Measuring PFAS in Air: The Next Frontier

W.E.B.S. PFAS 2026 - June 17, 2026

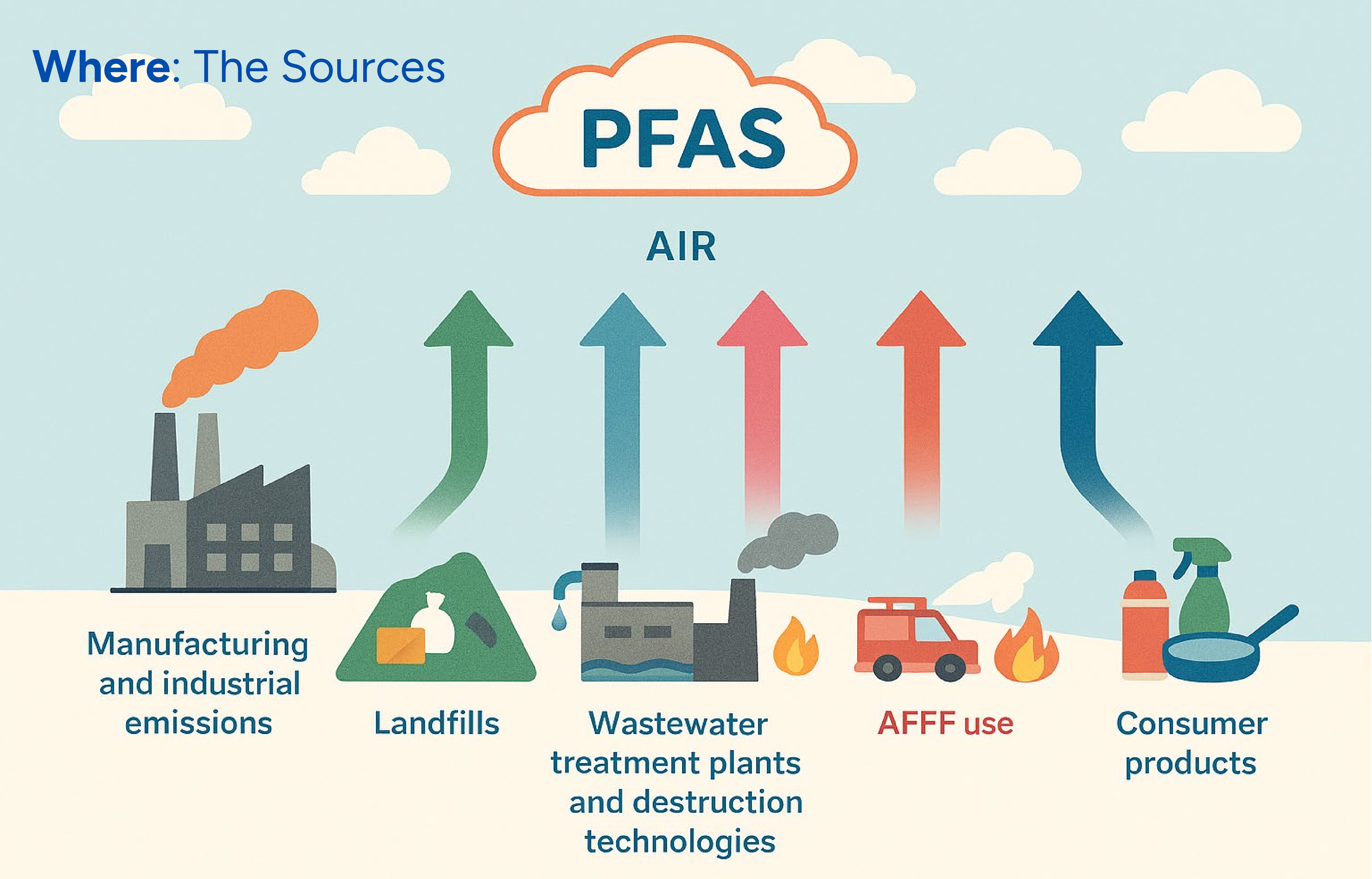
Presented by: Heather Lord

Outline

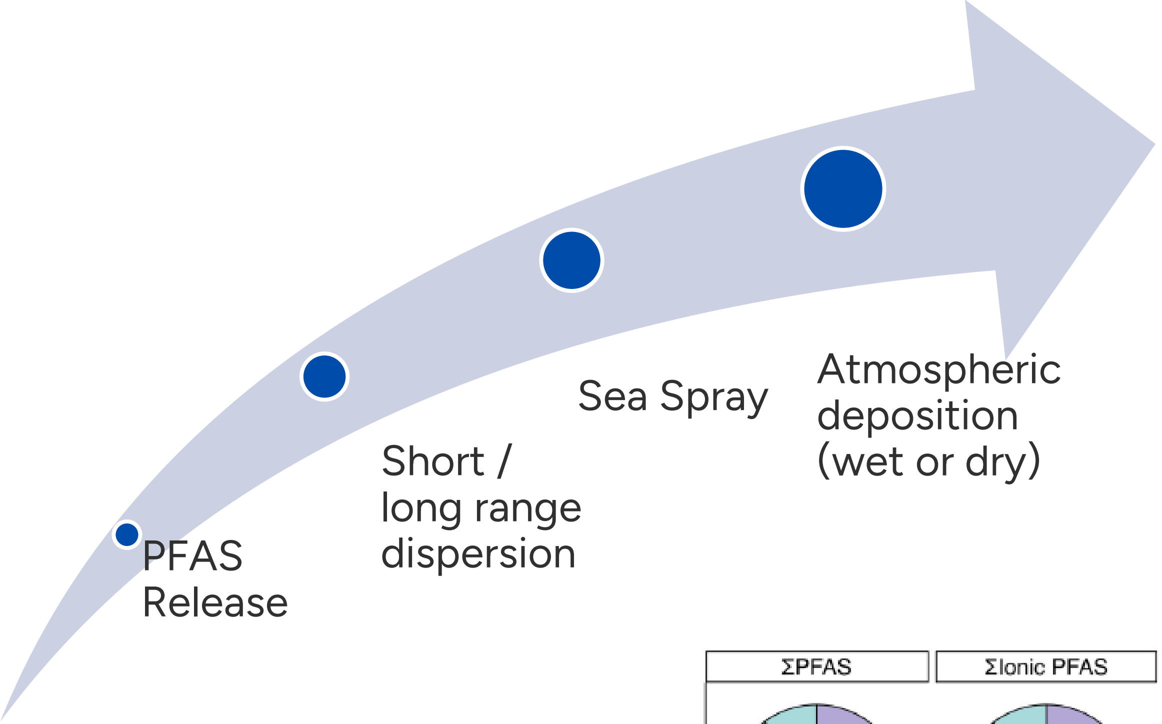
- PFAS Global Atmospheric Transport
- Human exposure
- US EPA published methods for stack gas
- What do we know about ambient exposures?
- How should we test for them?

