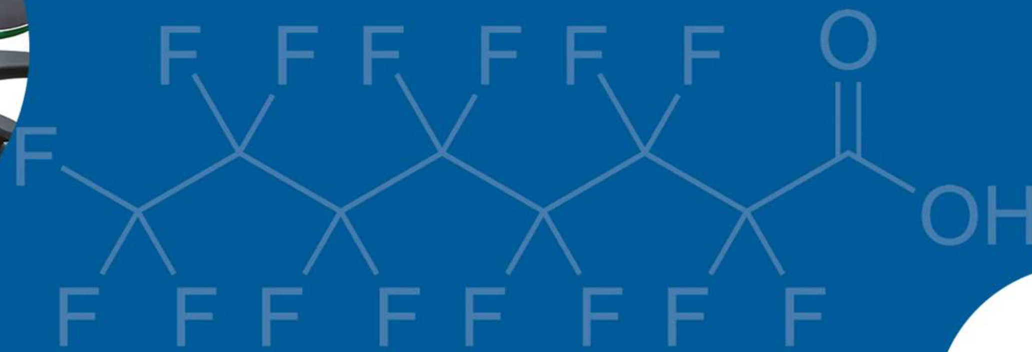


PFAS PRACTICAL GUIDE TO VAPOR INTRUSION

Northeast Waste Management Officials' Association

August 20, 2024

NEWMOA
NORTHEAST WASTE MANAGEMENT OFFICIALS' ASSOCIATION

trccompanies.com

Presentation Overview

- **PFAS Sources**
- **PFAS Migration Pathways and Routes of Exposure**
  - Worker Exposure
  - Residential Exposure
- **PFAS Toxicology**
- **PFAS in Dust & Indoor Air**
  - What we know….
- **PFAS Occupational Studies**

PFAS Sources

PFAS in the News

Dangerous 'forever chemicals' found in 300 animals

Top US smoothie company accused of deception after toxic PFAS discovered

Lawsuit alleges Bolthouse Farms deceived customers by claiming Green Goddess smoothie is made with '100% fruit juice'

dit: Tyler Nix/Unsplash

REI to ban PFAS in outdoor clothing and cookware

Freshwater Fish Contain Harmful 'Forever Chemicals'

Eating one serving of locally caught fish could equate to drinking contaminated water for a month, a new study finds

High PFAS Levels in Ketchup, Mayo, Olive Oil and More: New Lawsuit

Pollution: 'Forever chemicals' in rainwater exceed safe levels

Coca-Cola sued on allegations of high toxic PFAS levels in Simply Orange Juice

Toxic 'forever chemicals' found in toilet paper around the world

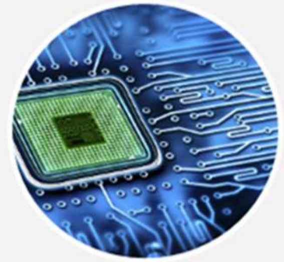
Research finds waste flushed down toilets and sent to sewage plants probably responsible for significant source of water pollution

Sources of PFAS

Mining

Fire-fighting Foams

Oil & Gas Industry



Electronics

Coatings: Waxes, Paints, Inks, Varnish

Metal Plating

Paper & Packaging

Pesticides

Personal Care Products

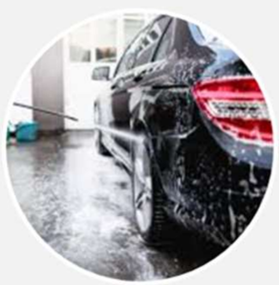
Textiles, Leather & Apparel

Photography

Medicine

Building & construction

Plastics



Cleaning Products

Refrigerants

Explosives

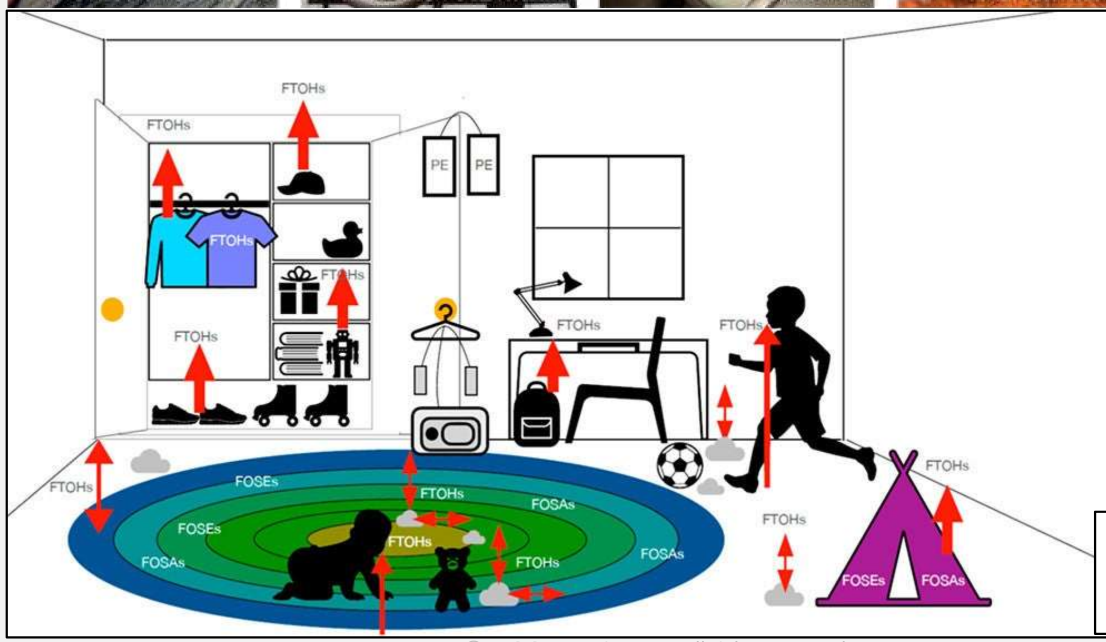
What Types of Sites Can Be Sources of PFAS?

- Fire training facilities
- Fire stations
- Refineries
- DoD sites/Military bases
- Commercial and private airports
- Landfills (leaching from consumer products)
- Biosolids land application
- Rail yards
- Car washes
- Chemical facilities
- Plating facilities
- Textile/carpet manufacturers
- Residential areas with septic systems

- Carpets
- Upholstery
- Clothing
- Paper
- Food packaging
- Nonstick cookware
- Cleaning products
- Personal care products
- Cosmetics
- Paints
- Varnishes
- Sealants

Sources of PFAS in Indoor Environments

TRC



Fluorotelomer Alcohols (FTOHs) are dominant PFAS in both ambient and indoor air

Source: We're breathing PFAS: URI-led study finds harmful forever chemicals in indoor air – Graduate School of Oceanography, 2021

PFAS Migration Pathways and Routes of Exposure

PFAS Exposure Depends on Migration Pathways

Industrial Site Example

- **1º Source: PFAS production** plants
- **2º Source: manufacturing** w/ PFAS
- **PFAS Accumulators** landfills, WWTPs, incinerators, AFFF releases

