EPA
United States
Environmental Protection
Agency

The Current State of PFAS Air Emissions Information

Outline

- ▶ What are PFAS?
- ▶ What are concerns about PFAS?
- ▶ What Are Known Human Exposure Pathways?
- ▶ Does PFAS Air Transport Cause Contamination?
- ▶ Sources of PFAS Emissions
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- ▶ The road ahead for PFAS Air Emissions Inventories

What are PFAS?

- **Per- and Polyfluoroalkyl Substances**
- **Industrially produced** compounds with chains of carbon (C) atoms surrounded by fluorine (F) atoms.
- **Highly mobile** - easily airborne; can be transported long-distances in water; widely distributed in the environment.
- **Ubiquitous** – potentially thousands of synthetic chemicals manufactured and used in a variety of industries since the 1940s. Products that resist heat, stains, and water (*e.g.*, cookware, food packaging, Scotchgard™, and Teflon™).
- Perfluorooctanoic Acid **(PFOA)** & Perfluorooctanesulfonic Acid **(PFOS)** - most extensively produced and studied. Although they are no longer made in the U.S., chemical manufacturers have replaced them with alternative PFAS, such as GenX and fluorotelomer compounds.

What are concerns about PFAS?

- Strong C-F bonds are highly resistant to breakdown and are known to:
  - Persist in the environment; and
  - Bioaccumulate in humans and animals.

- There is evidence that exposure to certain PFAS chemicals can lead to adverse human health effects:
  - Low infant birth weights
  - Effects on the immune system
  - Cancer (for PFOA)
  - Thyroid hormone disruption (for PFOS)

What Are Known Human Exposure Pathways?

- **Ingestion**
  - Drinking contaminated water – main route for human exposure
    - PFAS pollution in tap water of more than 30 states
    - PFAS pollution in groundwater in more than 35 states
  - Food-related exposure
    - Consuming fruits, vegetables, meat, milk, dairy products, or other food taken from PFAS-contaminated environments
    - Exposure via food packaging material that contains PFAS
  - Using consumer products, such as non-stick cookware, stain resistant carpeting, water repellent clothing, and PPE

- **Inhalation and dermal absorption -** currently considered insignificant, b limited.

Does PFAS Air Transport Cause Contamination?

- Air emissions can lead to contamination of water and soil. Several studies have documented air transport and deposition:
  - Numerous reports of downwind soil and groundwater contamination indicating air deposition.
  - One study detected PFAS ~300 miles away from the source indicating long range transport.
  - Legacy PFAS in rainwater often exceed safe levels despite phasing out production.
  - Legacy and emerging PFAS detected in $PM_{2.5}$ measured <5 km from fluoropolymer plant.
  - Modelling studies suggest that acids have a higher deposition due to water solubility and that 95% of total emitted PFAS are deposited >150 km from the facility.
  - Results from NC PFAS Testing Network show air transport and deposition is occurring.
  - 2024 study suggests landfill gas could be larger source of environmental PFAS than leachate.
  - 2024 study suggests atmospheric deposition is important in PFAS contribution to the Great Lakes.
- Ongoing Air Deposition work is being done through the National Atmospheric Deposition Network. A pilot PFAS-NTN subnetwork established Jan 2024.

