UNDERSTANDING PFAS IN THE WORLD & THE WORKPLACE

AIHA-FL Spring 2022 Meeting

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Marriott Hutchinson Island Beach Resort

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TODAY'S ENSAFE SPEAKERS

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UNDERSTANDING PFAS IN THE WORLD & THE WORKPLACE

PFAS

1. PFAS Context & Chemistry
2. Recent Regulatory Developments
3. Impacts on Human Health & Worker Risks
4. Environmental Impacts
5. PFAS – Industry Impacts

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PFAS Definition

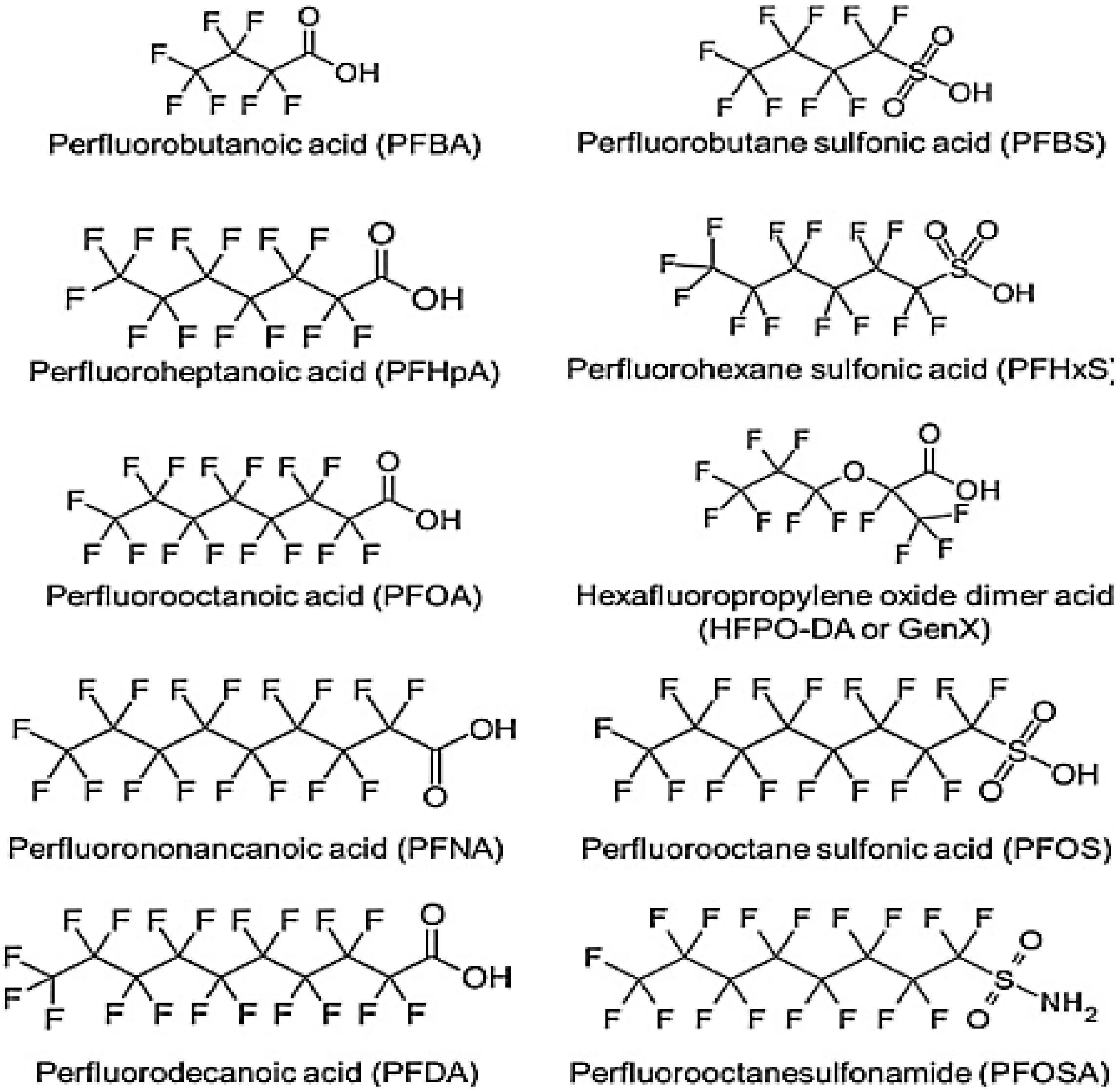
There is no universally accepted definition of per- and polyfluoroalkyl substances (PFAS).

*PFAS are **carbon atoms linked to each other and bonded to fluorine atoms** at most or all available carbon bonding sites.*

- Interstate Technology and Regulatory Council (ITRC)

***Highly fluorinated aliphatic substances** that contain one or more carbon (C) atoms on which all the **hydrogen (H) substituents** (present in the nonfluorinated analogues from which they are notionally derived) **have been replaced by fluorine (F) atoms**, in such a manner that they **contain the perfluoroalkyl moiety** C_nF_{2n+1} –.*

- Buck et al. (2011)

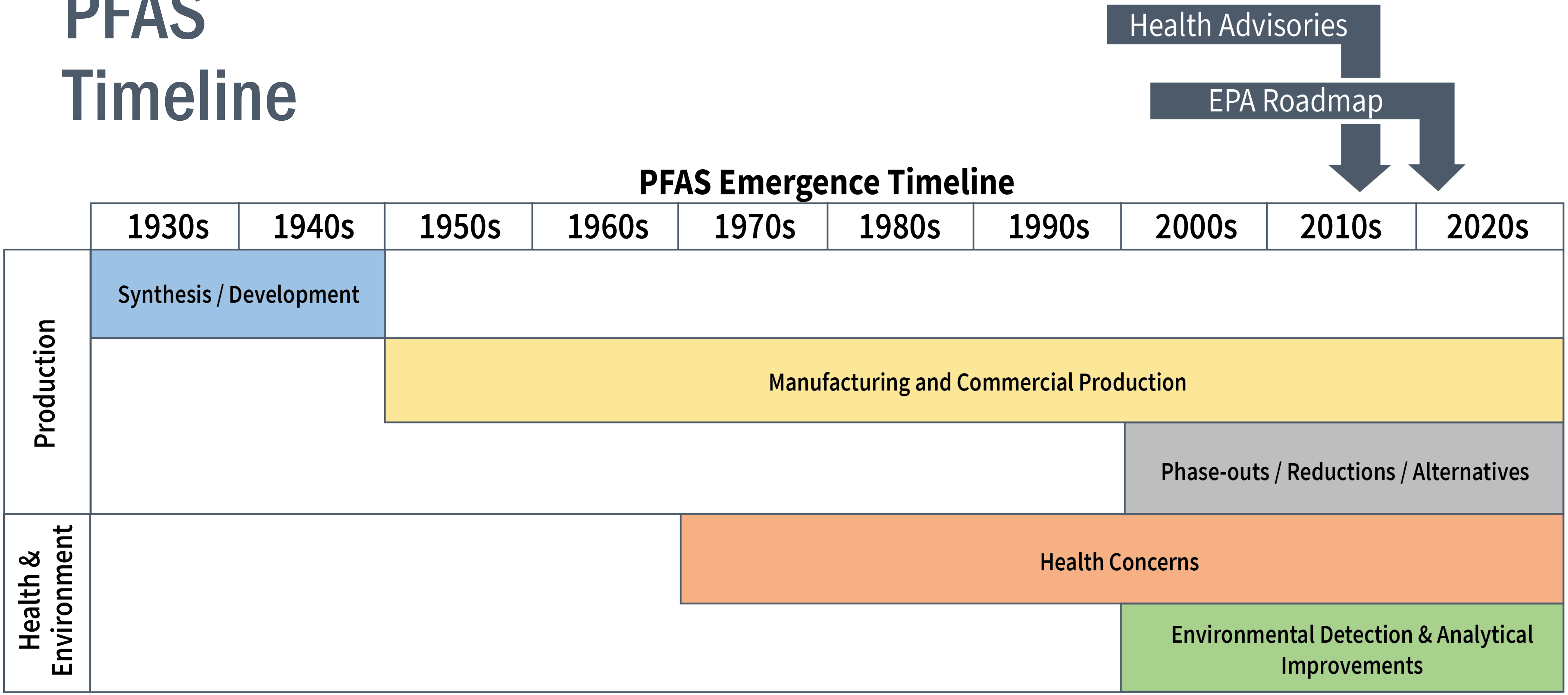


Blake and Fenton, Early life exposure to per- and polyfluoroalkyl substances (PFAS) and latent health outcomes: A review including the placenta as a target tissue and possible driver of peri- ad postnatal effects. Toxicology, Vol 443, Oct 2020. https://www.sciencedirect.com/science/article/abs/pii/S0300483X20302043

Context & History

- Since 1950s, more than 11,000 individual PFAS on the market, with 200 different use categories
- Environmentally persistent, cycling between air, water, soil, and biota – dubbed "forever chemicals"
- Found in blood, food, water, air, fish and soil worldwide

PFAS Timeline



https://pfas-1.itrcweb.org/2-pfas-chemistry-and-naming-conventions-history-and-use-of-pfas-and-sources-of-pfas-releases-to-the-environment-overview/

PFAS Sub-classes – Setting the Stage

Polymers vs. Non-polymers

- PFAS
  - Non-polymers
    - Perfluoroalkyl substances
    - Polyfluoroalkyl substances
  - Polymers
    - Fluoropolymers & Polymeric Perfluoropolyethers
      - Fluorinated urethanes
      - Fluorinated acrylates/ methylacrylates
      - Fluorinated oxetanes

PFAS Sub-classes – Setting the Stage

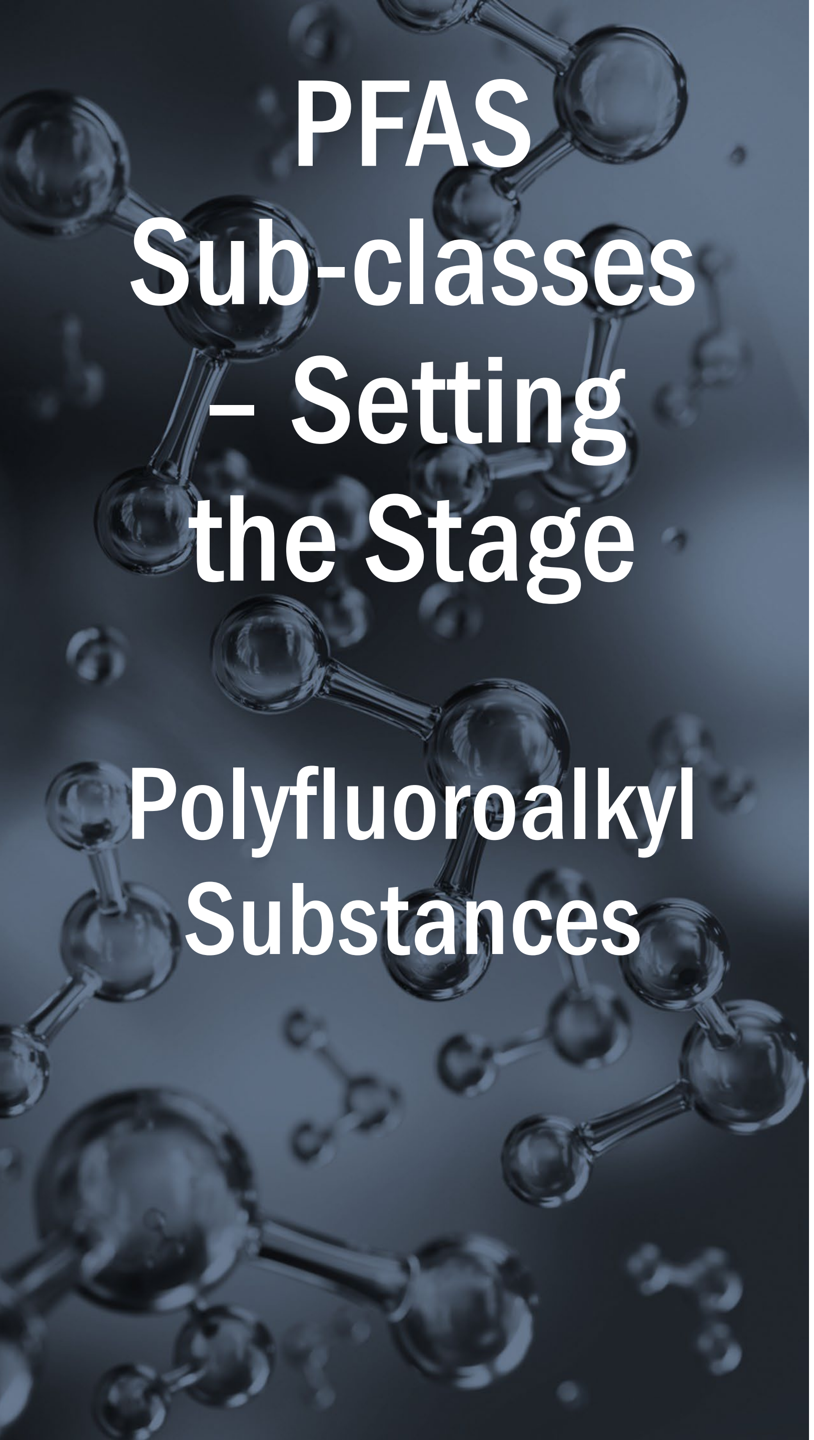
Perfluoroalkyl Substances

Perfluoroalkyl Substances
(all H atoms on all C atoms in alkyl chain attached to a functional group have been replaced with F)

- Perfluoroalkyl acids (PFAAs) [a]
  - Perfluoroalkyl carboxylic acids/ Perfluoroalkyl carboxylates (PFCAs) [1, a, 5]
  - Perfluoroalkane sulfonic acids/ Perfluoroalkane sulfonates (PFSAs) [1, b]
  - Perfluoroalkane sulfinic acids (PFSiAs) [2, b]
  - Perfluoroalkyl phosphonic acids (PFPAs) [1, c]
  - Perfluoroalkyl phosphinic acids (PFPiAs) [1, c]
- Perfluoroalkyl ether acids [d]
  - Perfluoroalkyl ether sulfonic acids (PFESAs) [5, d]
  - Perfluoroalkyl ether carboxylic acids (PFECAs) [5, d]
- Perfluoroalkane sulfonyl fluorides (PASFs) [3, b]
- Perfluoroalkane sulfonamides (FASAs) [2, b]
- Perfluoroalkanoyl fluorides (PFAs) [3, b]
- Perfluoroalkyl iodides (PFAIs) (Telomer A) [7, c]
- Perfluoroalkyl aldehydes (PFALs) [2, c]

PASFs, FASAs, PFAs, PFAIs, and PFALs are identified as "precursors" – they break down in the environment to shorter-chain PFAS

Taken from: https://pfas-1.itrcweb.org/wp-content/uploads/2021/12/PFAS_figure_2-4_family_tree_w_header_120221.pdf



PFAS Sub-classes – Setting the Stage

Polyfluoroalkyl Substances

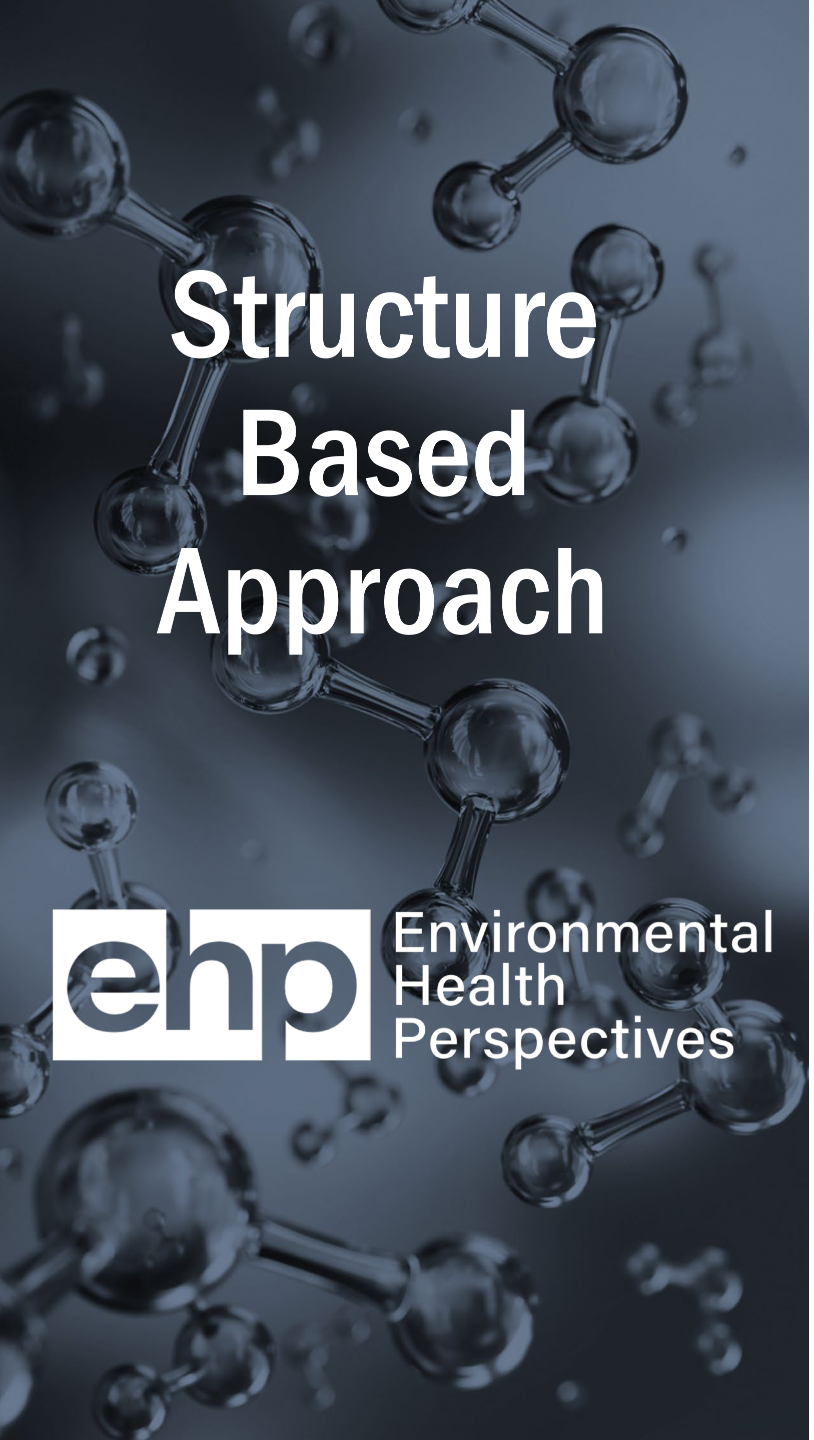
Polyfluoroalkyl Substances
(all H atoms on at least one (but not all) C atoms have been replaced with F)

- Polyfluoroalkyl ether acids [d]
  - Polyfluoroalkyl ether sulfonic acids (PFESAs) [5, d]
  - Polyfluoroalkyl ether carboxylic acids (PFECAs) [5, d]
- Chloropolyfluoroalkyl ether acids [2, d]
- Chloropolyfluoroalkyl acids [1, d]
- Fluorotelomer substances [c]
  - n:2 Fluorotelomer sulfonic acids (FTSAs) [1, 2, c]
  - n:2 or n:3 Fluorotelomer carboxylic acids and unsaturated carboxylic acids (FTCAs and FTUCAs) [2, (2), c]
  - n:2 Fluorotelomer alcohols (FTOHs) [7, (2), c]
  - n:2 Unsaturated Fluorotelomer alcohols (FTUOHs) [(2), c]
  - n:2 Fluorotelomer iodides (FTIs) (Telomer B) [7, c]
  - n:2 Fluorotelomer olefins (FTOs) [4, c]
  - Semifluorinated N-alkanes (SFAs) / alkenes (SFenes) [6, c]
  - n:2 Fluorotelomer acrylates/methacrylates (FTACs/FTMACs) [7, c]
  - n:2 Fluorotelomer aldehydes and unsaturated aldehydes (FTALs and FTUALs) [2, (2), c]
  - n:3 Saturated acids and n:3 unsaturated acids [2, c]
  - n:2 Polyfluoroalkyl phosphoric acid esters, polyfluoroalkyl phosphates, fluorotelomer phosphates (PAPs) [1, 10, c]
- Perfluoroalkane sulfonamido substances [2, 3, b]
  - N-Alkyl perfluoroalkane sulfonamides (MeFASAs, EtFASAs, BuFASAs) [3, b]
  - Perfluoroalkane sulfonamido ethanols (FASEs) and N-Alkyl perfluoroalkane sulfonamido ethanols (MeFASEs, EtFASEs, BuFASEs) [3, b]
  - N-Alkyl perfluoroalkane sulfonamidoethyl acrylates/methacrylates (MeFAS(M)ACs,EtFAS(M)ACs, BuFAS(M)ACs) [3,b]
  - Perfluoroalkane sulfonamido acetic acids (FASAAs) and N-Alkyl perfluoroalkane sulfonamido acetic acids (MeFASAAs, EtFASAAs, BuFASAAs) [2, b]

All polyfluoroalkyl substances have the potential to break down to perfluoralkyl substances (shorter chain analytes).

