Through the River and Over the Woods –
Global PFAS Exposure and Implications for Ecosystem Health

Woodard & Curran

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Woodard & Curran, Inc.

Soil and Water Conservation Society

Southern New England Chapter

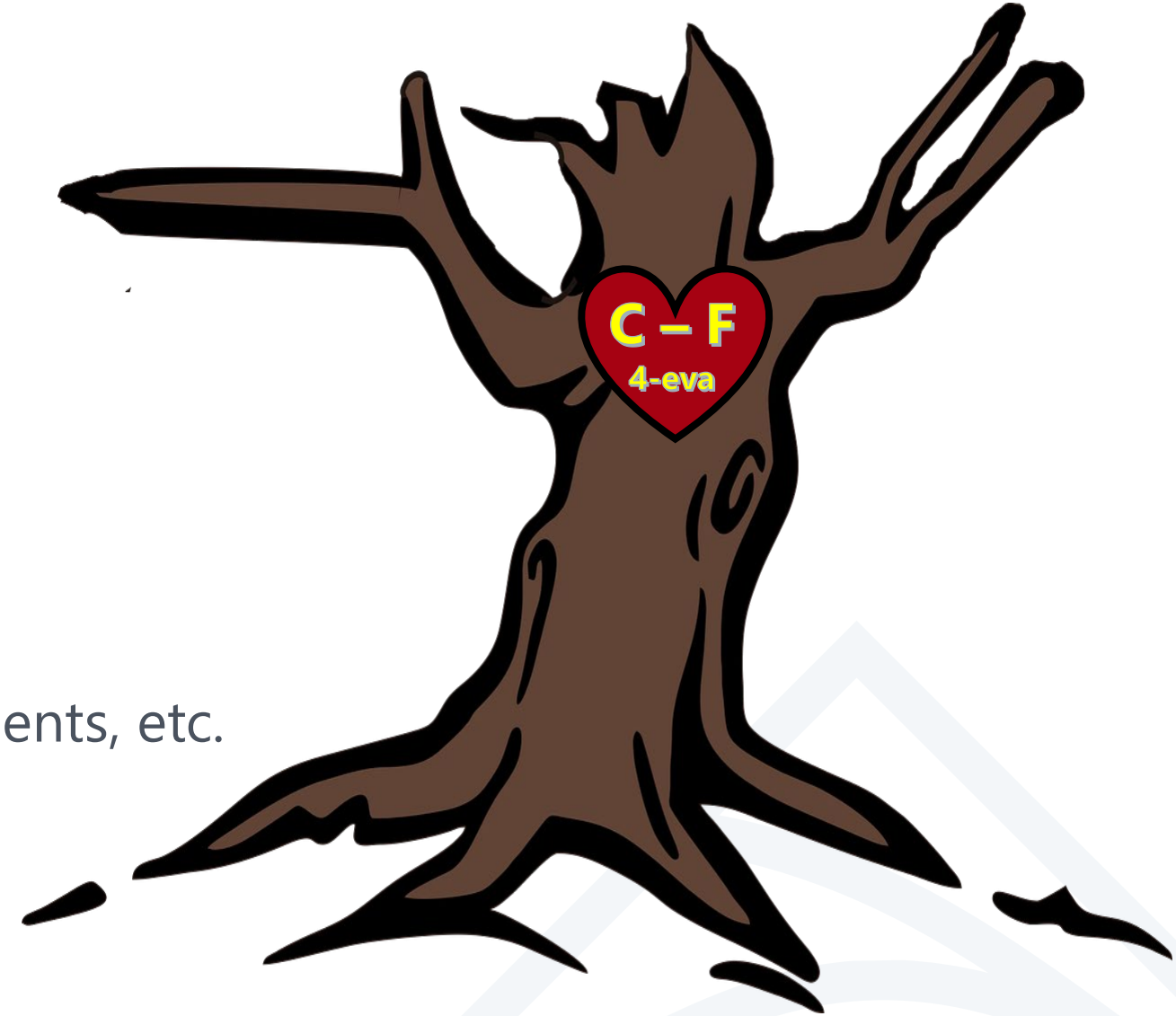
March 30, 2023

What are PFAS?

Per- and Polyfluoroalkyl Substances

- Large class of man-made compounds
  - Very stable, carbon-fluorine bonds
  - High thermal, chemical stability
  - Water soluble

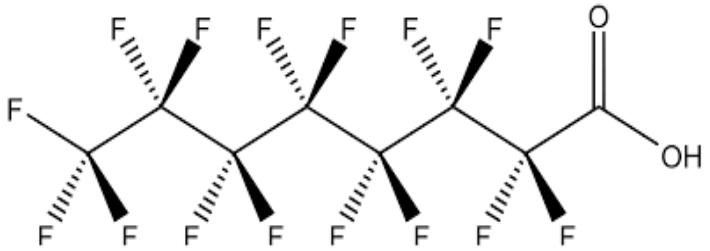
- Used as surfactants, water/stain repellents, etc.



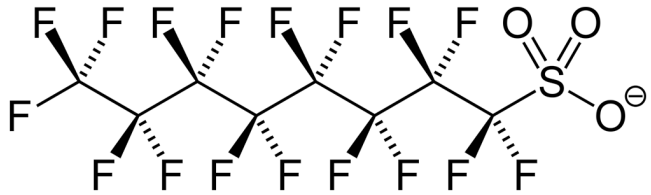
Environmental focus on perfluoroalkyl group

- Nonpolymers
- $C_n F_{2n+1} – R$
- Perfluoroalkyl carboxylic acids (PFCAs) - PFOA
- Perfluoroalkyl sulfonic acids (PFSA) – PFOS
- Long vs. short chain

- Some polyfluoroalkyl substances also important
  - Precursors to PFCAs
    - fluorotelomers



PFOA: Perfluorooctanoic acid (C8)



PFOS: Perfluorooctane sulfonic acid

Persistent, Bioaccumulative, Toxic

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PFAS Sources/Uses

- Fire-fighting foams (e.g., AFFF)

- Consumer products

- Industrial use
  - Aerospace, metal plating, automotive, electronics, construction, etc.