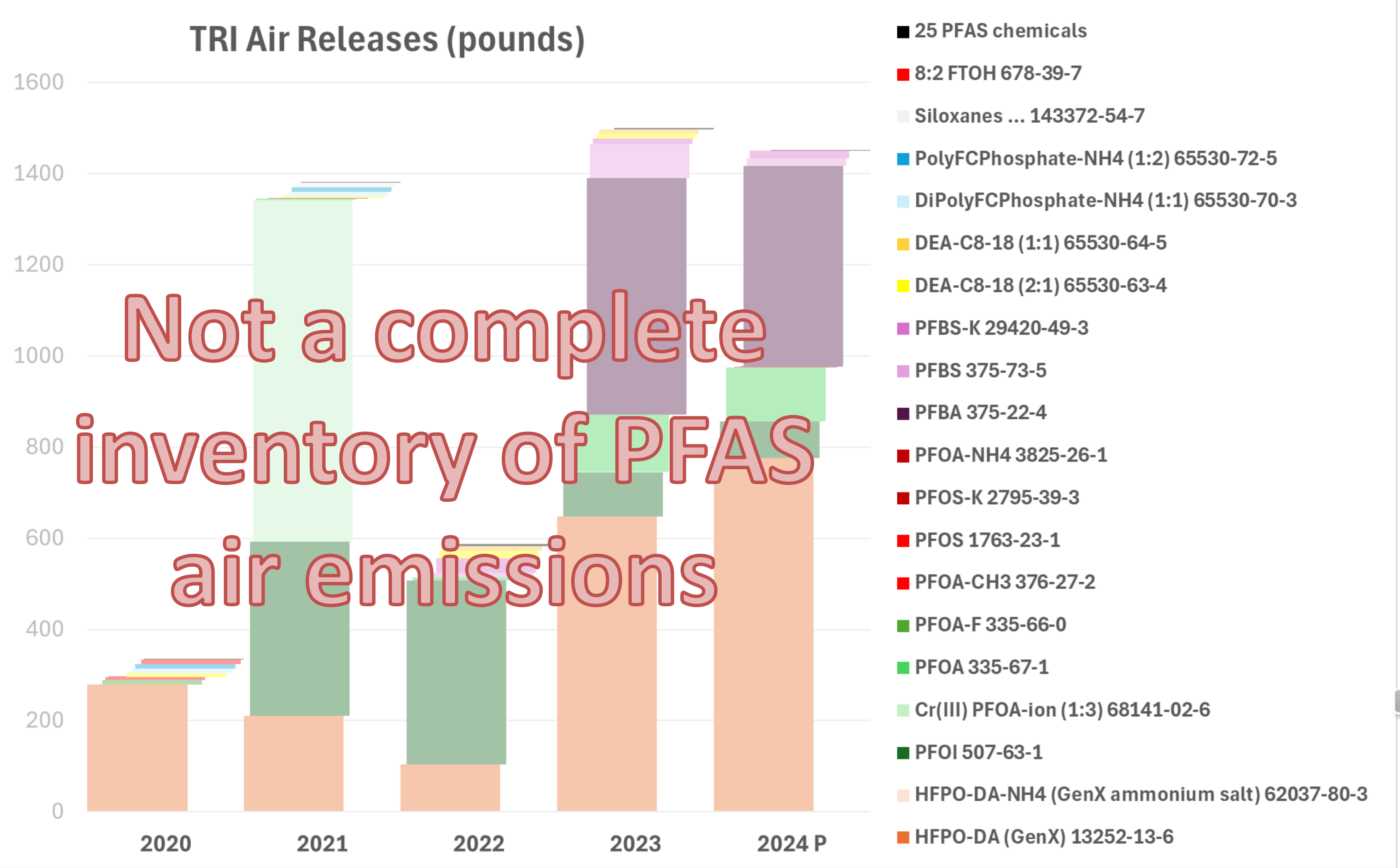
Sources of PFAS Emissions

- PFAS can be emitted to the air at all phases in the lifecycle
  - Manufacture:
    - Chemical and polymer synthesis
    - Coating formulations
    - Products formulations
  - Use:
    - Coating operations
    - Product manufacturing processes
    - Electroplating fume suppressants
  - Disposal
    - Incineration (Hazardous Waste, Sewage Sludge, Municipal Solid Waste, Medical Waste, *etc.*)
    - Landfills
    - Site Remediation of PFAS laden soils & fluids
- Passive receivers (*e.g.,* water treatment) have no control over PFAS received.
  - Separation processes and subsequent treatment of PFAS laden fluids/materials (*e.g.,* regeneration of Granulated Activated Carbon) will have a direct bearing on how much PFAS is reintroduced into the environment via emissions to the atmosphere.

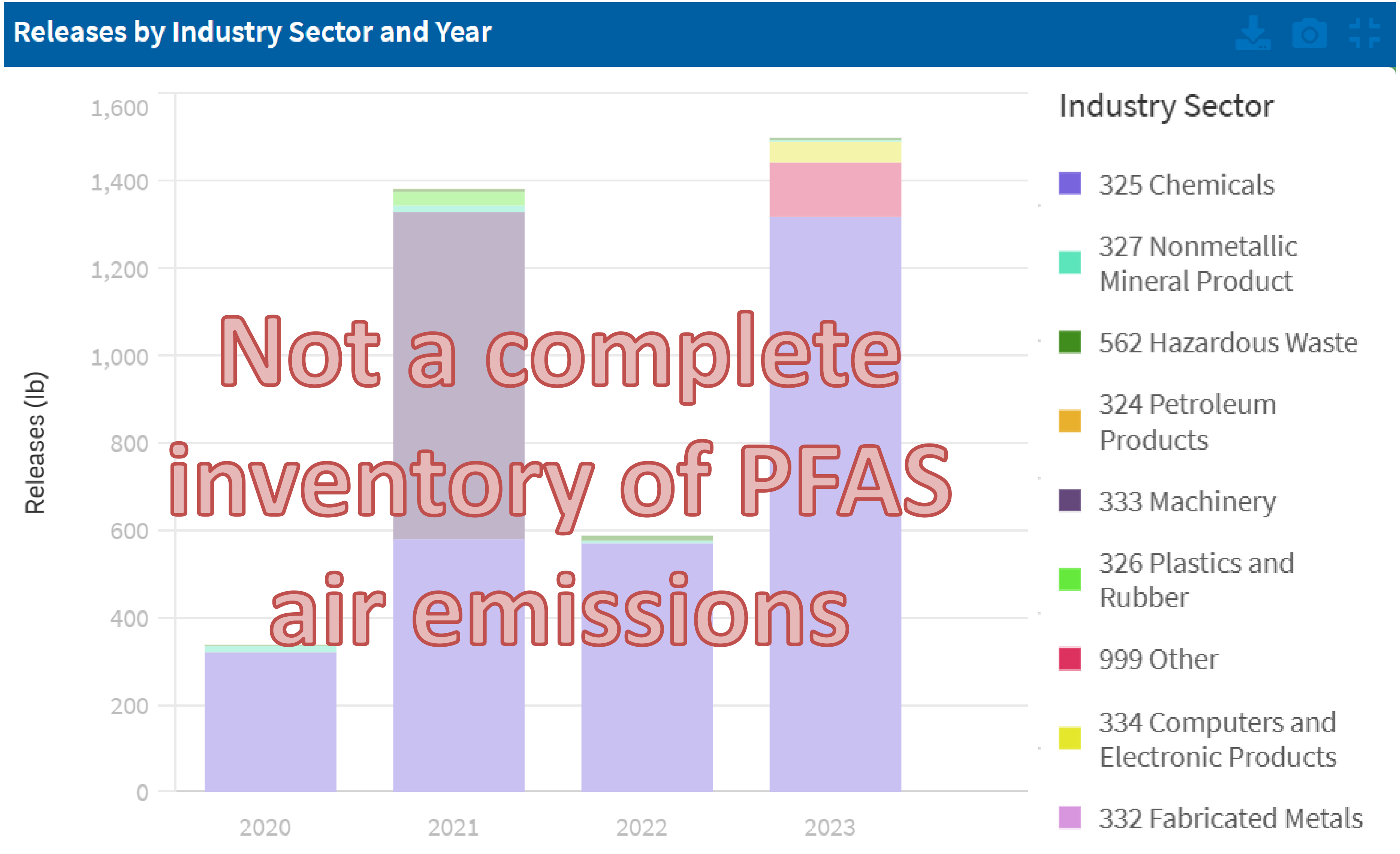
TRI Air Releases
2020 – 2023
& Preliminary 2024

TRI Toxics Tracker information

TRI Air Releases by PFAS CAS# (45 chemicals)



