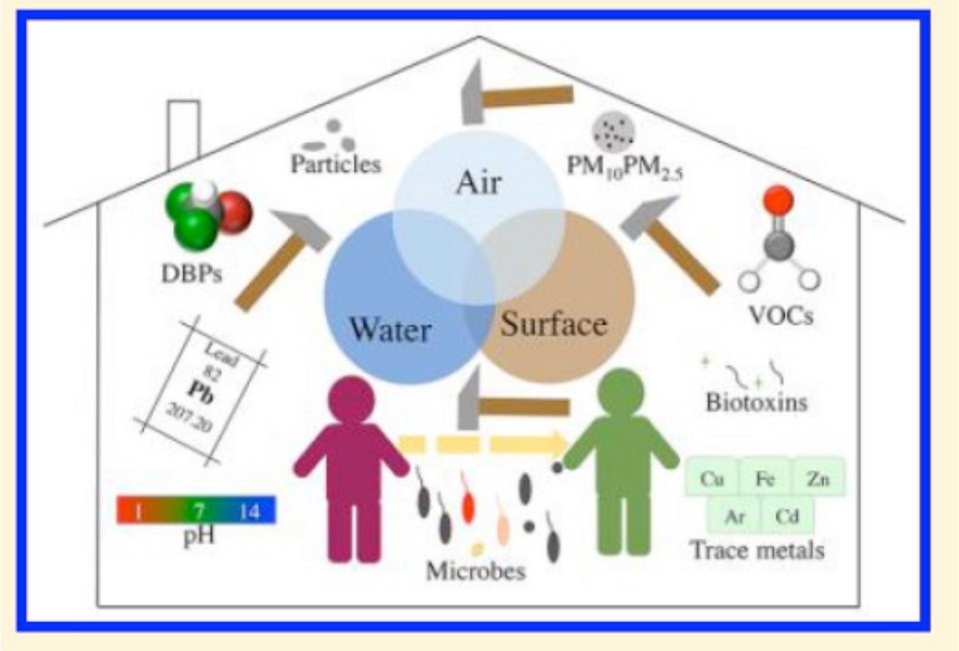
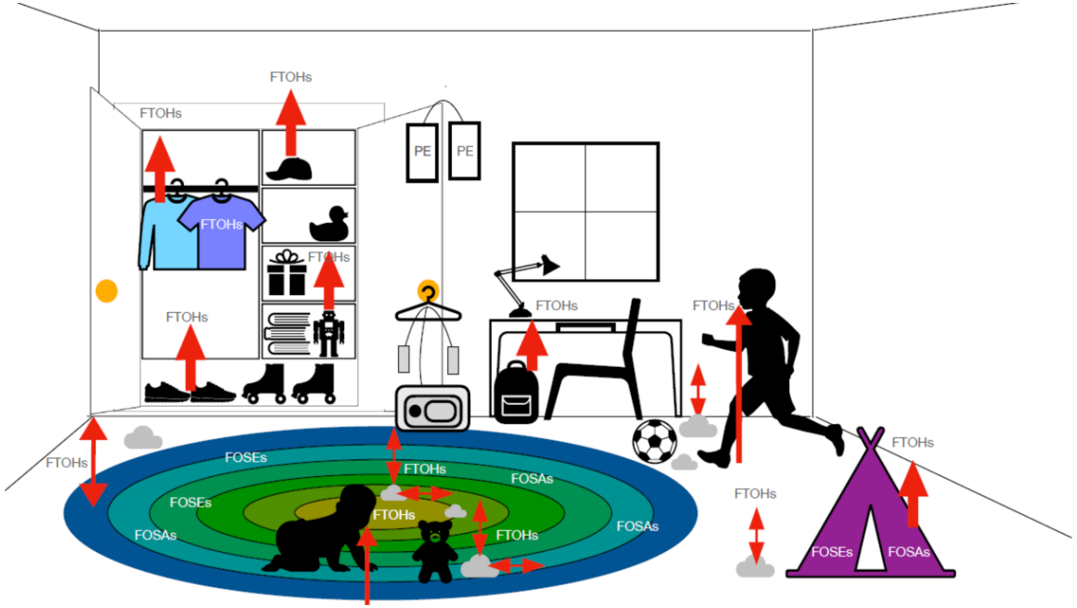


(Dai et al., 2017)



(Morales-McDevitt et al., 2021)

