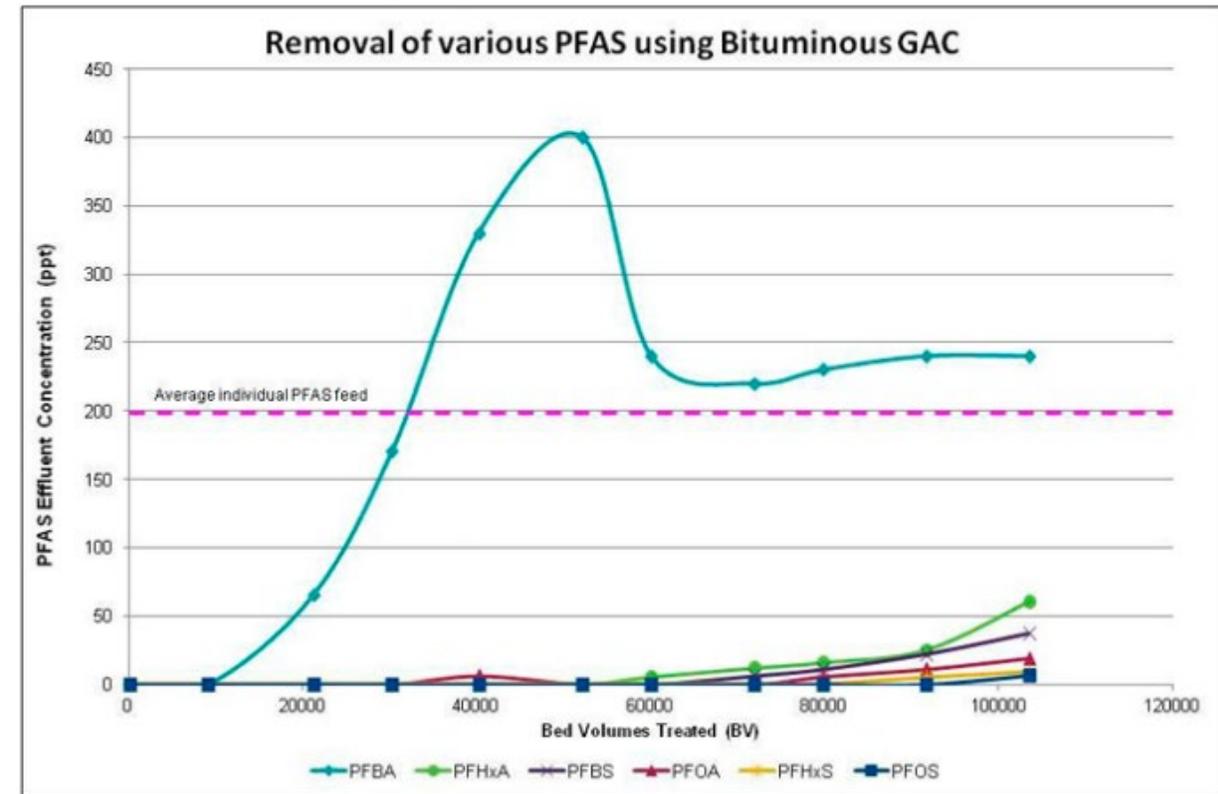
Adsorbent: reactivation, incineration, or disposal after use

Graphic used with permission, Scott Grieco, adapted from Stew Abrams and Purolite.  
Photo used with permission, Francis Boodoo, Purolite.