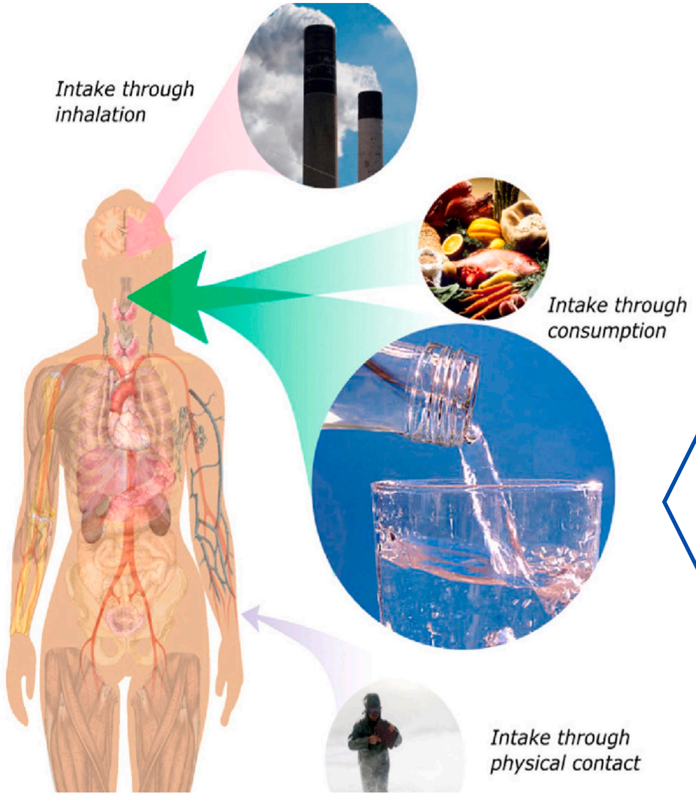
https://earthjustice.org/feature/breaking-down-toxic-pfas

Where: The Sources



Why : Environmental and Health Implications





The sizes of these circles need to be changed.

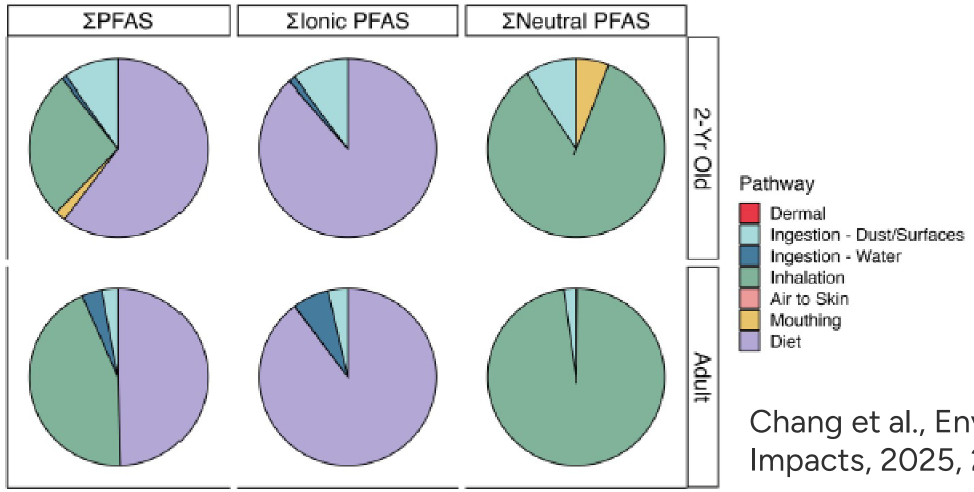
Colour Code

Green – inhalation

Purple – food

Light blue – dust

Dark blue - water

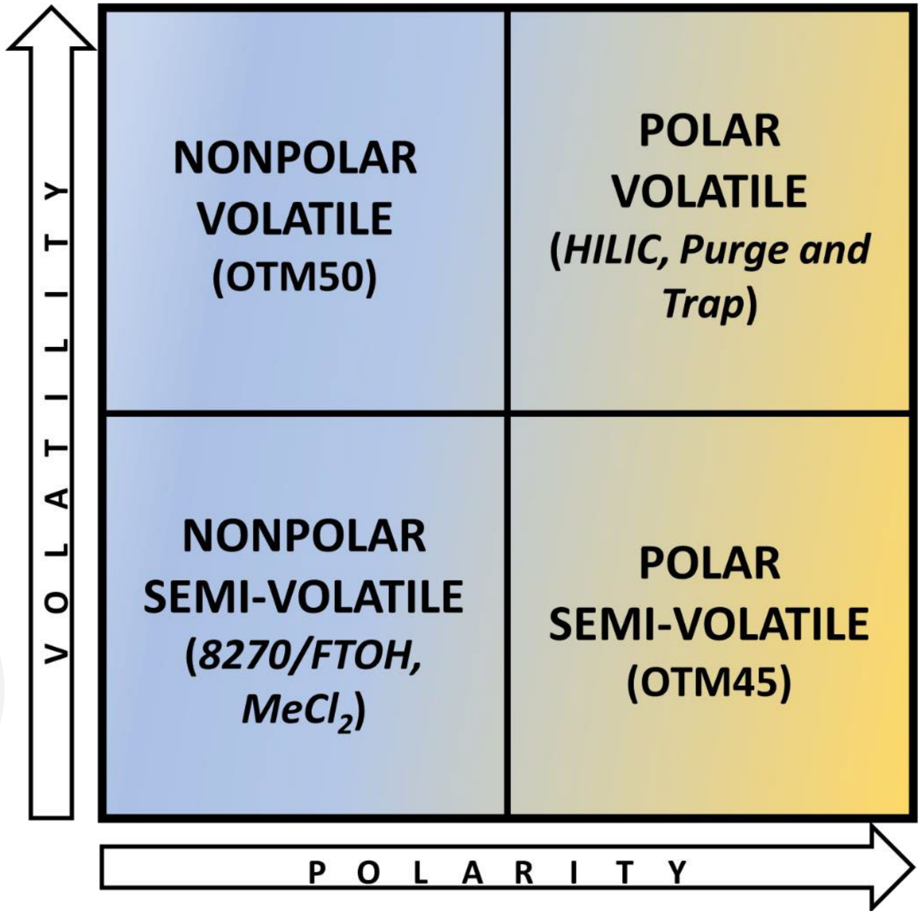


Chang et al., Environ. Sci.: Processes Impacts, 2025, 27, 1654–1670. Fig S3

How: PFAS Analysis in Air

- **Stack/source sampling**
- Canister collection
- GC-MS
- 30 compounds (mostly PID)

- **Ambient sampling**
- ASTM D8591 - TD tubes (Four FTOH)
- GC-MS/MS or LC-MS/MS
- FTOH, sulfonamides etc.
- No broad standard methods



Source: US EPA

Low Relevance
Not many known compounds in this category

- **Stack/source sampling**
- Sampling train collection
- LC-MS/MS
- 49 compounds (typical water analytes)

OTM-45 (Polar Semi-Volatile)