Residential exposure:
PFAS and other SVOCs inside out

Rainer Lohmann

Professor of Oceanography, University of Rhode Island

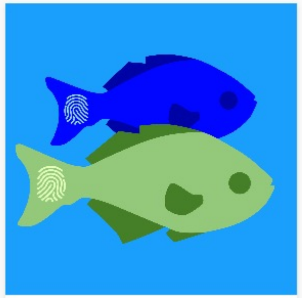
URI STEEP Superfund Research Center

STEEP II

Sources, Transport, Exposure & Effects of PFASs

UNIVERSITY OF RHODE ISLAND SUPERFUND RESEARCH PROGRAM

Connecting science and people

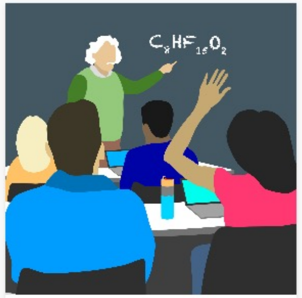


STEEP Research: Environmental Fate & Transport

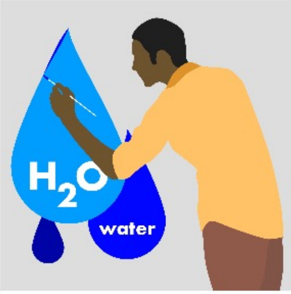
STEEP Research: Childhood Risk

STEEP Research: Metabolic Effects

STEEP Research: Detection Tools



STEEP Core: Next Generation



STEEP Core: Research Translation

STEEP Core: Community Engagement

STEEP Core: Administrative

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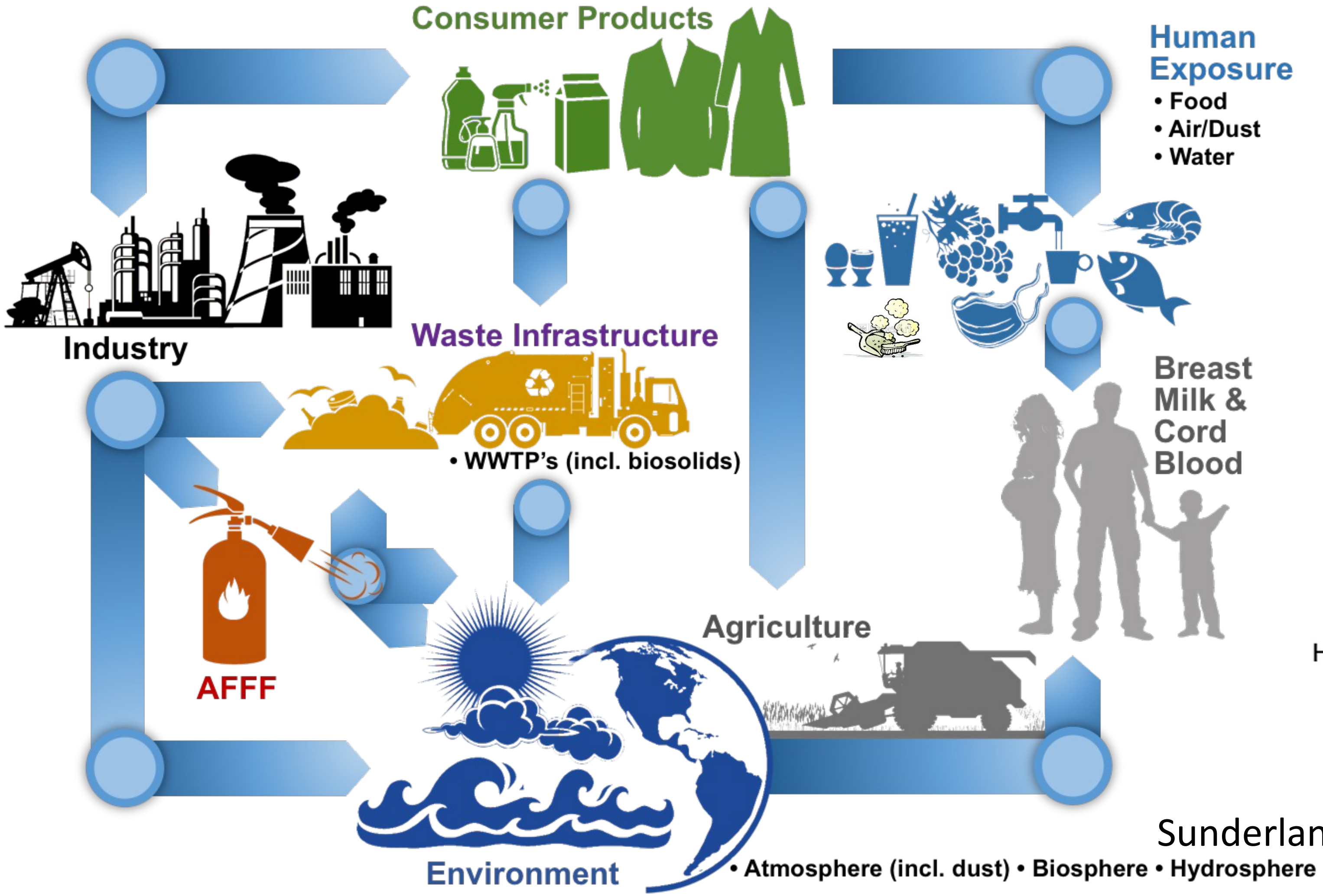
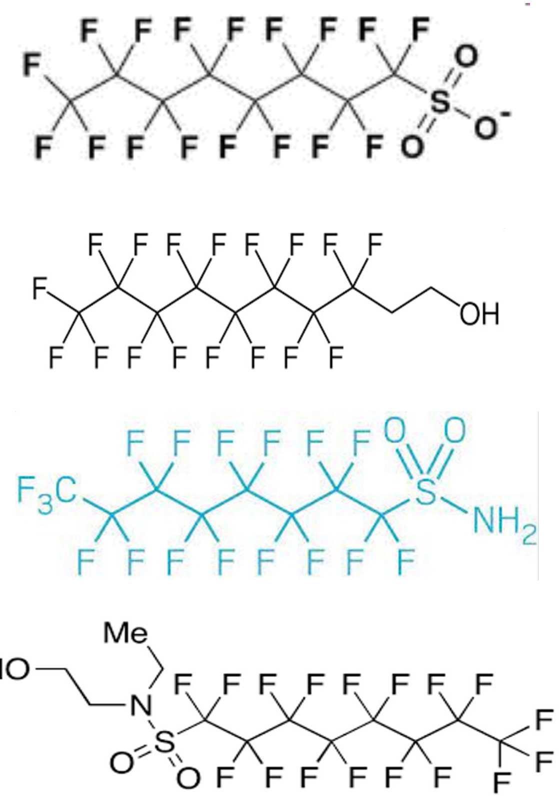
Human Exposure Pathways