# Activated Carbon

Field Implemented

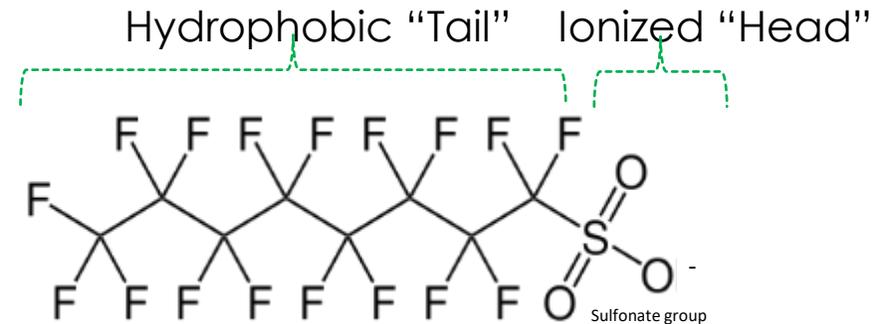
- Granular Activated Carbon (GAC) field implemented for PFAS treatment for >10 years.
- GAC performance varies based on site-specific conditions, carbon source types, GAC manufacturing methods, and target PFAS.
- Sizing and Design Issues
  - Vessel size based on 10 to 15 minute “Empty Bed Contact Time” (EBCT).
  - GAC usage rates are site specific
- Pretreatment processes – fouling mitigation



# Ion Exchange (IX) Resin

Field  
Implemented

- Field-demonstrated
- Selective IX Resin removed by both ion exchange (head) and adsorption (tail)
- High removal efficiency
- Shorter EBCT and small footprint relative to GAC
- High operating capacity
  - 100,000 to 350,000 bed volumes for low concentration drinking water
- Operation costs dependent on water quality and pretreatment needs
- Single use or regenerable options



Adsorbent: incineration or disposal after use

Short Contact Time  
~3 mins

PFAS-1, Section 12.2.1.2 Ion Exchange Resin.

Graphic used with permission, Scott Grieco, adapted from Stew Abrams and Purolite. Photo used with permission, Francis Boodoo, Purolite.

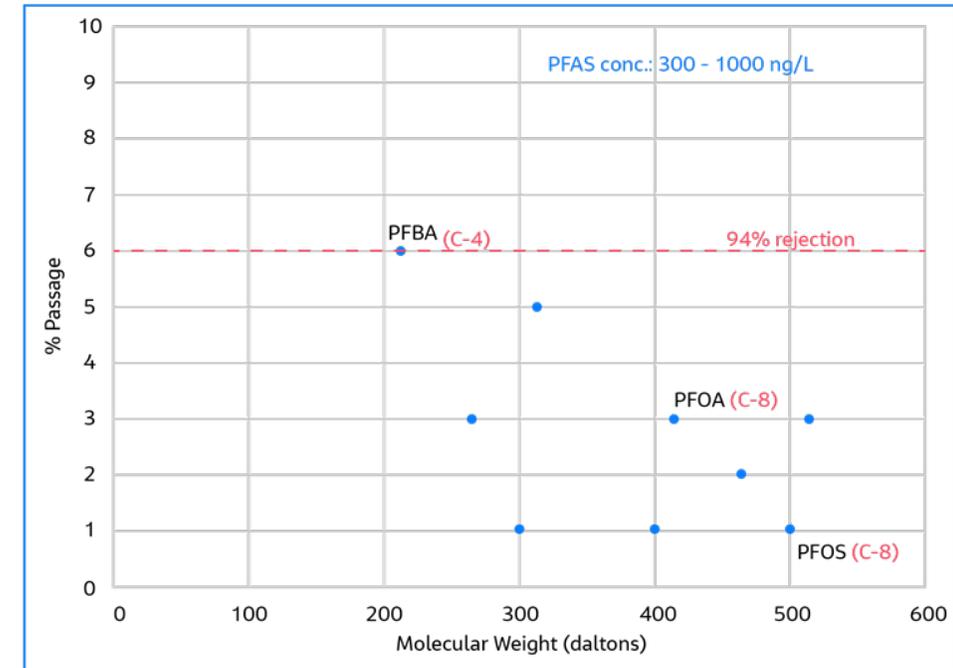
# High-Pressure Membranes

Field Implemented

- Reverse Osmosis (RO) is effective for long- and short-chain PFAS
- Nanofiltration (NF) is molecule size/charge dependent
- Advantages
  - Effective barrier for PFAS of concern
  - Provide dual role for softening/ inorganics removal
  - Can be effective for polar organics
- Concerns
  - Expense/energy use
  - Pretreatment requirements
  - Managing liquid concentrate



PFAS Passage through Dow NF-270 (polypiperazineamide) membrane (MWCO = 200 daltons)