Source: Riverside Public Utilities
https://riversideca.gov/press/understanding-pfas

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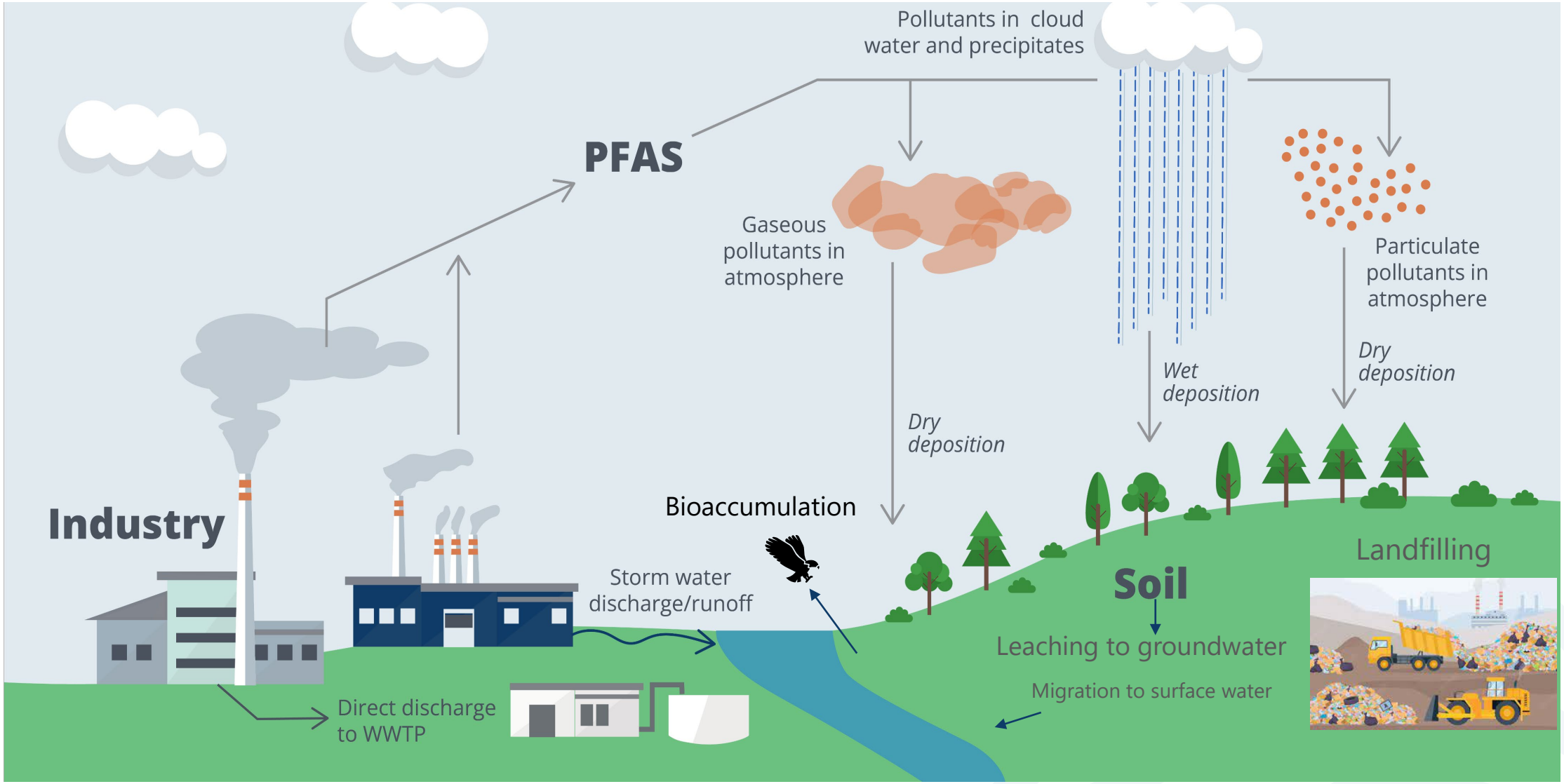
How do PFAS move through the environment?



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PFAS in the air

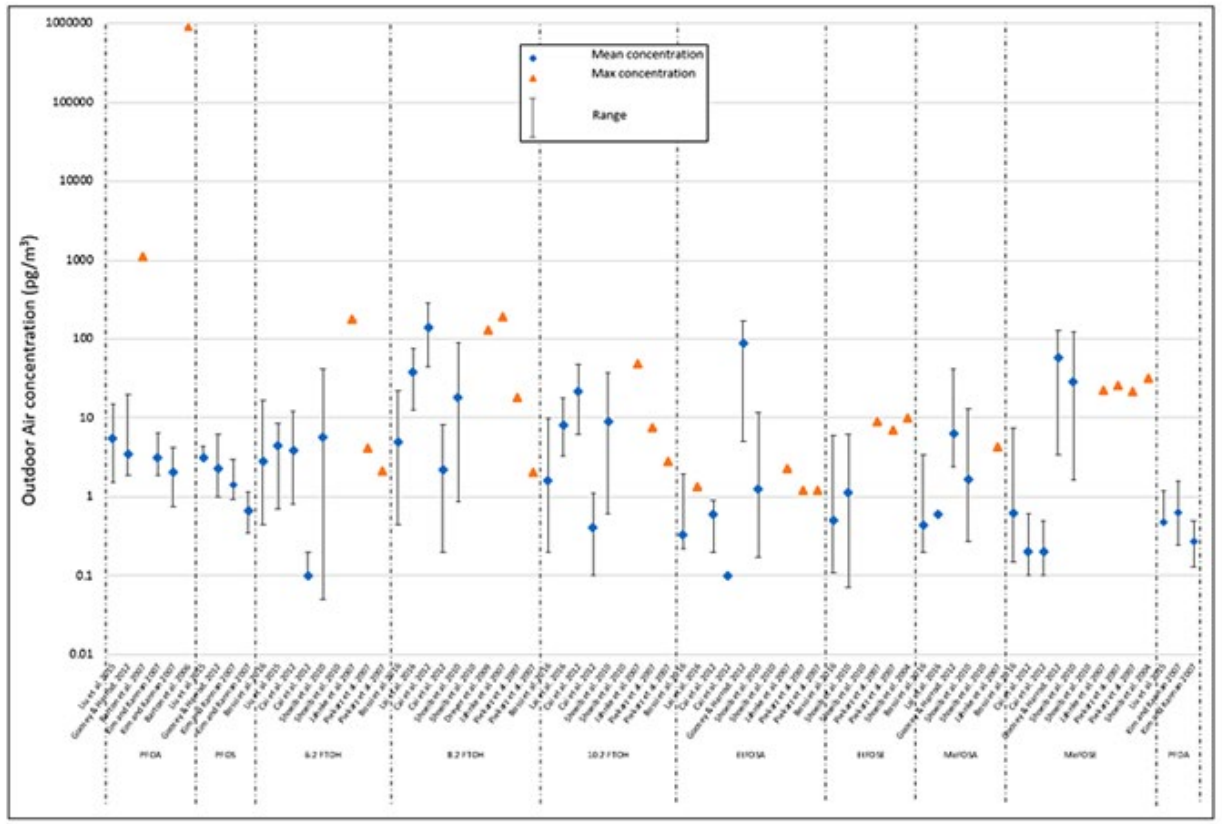

Figure 6-1A. Observed PFAS concentrations in outdoor air.