- **Stack sampling**
- Analysis by LC-MS/MS
- 49 compounds (typical water analytes)

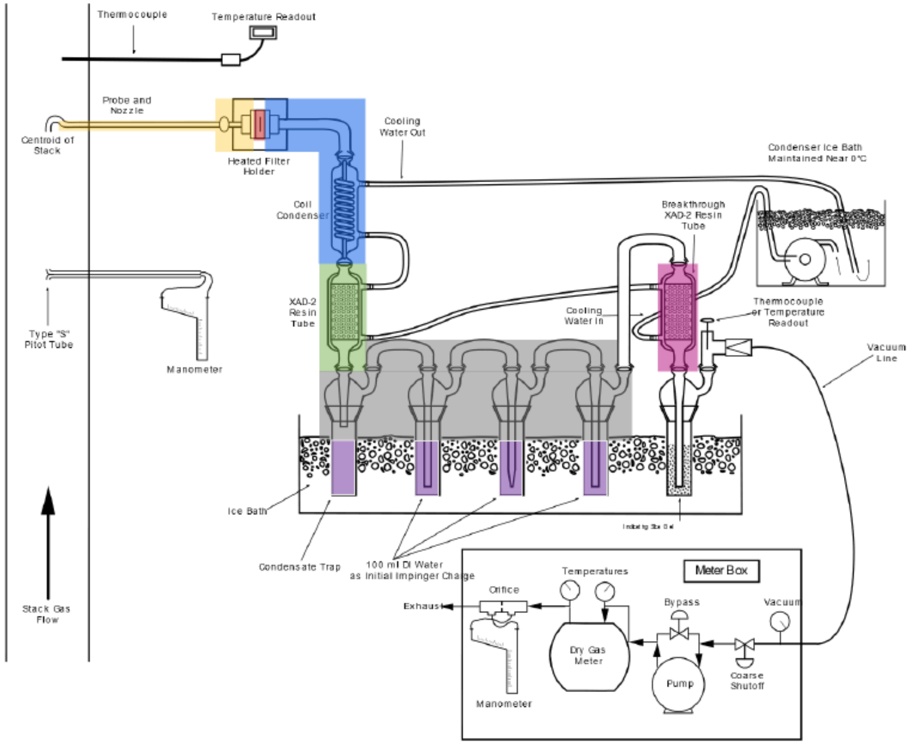


Figure OTM-45-1. Sampling Train

OTM 45 Visual Container Guide

- #1 Filter
- #2 Front Half Rinse
- #3 XAD-2
- #4 Back half Rinse
- #5 Condensate and Impinger Water
- #6 Impinger Rinse
- #7 Breakthrough XAD-2

Key Highlights – OTM-45

Targeted PFAS Analytes		Reporting Limits (ng/train)	
Acronym	CAS#	OTM-45	ALS
Perfluoroalkylcarboxylic acids (PFCAs)			
PFBA	375-22-4	12.6	2.5
PFPeA	2706-90-3	1.8	0.5
PFHxA	307-24-4	2.4	0.5
PFHpA	375-85-9	1.7	0.5
PFOA	335-67-1	2.5	0.5
PFNA	375-95-1	1.5	0.5
PFDA	335-76-2	1.5	0.5
PFUnDA	2058-94-8	2.0	0.5
PFDoA	307-55-1	1.5	0.5
PFTrDA	72629-94-8	1.5	0.5
PFTeDA	376-06-7	1.5	1.25
PFHxDA	67905-19-5		0.5
PFODA	16517-11-6		0.5
Perfluorinated sulfonic acids (PFSAs)			
PFPrS	359868-82-9		0.5
PFBS	375-73-5	1.5	0.5
PFPeS	2706-91-4	1.5	0.5
PFHxS	355-46-4	1.7	0.5
PFHpS	375-92-8	1.5	0.5
PFOS	1763-23-1	2.4	0.5
PFNS	68259-12-1	1.5	0.5
PFDS	335-77-3	1.5	0.5
PFDoS	79780-39-5		0.5
Perfluorinated sulfonamides (FOSAs)			
FOSA	754-91-6	2	0.5
MeFOSA	31506-32-8		1.25
EtFOSA	4151-50-2		1.25
Perfluorinated sulfonamide ethanols (FOSEs)			
N-MeFOSE	24448-09-7		1.25
N-EtFOSE	1691-99-2		1.25

Targeted PFAS Analytes		Reporting Limits (ng/train)	
Acronym	CAS#	OTM-45	ALS
Perfluorinated sulfonamidoacetic acids (FOSAAs)			
MeFOSAA	2355-31-9	2.4	0.50
EtFOSAA	2991-50-6	2.4	0.50
Fluorotelomer sulfonates (FTSs)			
4:2 FTS	757124-72-4	1.5	0.5
6:2 FTS	27619-97-2	2	0.5
8:2 FTS	39108-34-4	1.7	0.5
10:2 FTS	120226-60-0		0.5
Fluorinated Replacement Chemicals			
ADONA	919005-14-4	1.6	0.5
HFPO-DA	13252-13-6	16.6	0.5
9Cl-PF3ONS	756426-58-1	1.5	0.5
11Cl-PF3OUdS	763051-92-9	1.5	0.5
Additional Targets			
NFDHA	151772-58-6		0.5
PFEESA	113507-82-7		0.5
PFMBA	863090-89-5		0.5
PFMPA	377-73-1		0.5
PFecHS	67584-42-3		0.5
6:2 FTUCA	70887-88-6		0.5
8:2 FTUCA	70887-84-2		0.5
10:2 FTUCA / FDUEA	70887-94-0		0.5
6:2 FTCA	53826-12-3		1.25
8:2 FTCA	27854-31-5		1.25
10:2 FTCA	53826-13-4		1.25
3:3 FTCA	356-02-5		0.5
5:3 FTCA	914637-49-3		0.5
7:3 FTCA	812-70-4		0.5
6:2 FTAB	34455-29-3		0.5
6:2 diPAP	57677-95-9		1.25
8:2 diPAP	678-41-1		1.25
6:2 / 8:2 diPAP	943913-15-3		1.25

- Semi-volatile & particulate bound PFAS withdrawn from the gas stream, collected in a sampling train:
  - Quartz or glass fiber filter, XAD-2 adsorbent, four water impingers, final XAD-2 breakthrough trap.
- In the lab: Target compounds extracted from the individual sample collection media.
- Analysis by LC-MS/MS. Quantification by the isotope dilution technique.
- Targets similar to standard LC-MS/MS.
- **Field QA: Field blanks important for data validation and interpretation.**

OTM-50 (Non-Polar Volatile)

Sampling Times : 4,10, 20 or 60 minutes

1.4L Silonite canister

Dedicated PFAS canisters

Passivated silicon ceramic lined stainless-steel

Agilent 7010D GC-MS/MS
Entech 7200-PFAS pre-concentrator and SK-75 autosampler

What: OTM-50 (Non-polar Volatile)

Refrigerants

(FC-14) CF_4
(FC-116)
(CFC-11)
(CFC-13)
(HFC-41)
(HFC-143a)
(HCFC-22)
(HFC-23)
(HFC-32)
(HFC-125)
(HFC-134a)
(PFC-218)
(PFC-C318)
(PFC-C1418)

C_2F_4
HFPO
E1
E2

Industrial Chemicals

PIC/PID
fluorinated alkanes
and alkenes

C_3F_6
C_3HF_7
C_4HF_9
C_4F_{10}
C_5HF_{11}
C_5F_{12}
C_6HF_{13}
C_6F_{14}
C_7HF_{15}
C_7F_{16}
C_8HF_{17}
C_8F_{18}

- **Canister sample collection**
- Analysis by GC-MS/MS
- 30 compounds (mostly PIC/PID)

Volatile fluorinated compounds (VFCs)

- Products of incomplete combustion / destruction (PICs/PIDs)
- Fluorinated refrigerants
- Industrial compounds of interest

Some refrigerants and industrial chemicals are formed from PFAS during destruction.