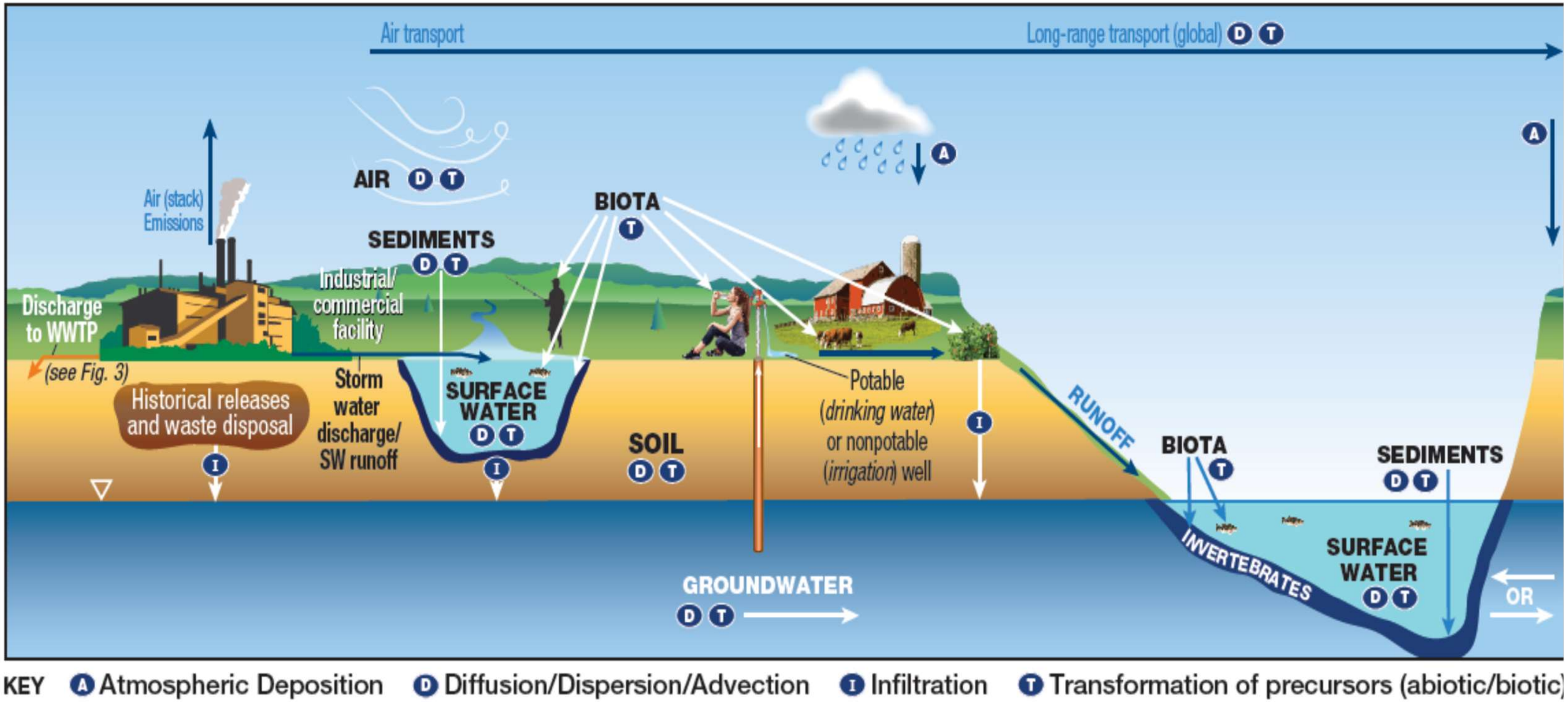


Figure 2. Conceptual site model for industrial sites.

(Source: Adapted from figure by L. Trozzolo, TRC, used with permission)

Source: June 2022 ITRC PFAS Guidance, Section 9: Site Risk Assessment, Fig 9-2

Atmospheric Emissions

Particles

- Dominated by anionic PFAAs
  (*Ge et al. 2017; Dreyer et al. 2015; Ahrens et al. 2012*)
  - PFOA sorbs to smaller particles
  - PFOS sorbs to larger particles

Vapor

- Dominated by neutral FTOHs
- FTOH vapors are dominant PFAS present in ambient air over urban areas, open oceans and remote areas (*Ahrens et al. 2012; Bossi et al. 2016; Lai et al. 2016; Wang et al. 2015; Dreyer et al. 2009*).

Atmospheric Transformation

- **Neutral volatile PFAS precursors transform into PFCAs and PFSAs** (PFOA, PFNA, and PFOS)
- **Transformation occurs abiotically through indirect photolysis/oxidation by hydroxyl radicals (OH^-)** (*Martin et al. 2006; Wallington et al. 2006; Ellis et al. 2003*)
- **Transformation reaction rates can be slow** (*Young and Maybury, 2010*)

Slow reaction rates, combined with precursor long atm τ, allows LRT of PFAS to extremely remote areas, including the Arctic and Antarctic
(*Piekarz et al. 2007; Martin et al. 2006; Ellis et al, 2003*)