TRI Toxics Tracker information

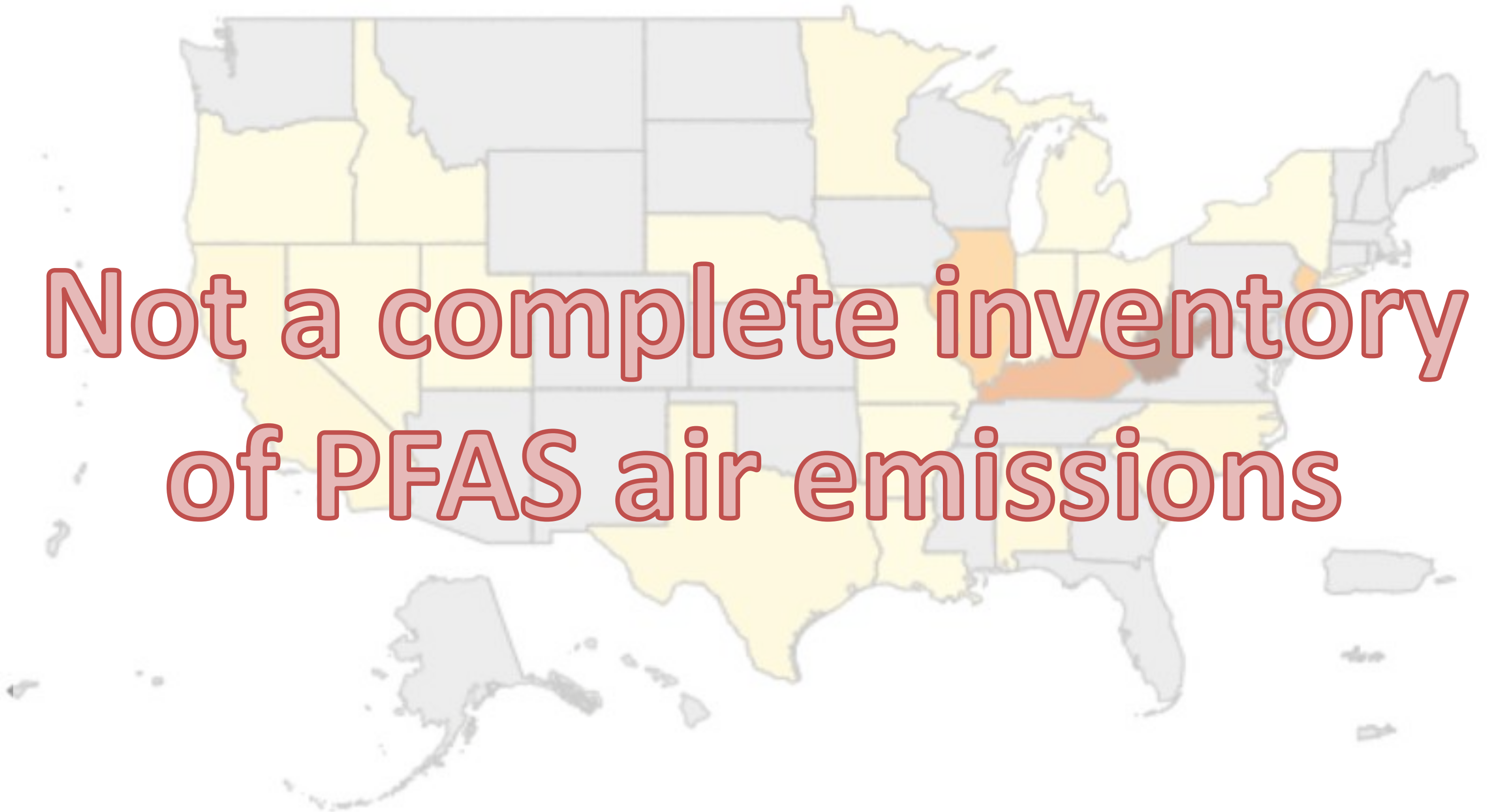


Not a complete inventory of PFAS air emissions

TRI Toxics Tracker information

Releases by State

2020-2023 (darker shades mean more emissions, grey means no emissions)



Not a complete inventory of PFAS air emissions

2023

City	Releases (lb)
Totals	1,500
WASHINGTON, WV	686
CORDOVA, IL	537
FLORENCE, KY	124
BLOOMINGTON, MN	47
DEEPWATER, NJ	30
DECATUR, AL	21
GARDEN GROVE, CA	20
FAYETTEVILLE, NC	13
PARLIN, NJ	11
HARLEYVILLE, SC	4
BEAUMONT, TX	2
EL DORADO, AR	2
KIMBALL, NE	2
BELLEVUE, OH	1

2024 P

City	ST	Air (lb)
WASHINGTON	WV	795.07
CORDOVA	IL	459.4
FLORENCE	KY	118
DEEPWATER	NJ	28.6
DECATUR	AL	16
FAYETTEVILLE	NC	15.4
PARLIN	NJ	12
HARLEYVILLE	SC	4.3
BEAUMONT	TX	1
GRAND VIEW	***ID***	***0.62***
EAST LIVERPOOL	***OH***	***0.59***
KIMBALL	NE	0.551
WALLINGFORD	***CT***	***0.5***
EL DORADO	AR	0.05
BEATTY	***NV***	***0.046***
BOWLING GREEN	***OH***	***0.02***
AVON LAKE	***OH***	***0.017***
GRANTSVILLE	***UT***	***0.017***
LA PORTE	***TX***	***0.017***
CATLETTSBURG	***KY***	***0.013***

State/Local Air Emissions Information

Limited emissions and modeling information available

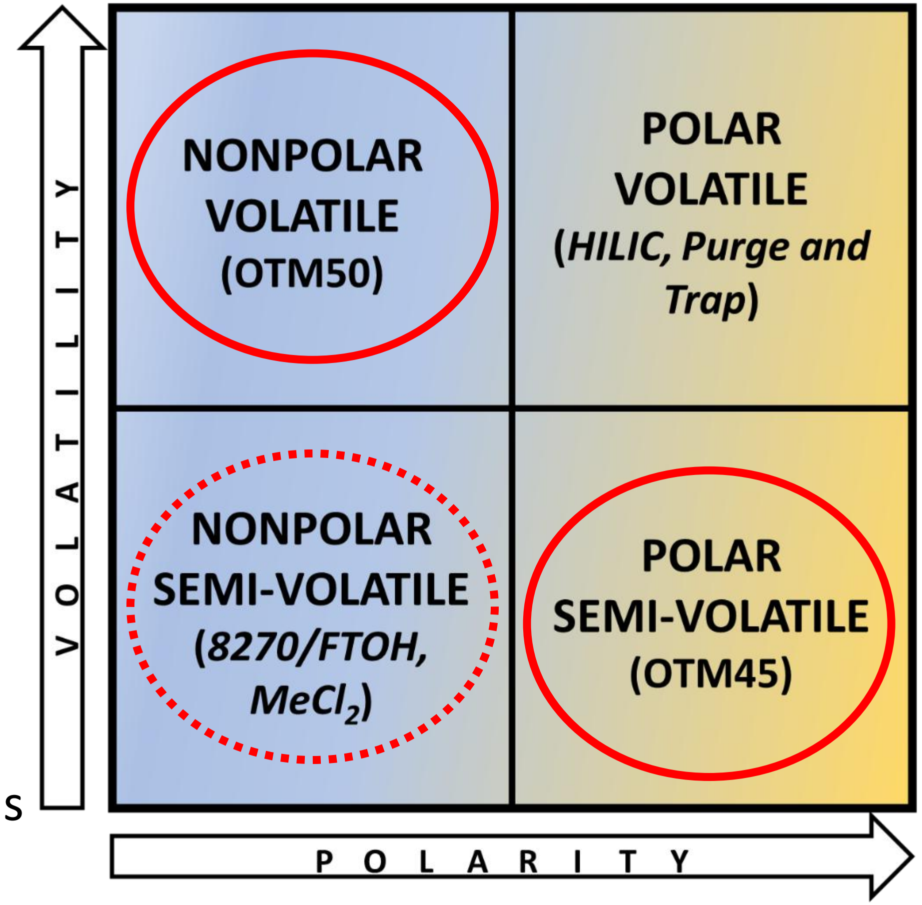
- NH St.-Gobain dispersion modeling (February 2, 2023 memo)
  - https://www4.des.state.nh.us/OneStopPub/Air/330110016522-0092TypeModeling1.pdf
    - Emissions rates (lb/hr) and maximum deposition rates
- NC Chemours Fluorinated Chemical Emissions (2017-2022) & Emissions Test Reports (2018-2024)
  - https://www.deq.nc.gov/news/key-issues/genx-investigation/air-quality-sampling
- Many State Environmental Agencies are leading efforts concerning characterization of air deposition of PFAS.
  - For example: California, Colorado, Maine, Michigan, Minnesota, New Hampshire, New Jersey, New York, North Carolina, New Mexico, Vermont, Washington, and Wisconsin
- Only a few agencies have voluntarily submitted to EIS air emissions information of PFAS since the 2020 inventory year.