Shields et al. ACS EST Eng. 2023, 3, 1308–1317.

Key Highlights – OTM-50

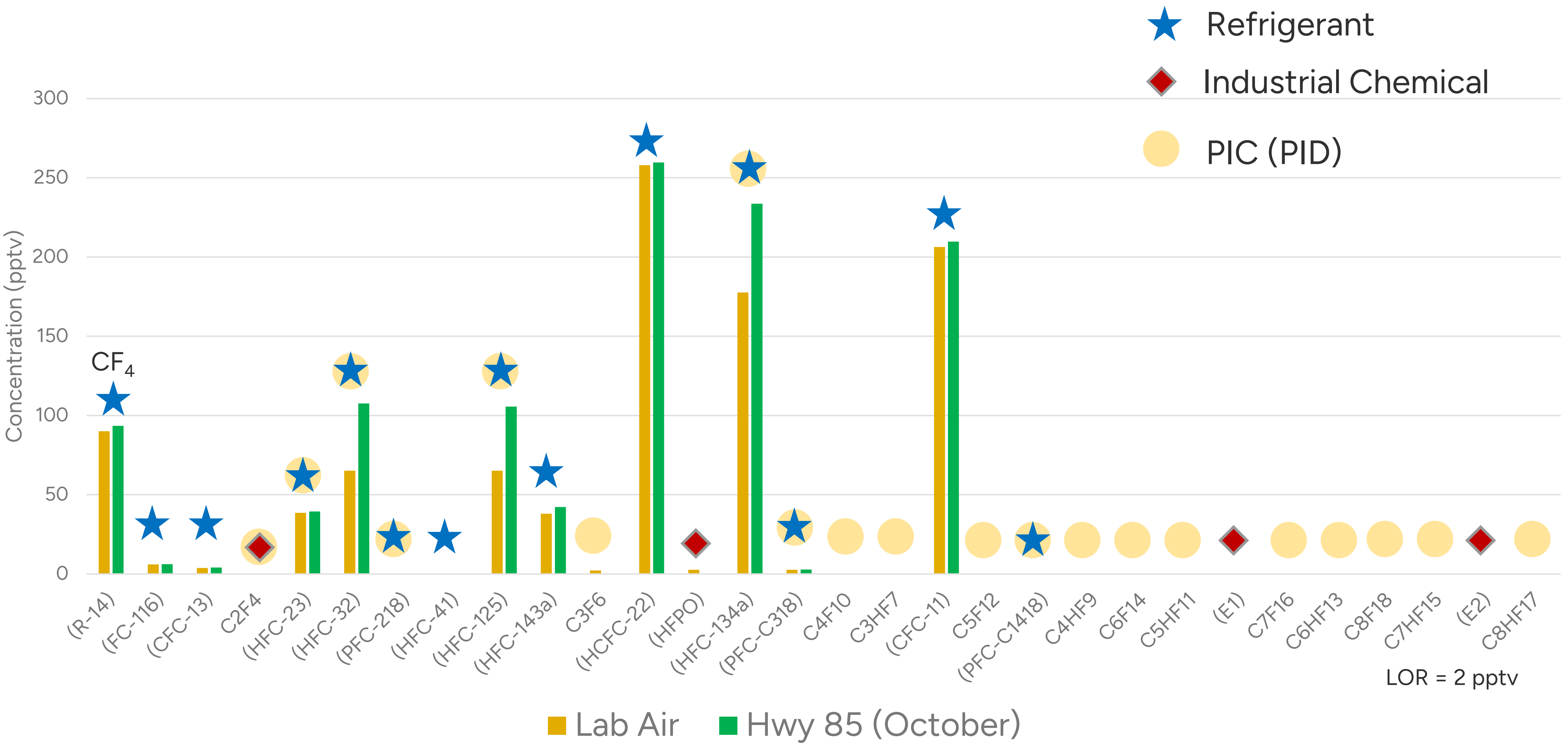
Parameter	Synonym	OTM-50 QRL (3xMDL)	ALS LOR
		--- --- --- ppbv --- --- ---	
Tetrafluoromethane	(FC-14)	0.090	0.002
Hexafluoroethane	(FC-116)	0.037	0.002
Chlorotrifluoromethane	(CFC-13)	0.037	0.002
Tetrafluoroethene	C2F4	0.033	0.002
Trifluoromethane	(HFC-23)	0.150	0.002
Difluoromethane	(HFC-32)	0.048	0.002
Octafluoropropane	(PFC-218)	0.037	0.002
Fluoromethane	(HFC-41)	0.057	0.002
1,1,1,2,2-Pentafluoroethane	(HFC-125)	0.037	0.002
1,1,1-Trifluoroethane	(HFC-143a)	0.096	0.002
Hexafluoropropene	C3F6	0.037	0.002
Chlorodifluoromethane	(HCFC-22)	0.033	0.002
Hexafluoropropylene oxide	HFPO	0.063	0.002
1,1,1,2-Tetrafluoroethane	(HFC-134a)	0.048	0.002
Octafluorocyclobutane	(PFC-C318)	0.037	0.002
Decafluorobutane	C4F10	0.037	0.002

Parameter	Synonym	OTM-50 QRL (3xMDL)	ALS LOR
		--- --- --- ppbv --- --- ---	
1H-Heptafluoropropane	C3HF7	0.042	0.002
Trichlorofluoromethane	(CFC-11)	0.042	0.002
Dodecafluoropentane	C5F12	0.069	0.002
Octafluorocyclopentene	(PFC-C1418)	0.037	0.002
1H-Nonafluorobutane	C4HF9	0.033	0.002
Tetradecafluorohexane	C6F14	0.048	0.002
1H-Perfluoropentane	C5HF11	0.048	0.002
Heptafluoropropyl-1,1,1,2-tetrafluoroethyl ether	E1	0.042	0.002
Hexadecafluoroheptane	C7F16	0.037	0.002
1H-Perfluorohexane	C6HF13	0.048	0.002
Octadecafluorooctane	C8F18	0.037	0.002
1H-Perfluoroheptane	C7HF15	0.033	0.002
2H-Perfluoro-5methyl-3-6,dioxanonane	E2	0.037	0.002
1H-Perfluorooctane	C8HF17	0.037	0.002

- Samples intended to be sampled from industrial source ducts, vents, stacks, etc.
- Canisters individually proofed, one report per batch on C of As. Others available on request.
- Target list: known industrial products and products of incomplete thermal destruction.
    - Stack carbon dioxide (CO_2) testing required.