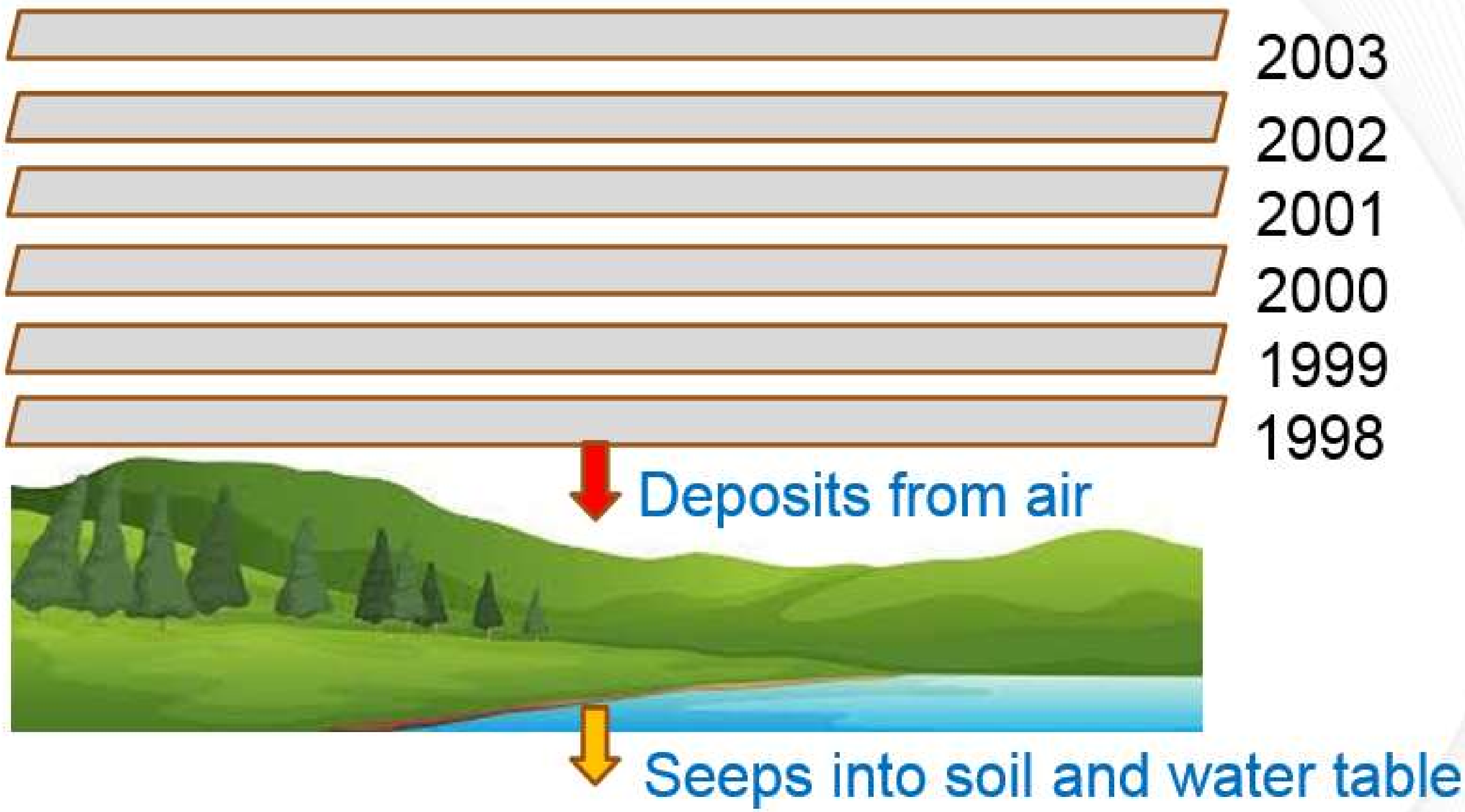
Atmospheric Deposition

Wet and dry deposition remove PFAS from the atmosphere

- **Particle-bound PFAS deposition through wet scavenging/deposition (precipitation) or dry deposition (settles to ground in dry weather)** (*Slinn, 1984; Sehmel, 1984*)
- **Partitioning of PFAS vapors to water droplets, which fall as rain or snow** (*Dreyer et al. 2010; Hurley et al. 2004*)
- **Deposition occurs over period of a few days (for particulates) to a few weeks (for vapors)** (*Chen et al. 2016; Lin et al. 2014; Dreyer et al. 2010; Hurley et al. 2004*)

Atmospheric Deposition Accumulates Over Time

- Pollutant disperses into the environment
  - Because the compounds are stable, they don't break down and work into the soil and water layers
- Each year adds a new layer

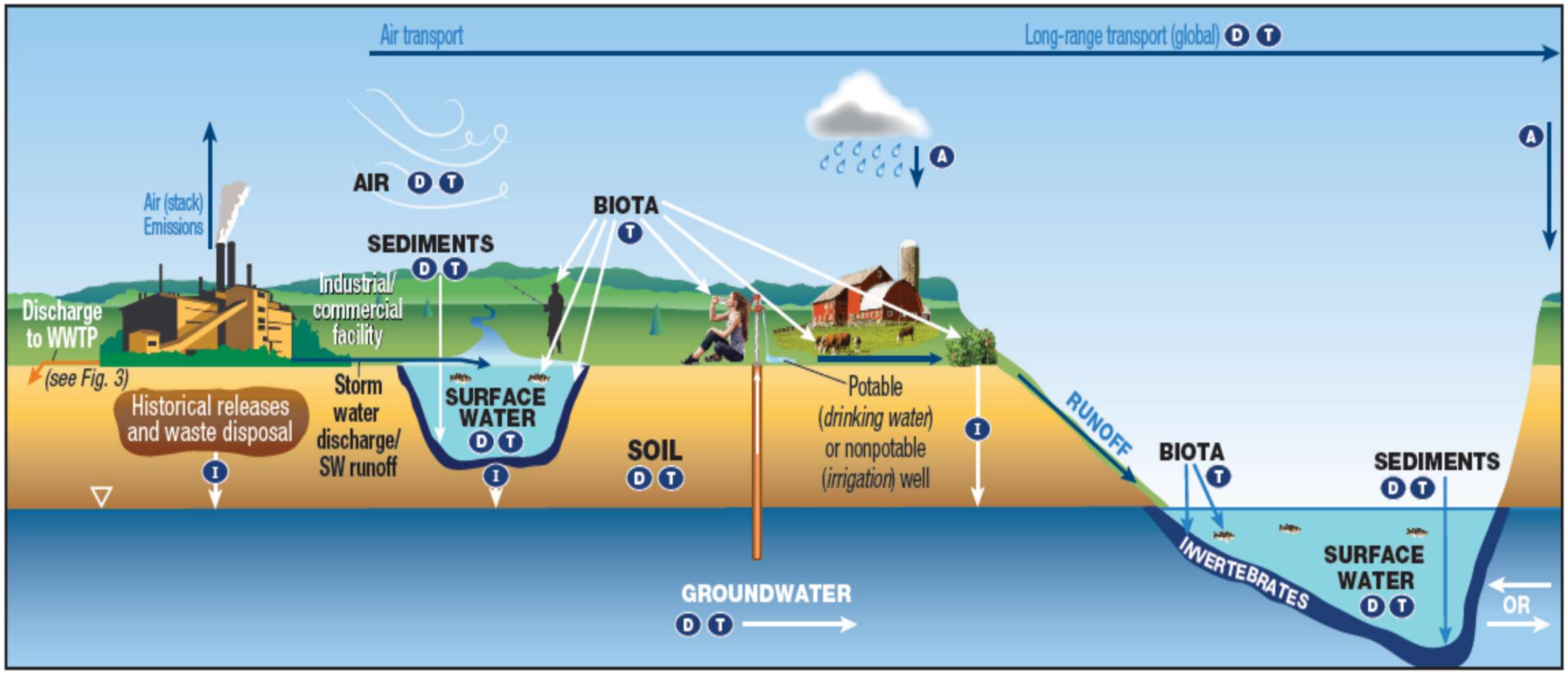


Courtesy of NH Department of Environmental Services

- Inhalation of airborne particulates/ vapors
- Direct contact with particulates and dust once settled out of atmosphere (atmospheric deposition)
- Leaching of atmospheric deposition into groundwater
- Surface water runoff from atmospheric deposition

PFAS Routes of Exposure

Industrial Stack Emission Example



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

Figure 2. Conceptual site model for industrial sites.

(Source: Adapted from figure by L. Trozzolo, TRC, used with permission)