Source: ITRC PFAS Technical and Regulatory Document
https://pfas-1.itrcweb.org/6-media-specific-occurrence/#figure_6_1a

- Important transport system
  - Local and global
  - Gas, aerosol, particulates
  - Volatile precursors can be prevalent
- Removal via deposition
  - Dry particulates
  - Precipitation

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Raining down

Woodard & Curran PFAS in Rain Study
(unpublished data)

	% Detected	Minimum Detected	Maximum Detected
1H,1H,2H,2H-Perfluorooctanesulfonic Acid (6:2FTS)	6%	1.82	3.48
Perfluorobutanoic Acid (PFBA)	13%	2.3	3.36
Perfluorohexanoic Acid (PFHxA)	2%	1.94	1.94
Perfluorononanoic Acid (PFNA)	2%	2.86	2.86
Perfluoropentanoic Acid (PFPeA)	6%	2.08	2.35

Fluorotelomer precursor

Short chain

Results in ng/l

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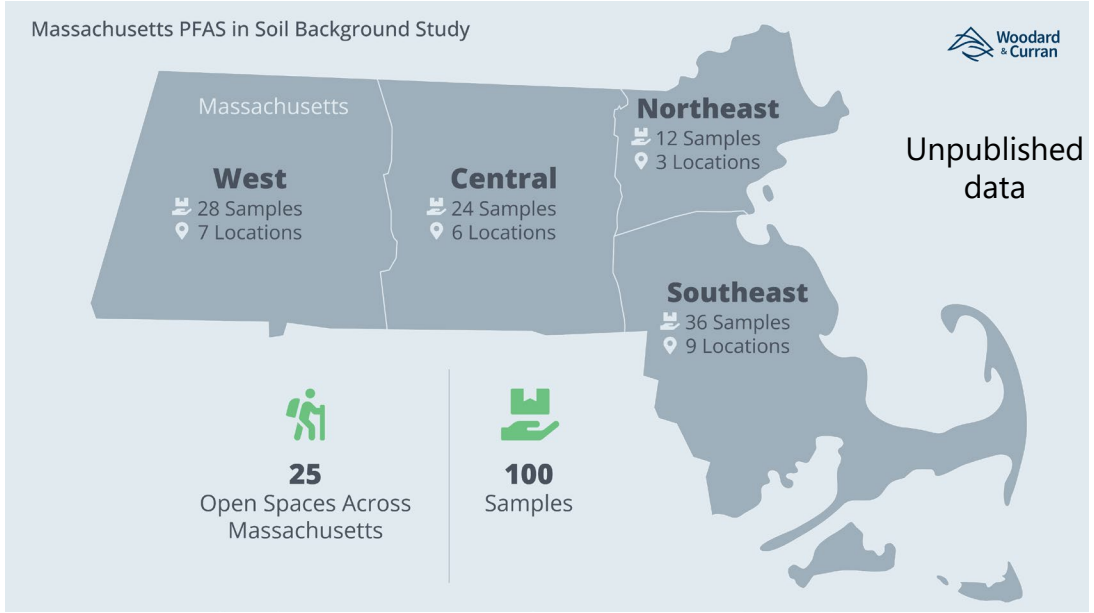
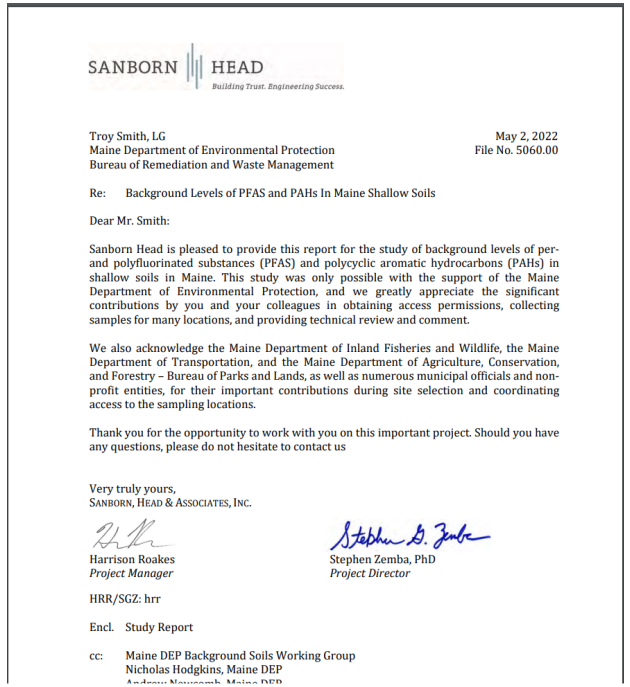
PFAS on the ground



Unpublished data



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Building Trust. Engineering Success.

Troy Smith, LG
Maine Department of Environmental Protection
Bureau of Remediation and Waste Management

May 2, 2022
File No. 5060.00

Re: Background Levels of PFAS and PAHs In Maine Shallow Soils

Dear Mr. Smith:

Sanborn Head is pleased to provide this report for the study of background levels of per- and polyfluorinated substances (PFAS) and polycyclic aromatic hydrocarbons (PAHs) in shallow soils in Maine. This study was only possible with the support of the Maine Department of Environmental Protection, and we greatly appreciate the significant contributions by you and your colleagues in obtaining access permissions, collecting samples for many locations, and providing technical review and comment.

We also acknowledge the Maine Department of Inland Fisheries and Wildlife, the Maine Department of Transportation, and the Maine Department of Agriculture, Conservation, and Forestry – Bureau of Parks and Lands, as well as numerous municipal officials and non-profit entities, for their important contributions during site selection and coordinating access to the sampling locations.

Thank you for the opportunity to work with you on this important project. Should you have any questions, please do not hesitate to contact us

Very truly yours,
SANBORN, HEAD & ASSOCIATES, INC.