Taken from: https://pfas-1.itrcweb.org/wp-content/uploads/2021/12/PFAS_figure_2-4_family_tree_w_header_120221.pdf

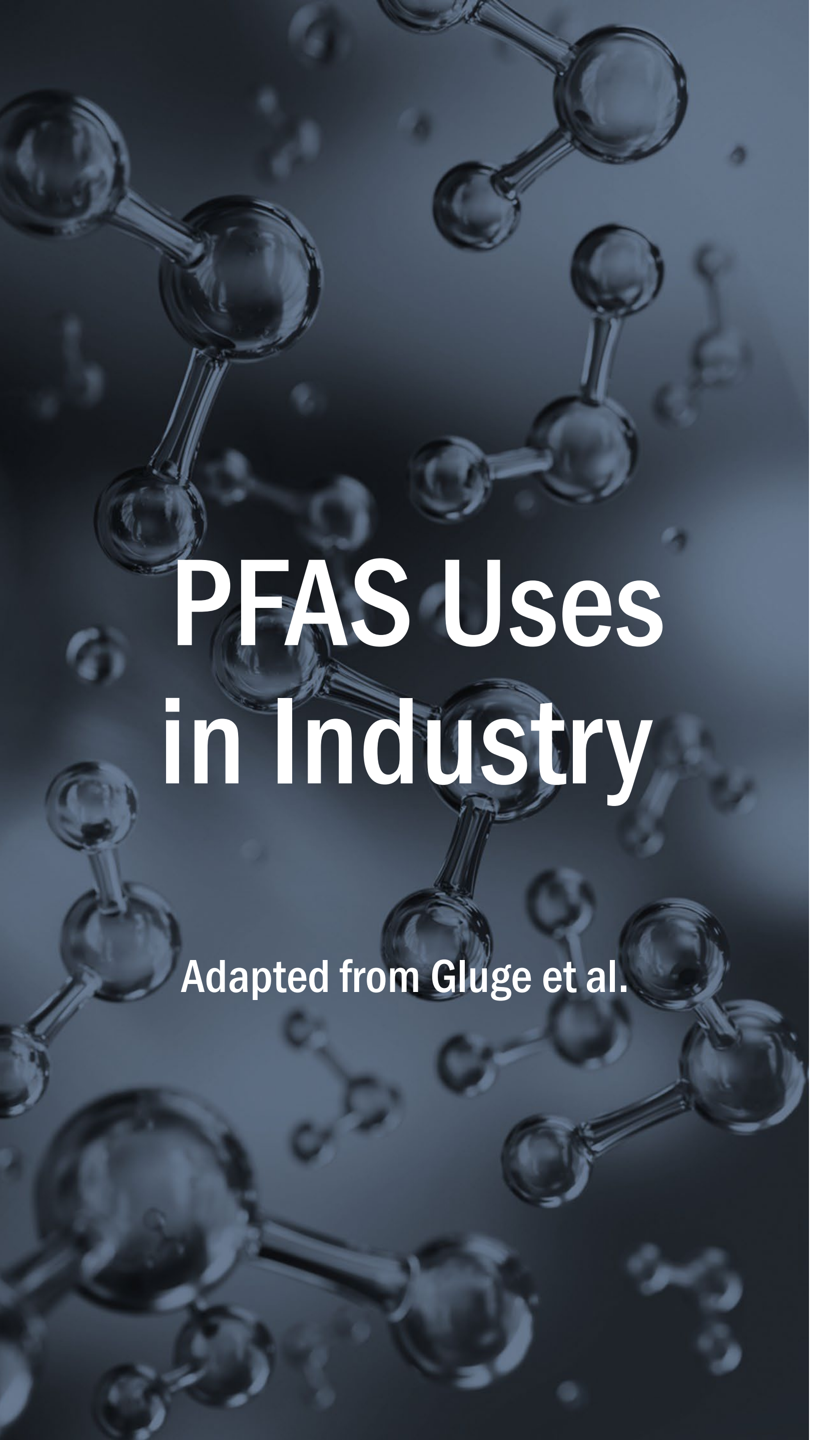
Structure Based Approach



- EPA/National toxicology Program/National Institute of Environmental Health Sciences (NIEHS) approach to structure-based testing being used to optimize PFAS testing
- Aims to capture structural diversity across PFAS family – particularly PFAS groups not previously analyzed
- Identified 75 chemicals for targeted testing
- Currently in development; while this is underway, EPA has been developing criteria for specific PFAS analytes

https://www.epa.gov/sciencematters/epa-and-partners-describe-chemical-category-prioritization-approach-select-75-pfas

https://ehp.niehs.nih.gov/doi/pdf/10.1289/EHP4555



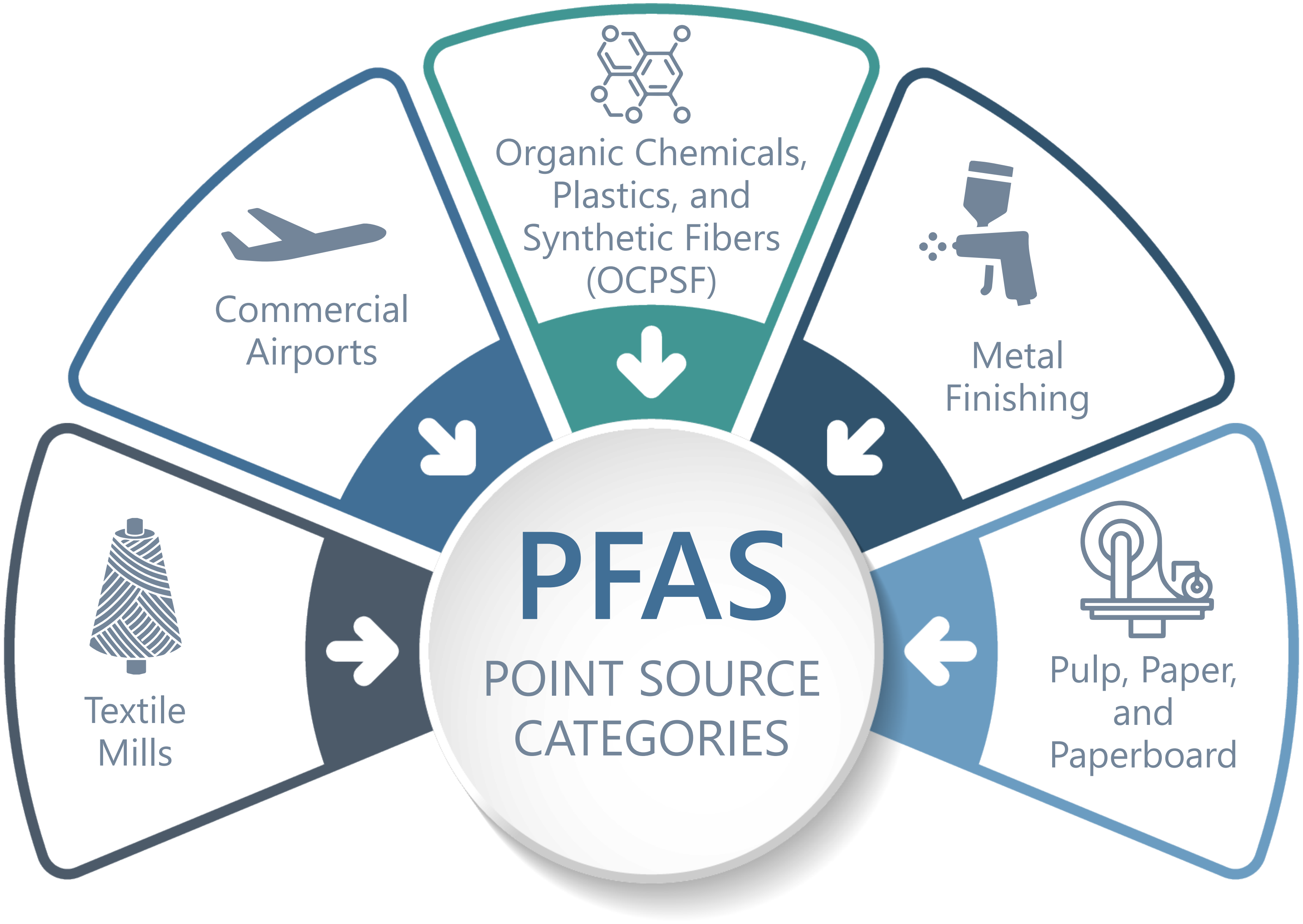
PFAS Uses in Industry

Adapted from Gluge et al.

Industry branches		
Aerospace (7)	Food production industry	Pharmaceutical industry
Biotechnology (2)	**Machinery and equipment**	Photographic industry (2)
Building and construction (5)	Manufacture of metal products (7)	Production of plastic and rubber (5)
Chemical industry (8)	Mining (3)	Semiconductor industry (11)
Electroplating (2)	Nuclear industry	Textile production (2)
Electronic industry (6)	Oil & gas industry (7)	Watchmaking industry
Energy sector (10)		

Other use categories		
Aerosol propellants	Glass (3)	**Pipes, pumps, fittings and liners**
Air conditioning	Household applications	Plastic and rubber (3)
Antifoaming agent	Laboratory supplies, equipment and	Printing (4)
Ammunition	instrumentation (4)	Refrigerant systems
Apparel	Leather (4)	Resins (3)
Automotive (12)	Lubricants and greases (2)	Sealants and adhesives (2)
Cleaning compositions (6)	Medical utensils (14)	Soldering (2)
Coatings, paints and varnishes (3)	Metallic and ceramic surfaces	Soil remediation
Conservation of books and manuscripts	Music instruments (3)	Sport article (6)
Cookware	Optical devices (3)	Stone, concrete and tile
Dispersions	Paper and packaging (2)	Textile and upholstery (2)
Electronic devices (7)	Particle physics	Tracing and tagging (5)
Fingerprint development	Personal care products	Water and effluent treatment
Fire-fighting foam (5)	Pesticides (2)	Wire, cable insulation, gaskets, hoses
Flame retardants	Pharmaceuticals (2)	

EPA Multi-Industry PFAS Study

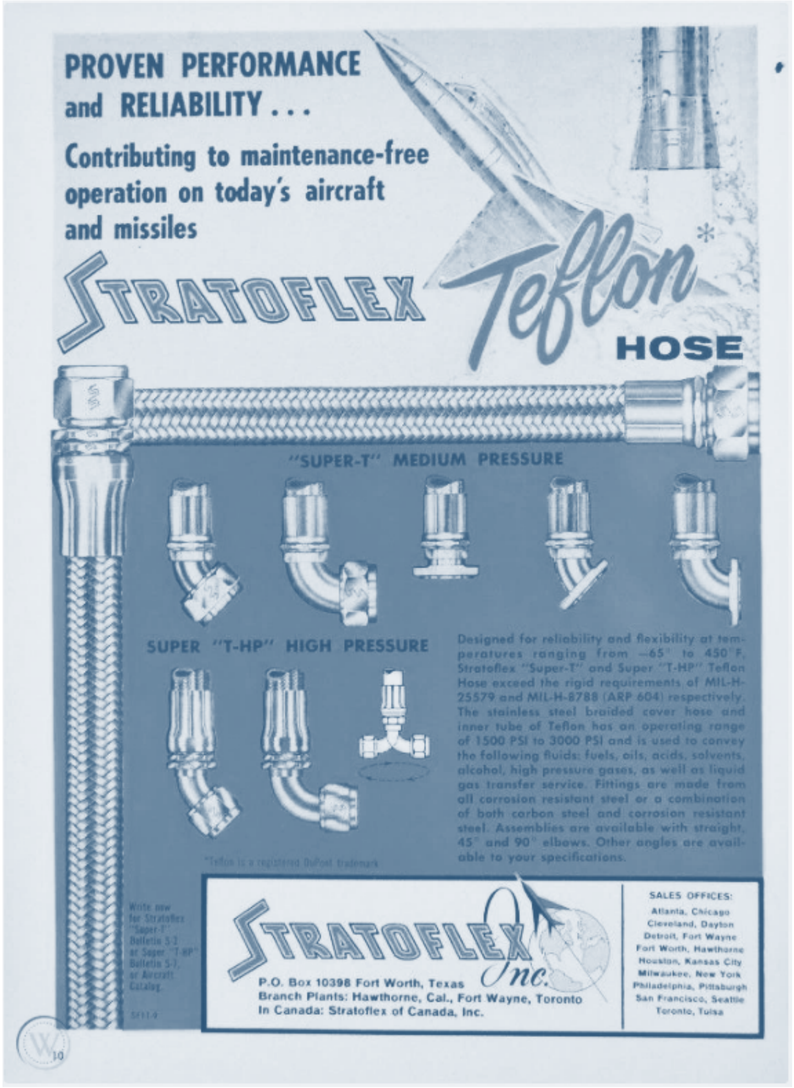


So where can we expect PFAS?... In the Facility....

Any process line which requires special:

- Oil/water/stain resistance
- Chemical/temperature resistance
- Reduce friction resistance
- Surfactant properties
- Wetting/antifoaming agent
- Mist suppressant
- Fire control/AFFF systems

So where is it, where are exposures occurring, and is it being discharged/ released?

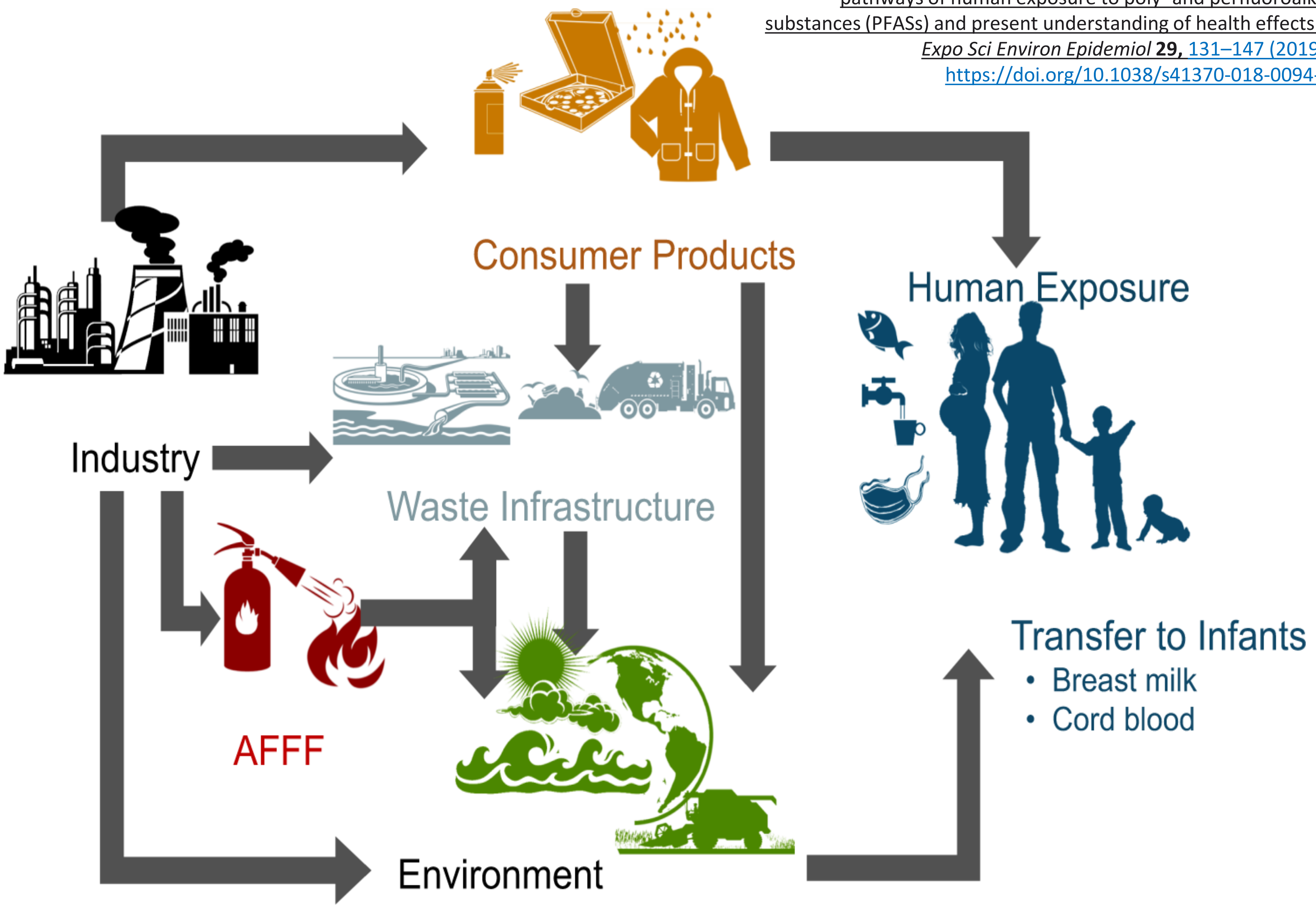


So where can we expect PFAS?... EVERYWHERE...

- Paper and packaging (microwave popcorn and other foods)
- Clothing and carpets (Scotchgard)
- Outdoor textiles and sporting equipment (e.g., ski/snowboard waxes)
- Non-stick cookware (Teflon)
- Cleaning agents and fabric softeners
- Polishes, waxes, varnishes, dyes, inks, latex and marine paints
- Adhesives
- Pesticides and herbicides
- Medical products
- Personal care products

Significance?

Sunderland, E.M., Hu, X.C., Dassuncao, C. *et al.* A review of the pathways of human exposure to poly- and perfluoroalkyl substances (PFASs) and present understanding of health effects. *J Expo Sci Environ Epidemiol* **29,** 131–147 (2019). https://doi.org/10.1038/s41370-018-0094-1



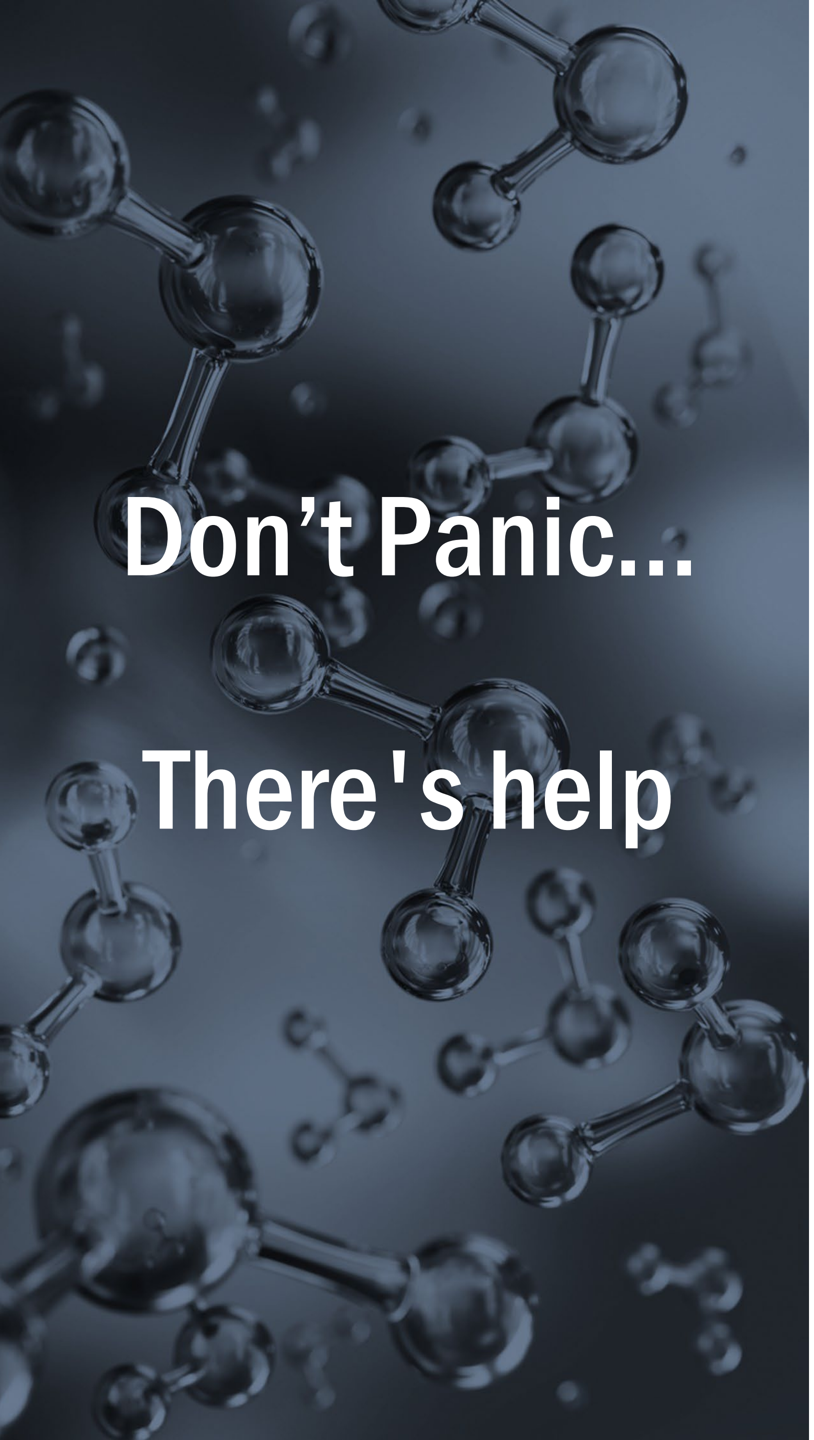
PFAS are complex

Experts
in specific PFAS issues

Technical/regulatory information is changing rapidly

Identify Questions & Data Gaps

Pending Impacts
to processes, IH, waste management



Just remember:

There are a vast number of sites with PFAS-related information available on the internet

For the most reliable information, check regulatory sites and technical organizations

Questions?