Source: June 2022 ITRC PFAS Guidance, Section 9: Site Risk Assessment, Fig 9-2

PFAS Routes of Exposure

Surface Release Example

COLOR KEY

Sources: identified with dark blue text

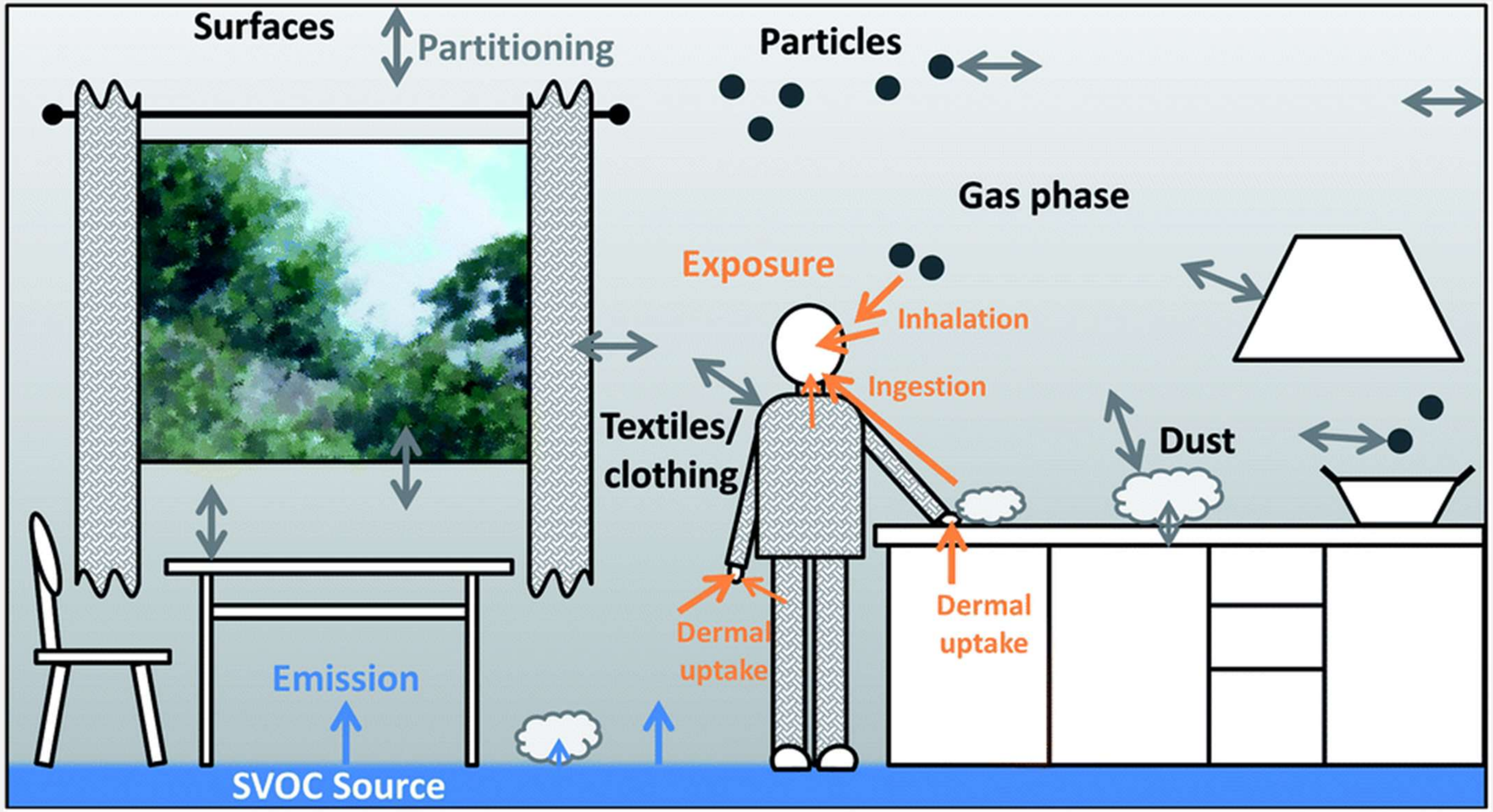
Migration Pathways: identified with lighter blue text

Human Health Receptors and Exposure: identified with green text

Ecological Receptors and Exposure: identified with white text

PFAS Routes of Exposure

Indoor Residential Example – Consumer Products, Household Textiles, Paint/Carpet

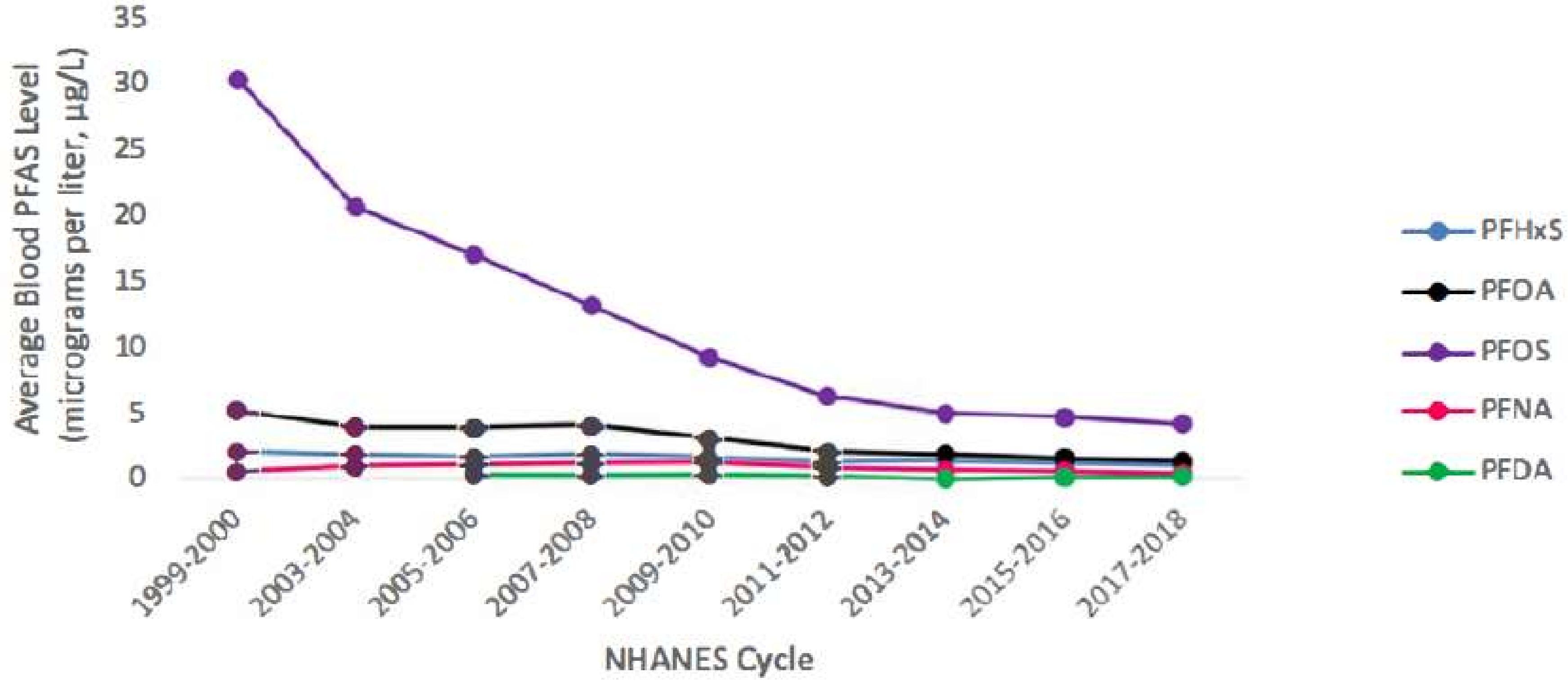


Source: A framework to model exposure to per- and polyfluoroalkyl substances in indoor environments - Environmental Science: Processes & Impacts (RSC Publishing); Eichler and Little, 2020

- **Inhalation of airborne particulates/ vapors from household PFAS products and carpets**
- **Incidental ingestion of PFAS dust (settled airborne particulates)**
- **Dermal contact with household textiles, cosmetics, and other consumer products**

PFAS Exposure Biomonitoring

- **Significant reduction (70-90%) in PFOA & PFOS blood levels since testing started in 1999 / 2000 (ATSDR 2022)**
- **Decreasing trend of long-chain PFAAs due to reduction in production and consumer use**



Blood Serum Levels of Specific PFAS Frequently Detected in the U.S. General Population (NHANES) Over Time (data from CDC 2022)