Test Methods

PFAS Sampling and Analysis

- **Canister sampling (OTM-50) with GC/MS analysis**
- Currently limited to 30 targeted C1-C8 PFAS
- Primarily known PICs, some industrial PFAS

- **Method 0010 sampling with GC/MS analysis (OTM-55)**
- Targeted analysis for FTOHs, select 8270 compounds and potential PICs
- Includes potential compounds of concern



- **Not a current focus**
- Impinger sampling?
- LC analysis?
- Limited number of PFAS in this class

- **OTM-45 sampling with LC/MS analysis**
- Currently includes 49 targeted PFAS (C4 and larger)
- Analysis (and standards) largely related to drinking water methods 533 & 537.1, 1633

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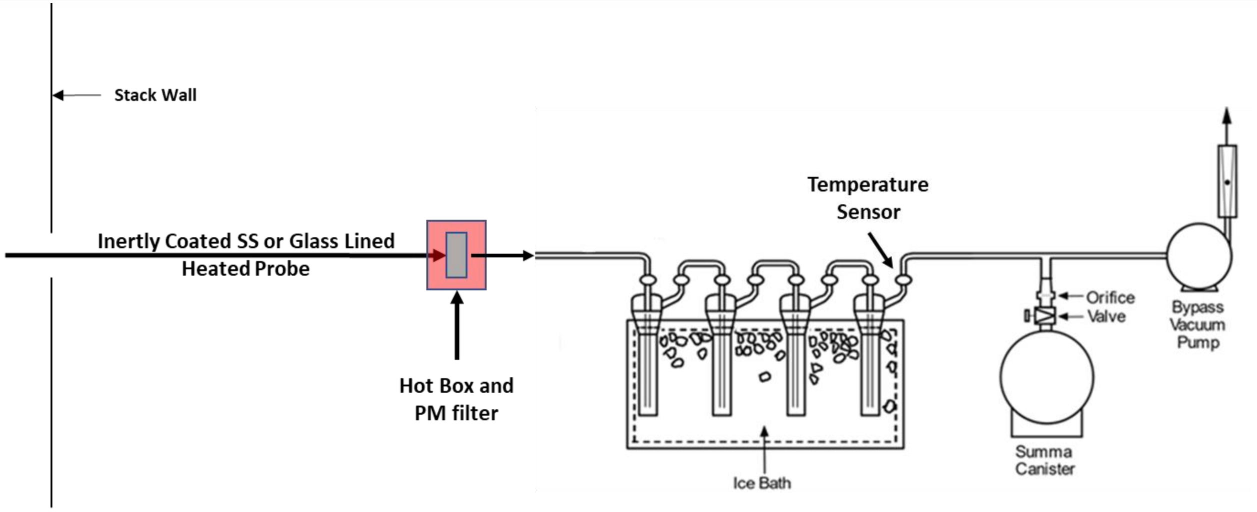
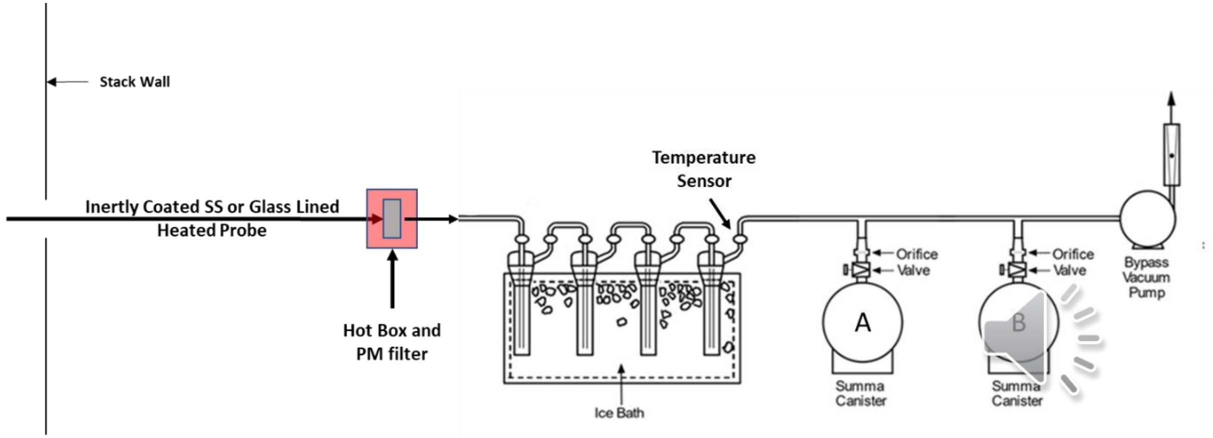
OTM-50 Train with Sample Conditioning