Adapted from Appleman et al., 2013

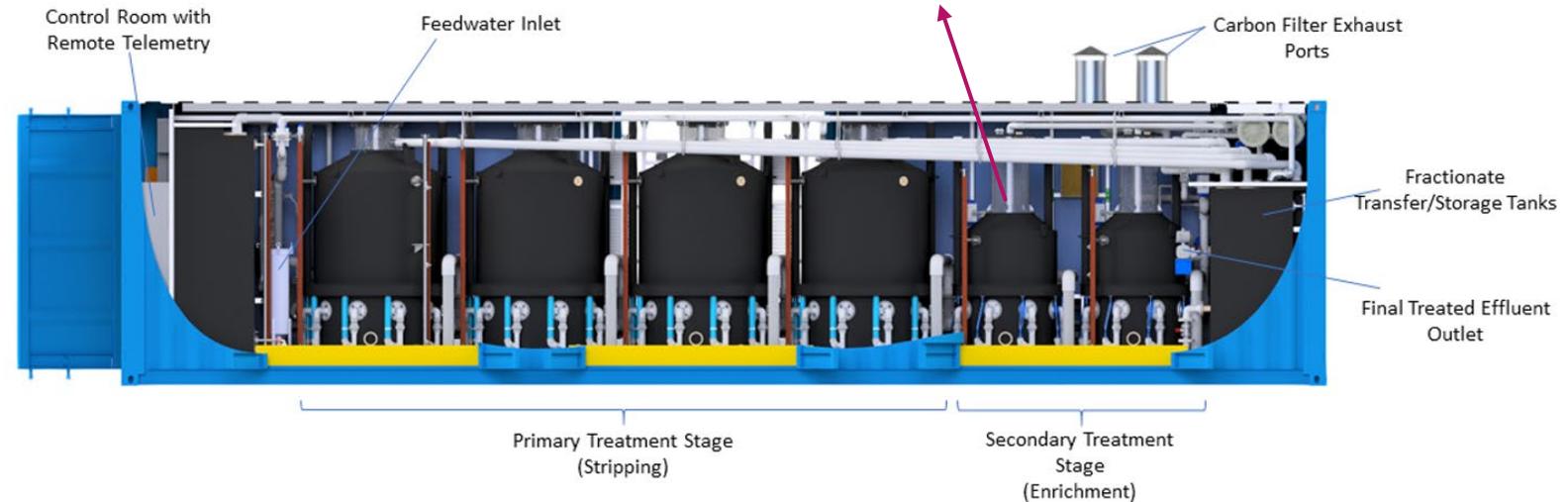
# Foam Fractionation

- PFAS partition to the air-water interface of the bubble surfaces and accumulate as foam
- Sequential fractionation steps concentrate PFAS into highly concentrated waste foam
- Foam concentrate needs management or destruction
- Standalone technology or combined with other technologies to improve PFAS removal

Field Implemented



PFAS concentrated foam

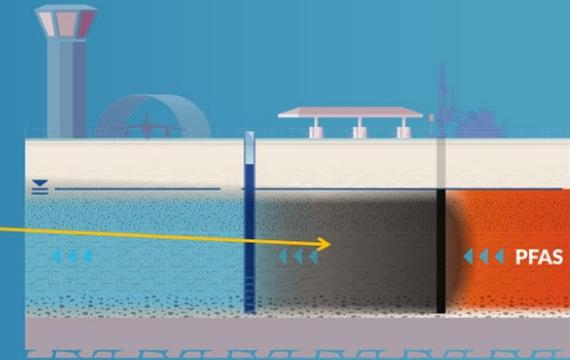


# Colloidal Activated Carbon (CAC) [in situ]

Field  
Implemented

- Injection (direct-push) of CAC into flux zones of an aquifer immobilizes contaminants to prevent further horizontal and vertical migration
- Colloidal size =  $\sim 2$  microns in diameter
  - Small enough to move through soil pores
  - Adsorption kinetics much faster than with traditional GAC
- Longevity of performance dependent on many factors
  - Modeling indicates it could be on the order of decades
- New case study added to Section 15