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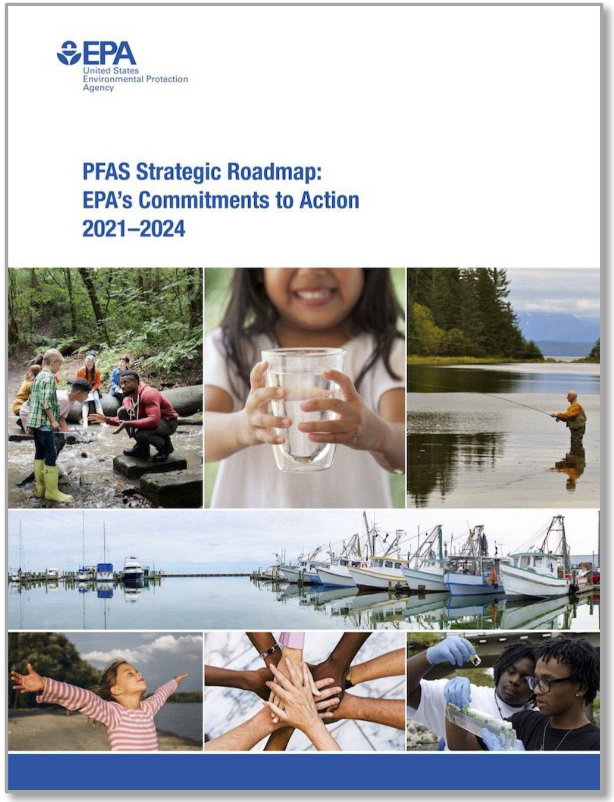
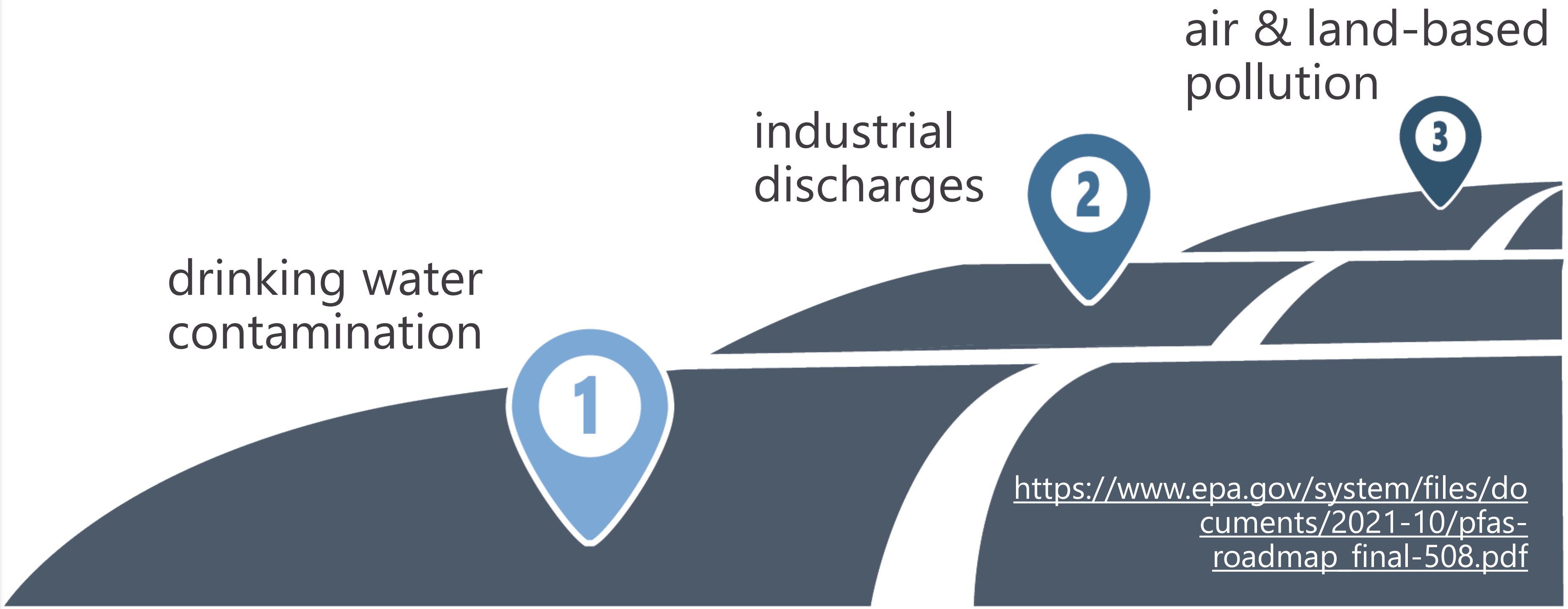
EPA's PFAS Strategic Roadmap

- Lays out anticipated regulatory actions from a federal perspective.
- Focus is on PFOA and PFOS, but EPA may regulate PFAS as a class or sub-classes of chemicals.





https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf

CERCLA/RCRA

PROPOSED DESIGNATION

EPA to designate PFOA/ PFOS *hazardous substances* under CERCLA (Superfund).

Final rule expected late 2023

RAMIFICATIONS

Investigation & Remediation of PFOA/PFOS contaminated sites

Reopening previously closed Sites

IMPACTS?

Waste management and disposal of PFOA/PFOS, requiring special handling and increasing costs.

Safe Drinking Water Act

1

EPA developing preliminary Maximum Contaminant Level Goals (MCLGs) for PFOA/PFOS. MCLGs in parts per quadrillion

Expected Fall 2022

2

EPA working on health advisories (HAs), interim, non-enforceable screening levels for PFBS and HFPO-DA in water.

3

EPA is implementing UCMR5, requiring water purveyors to collect PFAS data between 2023-2025. Will provide data on exposure in drinking water.

Preliminary Effluent Guidelines Program Plan 15

EPA to revise limits for Organic Chemicals, Plastics, and Synthetic Fibers (OCPSF) and chromium platers; begin studies on landfills and textile mills.

Clean Water Act

NPDES

Primary mechanism for controlling discharges of pollutants to receiving waters.

A few permits already include PFAS, expected to grow.

WQC

Criteria for aquatic life due in 2022. Will result in PFAS inclusion in permits and ecological risk assessments for aquatic species.

Clean Air Act

1

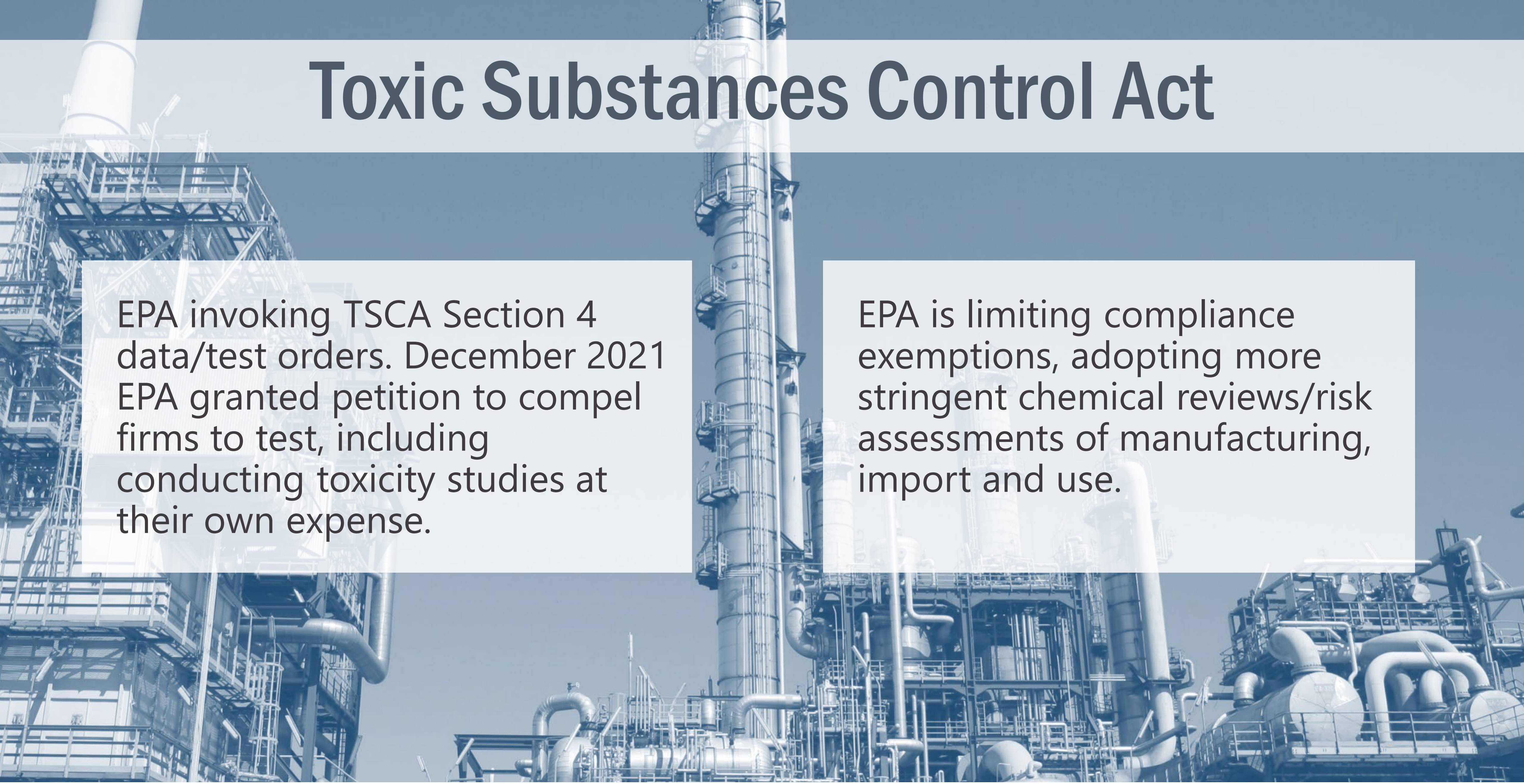
CAA currently does not list PFAS; EPA currently building dataset to address.

2

EPA currently evaluating air emissions controls.

3

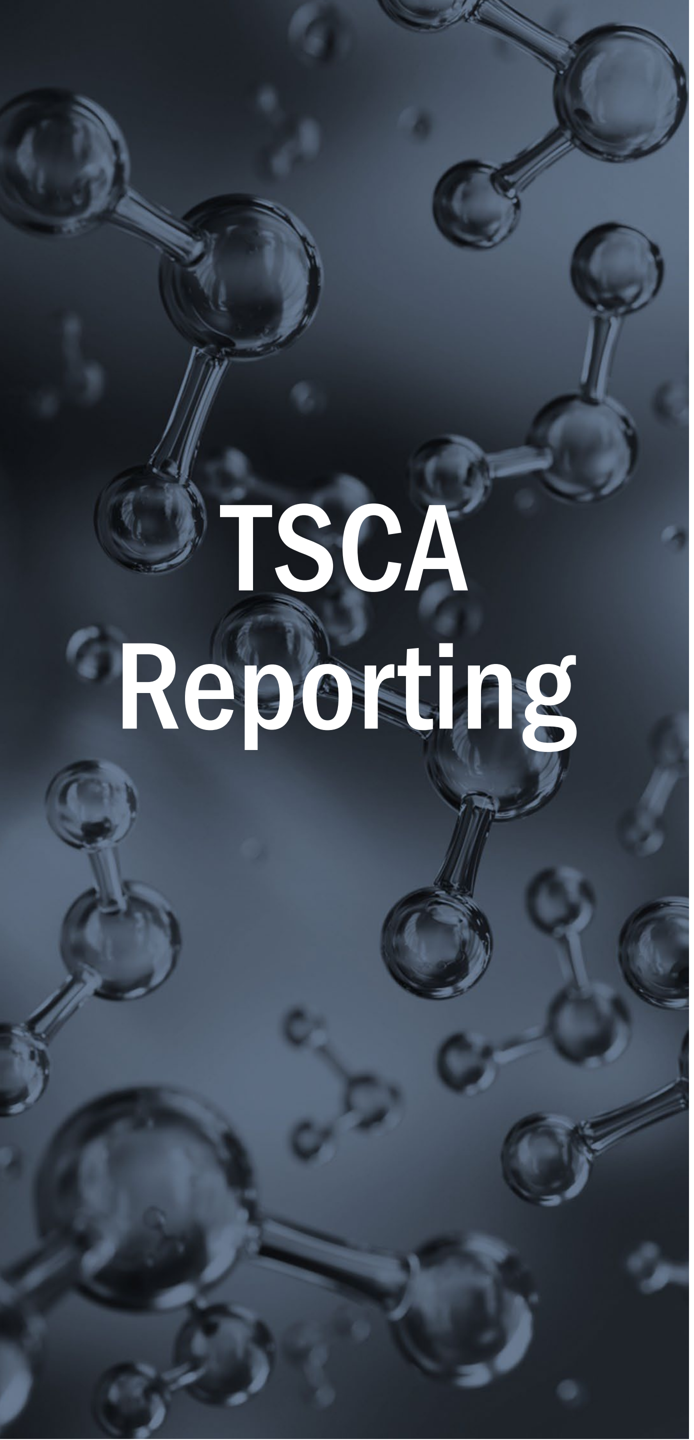
Pending PROTECT Act would list PFOA, PFOS, PFBA and HFPO-DA as hazardous air pollutants.



Toxic Substances Control Act

EPA invoking TSCA Section 4 data/test orders. December 2021 EPA granted petition to compel firms to test, including conducting toxicity studies at their own expense.

EPA is limiting compliance exemptions, adopting more stringent chemical reviews/risk assessments of manufacturing, import and use.

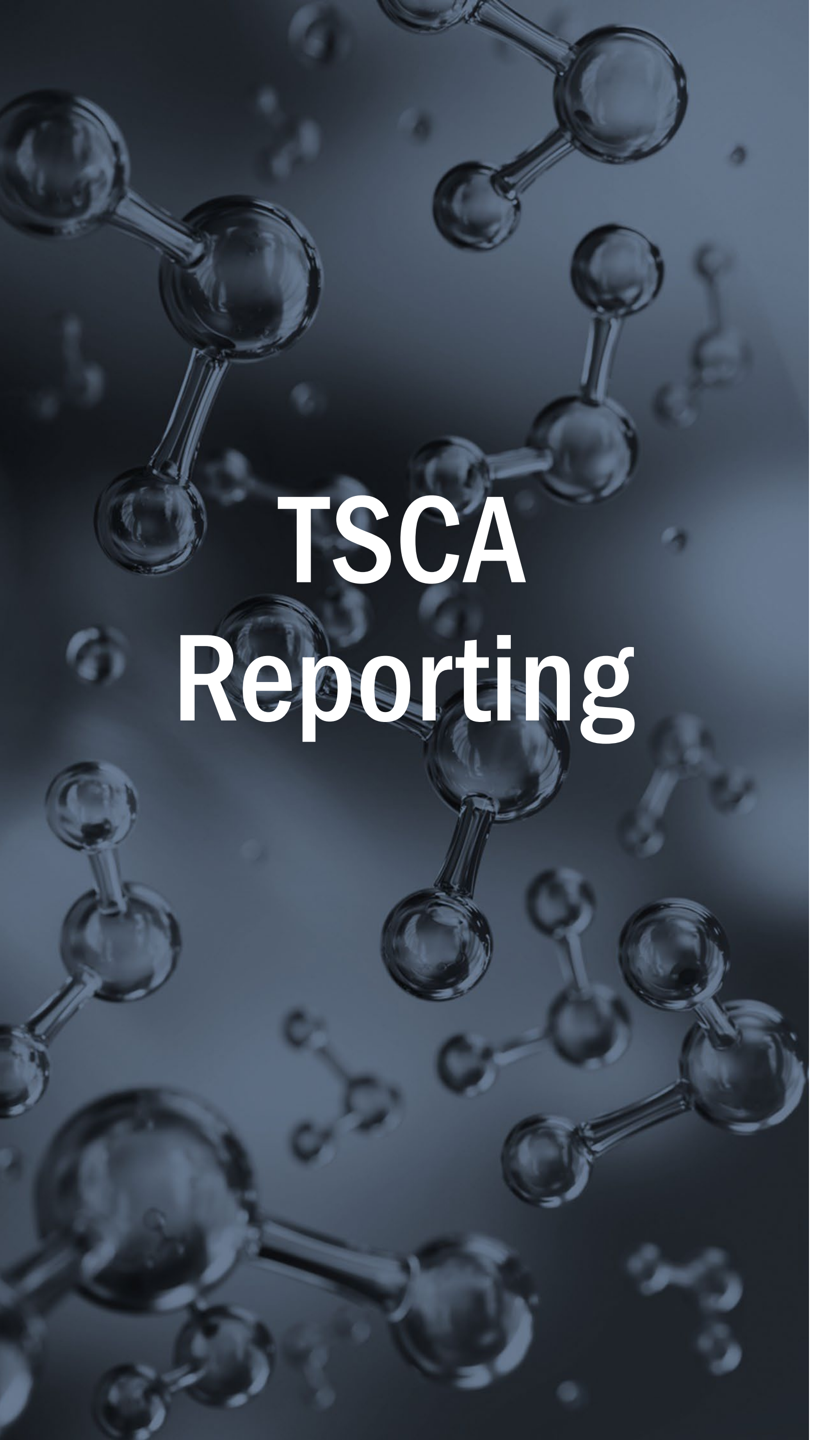


TSCA Reporting

The manufacture of PFAS as a byproduct is not exempt for the purpose of this proposed rule. (NAICS) code categories expected to be most affected include:

- NAICS 324—Petroleum and Coal Product Manufacturing;
- NAICS 325—Chemical Manufacturing;
- NAICS 326113—Unlaminated Plastics Film/Sheet (not Packaging) Manufacturing;
- NAICS 327910—Abrasive Product Manufacturing;
- NAICS 333999—All Other Misc. General Purpose Machinery Manufacturing;
- NAICS 334511—Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing;
- NAICS 336111—Automobile Manufacturing;
- NAICS 423510—Metal Service Centers/Other Metal Merchant Wholesalers;
- NAICS 424690—Other Chemical and Allied Products Merchant Wholesalers;
- NAICS 447190—Other Gasoline Stations;
- NAICS 551112—Offices of Other Holding Companies;
- NAICS 562—Waste Management and Remediation Services

https://www.regulations.gov/document/EPA-HQ-OPPT-2020-0549-0001



TSCA Reporting

- **Rule will impact large number of companies** by applying TSCA regulatory reporting requirements **to at least 1,364 PFAS** chemicals and mixtures manufactured or imported in any year since 2011
- No out for small business – TSCA provides no exemption in this rule for small business, even importers
- If you are working in any of the NAICS categories, you will need to know what your PFAS “exposure” (pun intended) **really** is, and that may take some research, planning, and consultation with PFAS experts

https://www.icemiller.com/blogs/ice-miller-blog/february-2022/epa-seeks-small-business-input-on-pfas-reporting-a/

Toxics Release Inventory

2022
TRI UPDATES
JAN 2022

2023
REPORTING
JULY 2023

FUTURE
FUTURE
PLANS

EPA added four more PFAS to the TRI, now totaling 179.

Facilities with >100 pounds annually track usage as of January 1, 2022; report July 1, 2023.

Plans to add more PFAS and reporting requirements (e.g., removing de minimis exemptions).

Moving Target…

More Regulations to come

- PFAS Action Act of 2021 tries to accelerate PFAS regulatory actions
  - Passed in the House April 2021
  - Currently with Senate Committee on Environment and Public Works
- Other laws proposed at state and federal levels which address some or all of the regulatory actions we've just discussed
- Lots of movement across regulatory agencies
- Significant effects to businesses using PFAS compounds in products or manufacturing processes

For a long time, folks have considered PFAS an "AFFF Problem", for investigation/remediation only – these rules are game changers for everyone using PFAS in their processes.

Due diligence

New ASTM standard

- On November 1, 2021, ASTM International approved an updated standard for Phase I environmental site assessments (ESAs, ASTM E1527-21. It includes options for emerging contaminants, e.g., PFAS which will need to be considered once designated a hazardous substance under CERCLA.
- Until then, prospective purchasers may elect to consider PFAS as a non-scope item. Some questions to consider:
  - Is PFAS used in manufacturing processes?
  - Are there possible PFAS issues from a prior business?
  - Has the property ever had a fire that required AFFF?
- Discuss PFAS potential with your legal team and with your Phase I/ESA team, who can pull in PFAS experts

https://www.natlawreview.com/article/pfas-action-act-2021-moves-forward-how-significant-progress
https://www.jdsupra.com/legalnews/welcome-astm-e1527-21-new-phase-i-2714901/

And in Florida?

- FDEP's PFAS Dynamic Plan, updated March 2022
  - Currently at research/ coordination stage
  - Presents path forward for PFAS investigations at direction of state
  - Sites prioritized based on current/historical use (DoD, fire-training, etc.) and receptors (wells, human, ecological, etc.)
  - FL-specific provisional screening/cleanup levels already in place
- Bill for PFAS actions pending; will impact Florida Industry.

PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

DYNAMIC PLAN

Division of Waste Management

Florida Department of Environmental Protection

March 2022

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

https://floridadep.gov/sites/default/files/Dynamic_Plan_March_2022.pdf

Questions?