Sunderland et al., 2019

When you stain-treat your carpet,
it stains you back

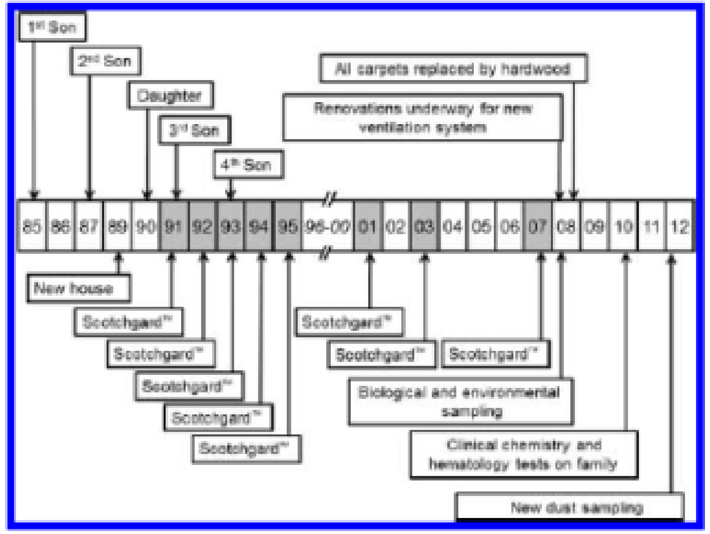
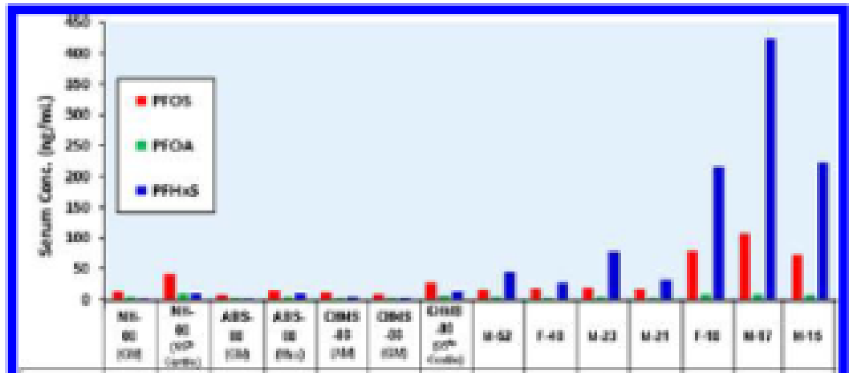