## CAC-Distribution Confirmation

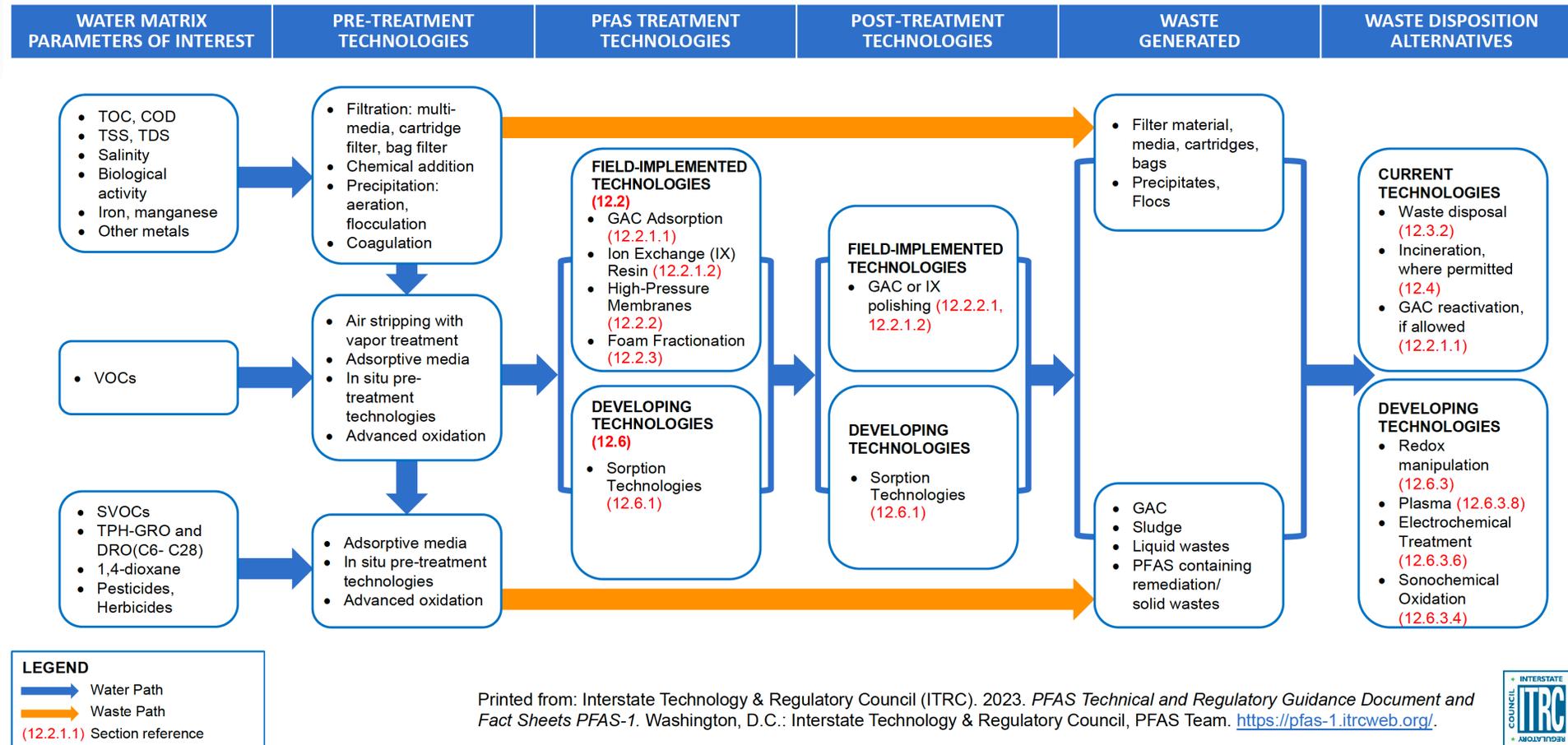


Vertical sections of a “searcher core” to verify presence of CAC at the desired interval

Source: Photos used with permission from S. Wilson, Regenesi

PFAS-1, Section 12.2.4 In Situ Remediation with Colloidal Activated Carbon.

# Integrated Remedial Solutions - Flowchart



Printed from: Interstate Technology & Regulatory Council (ITRC). 2023. *PFAS Technical and Regulatory Guidance Document and Fact Sheets PFAS-1*. Washington, D.C.: Interstate Technology & Regulatory Council, PFAS Team. <https://pfas-1.itrcweb.org/>.