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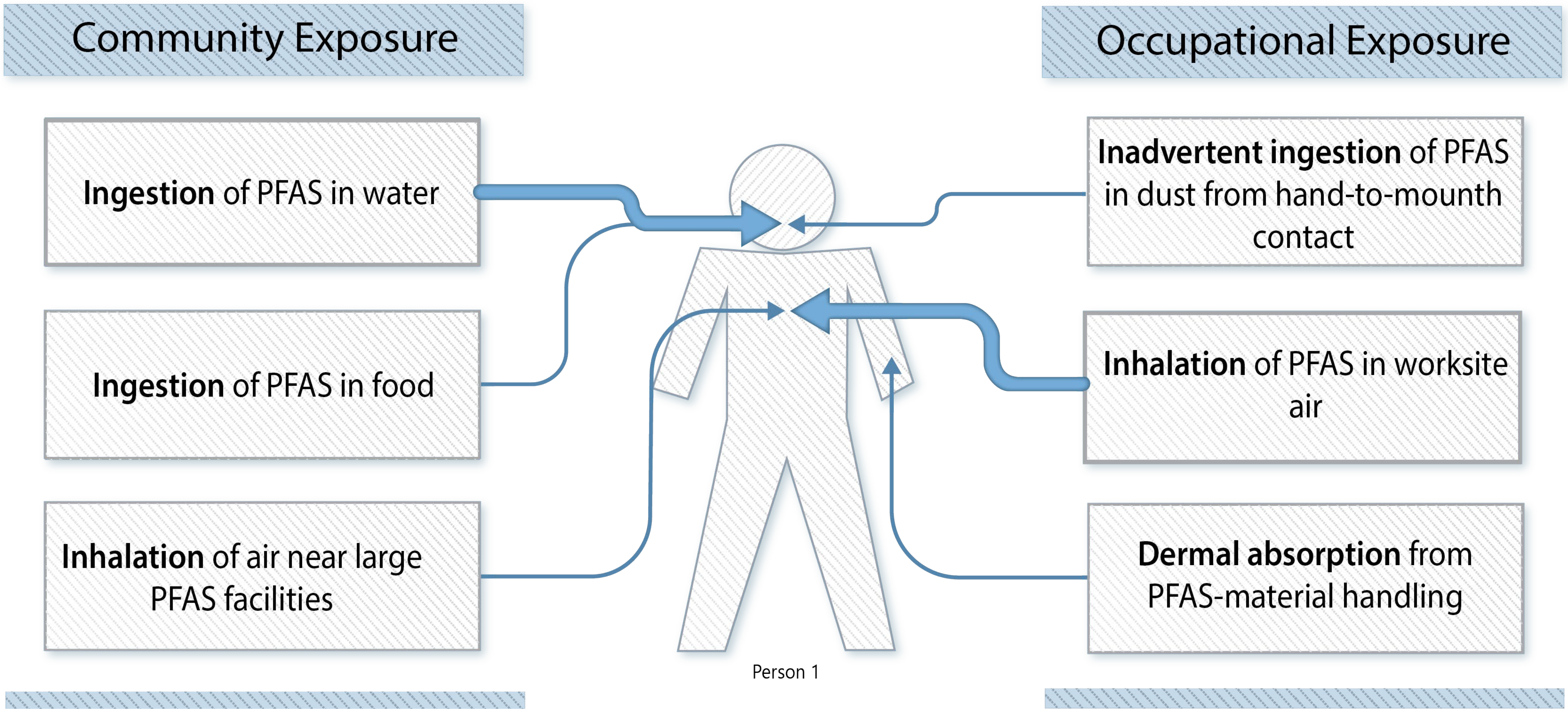
PFAS Exposure Routes and Pathways



Taken from: Piacento. Emerging Issues: NIOSH Update. Presentation to the California Industrial Hygiene Council. 5 Dec 2019.

High volume/exposure potential

Primary, secondary, or combined PFAS manufacturing industries.

Taken from: Piacento. Emerging Issues: NIOSH Update. Presentation to the California Industrial Hygiene Council. 5 Dec 2019.

Example Occupations

- PFAS manufacturer production assistant
- Manufacturer production assistant where PFAS is a byproduct
- Textile or paper manufacturer production assistant

Moderate volume/exposure potential

Industries where PFAS-product use involves transformation, aerosolization, raw compounds, or contact with the compound in/as a waste product

Example Occupations

- Ski wax technician
- Firefighter
- Environmental remediation worker

Low volume/exposure potential

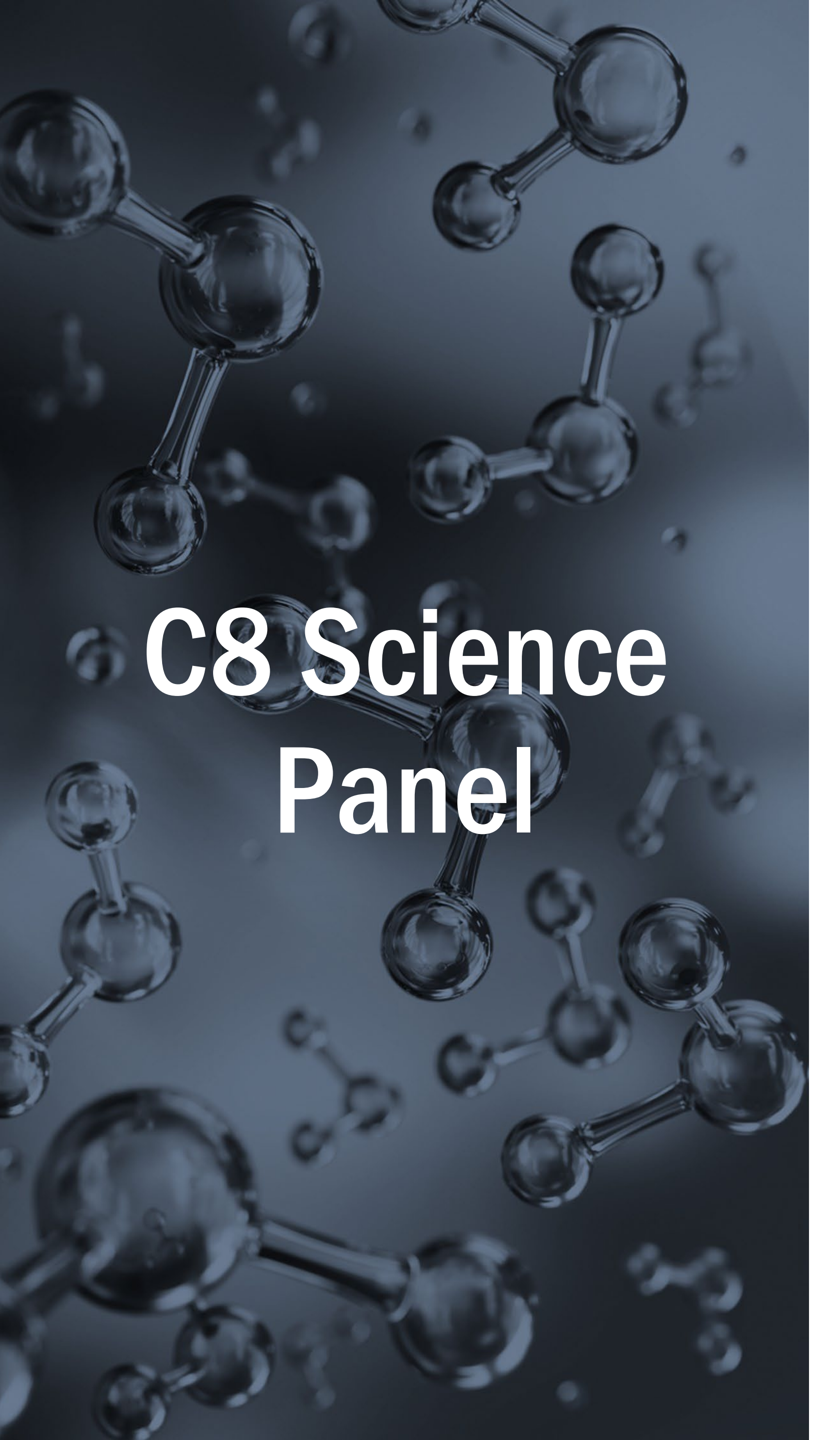
Industries where PFAS-product use does not involve transformation, aerosolization or raw compounds

Example Occupations

- Cosmetologist
- Fast food handler
- Environmental remediation worker

"Research suggests exposure to some PFAS might result in harmful health outcomes, including cancer, increased cholesterol levels, and immune system effects."

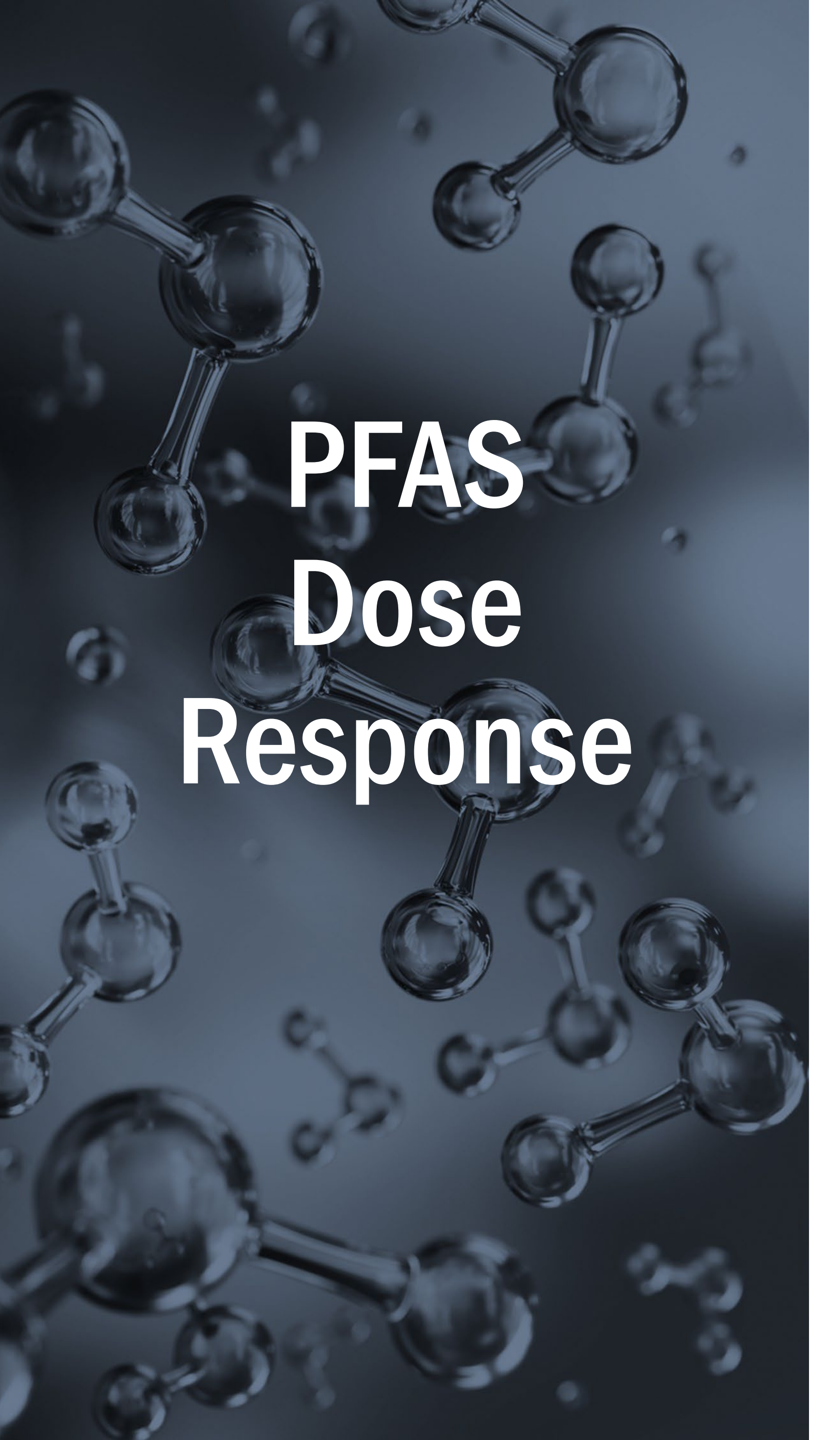
https://www.cdc.gov/niosh/topics/pfas/



C8 Science Panel

- Exposure/health studies conducted 2005-2013.
- Focused on Mid-Ohio Valley communities potentially affected by releases of PFOA (or C8) emitted since the 1950s from Washington Works in Parkersburg, West Virginia.
- ***For six disease categories, Panel concluded that there was a Probable Link to C8 exposure and diagnosed high cholesterol, ulcerative colitis, thyroid disease, testicular cancer, kidney cancer, and pregnancy-induced hypertension.***

http://www.c8sciencepanel.org/



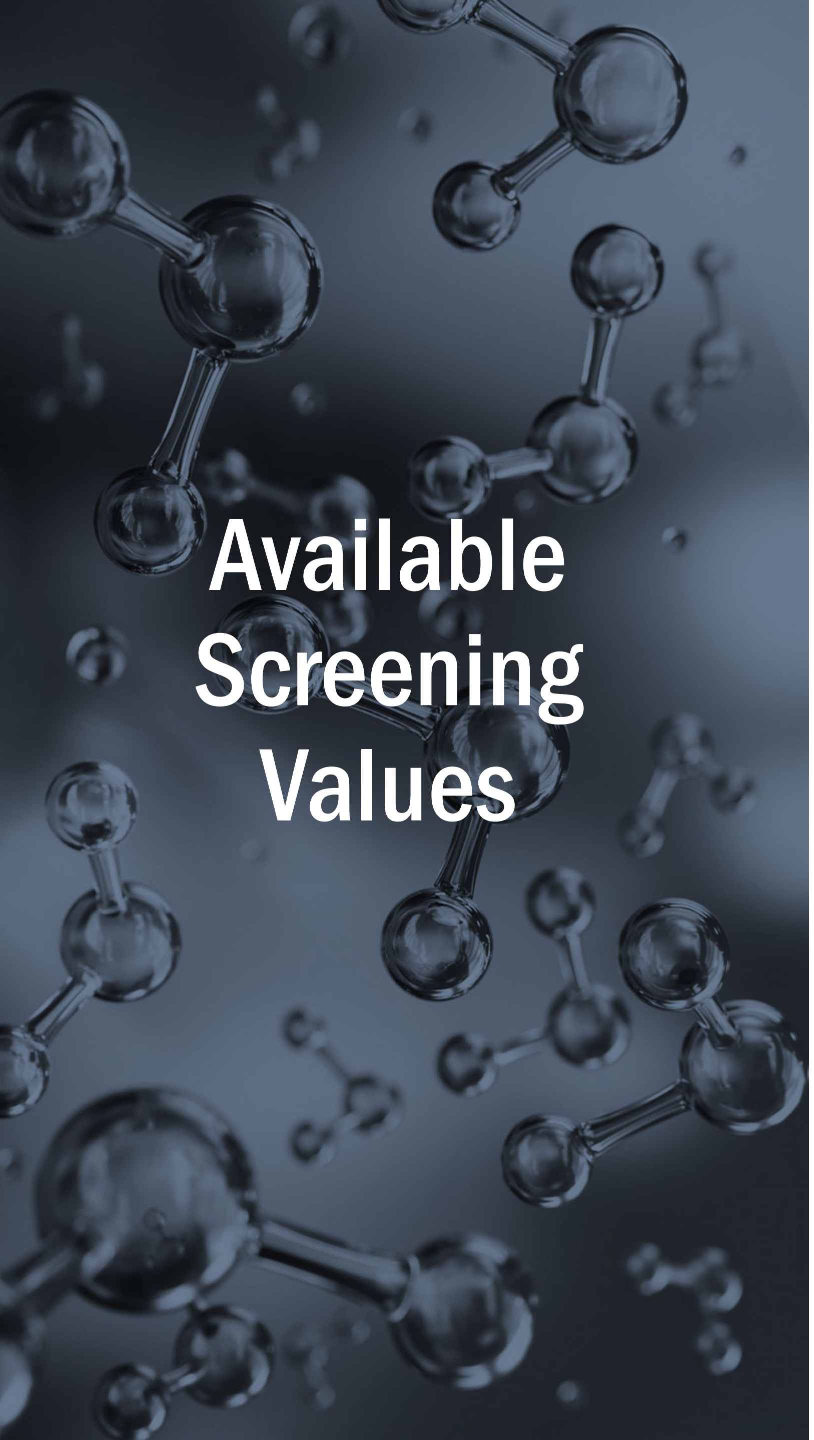
PFAS Dose Response

Not a traditional dose-response model

Chronic dose of small amounts increase body burden

At what point does the body burden result in response?

Responses not well defined



Available Screening Values

PFAS	ACGIH Value
APFO	0.01 mg/m3 Category 2 carcinogen
PFOA	No ACGIH TLV has been established. IARC – 2B Human Carcinogen German DFG Occupational Exposure Limit: 0.005 mg/m^3 Inhalable Fraction 8-hour Time-Weighted Average Maximum Concentration at the Workplace (AK)
Perfluoroisobutylene	0.01 ppm Ceiling Limit TLV (Not to be exceeded at anytime during a work shift) Upper Respiratory Tract (URT) Irritations Hematological Effects
Perfluorobutyl ethylene	100 ppm: 8-hour Time-Weighted Average TLV Hematological Effects

At Risk Occupational Populations

1

Firefighters

2

Chemical Manufacturing Workers

3

Professional Ski Waxers

PFAS Firefighter Exposure

Exposure Sources

- Turnout Gear Waterproofing
- Class B Foams (AFFF)

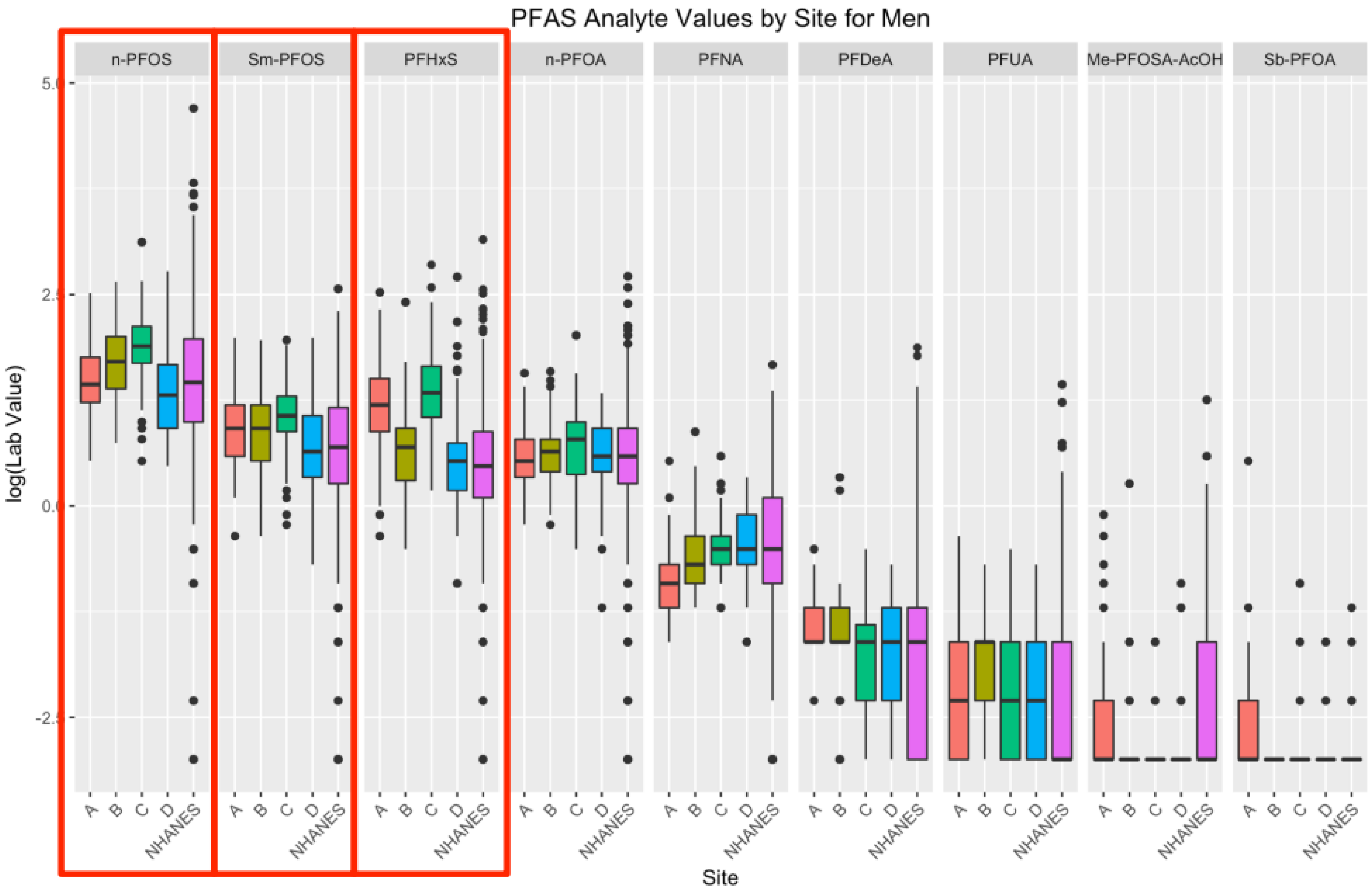
Exposure Pathways

- Inhalation
- Dermal
- Ingestion

What exposure studies have shown to date…

Firefighters

Serum PFAS in municipal firefighters & NHANES



National Health and Nutrition Examination Survey (NHANES), part of the CDC, assesses the health status of US adults and children

PFAS Exposure and Epigenetics in the Fire Fighter Cancer Cohort Study, Jeff Burgess, MD, MS, MPH U of Arizona, Jackie Goodrich, PHD U of Michigan at https://www.healthandenvironment.org/assets/images/webinarimages/Goodrich_Burgess_Presentation.pdf

Exposure Burden of Firefighters

Exposures to multiple hazards

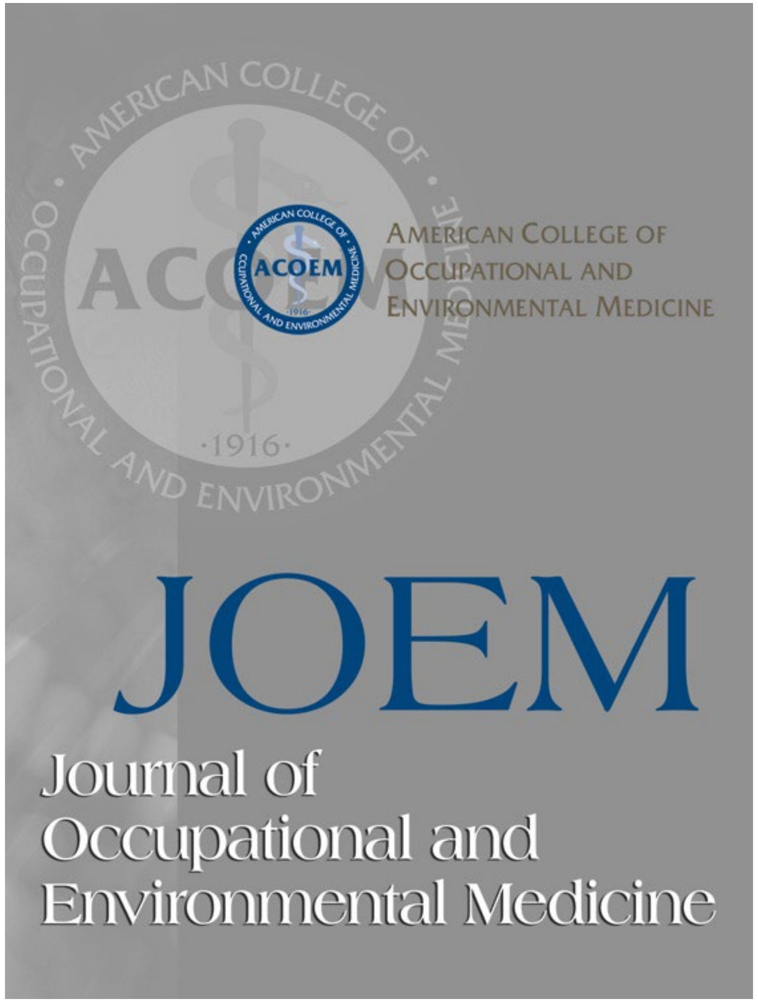
- Heat
- Stress
- Flame-retardant chemicals (PFAS in AFFF)
- Smoke/polycyclic aromatic hydrocarbons
- Other chemicals released from burning structures
- Shiftwork

Exposures vary by job/tasks

- Structural
- Aircraft rescue & firefighting
- Wildland-urban interface
- Trainers
- Investigators

Concentration Levels in Firefighters vs. Normal Adult Males

- Perfluorodecanoic acid (PFDA) concentrations were three times higher in this firefighter group than in NHANES adult males.
- PFOA and PFOS levels were only slightly higher in the firefighter group.