Figure 3. Timeline showing Scotchgard applications to the main floor family room carpet and occasionally (1995, 2003, and 2007) to the dining room carpet in relation to year in which the children in the family were born and sampling conducted for the current study.



	NH-08 (GM)	NH-08 (95th centile)	ABS-08 (GM)	ABS-08 ([illegible])	CHMS-08 (AM)	CHMS-08 (GM)	CHMS-08 (95th centile)	M-52	F-48	M-23	M-21	F-18	M-17	M-15
PFOS	13.2	40.6	7.40	14.0	11.3	8.00	27.5	15.2	17.7	19.9	16.4	78.4	108	72.3
PFOA	4.10	9.70	2.60	3.80	2.90	2.50	5.50	3.70	2.60	5.00	2.40	9.00	9.20	6.80
PFHxS	2.00	9.80	2.10	9.80	3.90	2.30	12.5	45.2	27.5	77.1	32.2	215	423	222

Figure 1. Serum concentrations of PFOS, PFOA, and PFHxS in the current family compared to concentrations in other biomonitoring studies in the United States and Canada. NH-08: NHANES study 2008; ABS-08: Alberta Biomonitoring Study 2008; CHMS-08: Canadian Health Measures Study 2008.

Environmental Science & Technology

Exceptionally High Serum Concentrations of Perfluorohexanesulfonate in a Canadian Family are Linked to Home Carpet Treatment Applications

Sanjay Beesoon,[†] Stephen J. Genuis,[‡] Jonathan P. Benskin,[†,§] and Jonathan W. Martin*,[†]

(Beeson et al., 2016)

Environmental Science & Technology LETTERS

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Letter

The Air That We Breathe: Neutral and Volatile PFAS in Indoor Air

Maya E. Morales-McDevitt, Jitka Becanova, Arlene Blum, Thomas A. Bruton, Simon Vojta, Melissa Woodward, and Rainer Lohmann*