Harrison Roakes
Project Manager

Stephen Zemba, PhD
Project Director

HRR/SGZ: hrr

Encl. Study Report

cc: Maine DEP Background Soils Working Group
Nicholas Hodgkins, Maine DEP

PFAS BACKGROUND IN VERMONT SHALLOW SOILS

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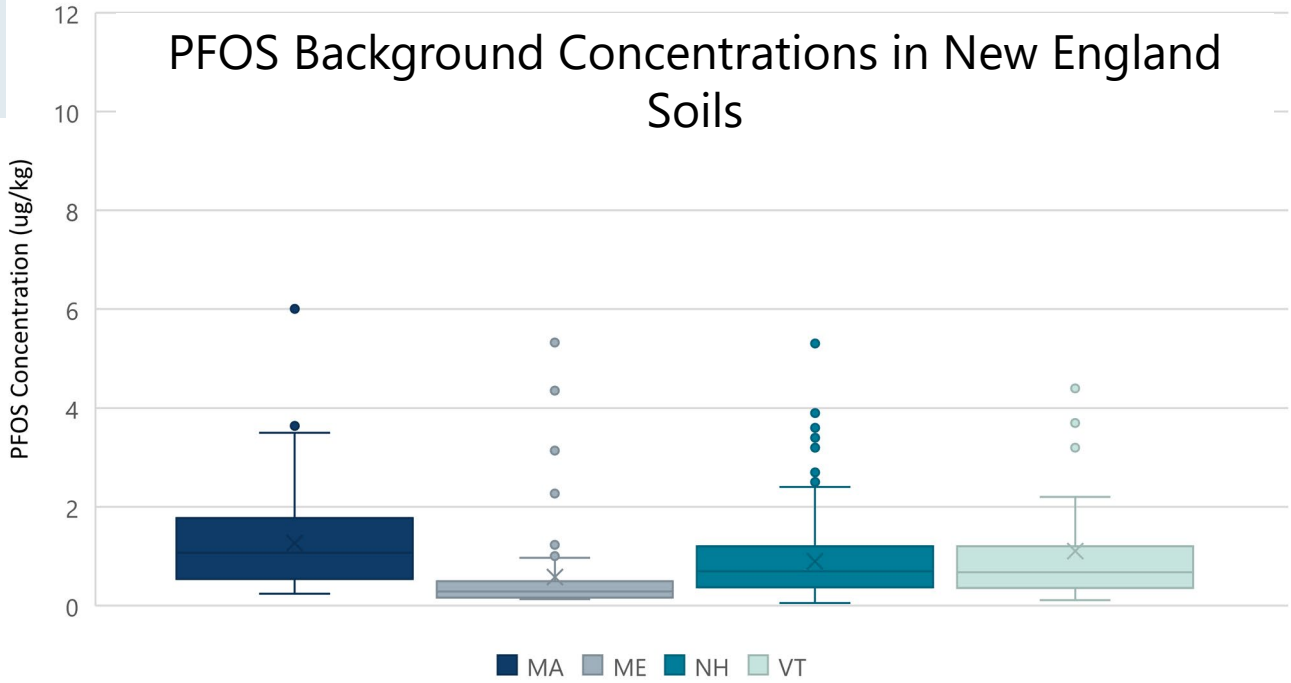
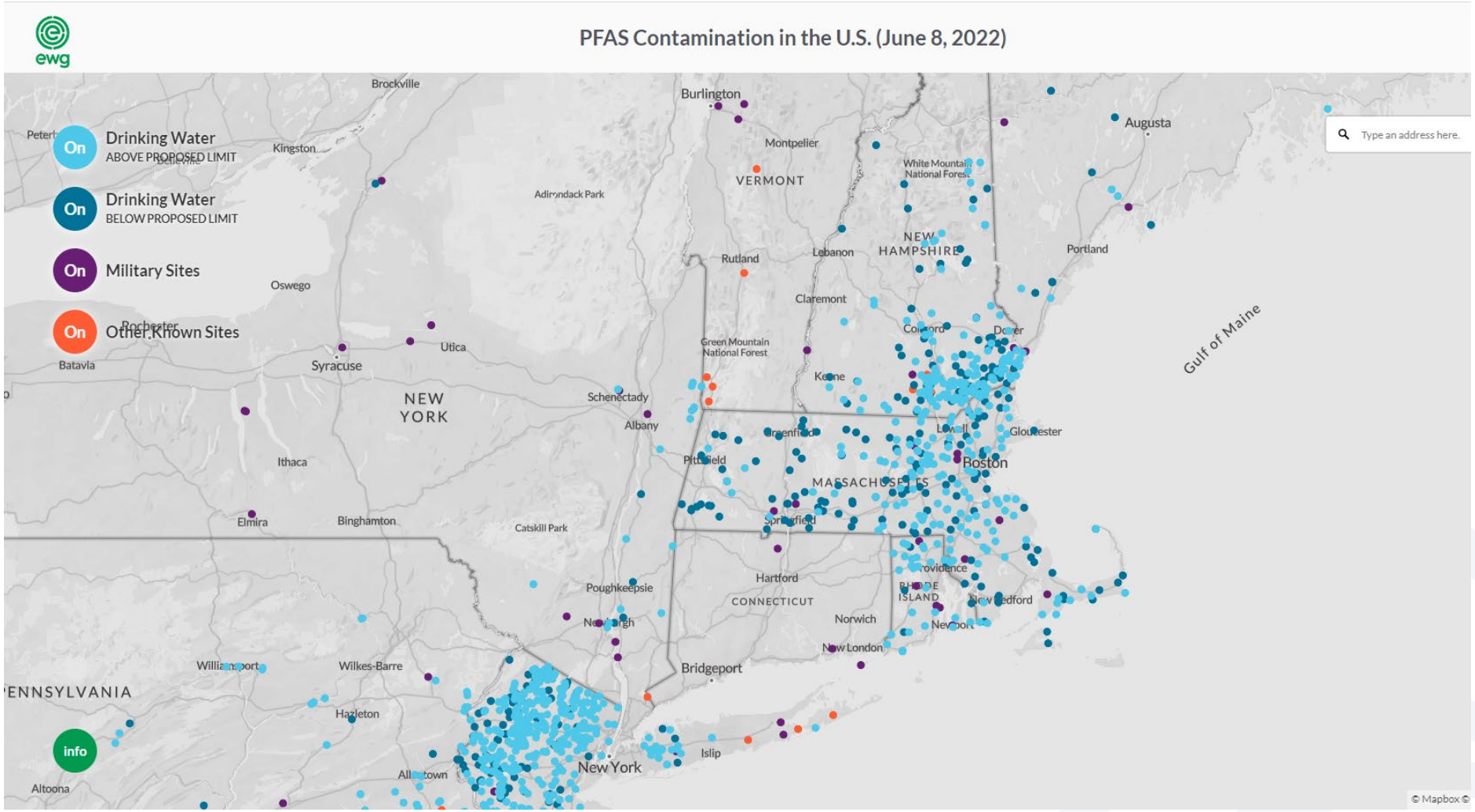


…and in the ground(water)



Source: Environmental Working Group
https://www.ewg.org/interactive-maps/pfas_contamination/map/

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...and waterways

- Direct inputs from atmosphere, wastewater, releases etc.
- Indirect input via groundwater, stormwater runoff
- Remote areas: pg/L to ng/L