[Journal of Occupational and Environmental Medicine: January 2015 - Volume 57 - Issue 1 - p 88-97]

Concentration Levels in Women Firefighters vs. Office Workers

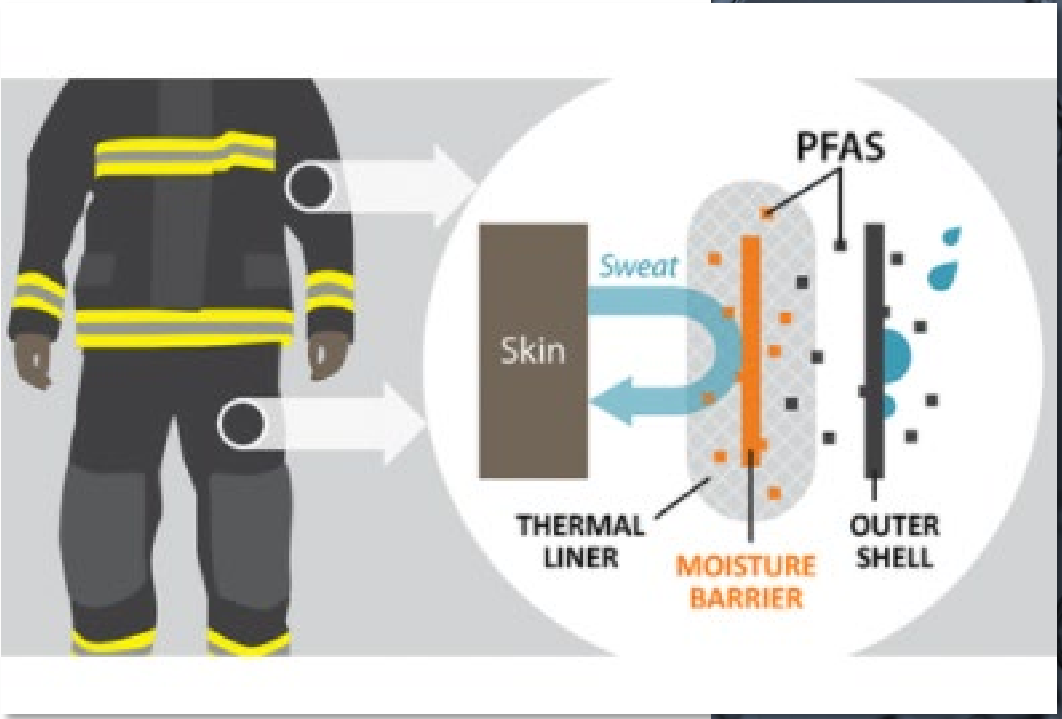
Women Firefighters Biomonitoring Collaborative created a biological sample archive and analyzed levels of PFAS among women firefighters and office workers in San Francisco.

- Firefighters and officers have higher PFNA, PFOA, PFDA, and PFUnDA levels compared to drivers.
- Women firefighters are exposed to higher levels of some PFAS compared to office workers.
- No association with PFAS exposures and health outcomes

https://www.biomonitoringcollaborative.org/wfbc

Firefighter Litigation

- Recent work studying PFAS in firefighter turnout gear
  - PFAS exposures in gear
  - PFAS migration into untreated material over time (i.e., into direct contact with skin)
  - PFAS exposures from dusts in turnout gear storage areas
- Current lawsuits against companies manufacturing the gear - 3M and DuPont
- PFAS is still required in turnout gear, per NFPA standards



https://pubs.acs.org/doi/abs/10.1021/acs.estlett.0c00410
https://trulaw.com/firefighter-turnout-gear-lawsuit/

PFAS in Class B Foams (AFFF) or other compounds…

How Can You Tell?

- PFAS is still used in AFFF which needs to meet MILSPEC requirements
- Anything that mentions fluorosurfactant, fluoroprotein, C6, or 'fluoro,' probably contains PFAS; however, **not all fluorinated surfactants are made of PFAS**.
- Safety Data Sheets (SDS) are not required to list PFAS, as it is **not (yet) considered a hazardous substance**. Moreover, SDSs may make a statement that PFOS is not used…that does not mean other PFAS are not present.
- We advise asking the manufacturer to provide analytical (in writing) demonstrating the PFAS content of the foam, in addition to the SDS.
- **Consider use of fluorine-free foam during a Pollution Prevention evaluation.**

https://www.michigan.gov/pfasresponse/0,9038,7-365-86514-496805--,00.html

Chemical Manufacturing Exposure[1,2]

Exposure Sources

- Manufacturing processes/wastes (e.g., filters)
- Wastewaters/sludges
- Air and airborne particles (dusts) in workplace and stack emissions
- Raw materials/containers

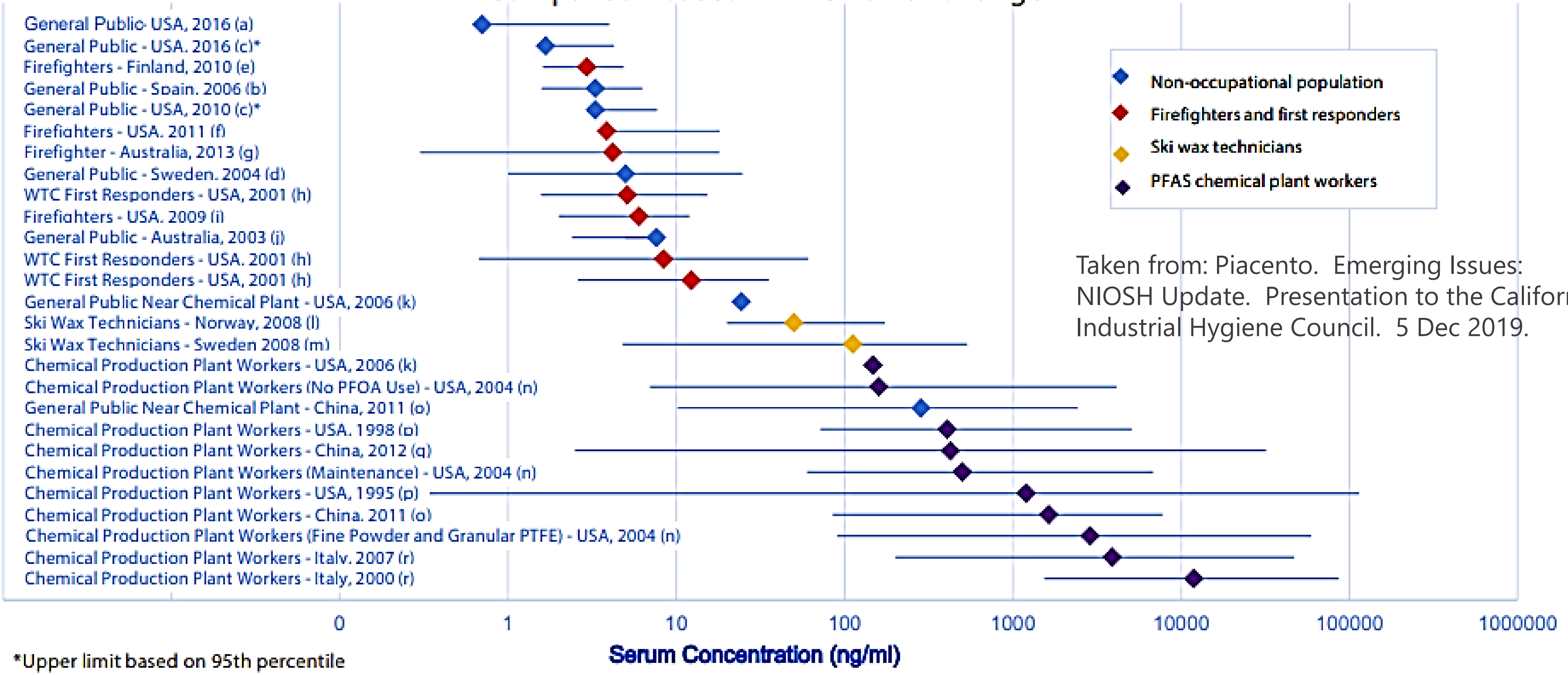
Exposure Pathways

- Inhalation
- Dermal
- Ingestion

[1] Heydebreck F, Tang, J, Xie Z, Ebinghaus R [2016]. Emissions of per- and polyfluoroalkyl substances in a textile manufacturing plant in China and their relevance for workers' exposure. Environ Sci Technol, 50(19), 10386-10396. doi:10.1021/acs.est.6b03213
[2] Olsen GW, Zobel LR [2007]. Assessment of lipid, hepatic, and thyroid parameters with serum perfluorooctanoate (PFOA) concentrations in fluorochemical production workers. International Archives of Occupational & Environmental Health, 81(2), 231-246.

Comparison of PFOA in Serum, Plasma, or Whole Blood by Population, Geographic Region, and Year of Most Recent Test

-Comparison based on median and range-



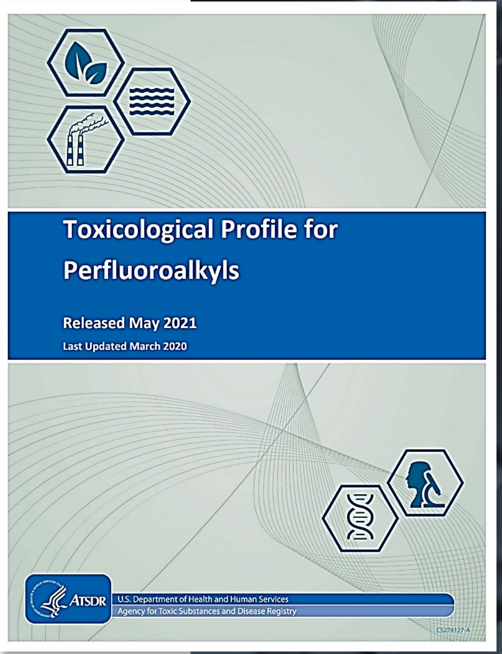
Taken from: Piacento. Emerging Issues: NIOSH Update. Presentation to the California Industrial Hygiene Council. 5 Dec 2019.

*Upper limit based on 95th percentile

(a) Kato et al., 2018; (b) Ericson et al., 2007; (c) CDC, 2019; (d) Karrman et al., 2006b; (e) Laitinen et al., 2014; (f) Dobraca et al., 2015; (g) Rotander et al., 2015; (h) Tao et al., 2008; (i) Shaw et al., 2013; (j) Karrman et al., 2006a; (k) Steenland et al., 2009; (l) Freberg et al., 2010; (m) Nilsson et al., 2010; (n) Woskie et al., 2012; (o) Wang et al., 2012; (p) Olsen et al., 2007; (q) Fu et al., 2016; (r) Costa et al., 2009

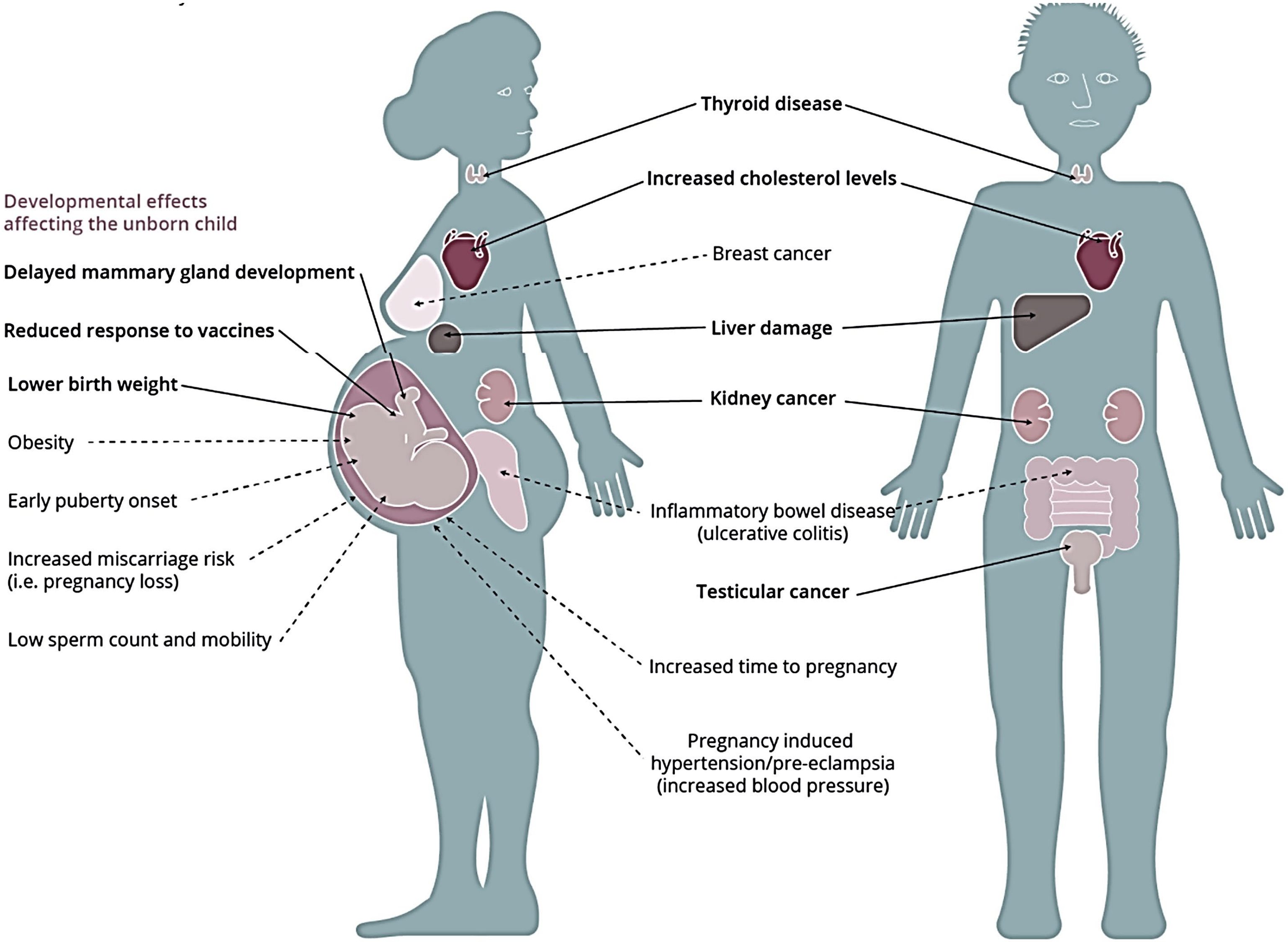
Health Effect Endpoints Examined in Epidemiological Studies

Health Effect Endpoint	Perfluoroalkyl: PFOA	PFOS	PFHxS	PFNA	PFDA	PFUnA	PFHpA	PFBS	PFBA	PFDoDA	PFHxA	FOSA
Body weight	•	•	•	•	•	•				•		•
Respiratory	•											
Cardiovascular	•	•	•	•	•	•	•	•	•	•	•	•
Gastrointestinal		•										
Hematological	•	•										
Musculoskeletal	•	•	•	•								
Hepatic	•	•	•	•	•	•	•	•	•	•		
Renal	•	•	•	•	•			•		•	•	
Dermal												
Ocular												
Endocrine	•	•	•	•	•	•				•		
Immunological	•	•	•	•	•	•	•	•		•	•	•
Neurological	•	•	•	•								
Reproductive	•	•	•	•	•	•		•		•	•	•
Developmental	•	•	•	•	•	•	•		•	•		•
Other noncancer	•	•	•	•	•	•	•					•
Cancer	•	•	•	•	•	•	•			•		•



From ATSDR's "Toxicological Profile for Perfluoroalkyls" https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf

PFAS Health Effects from Epidemiological Studies



(Eco)toxicology of PFAS: A few highlights, Jamie DeWitt, PhD, DABT https://pfasland.files.wordpress.com/2020/09/dewitt_eeb_14920.pdf

Toxicological Profile for PFAS May 2021

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY
DEPARTMENT OF HEALTH & HUMAN SERVICES · USA

Inhalation of indoor air is main pathway

- Estimated intakes >150 ng/kg/day

Absorption data suggests dermal contact contributes to body burden

Lack of historical exposure data is limiting where historical exposures were higher

Epidemiological data are not consistently available for the broad suite of PFAS encountered

Because there are so few studies, and study populations are small, results are inconsistent

NIOSH Research Focus FY20-23

- Sampling and analytical methods
- High- to moderate-exposure environments
- Biological samples, air samples
- Evaluate job task and PPE involved

Professional Ski Waxer Exposure

Exposure Sources

- Air and airborne particles (dusts)
- Raw materials/ containers
- Wastes

Exposure Pathways

- Inhalation
- Dermal
- Ingestion

Freberg et al. Occupational exposure assessment of airborne chemical contaminants among professional ski waxers. 2014.

Professional Ski Waxers Airborne Exposure Assessment

Method

Conical Inhalable Sampler cassettes equipped with 37-mm PVC filters (5 μm) and Casella respirable cyclones equipped with 37-mm PVC filters (0.8 μm), respectively.

Results

- Mean aerosol particle mass concentrations of 3.1 mg/m^3 and 6.2 mg/m^3 were measured in the respirable and inhalable aerosol mass fractions, respectively.
- Real-time aerosol sampling showed large variations in particle concentrations in the respirable and the inhalable aerosol particle mass fractions, respectively.
- The custom-made ventilation system reduced the concentration of all aerosol mass fractions by more than 90%.

https://www.ncbi.nlm.nih.gov/labs/pmc/articles/PMC4305115/

NIOSH: Gaps and Challenges.

1. Limitations of available analytical methods and scientific approach

- ***Limited Dataset.*** Most exposure assessments only used blood/blood serum to assess exposure - Blood preferred for long half-life, long-alkyl PFAS compounds. NHANES 1999-2004 urine PFAS detection results had infrequent detections and were general population centered.
- ***Labs are struggling to keep up.*** Limited analytical options/methods, with few published articles and limited advances.
- ***Analysis is complex***. Numerous PFAS chemical compounds "frustrate" Liquid Chromatography/Mass Spectrometry tandem analysis and compound differentiation.
- ***Expensive, without precision.*** PFAS specific IH sampling and analysis is costly, even with limited speciation capabilities.
  - Total Organic Fluorine or Total PFAS Oxidative Precursor Assays may be non-targeted analytical "gap solvers"
  - Particle-induced gamma ray emission (PIGE) spectroscopy is a possible analytical breakthrough, but not available widespread in commercial AIHA labs.

NIOSH: Gaps and Challenges.

2. Limited understanding of current exposures in occupational environments

- PFAS exposures in historically under-categorized occupational environments
  - 2020 PFAS Industrial Uses survey identified 200 industrial use categories and 1,400 PFAS chemicals – many with lower historical IH monitoring emphasis and research focus.
  - AFFF firefighters, on which a majority of published literatures represent, a small fraction of possibly exposed workforces.
- Variability in community vs. occupational exposures and to which PFAS's – No available comparative reference populations.