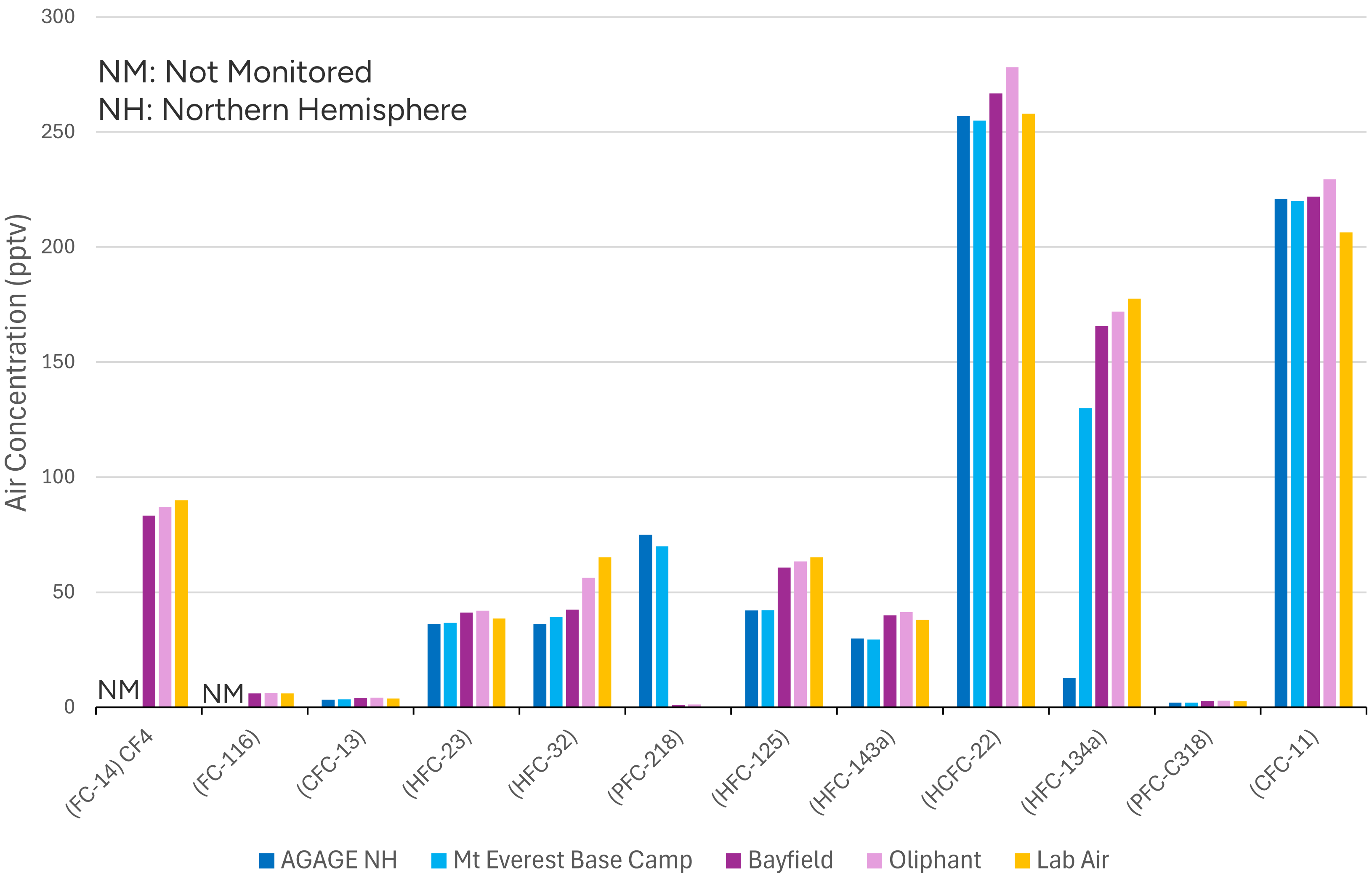
Note: Because the targets are fixed gasses, sorbent traps will not work and Tedlar™ bags have poor retention.

OTM-50 Ambient Air Sampling – Source Identification



Shields et al. ACS EST Eng. 2023, 3, 1308−1317.

OTM-50 Ambient vs Global Monitoring



Global data reference: Cong et al. 2024 Science of the Total Environment, 956, 177348.

PFAS in Ambient Air – What is next?

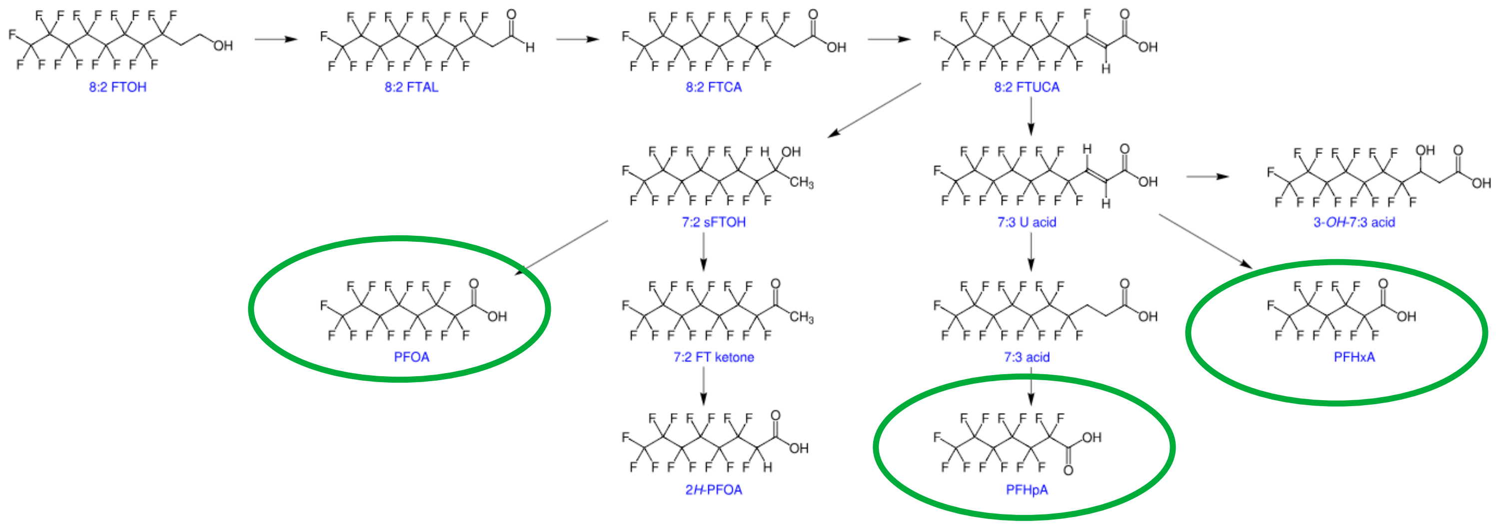
- EPA OTM-50 is offered from Waterloo, Canada
- EPA OTM-45 is offered in Melbourne, Australia.