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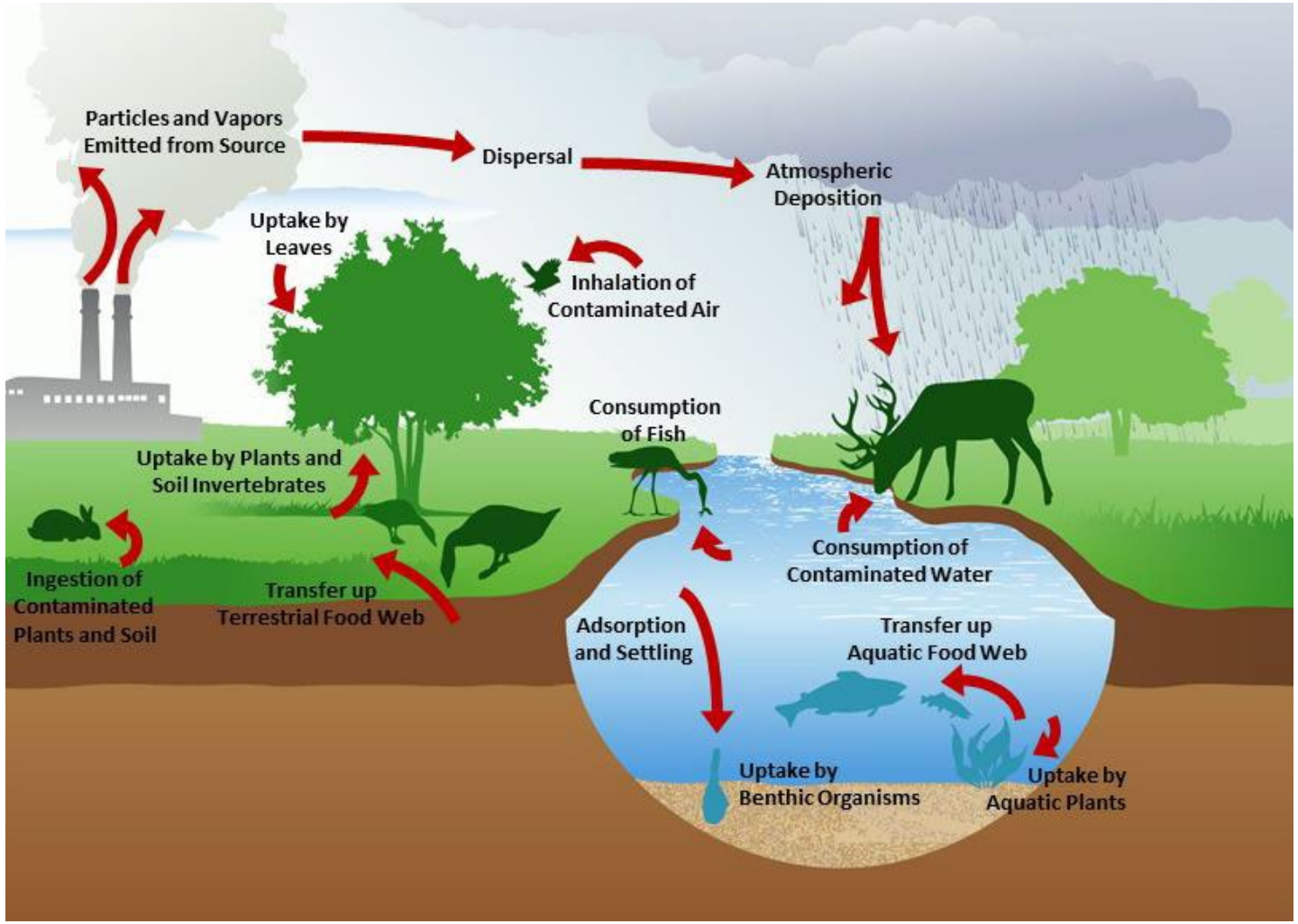
PFAS transport through the food web



Source: EPA EcoBox: https://www.epa.gov/ecobox/epa-ecobox-tools-exposure-pathways-exposure-pathways-era

Bioconcentration:
Uptake from water

Bioaccumulation:
Uptake from all surrounding sources

Biomagnification:
Increasing concentrations with increasing trophic levels

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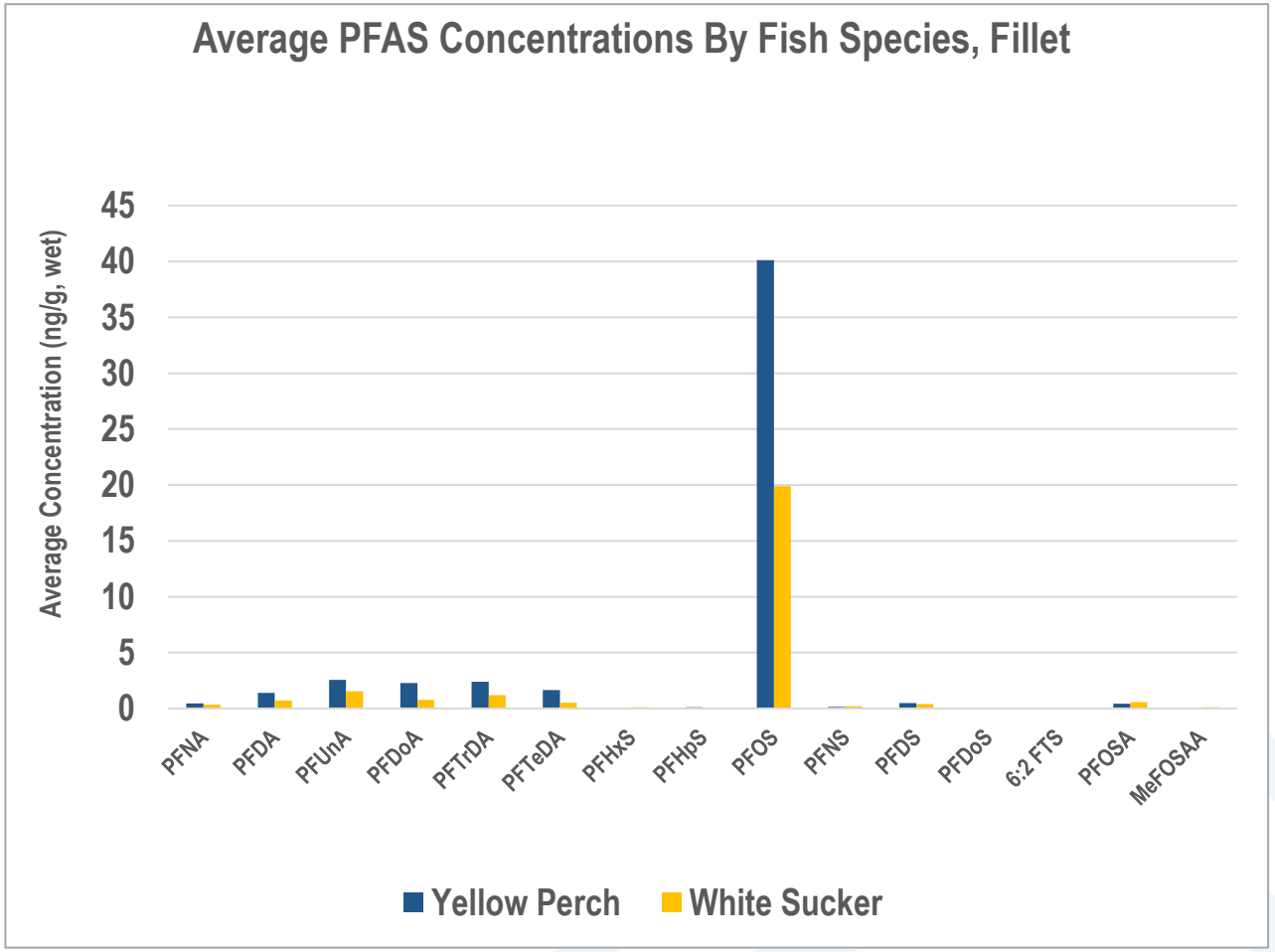
PFAS accumulate in biota

- Binds to proteins, phospholipids
- PFOS predominant
- Global exposure documented



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Bioaccumulation is highly variable

- Structure
- Media chemistry
- Organism

More bioaccumulative

C3

PFBA

C8

PFOS

C10

PFDS

More bioaccumulative

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The Big Question: does exposure translate into effect?