3. Limited data to develop health-based thresholds and recommendations

- Minimal OELs: ACGIH established TLVs for three PFAS in air, including AFPO (a form of PFOA), perfluoroisobutylene, and perfluorobutyl ethylene
- Occupational threshold-based guidance for PFAS is limited and lacking.
- Health-based studies with known health end-points (and recognized dose-effect relationships) are few & far between and tend toward communities.
- Adopting "Precautionary Principles" for PFAS mitigations and interventions – Costs and professional dilemma for Industrial Hygienists

NIOSH: A Path Forward

1. **Robust research community dedicated to PFAS**
   - 800+ annual PFAS-related articles published in 2020 & 2021
   - Increasing sense of urgency and researcher attention for better human health risks and outcomes.
   - American Journal of Industrial Medicine – spring 2022 special issue on occupational medicine and IH PFAS is planned to be discussed.
2. **New Guidance**
   - ATSDR and National Academy of Sciences clinician treatment guidelines for addressing PFAS exposures and national protocols on blood serum testing.
3. **Additional Funding**
   - Higher levels of US congressional funding for CDC, ATSDR and EPA emphasizing PFAS health outcomes and risks. Research priorities to address literature gaps.

NIOSH: A Path Forward

4. Product Removal/Replacement - Reducing Exposure

- Voluntary industrial PFAS removals/product substitutions
- Mandatory AFFF fire suppressant bans
- Non-PFAS replacements.

5. PFAS-Focused Initiatives from NIOSH

- *In vivo* and *in vitro* toxicological assessments underway and in publication.
- Firefighter personal protective equipment, turn-out gear, and respiratory research and PFAS-materials substitutions.
- Developments in Air Sampling Methods and Analytical Chemistry; PFAS and related chemical groups added to Manual of Analytical Methods.
- Dermal exposure measurement methods and instrumentation research to "fully" quantify exposure pathways.

Human Health Exposure Info Sources

- Environmental Protection Agency
- Agency on Toxic Substances and Disease Registry (ATSDR)
- National Institute of Environmental Health Sciences
- C8 Science Panel
- Consumer Product Safety Commission
- Argonne National Labs
- Society of Environmental Toxicology and Chemistry
- Strategic Environmental Research and Development Program
- Environmental Security Technology Certification Program
- Michigan PFAS Action Response Team
- Intl. Agency for Research on Cancer
- Interstate Technology and Regulatory Council (ITRC)

Questions?

UNDERSTANDING PFAS IN THE WORLD & THE WORKPLACE

PFAS

1. PFAS Context & Chemistry
2. Recent Regulatory Developments
3. Impacts on Human Health & Worker Risks
4. Environmental Impacts
5. PFAS – Industry Impacts

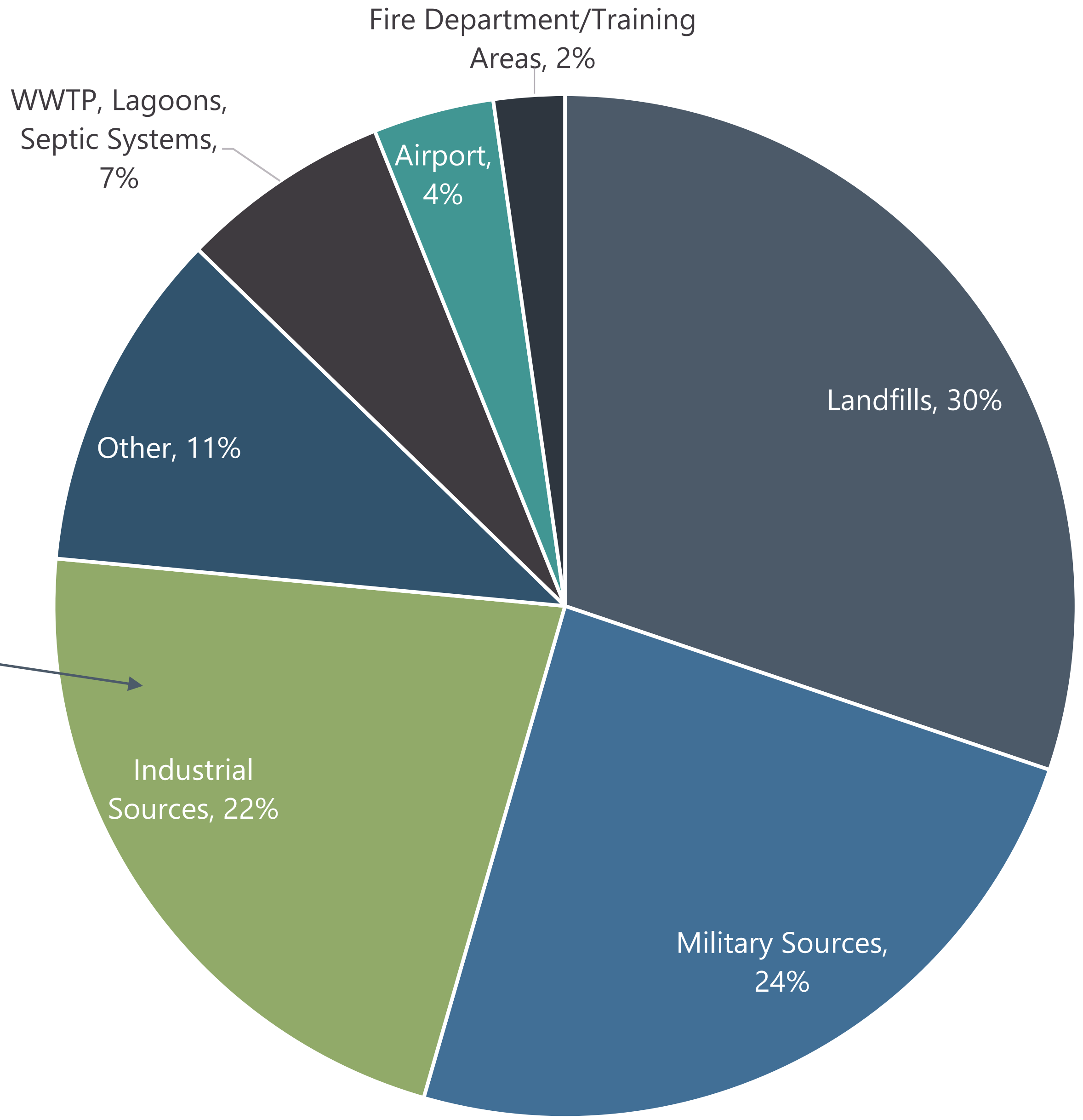
Regulatory Developments

- US focus to date has largely been on PFAS in drinking water and therefore, protection of human health.
- Starting to shift as environmental impacts are being discussed under effluent guidelines, which will begin regulatory consideration of PFAS impacts to ecological receptors.
- DoD Strategic Environmental Research and Development Program (SERDP) now has
  - Toxicity Reference Values for wildlife (birds, mammals, amphibians)
  - Uptake, bioaccumulation, biomagnification in aquatic systems
  - Direct toxicity studies on fish and invertebrates
- These and other studies will be integrated into basis for eco-tox values, ambient water quality criteria, etc.
- Aquatic life criteria are due in 2022. PFAS limits will be included in NPDES and SW discharge permits
  - Eco effects have direct implications for ***industrial*** discharges.

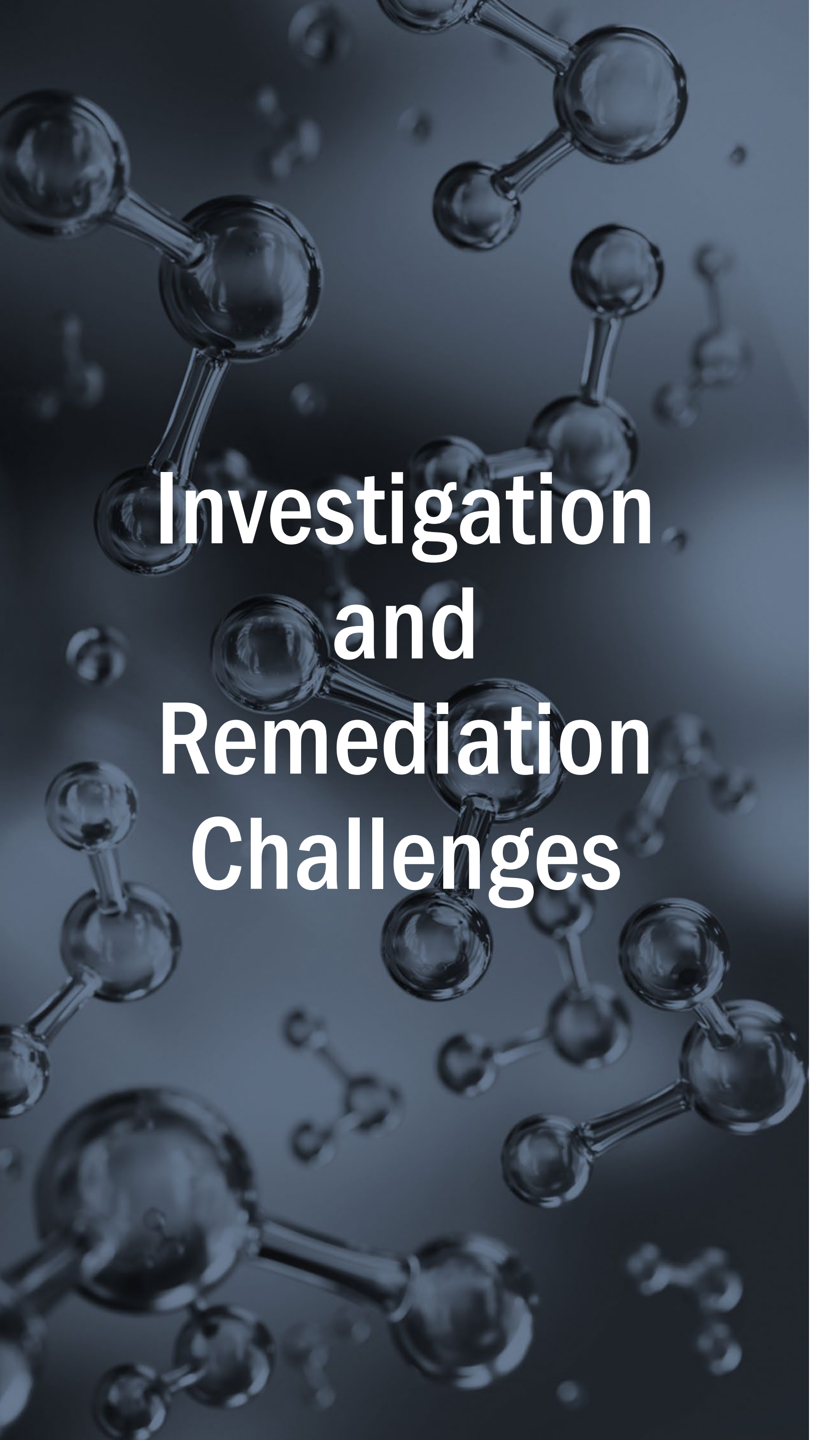
Types of PFAS-Contaminated Sites To-Date (2021)

Industrial Sources:

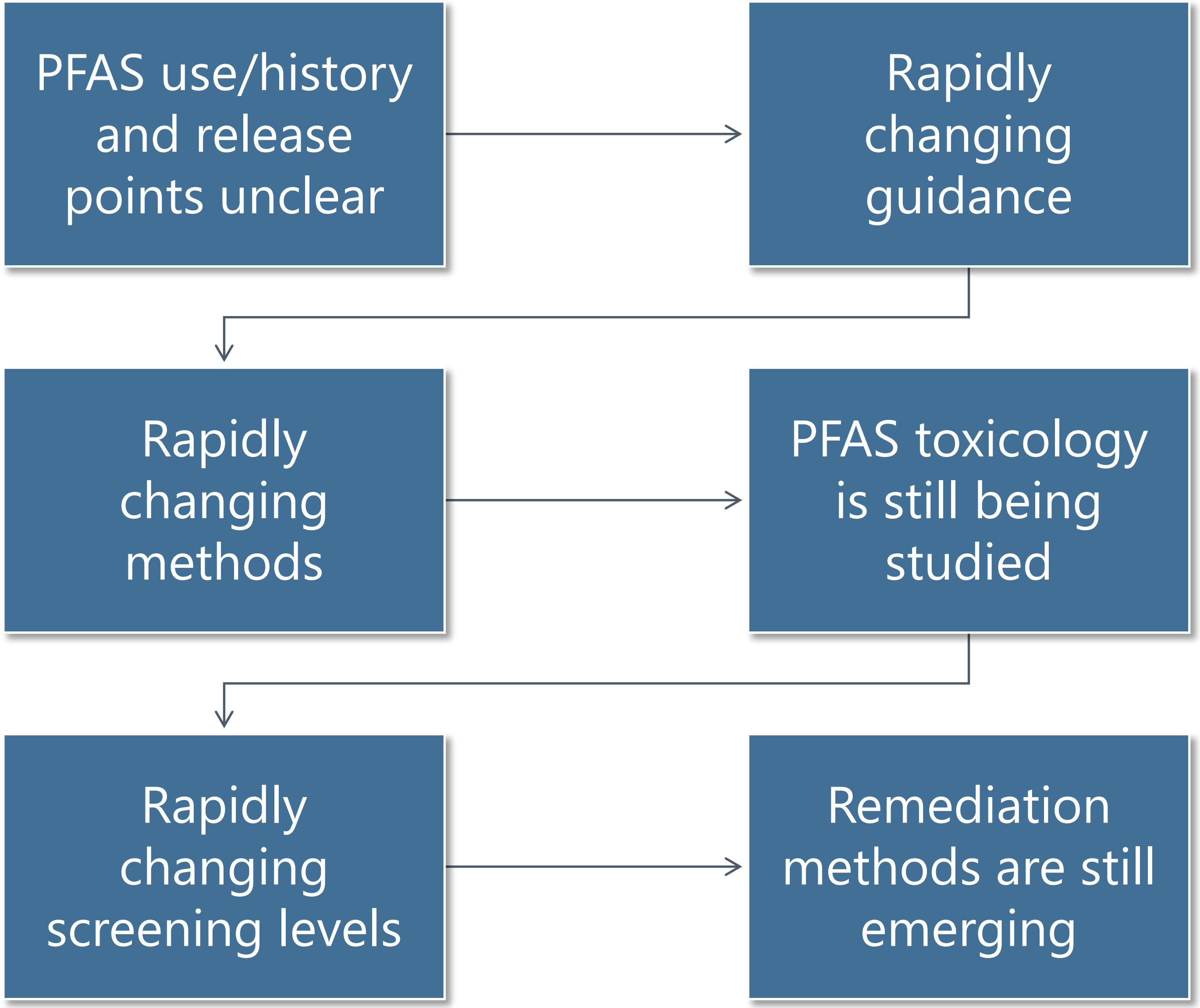
- Chemicals/Coatings
- Plastics
- Paper and Pulp
- Computers/Electronics
- Laundries
- Scrapyards
- Aerospace
- Automotive
- Carwash/Car Repair
- Metal Plating Shops
- Oil Terminals
- Textiles
- Tanneries
- Coal Tar/Gas Works



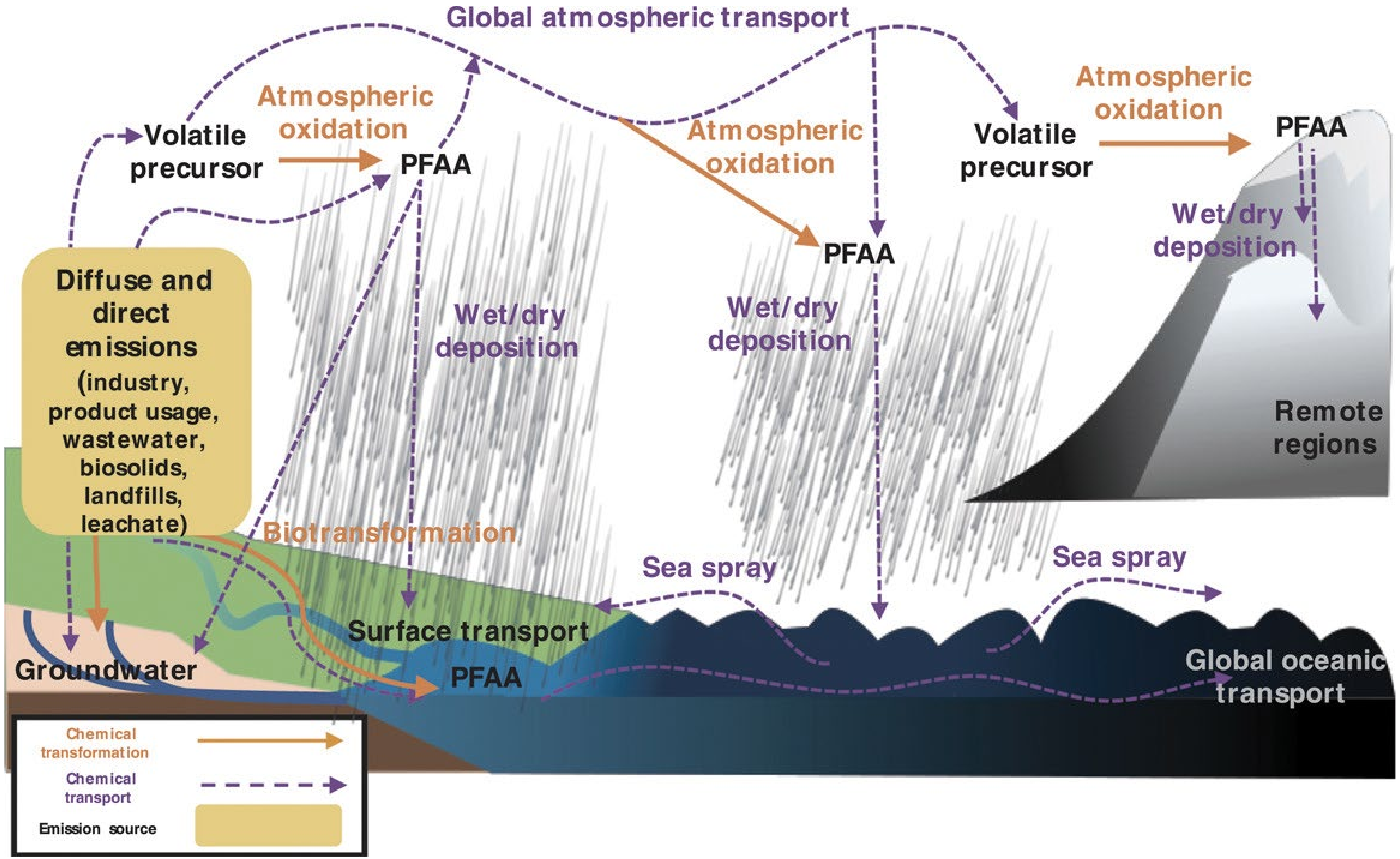
Source: Public SSEHRI PFAS Contamination Site Tracker, April 4, 2021, Update



Investigation and Remediation Challenges

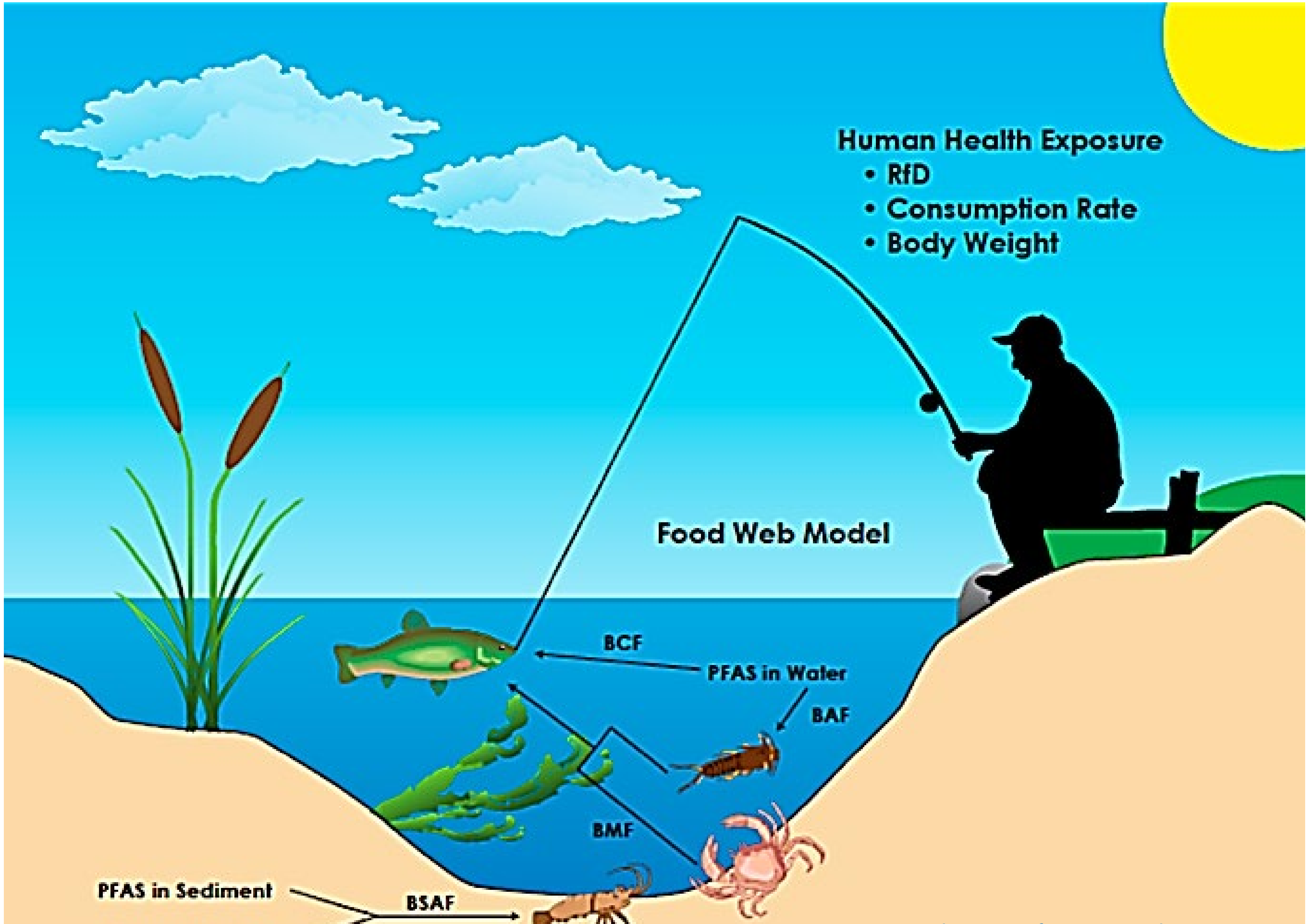


PFAS Exposure Pathways from Sources to Humans & Wildlife



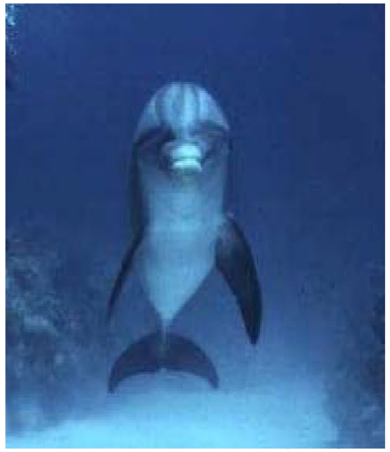
From: DeSilva et al. PFAS Exposure Pathways for Humans and Wildlife: A Synthesis of Current Knowledge and Key Gaps in Understanding. Env Tox & Chem Vol 40 No 3. 5 Nov 2020.