Cite This: https://doi.org/10.1021/acs.estlett.1c00481

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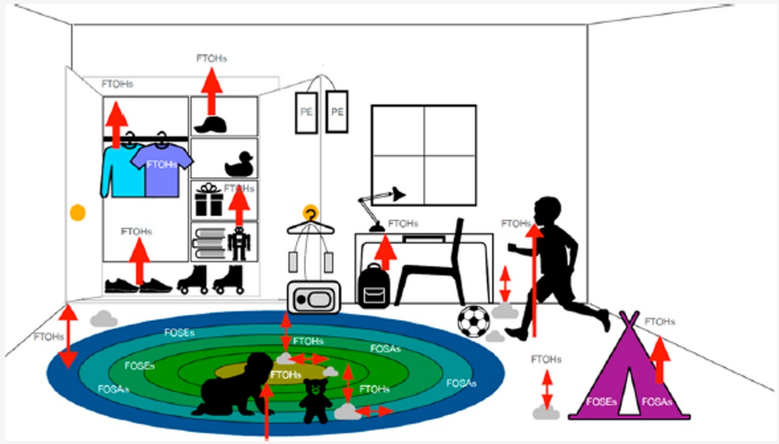
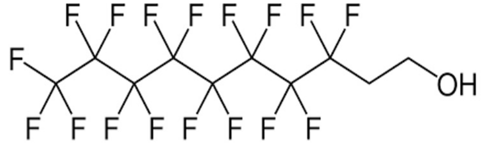
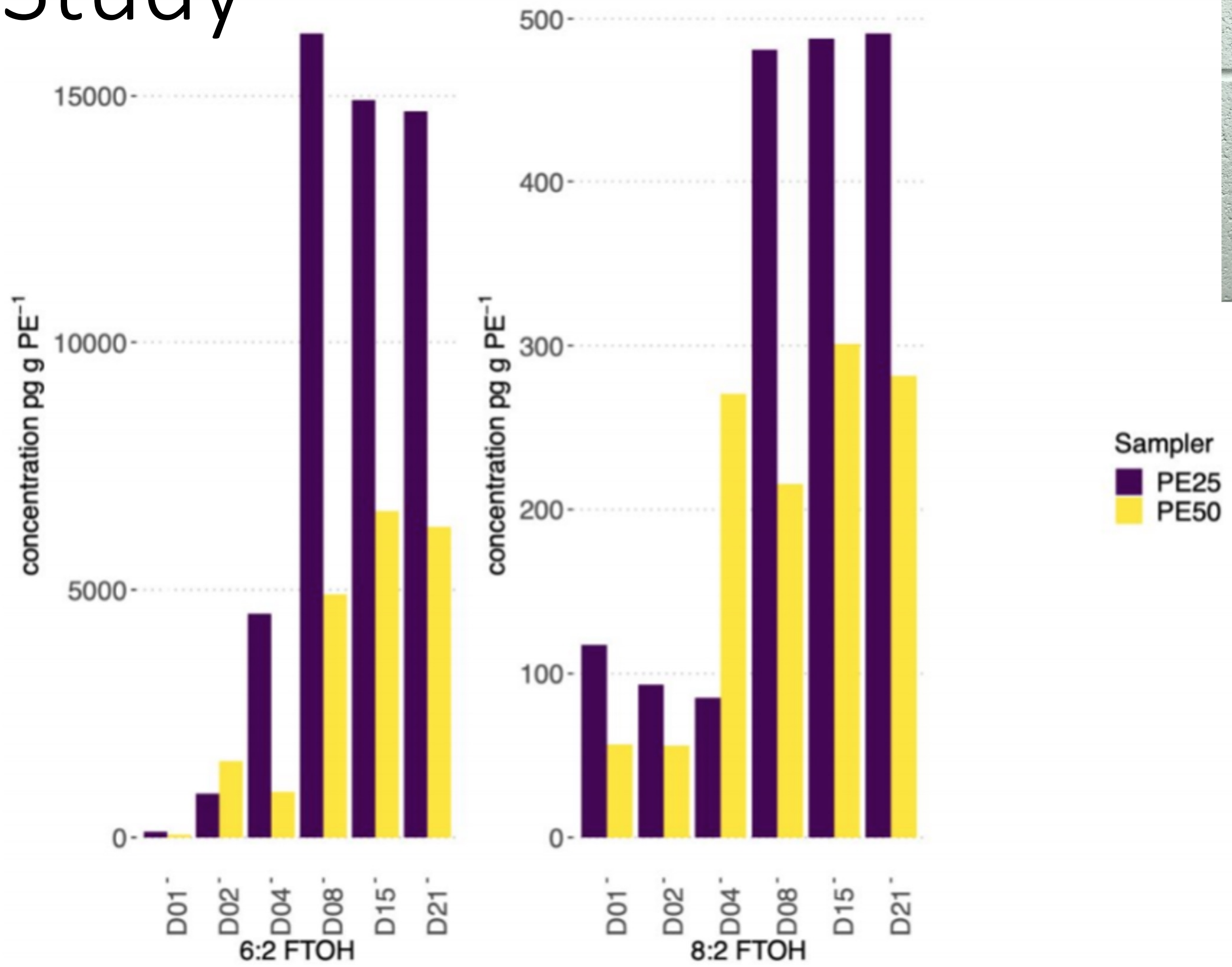


ABSTRACT: Sources of exposure to per- and polyfluorinated alkyl substances (PFAS) include food, water, and, given that humans spend typically 90% of their time indoors, air and dust. Quantifying PFAS that are prevalent indoors, such as neutral, volatile PFAS, and estimating their exposure risk to humans are thus important. To accurately measure these compounds indoors, polyethylene (PE) sheets were employed and validated as passive detection tools and analyzed by gas chromatography−mass spectrometry. Air concentrations were compared to dust and carpet concentrations reported elsewhere. Partitioning between PE sheets of different thicknesses suggested that interactions of the PEs with the compounds are occurring by absorption. Volatile PFAS, specifically fluorotelomer alcohols (FTOHs), were ubiquitous in indoor environments. For example, in carpeted Californian kindergarten classrooms, 6:2 FTOH dominated with concentrations ranging from 9 to 600 ng m^{-3}, followed by 8:2 FTOH. Concentrations of volatile PFAS from air, carpet, and dust were closely related to each other, indicating that carpets and dust are major sources of FTOHs in air. Nonetheless, air posed the largest exposure risk of FTOHs and biotransformed perfluorinated alkyl acids (PFAA) in young children. This research highlights inhalation of indoor air as an important exposure pathway and the need for further reduction of precursors to PFAA.