- Decades and multitude of laboratory data
- Mostly on PFOS and PFOA
- Mostly laboratory studies
- Toxicity is highly variable among organisms

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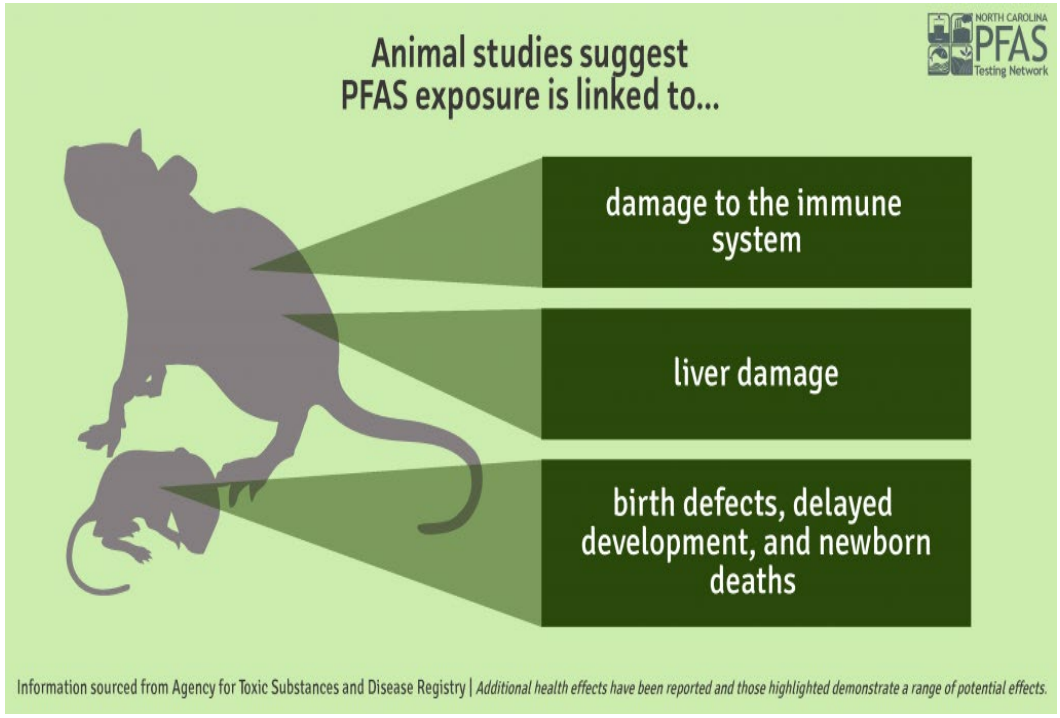
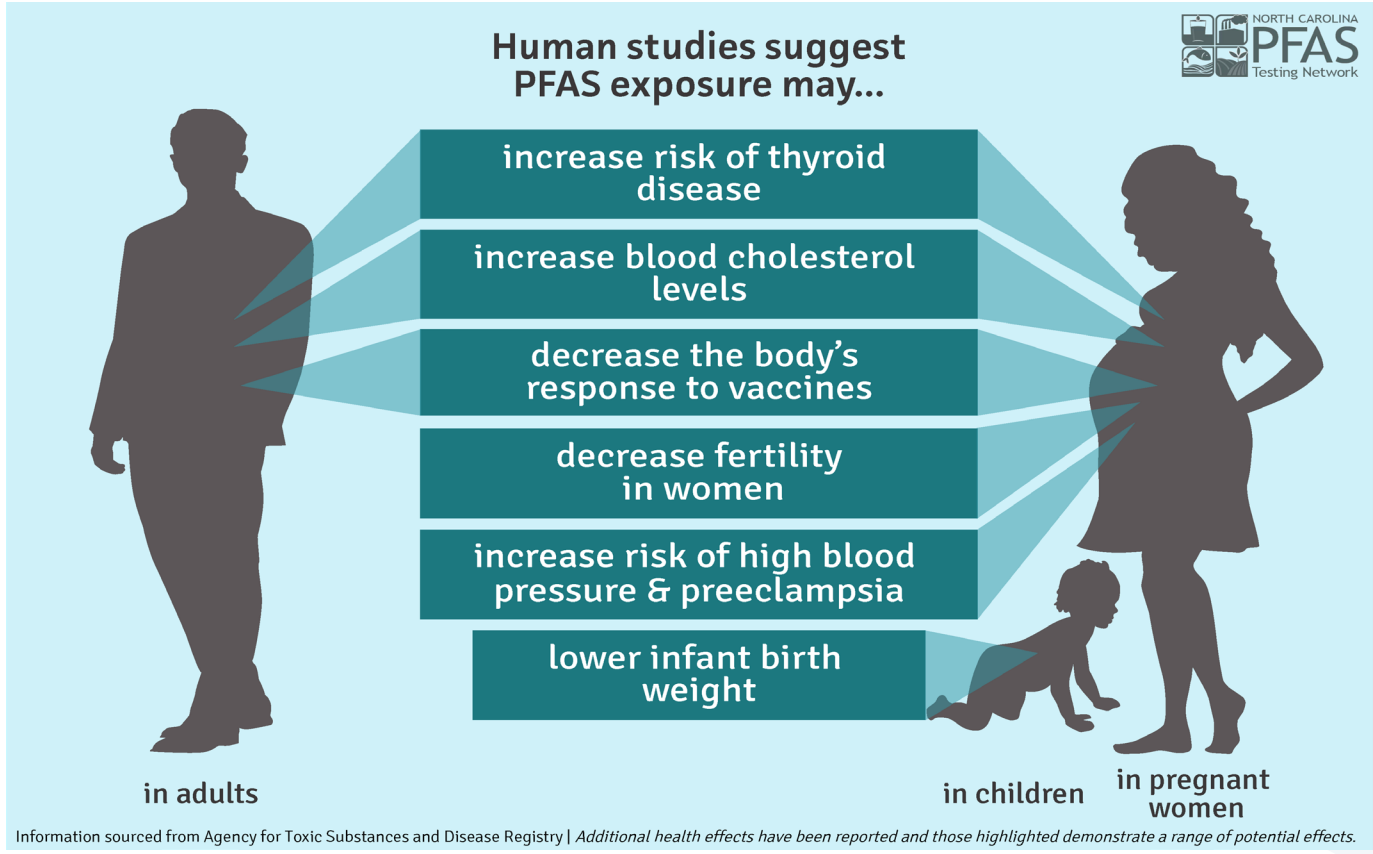
Health effects in mammals



Cancer

- PFOA: liver, testicular, pancreatic, kidney
- PFOS: bladder, prostate, kidney, breast

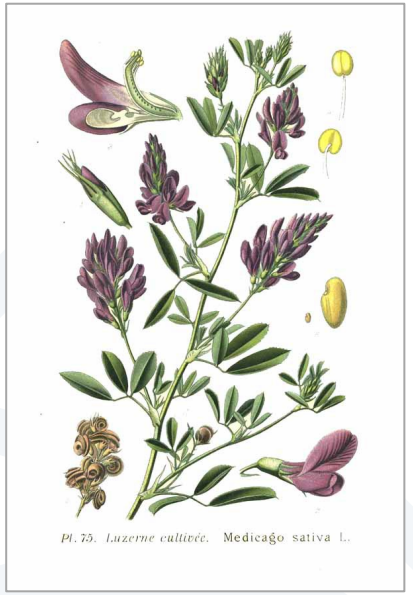


Graphics reproduced from
North Carolina NC PFAST Network:
https://ncpfastnetwork.com/printed-materials/

Effects on non-mammals

- Studies mainly focus on survival, growth, and reproduction
  - ppb to ppm levels
  - immune, developmental
  - transgenerational

- Highly variable
- Moderation by TOC and other factors



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What don’t we know?