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# Solids Treatment Technologies



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# Solids Treatment

- Field Implemented conventional approaches, with limitations:
  - Excavation and incineration or disposal (Section 12.3.2)
  - Activated carbon based in situ or ex situ stabilization (Section 12.3.1)
  - Soil washing (Section 12.3.3)
- Limited applications and developing technologies
  - Alternative sorption, stabilization/solidification (12.7.1)
  - Thermal treatment (12.7.2)

# Soil Remedial Technologies

Field  
Implemented

- Excavation with offsite disposal in a permitted landfill, where allowed
  - Some landfills no longer will accept PFAS soils
  - Do not assume this is straightforward
- Excavation with offsite incineration
  - Destruction assumed but not well documented
  - USEPA, USDOD and other research programs looking closely at destruction
- Pending CERCLA hazardous substances designation likely to impact these options

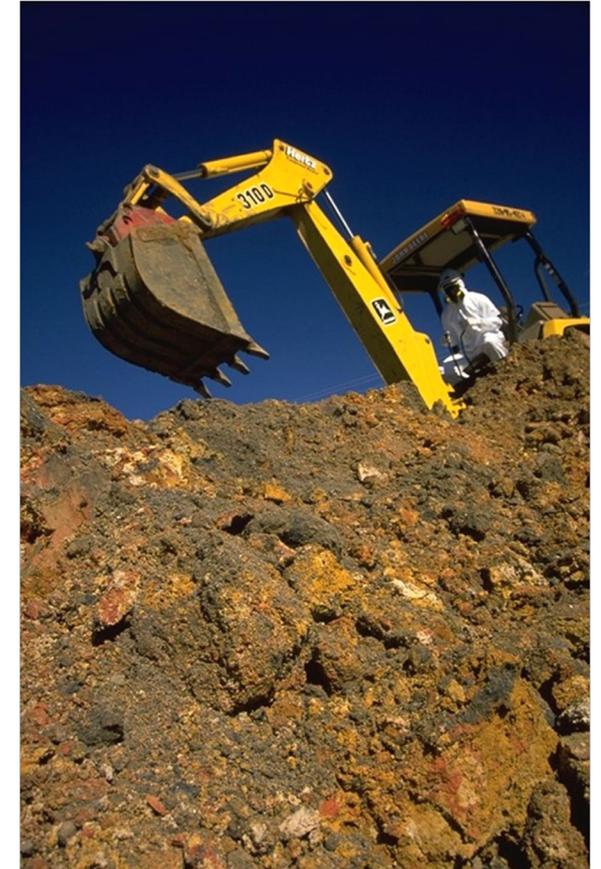
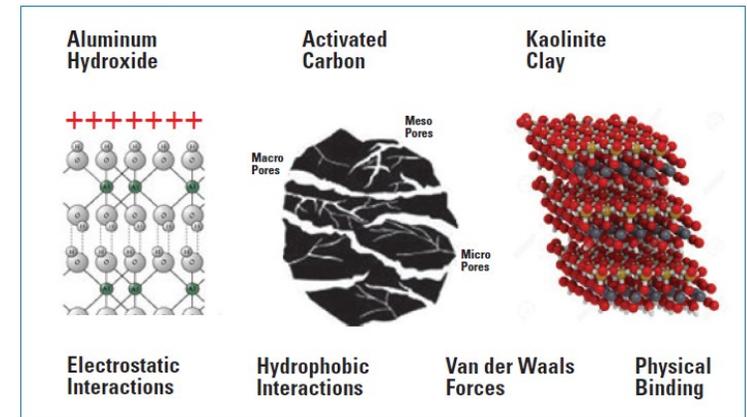


Photo courtesy of CH2M/Jacobs. Used with permission.

# Soil Stabilization

Field Implemented

- In-situ or ex-situ stabilization/immobilization via sorption
- Combination of powder-based reagents with high surface area and various binding methods:
  - For example: powdered activated carbon, aluminum hydroxide, kaolin clay
  - Added from 1-5% by weight to soil
  - Fully commercial & demonstrated in Australia
  - Extensive testing, research and demonstration in Europe
- Implementation in situ with large diameter augers possible



Images courtesy of Ziltek™ and AquaBlok Ltd. Used with permission.