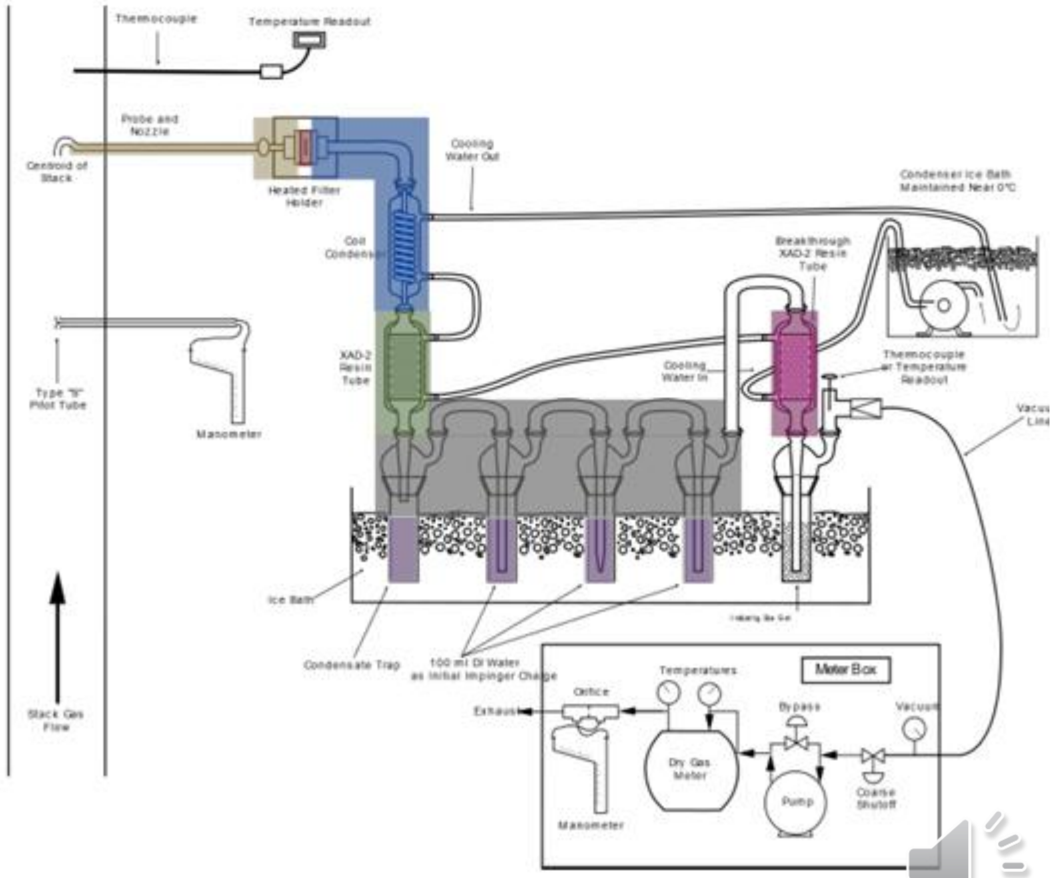
- Sampling system configuration depends on source
- Moisture and Acid Gas Management
  - Impingers included when
    - > 3% v/v H_2O
    - Acid gas present (combustion/incineration)
  - Multiple canisters in series allowed
    - Same orifice: paired samples
    - Different orifices: dilution for high concentrations





What is Method OTM 45?

- Semivolatile PFAS sampling
  - Temperature and Water Management
  - Sorbent collection
- Polar PFAS extraction
- Isotopic dilution or isotopic analog analysis
  - Analysis is based on OW Method 533
  - Performance Based Quality Control



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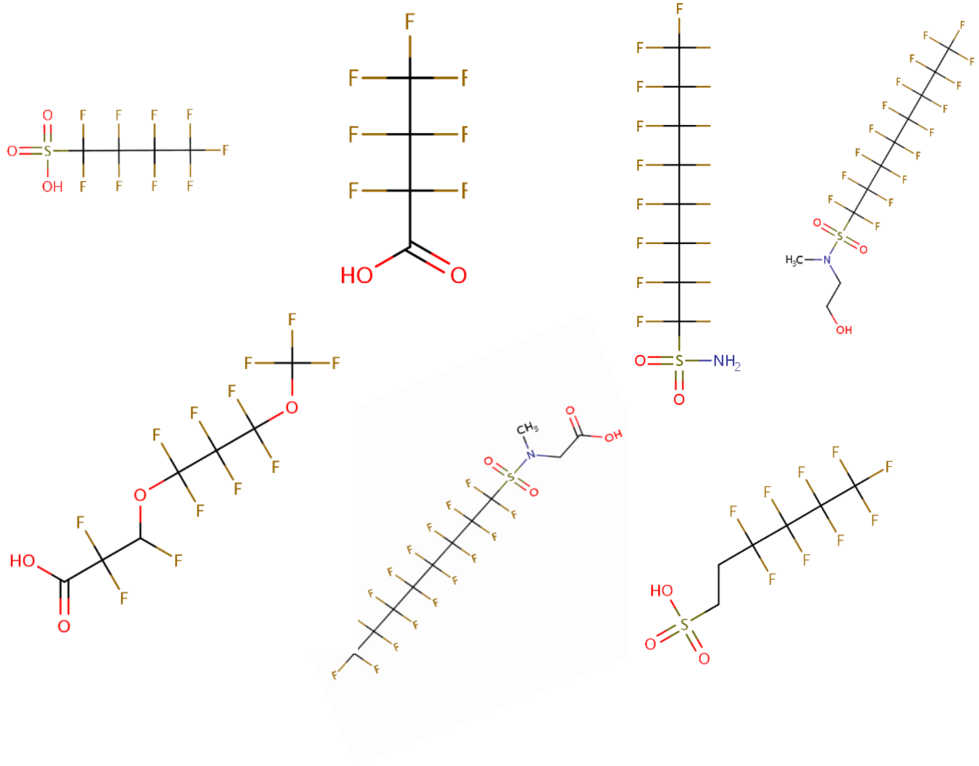
What Does OTM 45 Measure?



- Target analysis list includes fifty (50) individual PFAS from:
  - Test America method evaluation for EPA
  - EPA OW 537.1
  - EPA OW 533
  - SW 846 Method 8327
  - ASTM Method 7968
  - DoD QsM #5
  - Perfluoroalkylcarboxylic acids (PFCAs)
  - Perfluorinated sulfonic acids (PFSAs)
  - Perfluorinated sulfonamides (FOSAs)
  - Perfluorinated sulfonamide ethanols (FOSEs)
  - Perfluorinated sulfonamidoacetic acids (FOSAAs)
  - Fluorotelomer sulfonates (FTS)
  - Fluorinated Replacement Chemicals

What is Method OTM 55?