- Toxicity of most PFAS
- Toxicity in most species
- Toxicity of PFAS mixtures
- Modulation by environmental factors
- Population-level impacts

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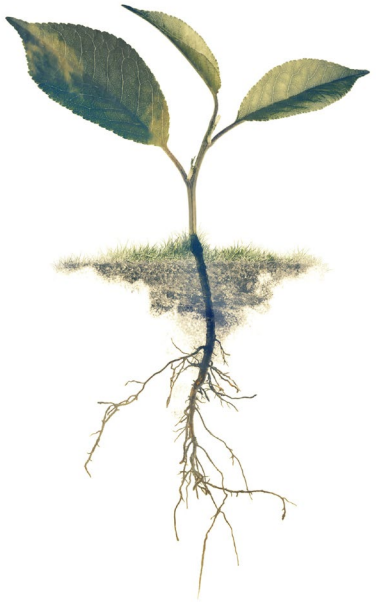
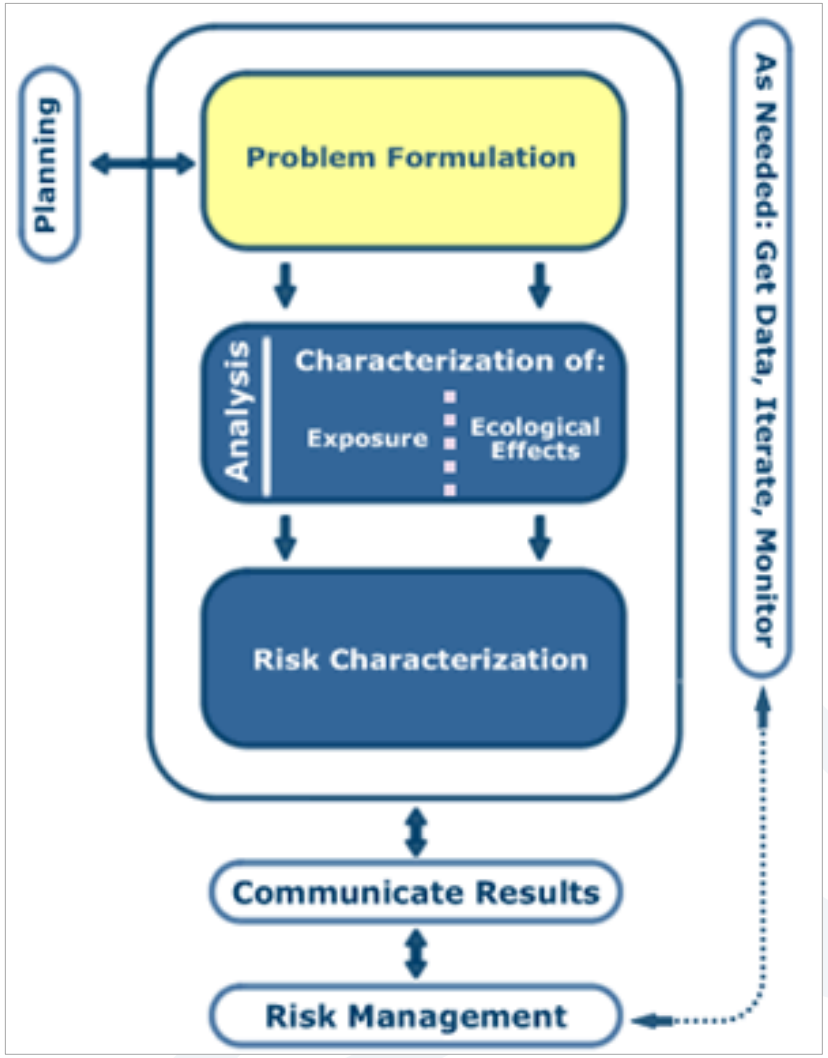
Ecological risk assessment of PFAS

- Stressors
- Migration pathways
- Exposure routes
- Exposure potential
- Toxicity
- Risk
- Uncertainty





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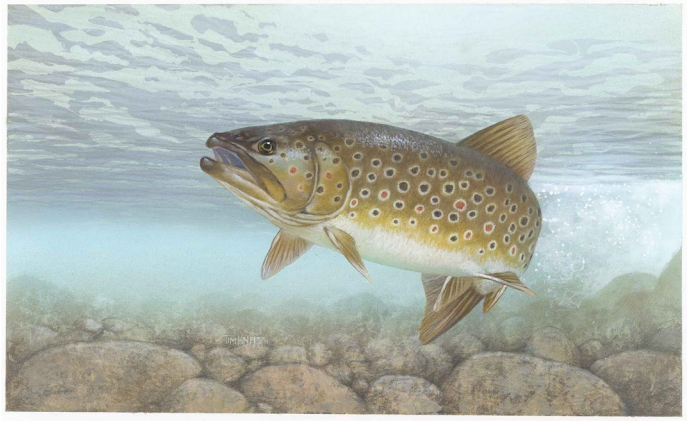
PFAS ecological benchmarks for surface water

Ecological Screening Value	Concentration ug/L	
	PFOS	PFOA
USEPA NRWQC-chronic (draft)	8.4	94
Ecological Screening Value[1]	22.6	307

1. Grippo, M., Hayse, J. , Hlohowskyj, I. and Picel, K. September 2021. Derivation of PFAS Ecological Screening Values. Argonne National Laboratory



- Many states promulgated or are in process of developing WQC
- USEPA proposed invertebrate/fish tissue-based NRWQC

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PFAS ecological benchmarks for soil

Receptor	Ecological Screening Value (ug/kg)[1]	
	PFOS	PFOA
Plants	40,200	79,500
Invertebrates	48,100	22,400
Mammals	8.7	3,840
Birds	38.6	--

Grippo, M., Hayse, J. , Hlohowskyj, I. and Picel, K. September 2021. Derivation of PFAS Ecological Screening Values. Argonne National Laboratory