Next:

- Method development for polar & non-polar PFAS in ambient air and soil vapour.

8:2 FTOH

Aerobic Biotransformation of 8:2 FTOH in Soil



https://commons.wikimedia.org/wiki/File:Aerobic_biotransformation_8-2_FTOH_soil_labeled.svg.

FTOH: Fluorotelomer Alcohols are volatile, but they rapidly degrade to stable intermediates and PFCAs that are monitored.

Ambient PFAS Analysis Literature Review

Wallace et al, 2024, Chemosphere.

- 84 papers reviewed where PFAS detected in indoor & outdoor air from 2002 to 2022 (active & passive sampling)
  - 62 used active sampling, of which,
  - 54 used common air collection methods, of which,
  - **33 were published 2010 or later**

Chemosphere 358 (2024) 142129

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

ELSEVIER

A review of sample collection and analytical methods for detecting per- and polyfluoroalkyl substances in indoor and outdoor air

HV-AAS: High Volume Active Air Sampling used in 40 of 46 articles

- Most used some form of PUF/XAD trap
- Half used a filter in front to trap particulate
- Half used GC-MS or GC-MS/MS, Half used LC-MS/MS (some used both)

13 Additional Articles Reviewed, Published 2011 to 2025, Covering Other Applications:

- WWTP/Landfill Vicinity
- Landfill Gas
- Landfill Gas - Food Packaging
- WWTP Sludge Aeration
- Atmosphere - Manufacturing
- Sea Spray

46 Total Articles Reviewed

Wallace et al. divided PFAS compounds into the following classes:

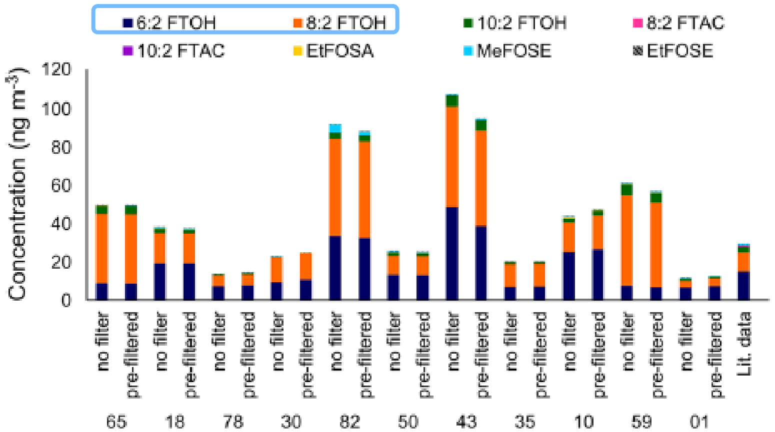
Acronym	Name
FTOH	Fluorotelomer alcohols
FASA	Perfluoroalkane sulfonamides
FASE	Perfluoroalkane sulfonamide ethanols
PFCA	Perfluorocarboxylic acids
FTS & PFSA	Fluorotelomer sulfonates and Perfluorinated sulfonic acids
FTMAC, FTAcr, FTO, FASAC	Monomers
FTUCA	Fluorotelomer unsaturated carboxylic acids

Chemical Classes vs Manufacturing Application

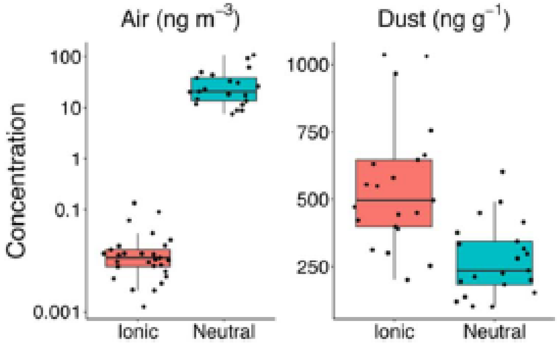
Application	FTOH	FASA	FASE	PFCA	FTUCA	PFSA and FTS	Monomers (FTAC, FTMAC, MeFOSAC, FTO)
AFFF		Y	Y	Y		Y	
Ammunition				Y			
Apparel & Textiles	Y	Y	Y	Y		Y	Y
Automotive				Y			Y
Building & Construction			Y	Y		Y	
Carpet	Y	Y		Y		Y	
Cleaning Products	Y			Y			
Cookware	Y						
Degradation/Transformation Products		Y			Y		
Electronics & Semiconductors		Y		Y		Y	Y
Electroplating						Y	
Hydraulic Fluid				Y		Y	
Ink	Y	Y	Y			Y	
Lubricants	Y					Y	
Manufacturing, Chemical			Y				
Manufacturing, Fluoropolymer				Y			Y
Medical							Y
Metal Coating		Y	Y				
Mining			Y				
Oil				Y	Y	Y	
Optical							Y
Paint		Y	Y	Y			
Paper & Packaging	Y	Y	Y	Y	Y	Y	
Personal Care Products	Y	Y		Y		Y	Y
Pesticides		Y					
Photography				Y			
Plastics and Rubber						Y	Y
Ski Wax	Y			Y		Y	
Surface Protection	Y	Y	Y	Y			Y
Surfactants	Y	Y	Y	Y		Y	

Focus on Indoor Air, Landfill, WWTP Emissions

Indoor Air

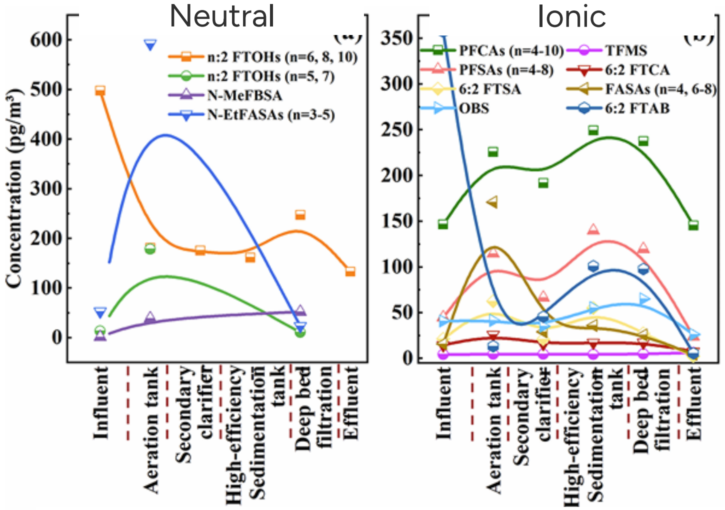


Eichler et al., Environ. Sci. Technol. 2023, 57, 15173–15183.