- Non-polar semivolatile PFAS sampling
  - Method 0010 sampling train
  - Sorbent collection
- Non-polar extraction similar to Method 8270 – Maybe two different analytical finishes
  - Standard SVOA Analysis – GC/MS
  - Isotopic dilution or isotopic analog analysis – GC/MS/MS

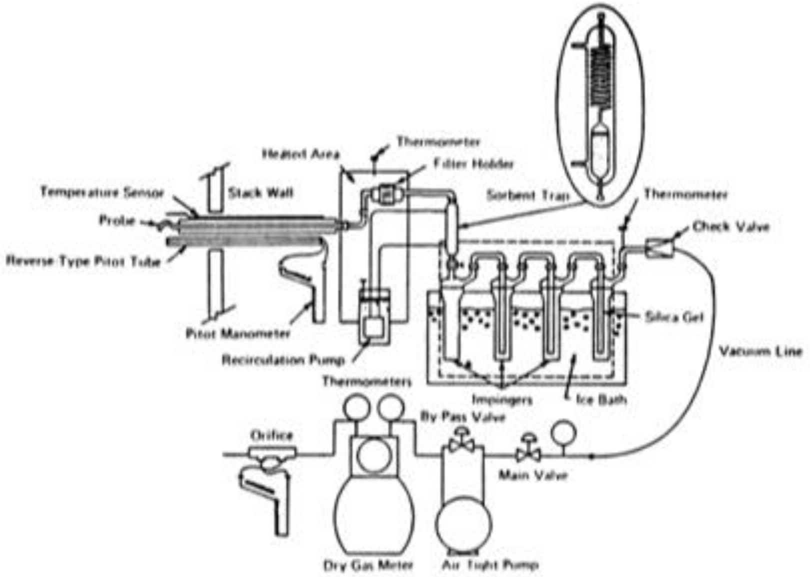


Figure 1. Modified Method 5 Sampling Train.

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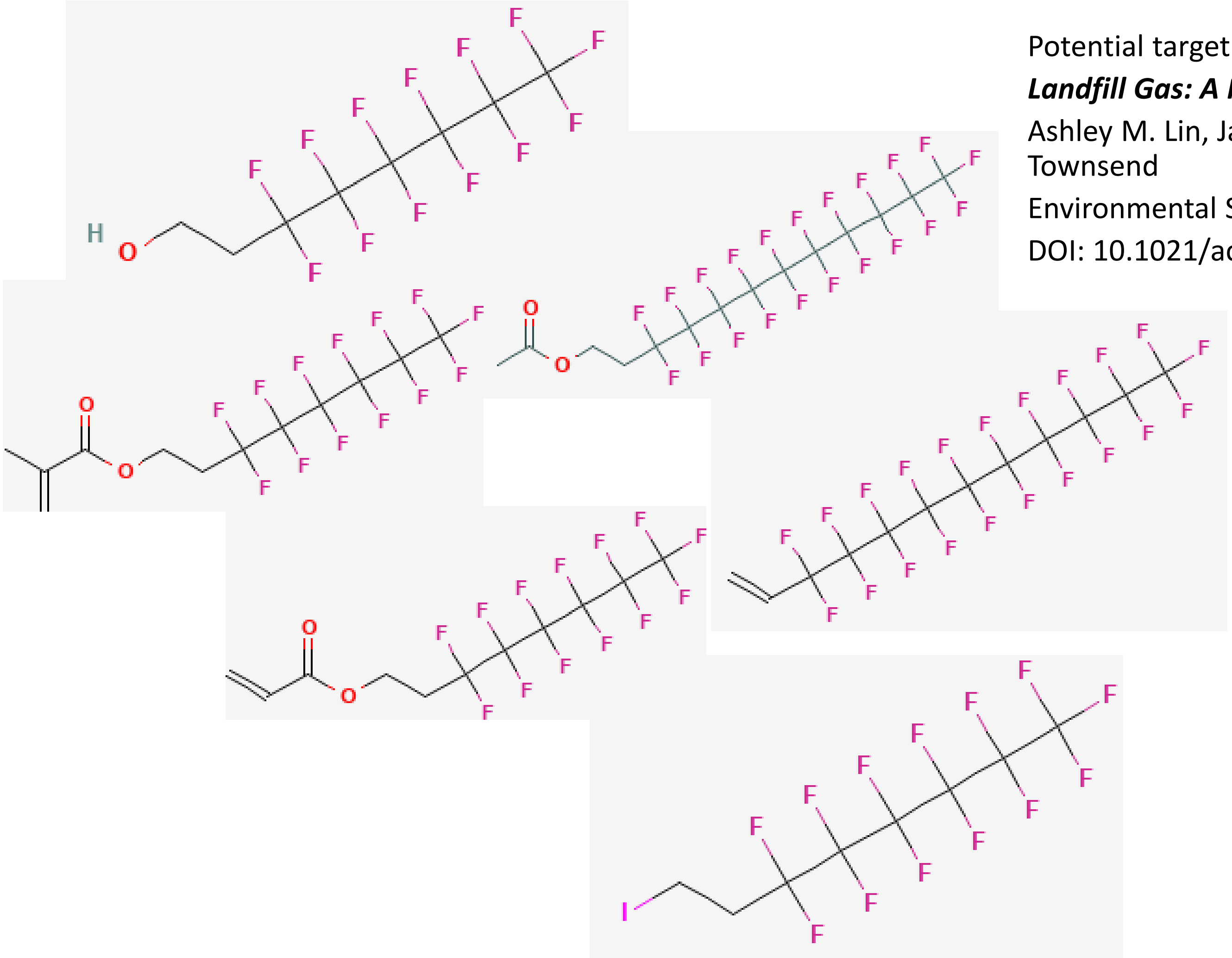
What Does OTM 55 Measure?