Kinetic Study





Amounts of 6:2 FTOH and 8:2 FTOH reached equilibrium after 14 days

$$C_{PE}: \left({}^{N_s}/_{m_s}\right) - N_{blk}$$

Figure S1. Weight-normalized, blank-corrected concentrations of 6:2 FTOH and 8:2 FTOH per gram of PE sheet.

PE-air Partitioning

Table 1. Indoor Log $K_{PE\text{-}air}$ Values from the Validation Study for 25 and 50 μm PE Sheets

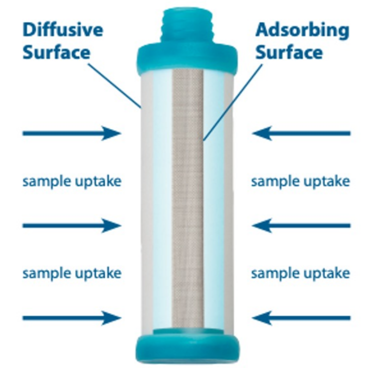
compound	molecular weight ($g\ mol^{-1}$)	mean log $K_{PE\text{-}air\ 25}$ (this study)	mean log $K_{PE\text{-}air\ 50}$ (this study)
6:2 FTOH	364.1	4.4 ± 0.1	4.3 ± 0.0
8:2 FTOH	464.1	4.3 ± 0.1	4.5 ± 0.0
10:2 FTOH	564.1	5.0	5.0 ± 0.0
8:2 FTAcr	518.1	4.9 ± 0.4	5.0 ± 0.2
10:2 FTAcr	618.1	5.2[a]	5.3[a]
MeFOSA	527.2	5.1[a]	5.2[a]
EtFOSA	513.1	ND[b]	ND[b]
MeFOSE	571.2	5.2[a]	5.3[a]
EtFOSE	557.2	5.2[a]	5.2[a]

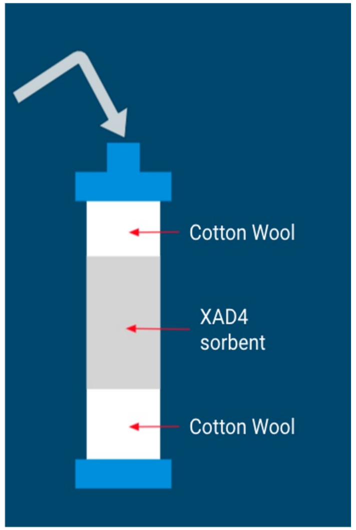
[a] $K_{PE\text{-}air}$ values from this study were estimated on the basis of a correlation between those measured here and those reported by Dixon-Anderson and Lohmann.[16] Estimated $K_{PE\text{-}air\ 50} = 0.44 K_{PE\text{-}air,measured}$ (Dixon-Anderson and Lohmann, 2018) + 1.30 ($RSQ_{PE50} = 0.67$). [b] Not detected.

$$K_{PE\text{-}air} = \frac{C_{PE}}{C_{air}} \quad (1)$$

where C_{PE} is the concentration in PE sheets (nanograms per gram of PE) and C_{air} is the gas-phase concentration (nanograms per cubic meter).