Chang et al., Environ. Sci.: Processes Impacts, 2025, 27, 1654–1670

WWTP Emissions



Qiao et al., Environ. Sci. Technol. 2023, 57, 20127–20137.

Dominant:

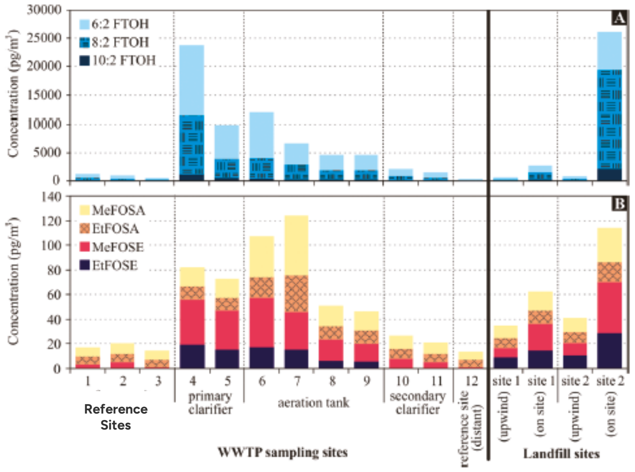
FTOH

Sulfonamides

FOSEs

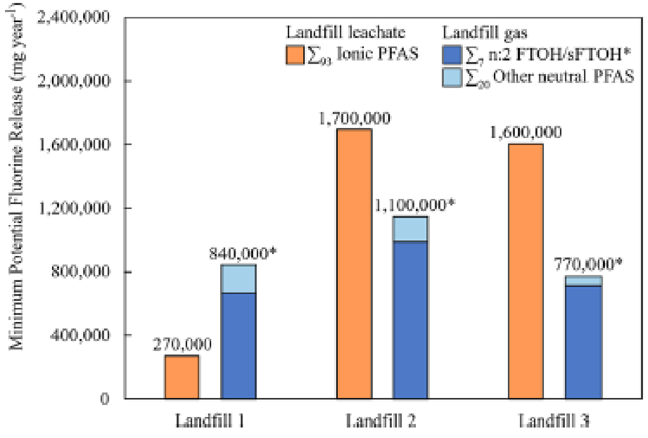
PFCA

FTAB in influent



Ahrens et al., Environ. Sci. Technol. 2011, 45, 8098–8105.

Landfill Emissions



Lin et al., Environ. Sci. Technol. Lett. 2024, 11, 730–737.
Orange: leachate; Blue: gas

Dominant:

FTOH

Sulfonamides

FOSEs

Consensus Monitoring Method:

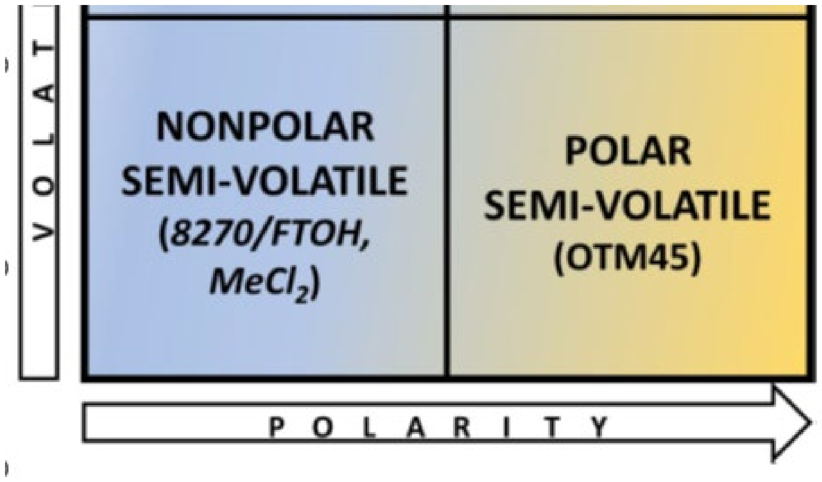
What is needed is a method that can report from a broad range of ambient environments:

- Covering both polar and non-polar semi-volatiles.
- Indoor air environments, landfill gasses, wastewater treatment plants, remedial settings such as thermopiles, foam fractionation, and fence line monitoring.

The currently available literature points to:

- Sample 1 m above floor level, 3 separate days
- Sampling rate: 0.3 m^3/h for ~72 hr ~21 m^3
- PUF-XAD2-PUF sorbent tube, with filter if particles to be collected separately
- Solvent extraction of the media with:
  - 3:1 (v/v) hexane/methanol (GC), or methanol only (LC)
- Analysis by MS/MS preferable

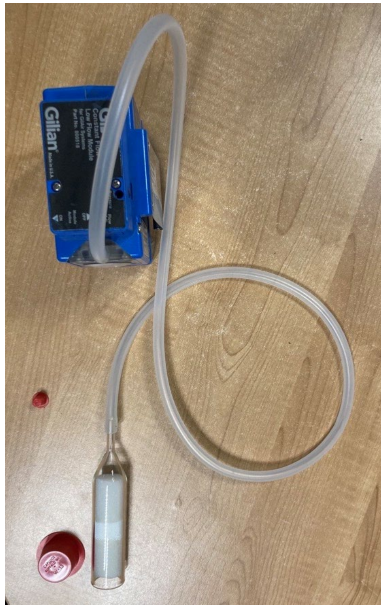
A single method that can covers the broad range of polarities observed for PFAS in ambient environments.



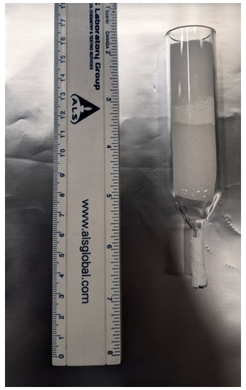
Technology Options

GC

TD Tubes



GC and LC



PUF/XAD-2 Tubes & Filters

FTOAc
FAMAC
FASAC
FASA
FTAc
FASE
FTAcr
FTO
FTI
FTOH
Iodofluoroalkanes

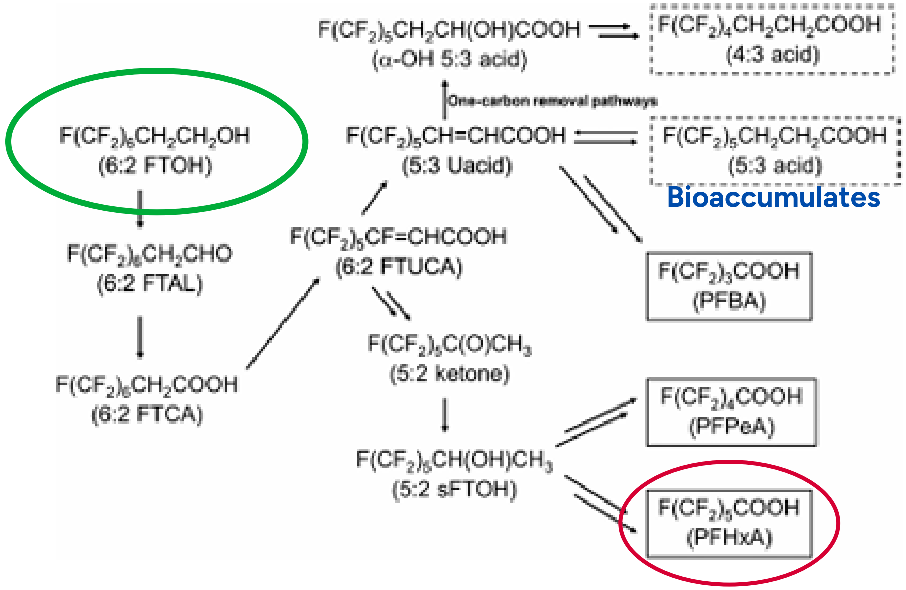
FOSAA
PFCA
FTUCA
PFSA
FTS
Fluoroalcohols