Question Time

PFAS Toxicology

PFAS Toxicology

"Dose Makes the Poison" - Paracelsus

- Not all toxicity values are the same
- EPA's 2003 Tiered Approach to Toxicity Sources
  - **Tier 1** – EPA Integrated Risk Information System (IRIS) Database (gold standard)
  - **Tier 2** – EPA Provisional Peer-Reviewed Toxicity Values (PPRTVs)
  - **Tier 3** – Other tox values (states, ATSDR MRLs, and HEAST)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE

December 5, 2003

OSWER Directive 9285.7-53

MEMORANDUM

SUBJECT: Human Health Toxicity Values in Superfund Risk Assessments

FROM: Michael B. Cook, Director /s/
Office of Superfund Remediation and Technology Innovation

TO: Superfund National Policy Managers, Regions 1 - 10

Purpose

This memorandum revises the hierarchy of human health toxicity values generally recommended for use in risk assessments, originally presented in Risk Assessment Guidance for Superfund Volume I, Part A, Human Health Evaluation Manual (RAGS) (OSWER 9285.7-02B, EPA/540/1-89/009, December 1989). (http://www.epa.gov/superfund/programs/risk/ragsa/index.htm)

It updates the hierarchy of human health toxicity values and provides guidance for the sources of toxicity information that should generally be used in performing human health risk assessments at Comprehensive Environmental Response Compensation and Liability Act (CERCLA or "Superfund") sites. It does not address the situation where new toxicity information is brought to the attention of the U.S. Environmental Protection Agency (EPA). It also does not provide guidance or address toxicity or reference values for ecological risk.

This memorandum presents current Office of Solid Waste and Emergency Response (OSWER) technical and policy recommendations regarding human health toxicity values in risk assessments. EPA and state personnel may use and accept other technically sound approaches, either on their own initiative, or at the suggestion of potentially responsible parties, or other interested parties. Therefore, interested parties are free to raise questions and objections about the substance of this memorandum and the appropriateness of the application of this document to a particular situation. EPA will, and States should, consider whether the recommendations or interpretations in this memorandum are appropriate in that situation. This memorandum does not impose any requirements or obligations on EPA, States, or other federal agencies, or the

PFAS Toxicology

Toxicity Value Introduction into EPA's RSL Table

Nov 2014
Oral RfD for **Perfluorobutane Sulfonate** & **Potassium Perfluorobutane Sulfonate** added to RSL table

Nov 2017
Oral RfD for **PFBS** added to RSL table

May 2021
Oral RfDs for all 3 PFAS drop from **2E-02 mg/kg-d** to **3E-04 mg/kg-d** (based on recent EPA PPRTV studies)

Nov 2021
PFAS heading and 3 new PFAS oral RfDs for **PFOA, PFOS**, and **Perfluorooctanesulfonate** added to RSL table (based on recent DWSHA studies); 1 new PFAS oral SF for **PFOA** added (based on DWSHA study)

May 2022
Oral RfDs for **7 new PFAS** (based on DWSHA or ATSDR studies), including 1 new oral SF (based on DWSHA study); oral RfDs lower for **PFOA, PFOS**, and **Perfluorooctane sulfonate** (based on ATSDR study)

Nov 2022
No PFAS changes to RSL table

May 2023
Oral RfDs for 9 new PFAS (based on IRIS studies)

Nov 2023
Oral RfDs for 7 new PFAS [based on Wisconsin studies (4 PFAS) and ORD studies (3 PFAS)];

Change in volatile status for 4 PFAS (1 became volatile and 3 became non-volatile)

May 2024
Chronic and Subchronic Oral RfDs + Oral SFs for 6 PFAS (based on EPA Office of Water); 6 new MCLs added

Oral Cancer Toxicity Values Available for PFOA / Perfluorooctanoates

Including Derivatives of 14 PFAS, 31 Analytes in EPA RSL Table with Oral Noncancer Toxicity Values

14 PFAS Currently in EPA RSL Table
PFOA
PFOS
HFPO-DA (Gen-X)
PFBS
PFHxS
PFNA
PFBA
PFHxA
PFUnDA
PFDoDA
PFTetDA
PFODA
PFPrA
TFSI

Notes:

DWSHA = Drinking Water Standards and Health Advisories (EPA Office of Water)

ORD = Office of Research and Development (EPA)

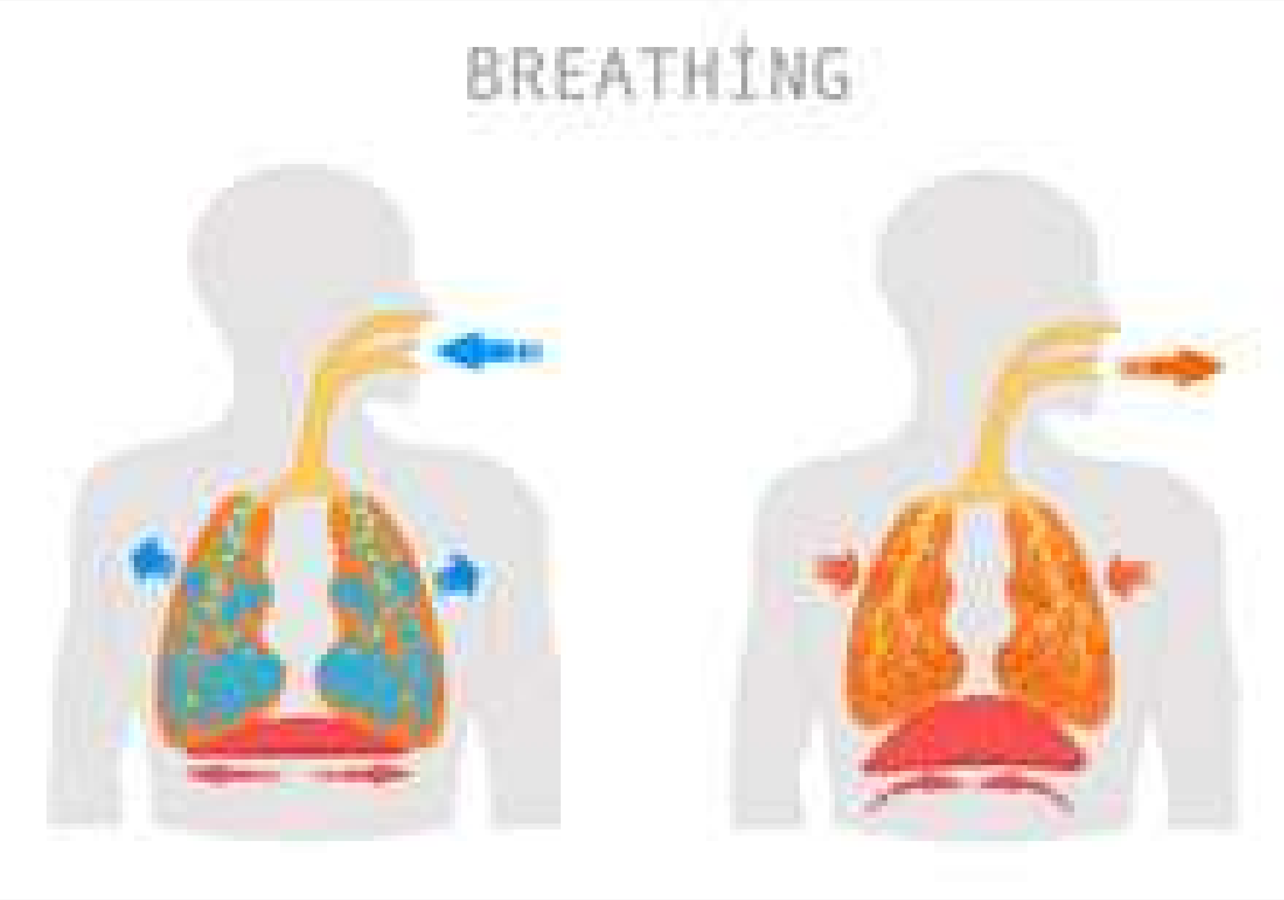
PPRTV = Provisional Peer-Reviewed Toxicity Values