Detail – Ecological Food Web Model



https://pfas-1.itrcweb.org/17-additional-information/#figure_17_1

Significant Ecological Impacts to Wildlife



Vertebrate wildlife [max PFOS]

Up to 3073 ng/mL in plasma of **Bottlenose dolphin**

Up to 1325 ng/g in liver of **polar bear**

Up to 96.8 ng/mL in plasma of **Loggerhead sea turtle**

Up to 450 ng/mL in plasma of **Herring gulls**

Up to 176 ng/mL in plasma of **rockfish**

(DeWitt et al., 2012)

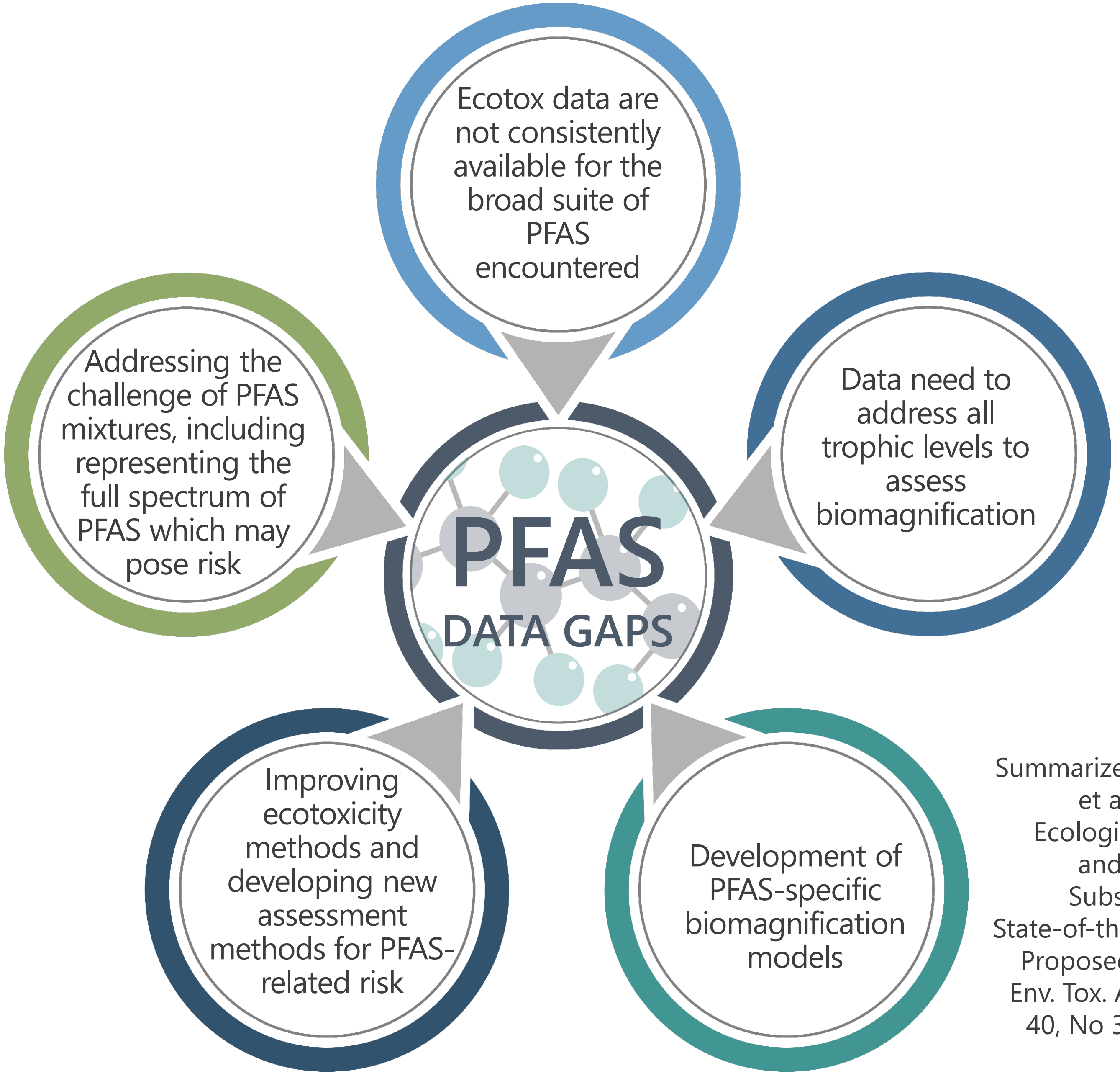
Images from various sources.

Taken from DeWitt. (Eco)toxicology of PFAS: A few highlights. Session 2 Webinar, Europe's PFAS Problem: Situation Briefings by Independent Experts 14 Sept 2020.

Significant Data Gaps

*"Legacy PFAS such as PFOS are still abundant at many contaminated sites, **<u>and novel PFAS are increasingly being detected</u>**."*

- DeSilva et al., 2020 (emphasis added)



Summarized from: Ankley, et al. Assessing the Ecological Risks of Per- and Polyfluoroalkyl Substances: Current State-of-the Science and a Proposed Path Forward. Env. Tox. And Chem. Vol. 40, No 3. 31 Aug 2020.

Florida Ecotox Study Cui et al., 2020

"Although the number of studies on PFAS occurrence in animals and humans is very limited in Florida, the studies demonstrate their presence and the need for future assessments to evaluate environmental risks of PFAS exposure to aquatic organisms and humans."

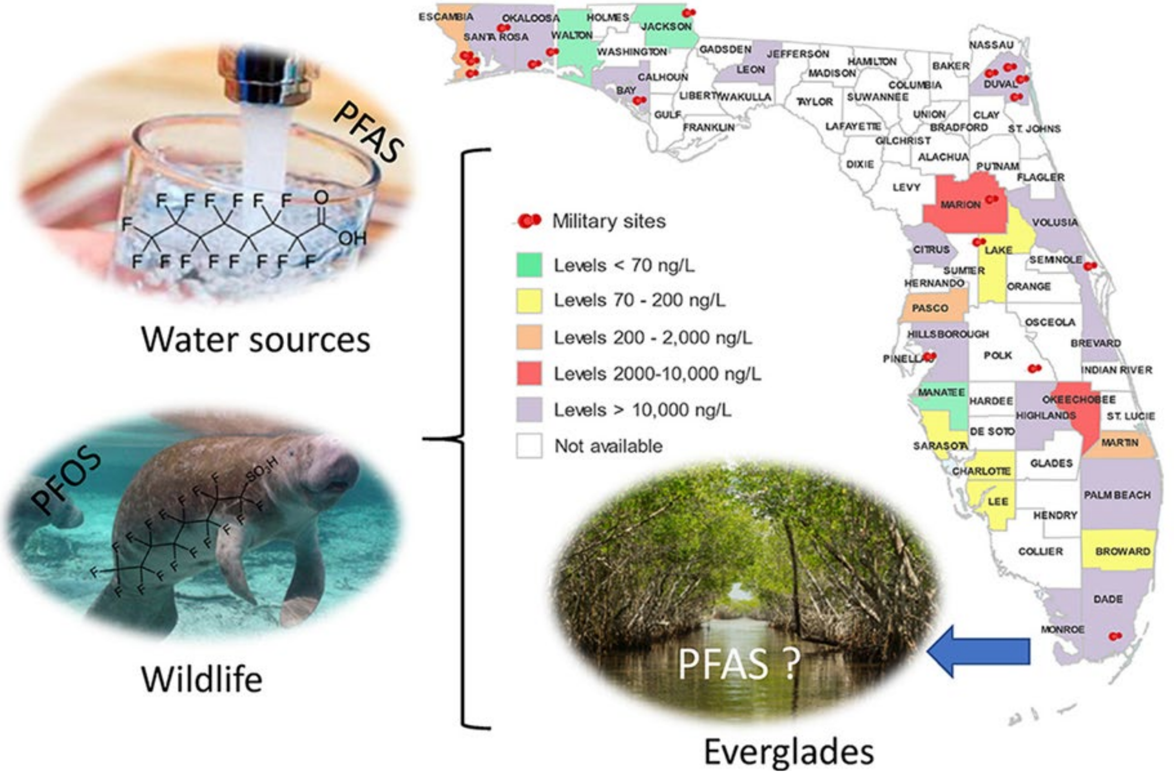
Year	Animal	Tissue sampled	Detected PFAS	Concentrations
2001	Whales	liver	PFOS	6.6-1520 ng/g
2006	Bottlenose dolphin	Plasma, milk, urine	PFOA, PFNA, PFDA, PFUnDA, PFDoA, PFHxS, PFOS	Plasma – 1000 ppt
2017	Manatee	plasma	17 PFAS	PFOS, 0.13-116 ng/g PFNA, 0.038-3.52 ng/g
No Date	American alligator (Kennedy Space Center)	plasma	PFUnA, PFDoA, PFOA, PFHxS, PFNA, PFTrA, PFTA, PFOS, PFHxA	PFOS (median 185 ng/g) PFHxA (median 7.95 ng/g)
No Date	American alligator (8 other sites)	plasma	PFOS, PFUnA, PFDA, PFNA, PFHxS, PFDoA, PFTrA, PFTA, PFOA	PFOS (median 11.2 ng/g)

Taken from: Cui et al. Occurrence, fate, sources and toxicity of PFAS: What we know so far in Florida and major gaps. Trends in Analytical Chemistry. 130 (2020) 115976.

Florida Ecotox Study Cui et al., 2020

“Wildlife areas in South Florida could be impacted by accumulation and biomagnification of PFAS. Knowledge on PFAS contamination status in South Florida is needed to provide detailed information to local and regional governmental agencies on water quality and the impact of PFAS in the conservation of threatened and endangered species.”

- Most counties in Florida have groundwater concentrations above the EPA HA of 70 ppt, with the highest levels in Brevard, Citrus, Dade, Duval, Highlands, Hillsborough, Leon, Monroe, Okaloosa, Palm Beach and Santa Rosa counties.
- Fifteen out of twenty-two fire training facilities reported the occurrence of PFOA and PFOS in surface water. The most contaminated surface water was near Volusia County Fire Rescue Training Center with concentrations up to 6,760 ppt; however, four other facilities exhibited PFOS+PFOA >100 ppt.



FDEP Dynamic Plan: Ecological Research and Support

- Research projects/case studies with University of Florida, Florida International University, and University of Miami
  - Surface waters across the state
  - Waste streams
  - Impacts of flooding and extreme weather events on PFAS transport
  - Evaluation of analytical methods for low-level PFAS in surface water and tap water
- Toxicological support from University of Florida Center for Environment and Human Toxicology

PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

DYNAMIC PLAN

Division of Waste Management

Florida Department of Environmental Protection

March 2022

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

https://floridadep.gov/sites/default/files/Dynamic_Plan_March_2022.pdf

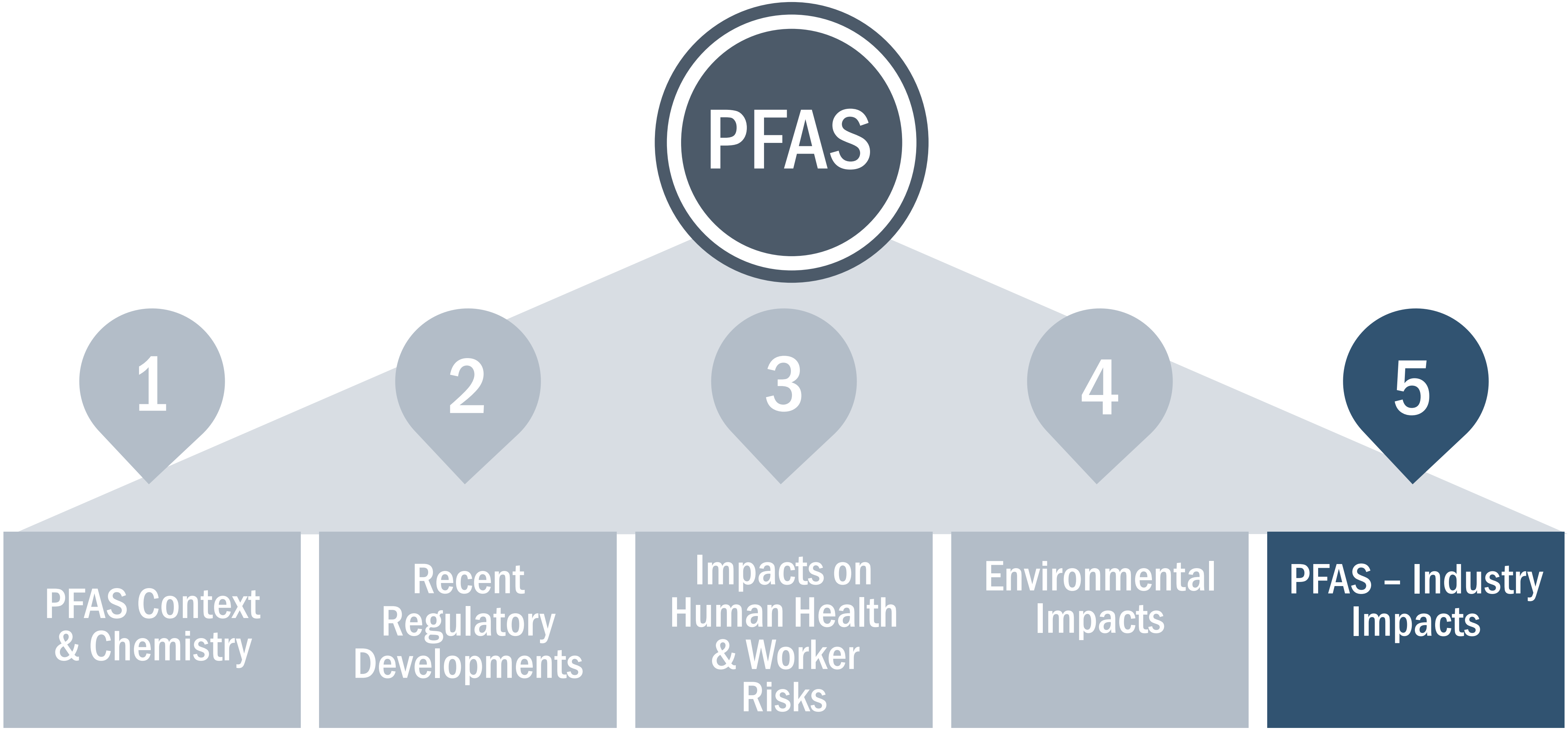
Takeaways

Still learning…
A lot to do…

- Although PFAS chemicals are not "new" – our understanding of their fate, transport, and effects remains incomplete.
- Evolving analytical methods, toxicity data, etc., adds to uncertainties in risk assessment.
- Small fraction of the PFAS family has been studied – huge challenge.
- Available data suggests effects can vary between test animal species, sexes, salt vs. freshwater - extrapolation of findings increases uncertainties.
- For ecological impacts – need to understand which receptors may be most sensitive – and how that may change depending on the PFAS (long vs. short chains, etc.) to which they are exposed.
- One size does not fit all!

Questions?

UNDERSTANDING PFAS IN THE WORLD & THE WORKPLACE



ENSAFE

A Perfect Storm

- Rapidly unfolding regulatory framework and focus moving towards full regulation and discharge limits.
- Very difficult “impossible” to treat family of molecules. Persistent in all environmental media.
- Bioaccumulates in the food chain, human excretion poor.

Industrial Perspective

Wake Up Call

Industrial users not fully sure if and or where the material may be present in their facility or manufacturing operations

Chemical suppliers just starting to better understand the issue and needs of their customers.

The “phase-out” clock is ticking.

PFAS Challenges / Questions

- Where is it? Is it in my plant and or manufacturing process now?
- Reduce or eliminate?
- Can it be treated it or discharged?
- Sooner or later, we will need to face this. What responsibility do I have now / future?
- End users' “industry” lack of full understanding.
- What steps to take?

PFAS – Unique Properties

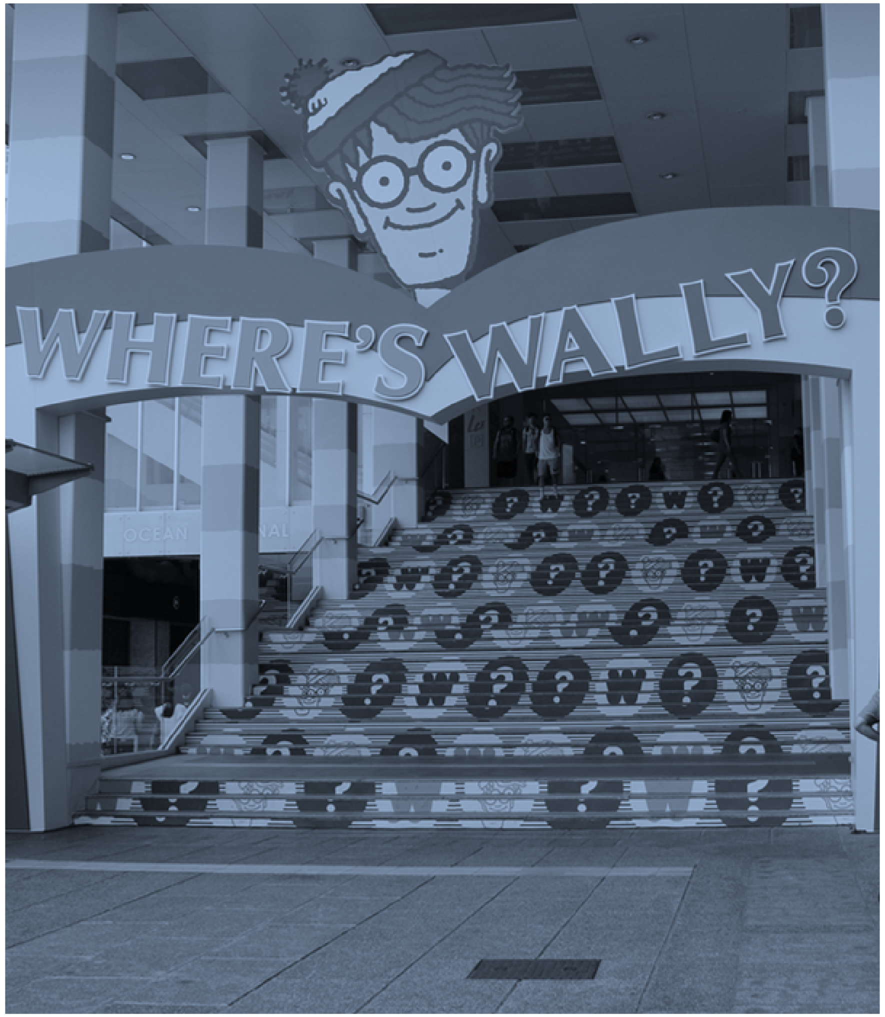
- Ability to alter electrical potential of metals –reduces corrosion.
- Reduce surface tension of aqueous solutions, better wetting, rinse-off – plating and cleaning applications.
- Essential versus non-essential applications.
- PFAS fluorosurfactants reduce surface tension of water half of what is attainable with hydrocarbons.

PFAS Uses - Which Industries?...

- PFAS extensive use in aerospace, automotive, construction and military.
- Textiles, electroplating, aviation components, paper, packaging.
- Airports, chemical, plastics manufacturing.
- Impacting public water systems, landfills, airports.