GC-MS/MS Compounds

LC-MS/MS Compounds

6:2 FTOH Environmental Transformation

Zhao et al., Chemosphere 90 (2013) 203–209



Mol % Produced Soil

1%

15%

2%

30%

8%

Total: 56%

Relative Potency Factors - 2021

PFOS 2; PFOA 1; PFHxA 0.01; PFBA 0.05

6:2 FTOH 0.02; 8:2 FTOH 0.04

Bil et al., Environ. Toxicol. Chem. 2021, 40:3, 859–870.

Luz, Anderson, Goodrum, Durda – PFHxA Toxicity, Part I

Regulatory Toxicology and Pharmacology 103 (2019) 41–55

- PFHxA is a primary degradant of 6:2 FTOH.
- Recommends using PFHxA toxicological data & Relative Potency Factors to assess human health risk from 6:2 FTOH exposure.

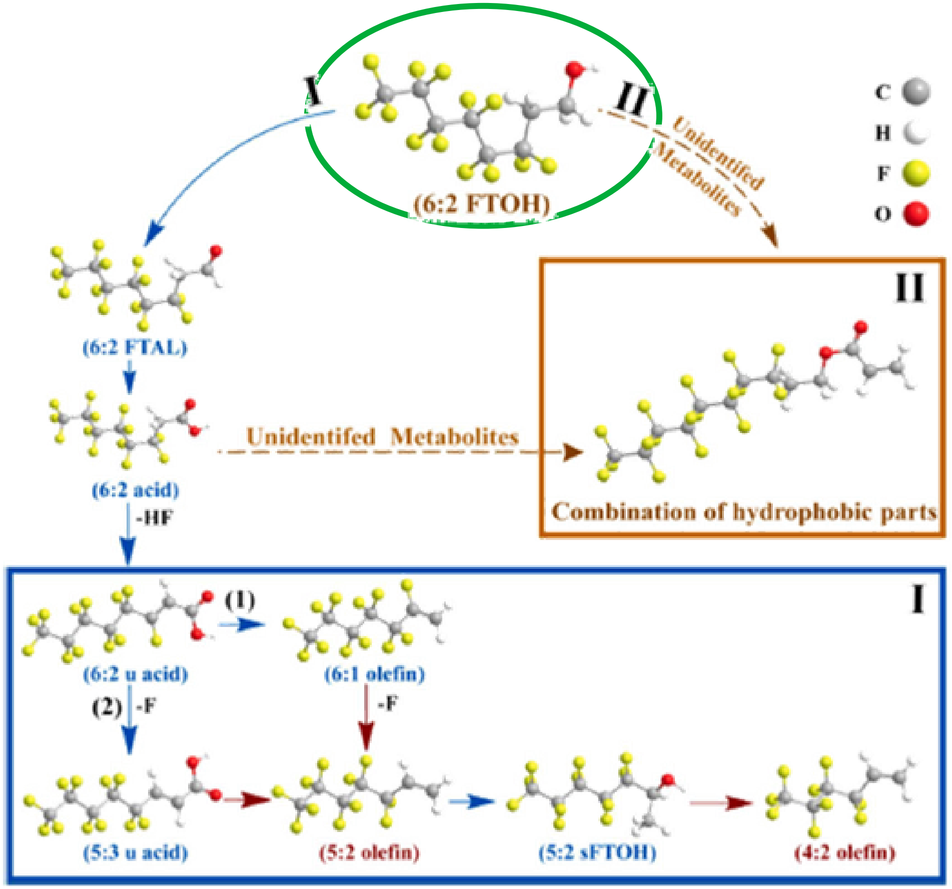
Anderson, Luz, Goodrum, Durda – PFHxA Toxicity, Part II

Regulatory Toxicology and Pharmacology 103 (2019) 10–20

- Low detection frequency and levels of PFHxA noted in the general global population
- Therefore, PFHxA and related fluorotelomer precursors present negligible human health risk and are not likely to drive risk at sites contaminated with PFAS mixtures.

6:2 FTOH Inhalation Toxicity

Zhang et al., Environment International 2026 210: 110222



Proposed biotransformation pathway of 6:2 FTOH in the lung.

Solid arrows: transformations supported by previous literature. Dotted arrows: transformations inferred from the current work, but which remain to be confirmed.

Rice et al., Food and Chem Toxicol 2020 138: 111210

Toxicology dataset for PFHxA not appropriate for assessing the human health effects of 6:2 FTOH exposure.

- The 5:3 acid metabolite of 6:2 FTOH bioaccumulates in rats, PFHxA is rapidly eliminated.
- Toxicological profile of 6:2 FTOH appears significantly more concerning than that of PFHxA.

Lin et al., Environ. Sci. Technol. Lett. 2024, 11, 730–737

Research suggests 6:2 FTOH toxicity via inhalation is significantly higher than its ionic degradants.

Zhang et al., Environ. Int. 2026 210: 110222

6:2 FTOH integrates into the air-water microlayer in lung alveoli, causing reactive oxygen species (ROS, e.g. peroxide) generation at the pulmonary surface.

- ROS triggers transformation of 6:2 FTOH to other species.
- Lipid and protein degradation occurs
- **PFHxA is not produced in lung tissue.**

Conclusions

- PFAS have been circulating in the global atmosphere for ~75 Years.
- Where significant point sources are absent, inhalation is a major route for PFAS exposure.
- The US EPA has published two standard methods that enable regulators to control PFAS redistributed to the atmosphere during destruction / incineration.
- A significant gap exists for a standard method to monitor PFAS in relevant ambient air environments.
  - Publicly available literature points to a (relatively) simple monitoring protocol.
- Household indoor air contains predominantly fluorotelomer alcohols (FTOHs).
  - Industrial, manufacturing and general occupational air environmental PFAS data are largely unavailable.
- Recent research suggests FTOHs present greater mammalian toxicity than previously recognized.
- Several potential sources of demand are on the horizon for PFAS testing in air.
- A simple, flexible sampling and analysis method will allow labs to pivot quickly to meet demands as they arise.

Questions?

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Special Thanks To:
Andrea Armstrong, Air Quality Manager, Canada
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