Wisconsin = Wisconsin Department of Health

PFAS Toxicology 101

Status of Inhalation Toxicity Values

- Need toxicity values specific to route of exposure
- Aside from some states with draft inhalation reference concentrations (noncancer toxicity values), EPA has not issued any inhalation toxicity values for PFAS
- Therefore, inhalation risks can not be estimated at this time, including from vapor intrusion concerns.
- This may change at any time once inhalation toxicity values become available and are endorsed by EPA



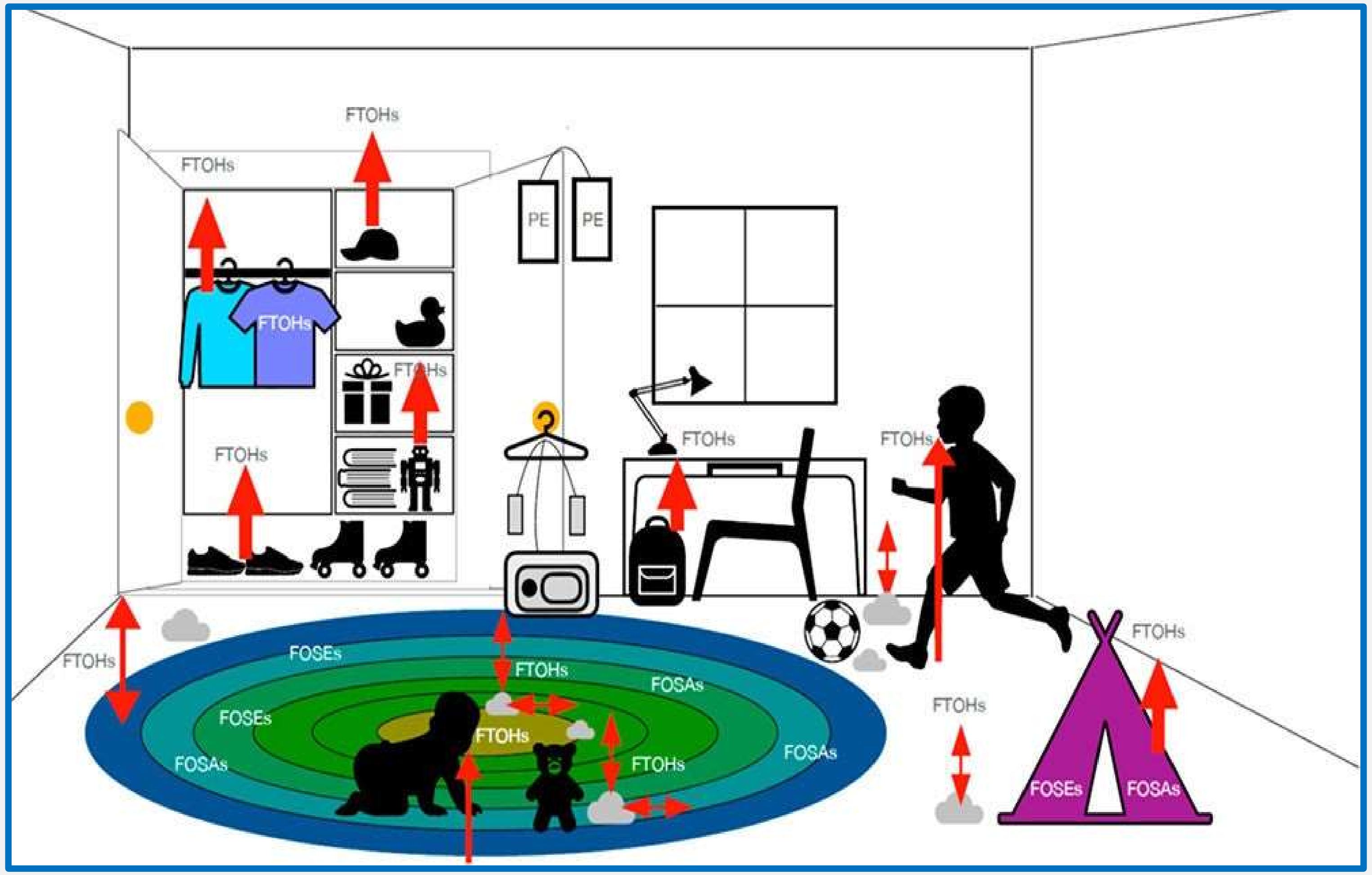
PFAS in Dust and Air: What We Know

PFAS in Indoor Air

Indoor air concentrations driven by volatile neutral FTOHs

- Stain-repellent consumer products [clothing, furniture, carpeting, textiles (linens, drapes, bedding)]
- Stain-repellent applications to clothing, furniture, carpeting

Both volatile and non-volatile PFAS settle into carpet and household surfaces



Source: We're breathing PFAS: URI-led study finds harmful forever chemicals in indoor air – Graduate School of Oceanography, 2021