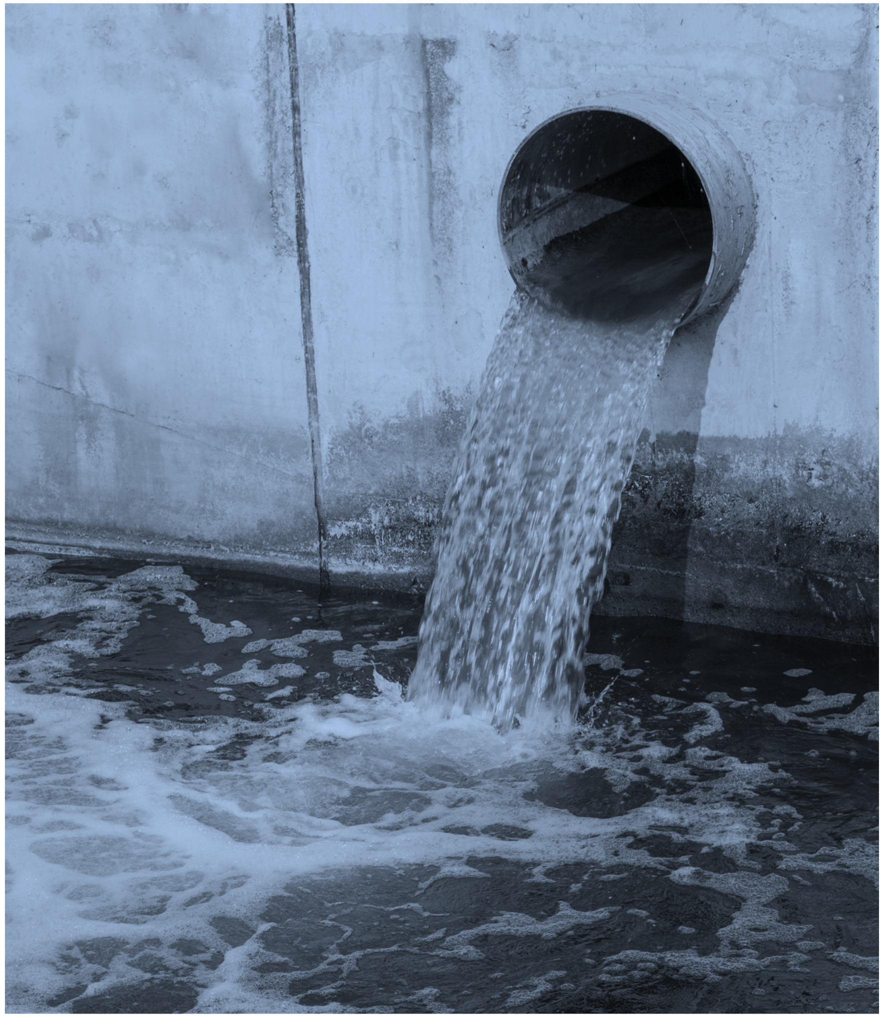
PFAS – Often Hidden in Process Use

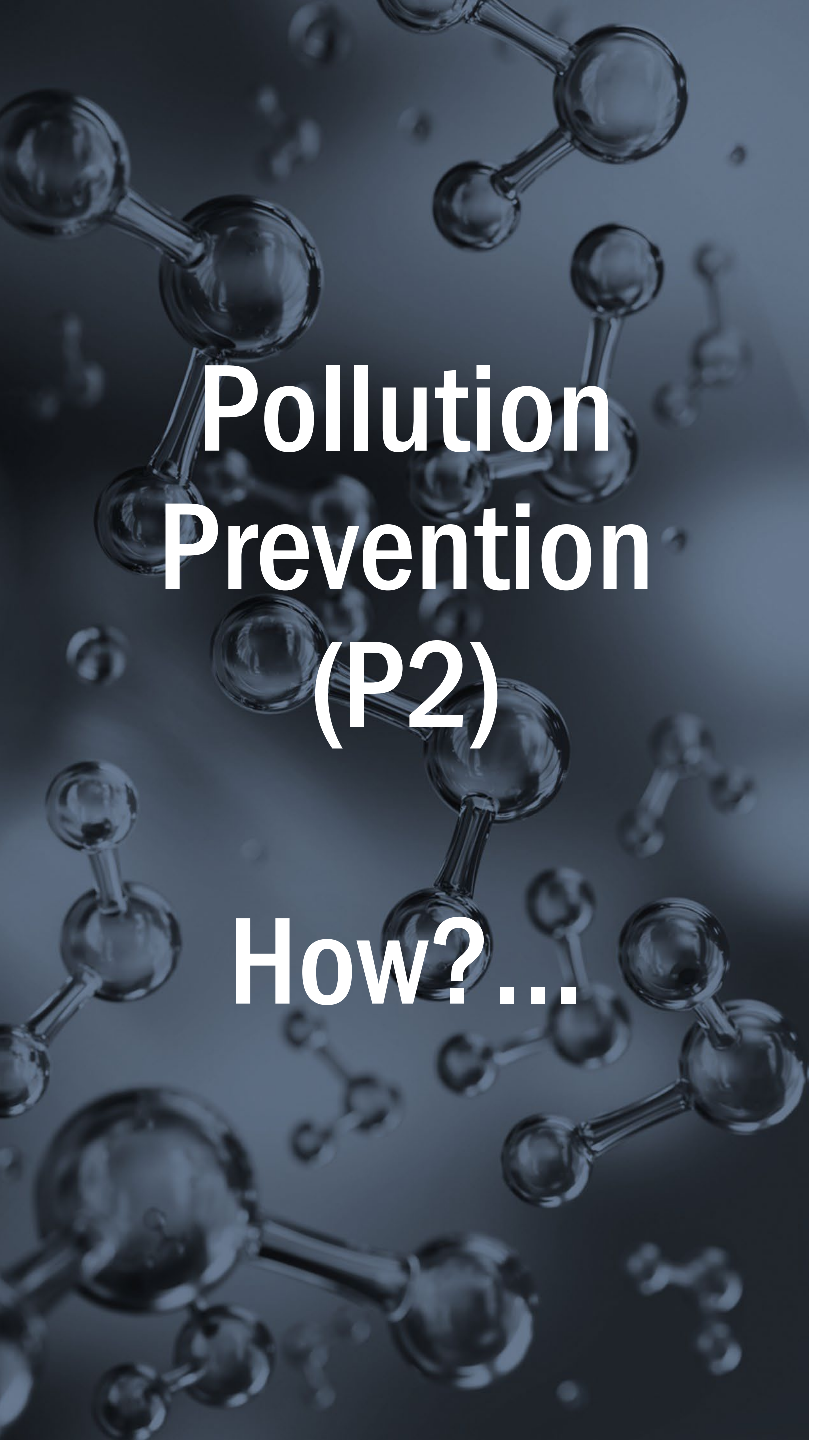
- Think about coatings, defoamers, anti-stick compounds, waterproofing, plating.
- Review of SDS sheets alone is not adequate.
  - Process flows
  - Inventories / additives
  - Chemical, product, and/or waste sampling
- Look at secondary processes and chemicals.
- Customer specifications, chemicals and processes.



EPA – Interim NPDES Strategy

- EPA working to address point source discharges – ***will impact industry***.
- EPA/states will include PFAS in permit requirements when it's expected to be present in…
  - Wastewater discharge
  - Stormwater discharge





Pollution Prevention (P2)

How?...

Pollution prevention means eliminating or reducing the amount of toxicity and potentially harmful substances at their sources, prior to generation, treatment, off-site recycling or disposal.

It emphasizes preventing or minimizing pollution, rather than controlling it once it is generated.*

*Connecticut Department of Energy and Environmental Protection

Aerospace – Where do we expect PFAS?

- Brake and hydraulic fluids – corrosion protection.
- Wire and cable – stable non-flammable polymers.
- Turbine engine – lubricant, elastomeric seals.
- Coatings / paints – improved performance and appearance.
- Electroplating – chrome, nickel, copper, tin – low surface tension, deposition of fluoropolymer particles onto steel.
- Etching of aluminum – improves alkaline bath life.
- Emergency Response/Fire Suppression.

PFAS Bans – Food Packaging

- Food containers PFAS Act – November 2021.
- Seven states adopted legislation banning PFAS in food packaging – New York in effect by end of 2022.
- "Intentionally introduced or added"
- California (effective Jan 2023) – Includes ban of PFAS present in product or product component at or above 100 ppm as measured in total organic fluoride.

PFAS Bans – Fluorocarbon Ski Wax

- U.S. Ski and Snowboard, International Ski Association.
- Ban of fluorinated waxes starting July 1, 2021.
- Developed ski decontamination procedures.
- Developed ski sampling and testing procedures using adhesive films.
- Random testing to confirm compliance.

Fire Fighting Foam – Mission Critical

- PFAS Foam Example
  - Under FAA Part 139 for ARFF, fluorine foams are still required per MILSPEC
  - Where MILSPEC foams are not required, FFF may be an option
- Recent client scenario: AFFF vs. FFF in a non-airport facility (non-MILSPEC)
  - Was it compatible with existing fire suppression equipment?
  - Was it truly FFF, or was it a lesser fluorinated (next-gen) AFFF?   How did this affect their future liabilities as regulations changed (releases, NPDES/SW discharges, etc.)

Substitution – Not a Simple Task

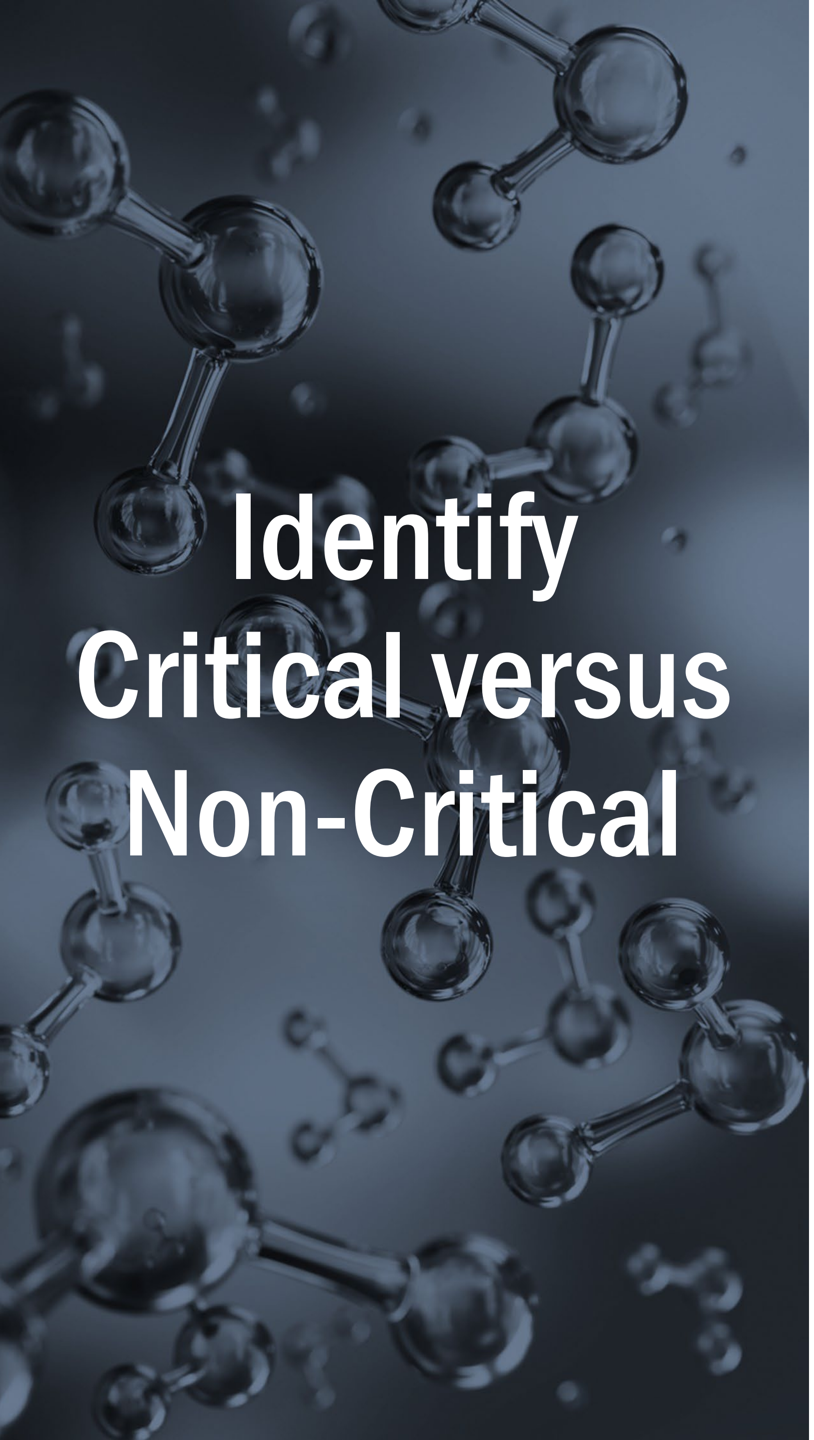
Will substitute work in my system?

Does it meet my specifications?

FAA / DoD requirements versus EPA.

Replacement equipment and training.

Legacy materials and processes.



Traditional Pollution Prevention

- Find out where you are using it.
- For critical applications isolate the waste streams and treat them.
- For non-critical – eliminate use.
- Pollution prevention likely one of our best tools.

Novel Approach Needed

- Treatment of water phase difficult and results in contaminated media with limited disposal options.
- PFAS management will also need to consider filters, sludges, dusts, containers.
- Typical treatment / remediation options pose challenges given pending regulatory changes:
  - Incineration
  - Landfilling
  - Deep well injection
- Plant based PFAS bio-filtration showing promise.

Begin to Develop Strategy

- Do nothing now / "head in sand" – poor plan.
- Work with suppliers – trust but verify.
- Stay abreast of regulatory developments.
- Coordinate closely with management and process engineering teams.
- Identify / understand your exposures and liabilities. Plan financial reserves.

UNDERSTANDING PFAS IN THE WORLD & THE WORKPLACE

PFAS

1. PFAS Context & Chemistry
2. Recent Regulatory Developments
3. Impacts on Human Health & Worker Risks
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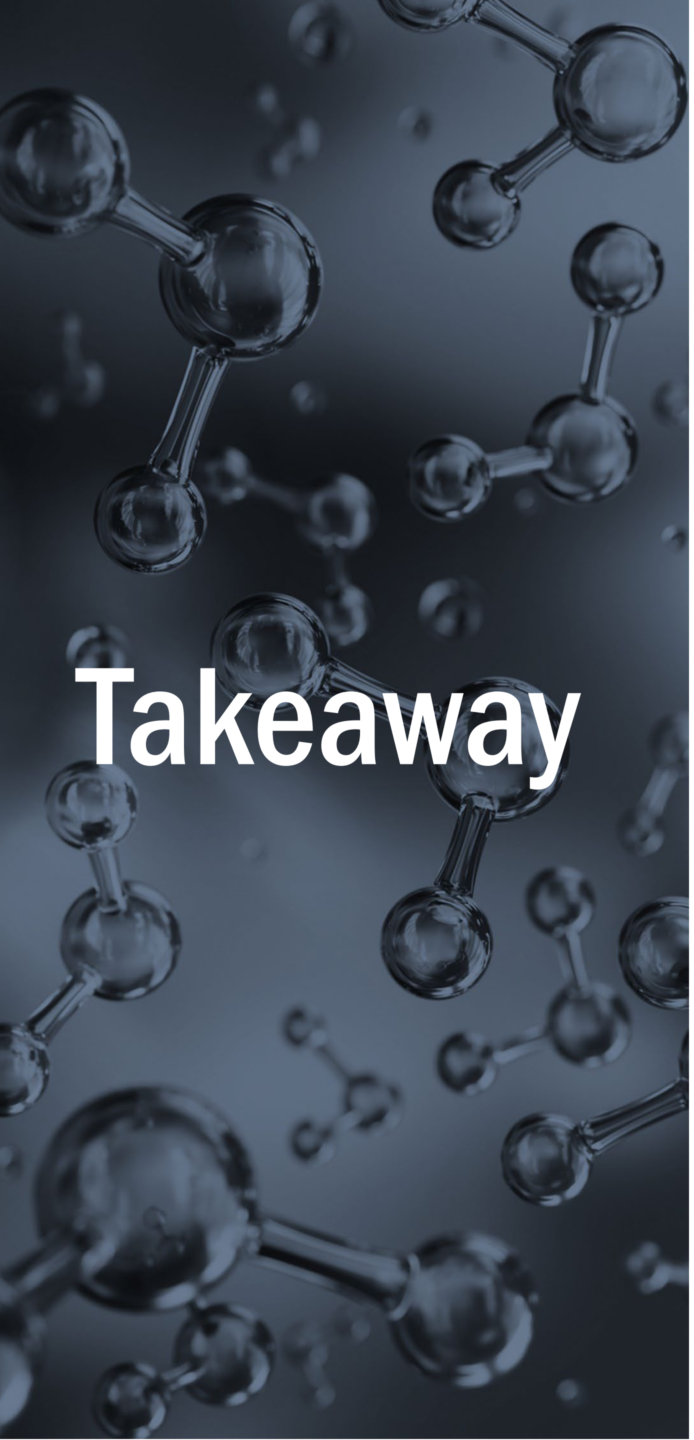
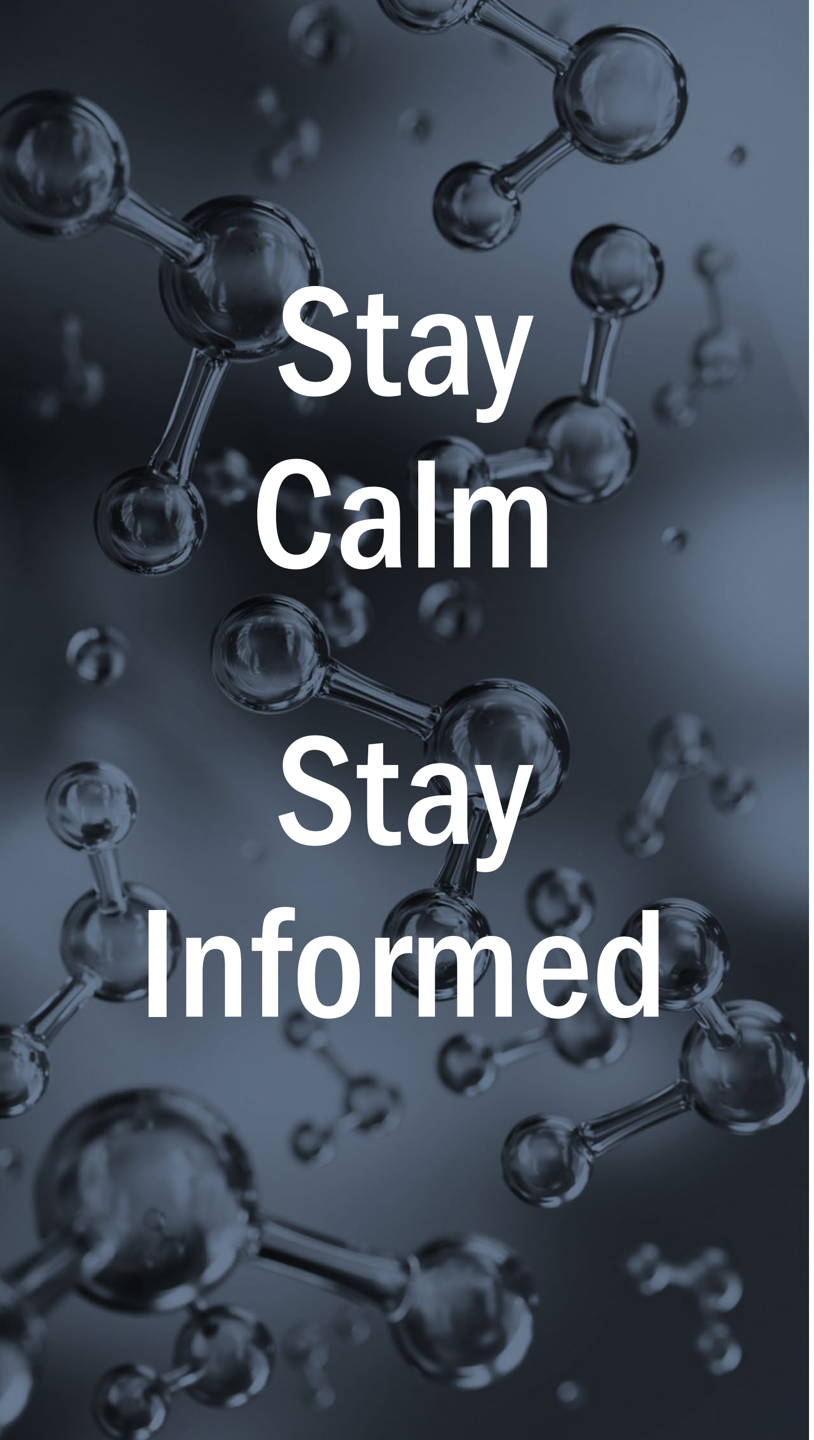
5. PFAS – Industry Impacts



Takeaway

1. PFAS are **everywhere**, are environmentally persistent, and are extremely complex – which complicates risk and regulatory actions.
2. Major regulatory changes are pending, which will affect every aspect of how PFAS are managed – from reporting to waste management to effluent discharge.
3. While data on PFAS have been collected since the 1960s/1970s, and data suggest a wide range of health effects, we don't have sufficient data for IH at this time.
4. NIOSH has developed a path forward, including accelerated research, more standardized testing, a focus on BMPs, and multiple PFAS-focused initiatives.
5. Changes in ecological criteria will facilitate development of NPDES and surface water discharge criteria, and regulation of PFAS impacted wastewaters over the next 2-4 years..
6. Pollution prevention and waste minimization processes may be the best tools to minimize future PFAS liabilities. Start coordinating with management and planning for future reserves.



Stay Calm

Stay Informed

KNOW

who to ask, where to find trusted info

MONITOR

changing PFAS regulations and processes

SIFT

through the avalanche of information

ASSEMBLE

a team of experts

(CIH, permitting, risk, remediation and more)

Questions?

THANK YOU!
We're here to help!

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