# Soil Washing

Field  
Implemented

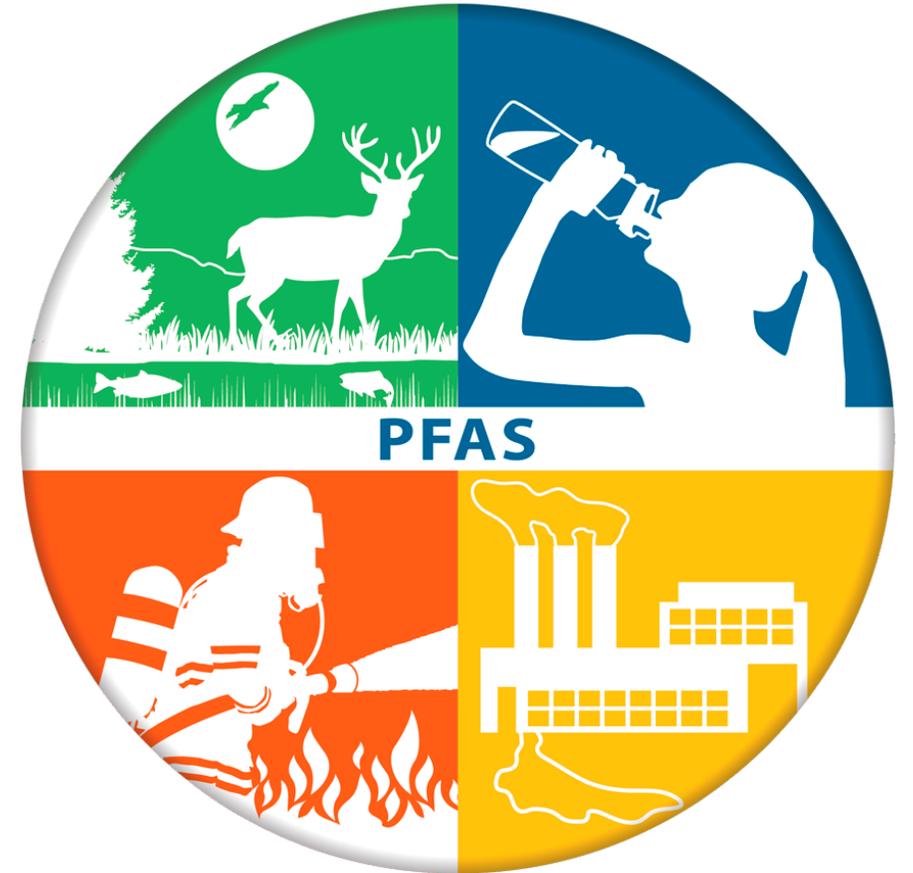
- Full-scale systems operating in Australia and Canada, some US pilot testing
- Can be enhanced specifically to keep PFAS in solution longer
- PFAS treated with GAC and/or IX resins, yielding these wastes
- Results in >99.4% mass reduction
- Lower throughput for clay-rich soils as compared to sandy soils (10 tons/hour vs 25 tons/hour)

# Incineration for PFAS-Contaminated Media

- Incineration has the potential to destroy PFAS
  - Vaporized combustion products can be further oxidized and/or captured (precipitation, wet scrubbing)
- Solids
  - soil/sediment/spent adsorbents/waste
- Liquids
  - water/wastewater/leachate/chemicals
- Questions remain
  - Products of incomplete combustion, stack gas analysis, fallout onto land adjacent to the incinerator and other risk factors
  - USEPA and others are currently conducting research to help answer these questions
- Considerations for using different facilities – transportation costs, energy costs, final disposition of process waste residues, state or local regulatory program

# Questions

Please use the Q&A Pod to ask questions.



# Web Sites

- Published Guidance Document, Fact Sheets, Videos, Training

<https://pfas-1.itrcweb.org>

- PFAS Team Public page

<https://itrcweb.org/teams/active/pfas>

# Thank you!

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