8270	Added
1,2-Dichlorobenzene	1-Chloro-4-fluorobenzene
1,3-Dichlorobenzene	1-chloro-2-fluorobenzene
1,4-Dichlorobenzene	1-chloro-3-fluorobenzene
Hexachlorobenzene	
Pentachlorobenzene	2-Fluoronaphthalene
1,2,4-Trichlorobenzene	1-Fluoronapthalene
	Octafluoronaphthalene
Hexachloroethane	2-Fluorofluorene
Hexachlorophene	2,7-difluoro-9H-fluorene
Hexachloropropene	1-FLUORO-7-METHYLBENZO[A]ANTHRACENE
	1-FLUORO-12-METHYLBENZO(C)PHENANTHRENE
2,4-Dichlorophenol	9-(1,1-Difluoroethyl)anthracene
2,6-Dichlorophenol	
2,4,5-Trichlorophenol	4-Fluorobiphenyl
2,4,6-Trichlorophenol	2-Fluorobiphenyl
2-Chlorophenol	2,2'-Difluorobiphenyl
Pentachlorophenol	3,3'-Difluorobiphenyl
	2,4-Difluorobiphenyl
1-Chloronaphthalene	4,4'-Difluorobiphenyl
2-Chloronaphthalene	Octafluorobiphenylene
Acenaphthene	4-chloro-2-fluoro-1,1'-biphenyl
Acenaphthylene	3-chloro-4-fluoro-1,1'-biphenyl
Anthracene	
Benzo(a)anthracene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Benzo(g,h,i)perylene	
Benzo(a)pyrene	
Benzo(e)pyrene	
Chrysene	
Dibenz(a,h)anthracene	
Dibenzo(a,e)pyrene	
7,12-Dimethylbenz(a)anthracene	
Fluoranthene	
Fluorene	
Phenanthrene	
Pyrene	
Naphthalene	

Potential target analysis list includes:

- Standard chlorinated aromatic and PAH compounds from Method 8270
- Chlorinated and fluorinated benzenes and PAH

What Does OTM 55 Measure?



Potential target analysis list of PFAS from:

Landfill Gas: A Major Pathway for Neutral Per- and Polyfluoroalkyl Substance (PFAS) Release

Ashley M. Lin, Jake T. Thompson, Jeremy P. Koelmel, Yalan Liu, John A. Bowden, and Timothy G. Townsend

Environmental Science & Technology Letters 2024 11 (7), 730-737

DOI: 10.1021/acs.estlett.4c00364

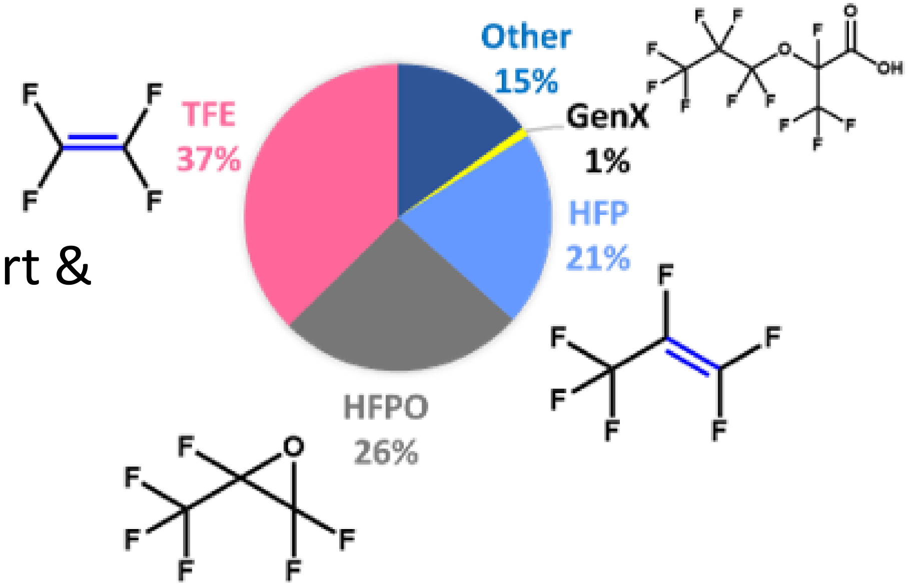
Examples Include:

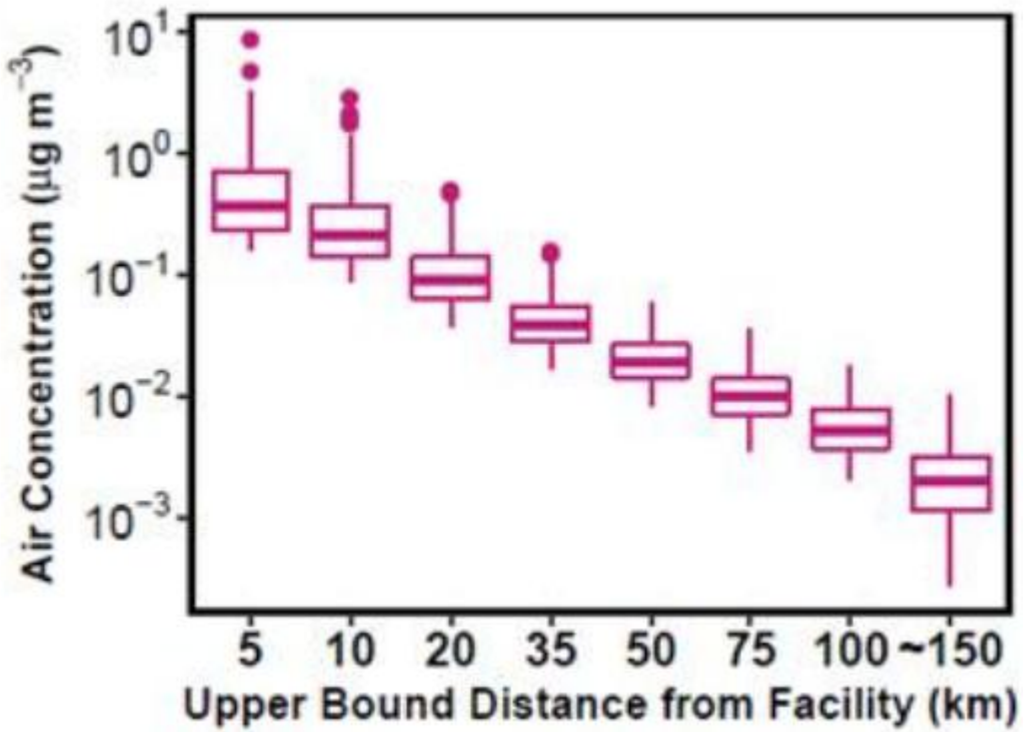
- Fluorotelomer alcohols (FTOH)
- Fluorotelomer olefins (FTOs)
- Fluorotelomer acetates (FTOAc's)
- Fluorotelomer acrylates (FTAc's)
- Fluorotelomer methacrylates (FTMAc's)
- Fluorotelomer iodides (FTIs)