PFAS Composition in Indoor Air - predominantly neutral FTOH

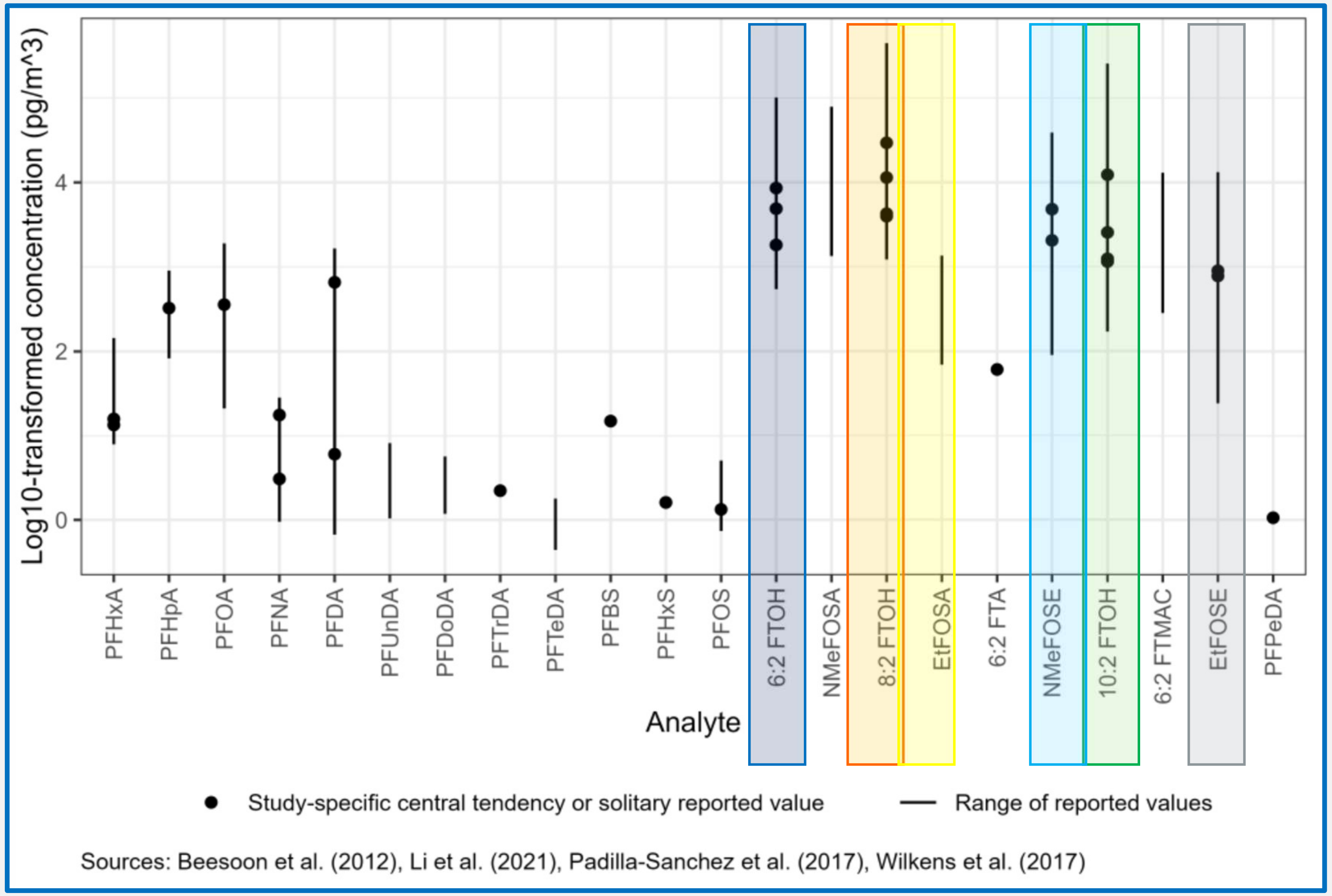
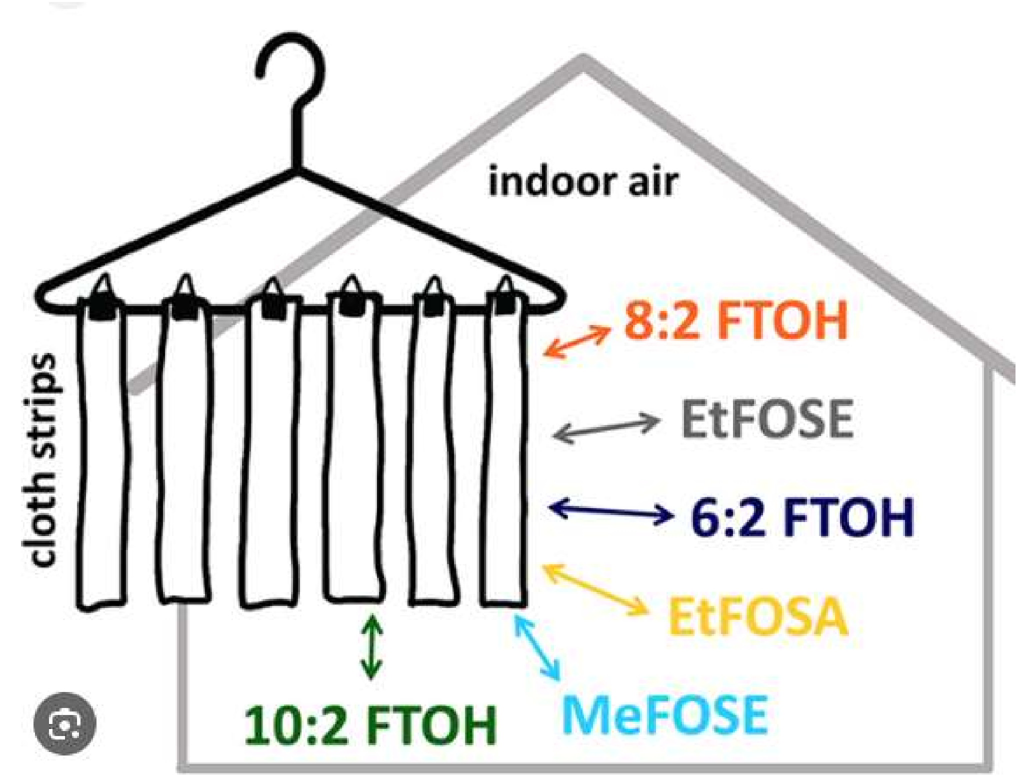


Figure 6-1B. Observed PFAS concentrations in indoor air.

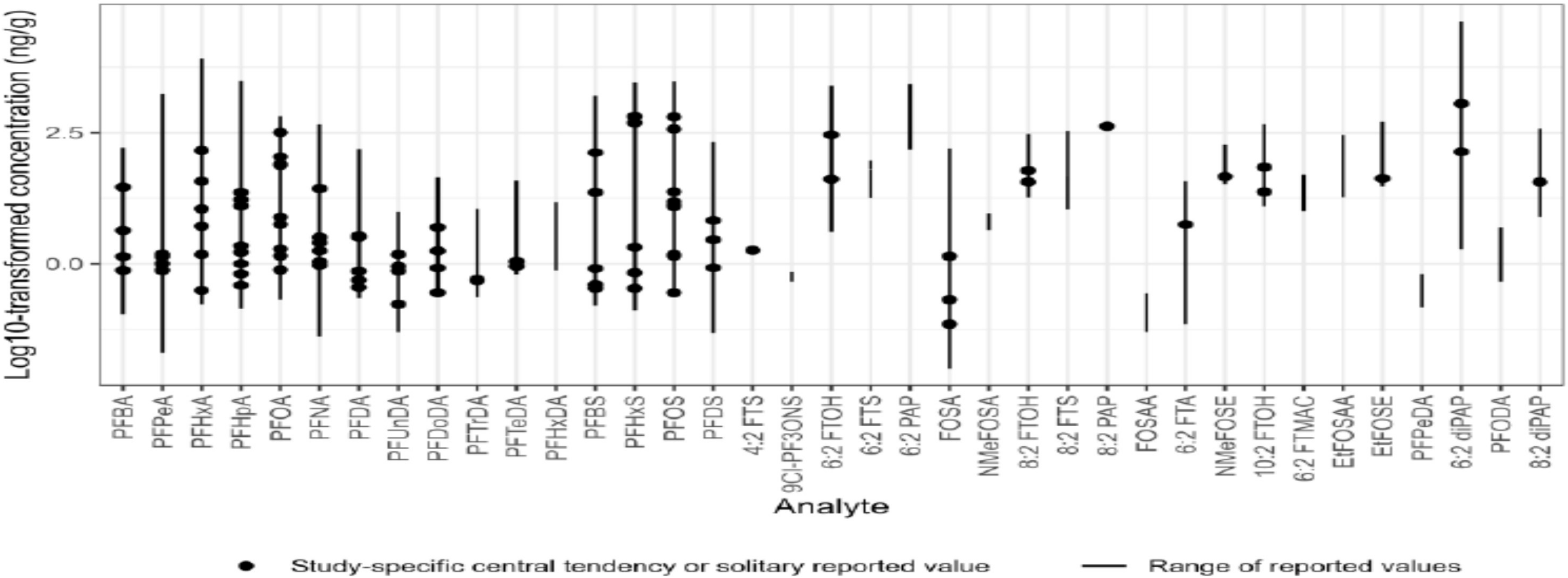
Source: Figure developed using ggplot2 (Wickham 2016)