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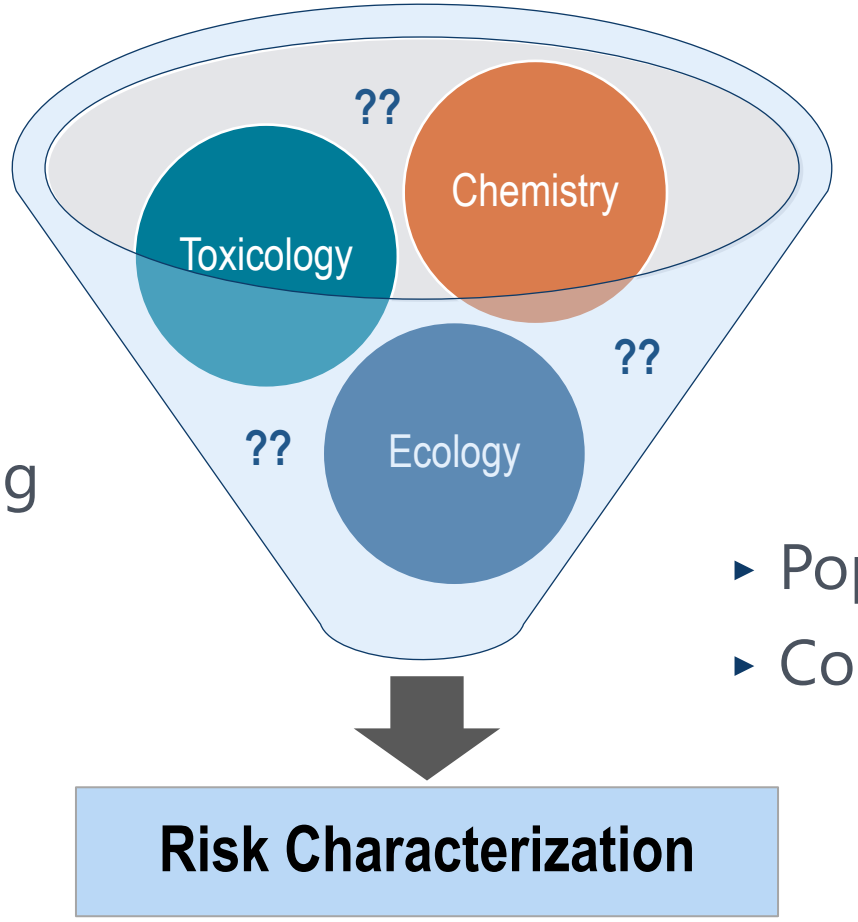
Use multiple lines of evidence to assess risk

- Literature tox values
- Lab toxicity studies
- Bioaccumulation testing



- Abiotic concentrations
- Reference levels
- Tissue samples

- Population surveys
- Condition indices

Weight of Evidence is Critical

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Understand limitations and uncertainties

Line of Evidence	Uncertainties
Benchmarks	Few currently available; not site-specific
Toxicity Testing	Which species is most sensitive?
Bioaccumulation Testing / Tissue Sampling	Standardized analytical methods lacking
Food Chain Models	How to best predict uptake?
Field Surveys	Chemical, physical and biological confounders

So what does all this mean?

- PFAS are prevalent in our environment.
  - Organisms are exposed to PFAS on a global scale.

- Exposure associated with adverse effects at environmental levels
  - Considerable uncertainty/variability

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Have any good news?

- **PFAS is a priority**
  - Regulatory impetus
- Phase out of PFOS/PFOA
  - Human PFOS and PFOA serum levels have decreased
- Push for:
  - Research & Development
  - Analysis
  - Remediation

EPA's PFAS Action Plan, 2019:
"Ecological toxicity information is also needed by stakeholders to inform risk assessment and management to protect ecosystems, animals, and plant resources they support …."

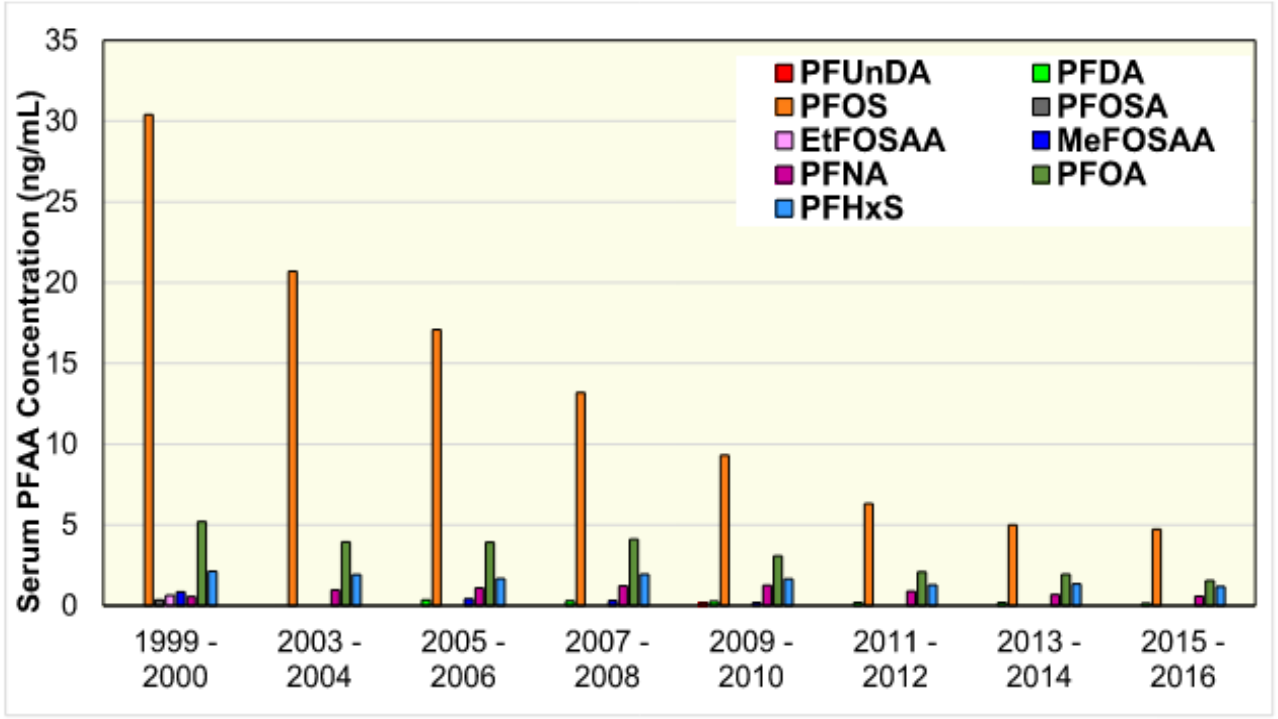

Figure 1. Geometric Mean Human Serum Concentrations (ng/mL) of Selected PFAAs (NHANES,2019)

PFAS resources

- USEPA PFAS Website: https://www.epa.gov/pfas
- Interstate Technology and Regulatory Council (ITRC): PFAS Technical and Regulatory Document: https://pfas-1.itrcweb.org/
- Argonne National Laboratories, Grippo, M., Hayse, J. , Hlohowskyj, I. and Picel, K. September 2021. *Derivation of PFAS Ecological Screening Values*. https://www.denix.osd.mil/dodepa/
- National Groundwater Association
  - *Groundwater and PFAS: State of Knowledge and Practice*. https://my.ngwa.org/NC__Product?id=a183800000kbKF9AAM
- Vermont Soil Study: https://anrweb.vt.gov/PubDocs/DEC/PFOA/Soil-Background/PFAS-Background-Vermont-Shallow-Soils-03-24-19.pdf
- Maine Soil Study: https://www.maine.gov/dep/spills/topics/pfas/Maine_Background_PFAS_Study_Report.pdf
- New Hampshire Soil Study (data): https://www.usgs.gov/data/statewide-survey-shallow-soil-concentrations-and-polyfluoroalkyl-substances-pfas-and-related

Thank You!

Questions?

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