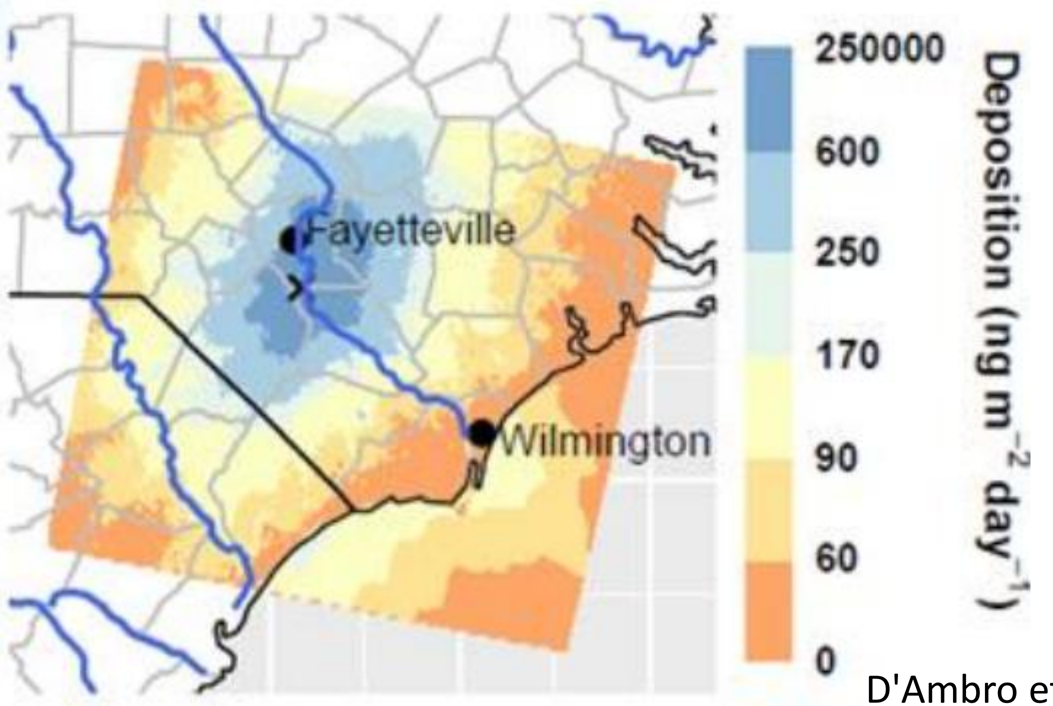
Existing Studies

CMAQ-PFAS

- PFAS emissions were obtained from one manufacturer and modeled with CMAQ to understand their atmospheric transport & fate
- Most of the emitted volatile PFAS compounds have 2-3 carbon atoms
- CMAQ-PFAS provides information on both total PFAS...



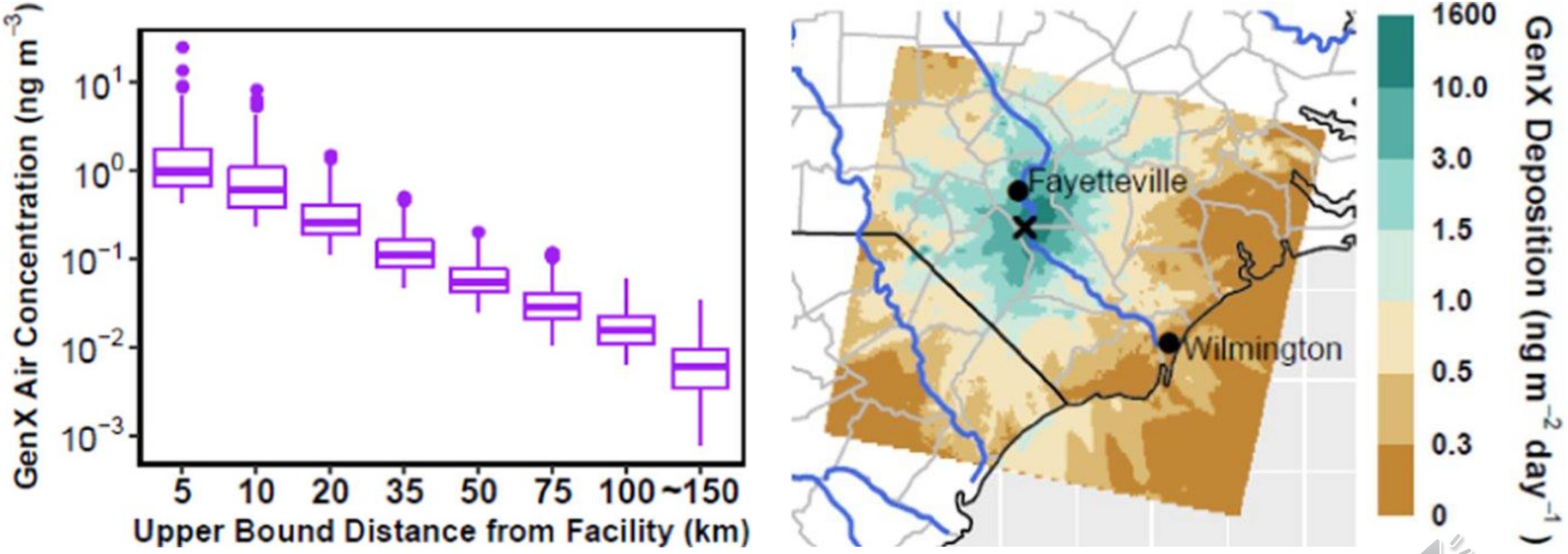




D'Ambro et al., ES&T, 2021

CMAQ-PFAS

- And specific species of interest:



- CMAQ-PFAS is publicly available: https://github.com/USEPA/CMAQ/tree/CMAQ-PFAS

D'Ambro et al., ES&T, 2021

The road ahead for PFAS Air Emissions Inventories

- Toxic Release Inventory PFAS air emissions are a starting point, but sizable gaps exist.

- EPA Test methods to measure PFAS and Products of Incomplete Combustion (PICs) are available for use.
  - OTM-45
  - OTM-50
  - *OTM-55 (in progress)*

- EIS is ready to accept PFAS air emissions:
  - All TRI PFAS Chemicals & Targeted Analytes from OTM-45 & OTM-50 are in the EIS pollutant code table
    - 246 pollutant codes

- Development of CMAQ-PFAS model to estimate wet and dry deposition of PFAS air emissions is in progress.