Source: September 2023 ITRC PFAS Guidance



Source: Cloth–Air Partitioning of Neutral Per- and Polyfluoroalkyl Substances (PFAS) in North Carolina Homes during the Indoor PFAS Assessment (IPA) Campaign (Eichler et al, 2023)

PFAS Composition in Settled Dust



Sources: Ao et al. (2019), Beesoon et al. (2012), Besis et al. (2019), Byrne et al. (2017), de la Torre et al. (2019), Giovanoulis et al. (2019), Young et al. (2020), Zheng et al. (2020)

Figure 6-1C. Observed PFAS concentrations in settled dust.
Source: Figure developed using ggplot2 (Wickham 2016)

Source: September 2023 ITRC PFAS Guidance

PFAS Occupational Standards and Studies

Occupational PFAS Air Standards

- **Occupational Safety & Health Administration (OSHA)**
  - No Permissible Exposure Limits (PELs) available for PFAS
- **National Institute of Occupational Safety & Health (NIOSH)**
  - No Recommended Exposure Limits (RELs) available for PFAS
  - NIOSH has been conducting research on PFAS, including
    - Worker exposure / health assessments
    - Dermal absorption studies
    - Sample & analytical methods
    - Toxicity testing in animals
    - Firefighter gear testing for PFAS
- **American Conference for Governmental Industrial Hygienists (ACGIH)**
  - Air Threshold Limit Values (TLVs) established for 3 PFAS:
  - perfluoroisobutylene (PFIB) Ceiling limit = 0.01 ppm,
  - perfluorobutyl ethylene 8 hr TWA = 100 ppm, and
  - ammonium perfluorooctanoate (APFO) - a salt of PFOA 8 hr TWA = 0.01 mg/m^3 (skin*, A3).

TLVs are not standards; however, they are health-based guidelines recommendations for safe levels of substances in air based on an 8-hour workday and 40-hour work week.

* Skin contact potential exposure route

A3 = Confirmed Animal Carcinogen with Unknown Relevance to Humans

Occupational Exposure:
Some Recent Studies Available

Received: 22 July 2022 | Revised: 13 January 2023 | Accepted: 17 January 2023
DOI: 10.1002/ajim.23461

REVIEW ARTICLE

AMERICAN JOURNAL OF INDUSTRIAL MEDICINE WILEY

Occupational exposures to airborne per- and polyfluoroalkyl substances (PFAS)—A review

Tamara Paris-Davila[1] | Linda G. T. Gaines[2] | Katherine Lucas[1] | Leena A. Nylander-French[1]

Journal of Exposure Science & Environmental Epidemiology www.nature.com/jes

REVIEW ARTICLE

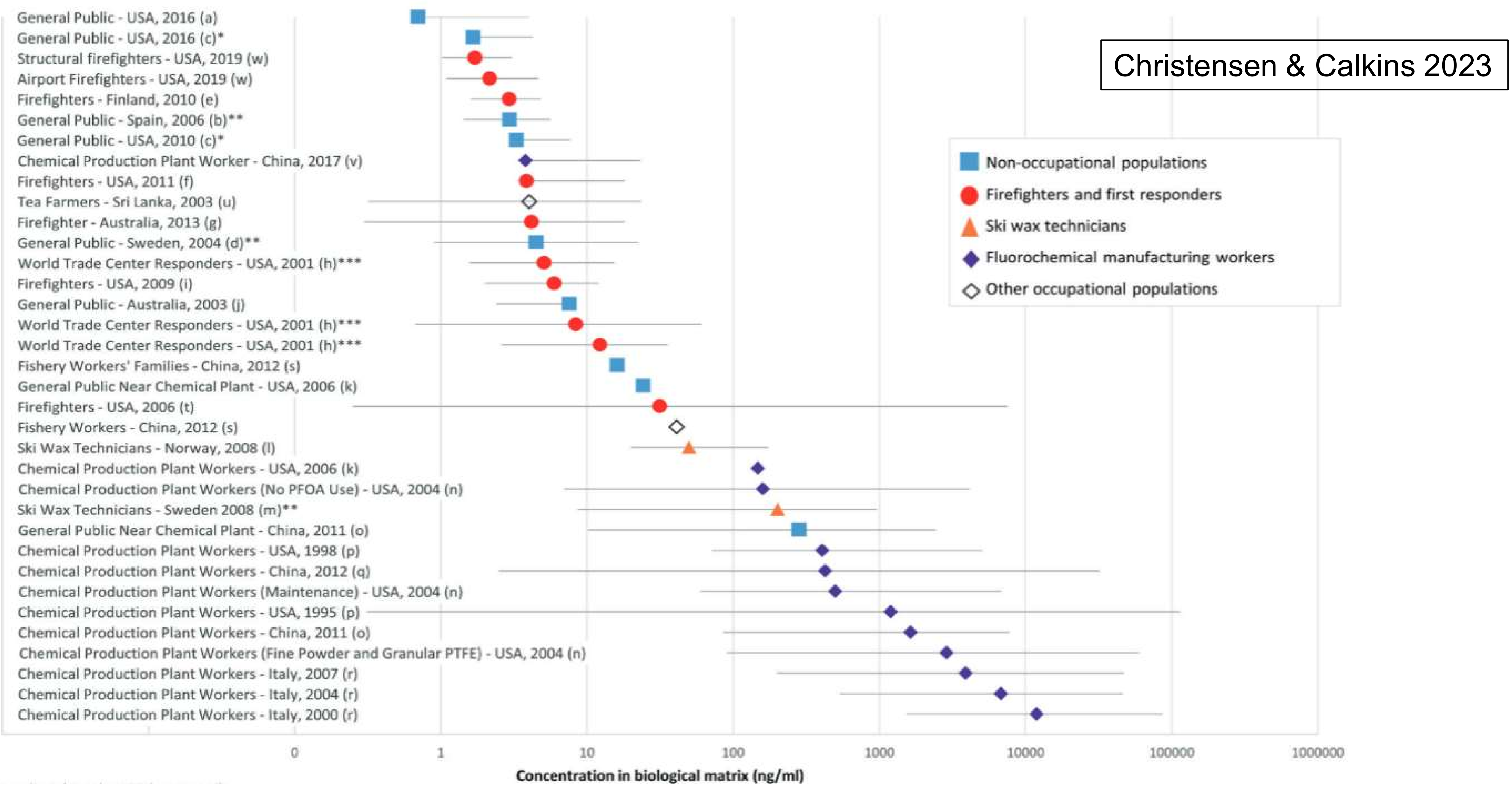
Check for updates

Occupational exposure to per- and polyfluoroalkyl substances: a scope review of the literature from 1980–2021

Brian T. Christensen[1] ✉ and Miriam M. Calkins[1]

- Focus on workers exposed to chemical production, firefighters, ski-wax technicians
- Two recent articles
- Looking at serum monitoring
- Looking at air/dust in workplace air but not necessarily breathing zone
- Questions to answer:
  - Which specific PFAS do we measure?
  - Are there other workplace environments we need to look at?

Worker Exposure Serum Consolidated



Questions?

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Thank you

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