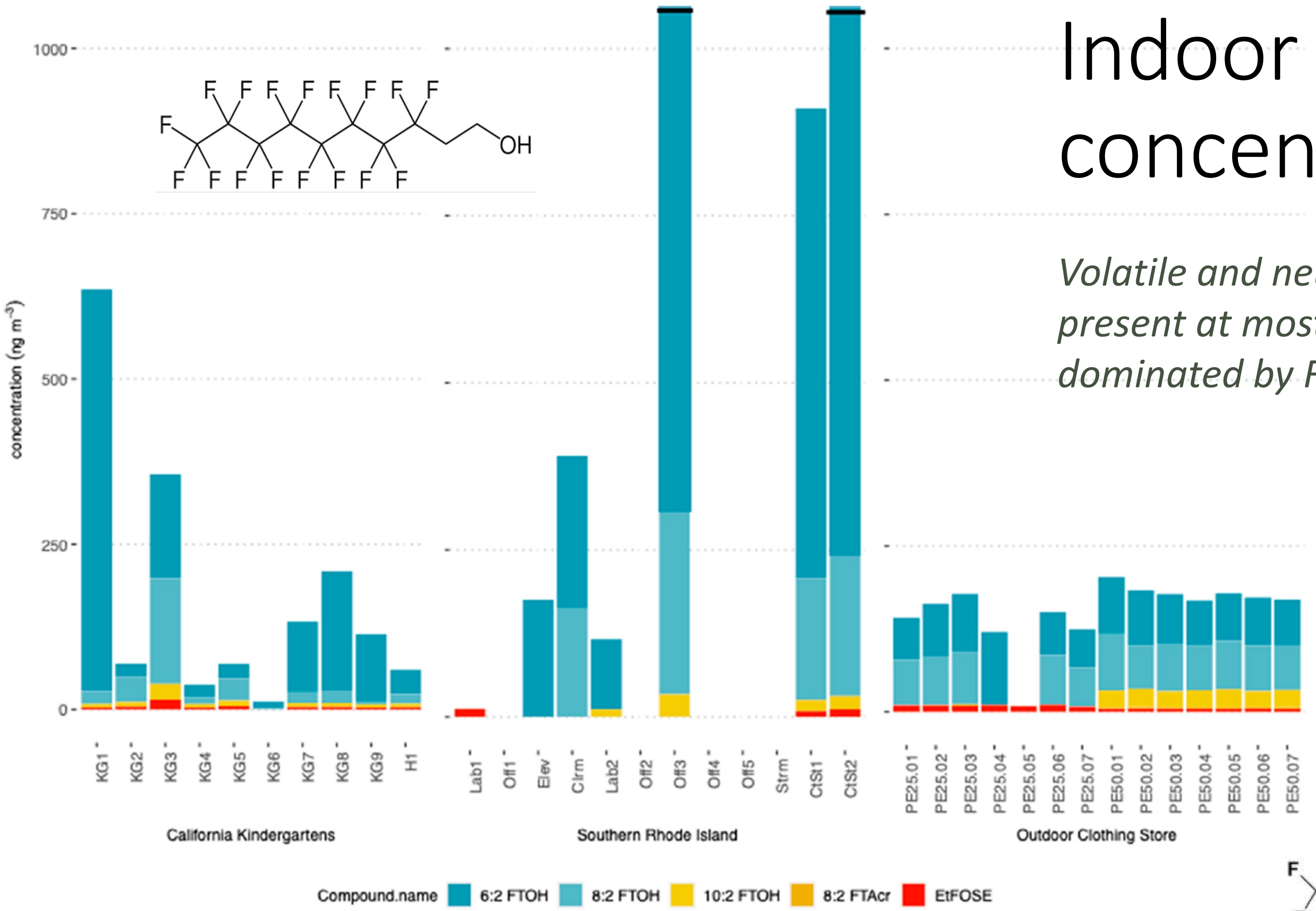
Increasing KPEa with increasing molecular weight





Indoor concentrations

Volatile and neutral PFAS were present at most locations, dominated by FTOHs



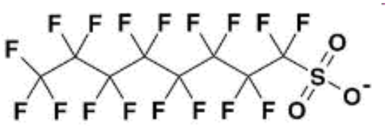


Figure 1. Indoor air concentrations measured in California kindergarten classrooms, an outdoor clothing store, university classrooms, offices and laboratories, and a carpet store in southern Rhode Island. Abbreviations: H, home; KG, kindergarten classrooms; Lab, laboratory; Off, office; Elev, elevator; Clrm, classroom; Ctst, carpet store; Strm, storage room. Numbers (i.e., KG7) are indicative of separate/individual samples. Off3 (2220) and CtSt2 (1040) have concentrations of >1000 ng m^{-3}.

$$EDI_{volatile\ PFAS} = \sum\left(\frac{CneutPFASair \times q_{air} \times f_{time-in}}{mbw} \times F_{uptake}\right) + \sum\left(\frac{CneutPFASdust \times q_{dust} \times f_{time-in}}{mbw} \times F_{uptake}\right)$$

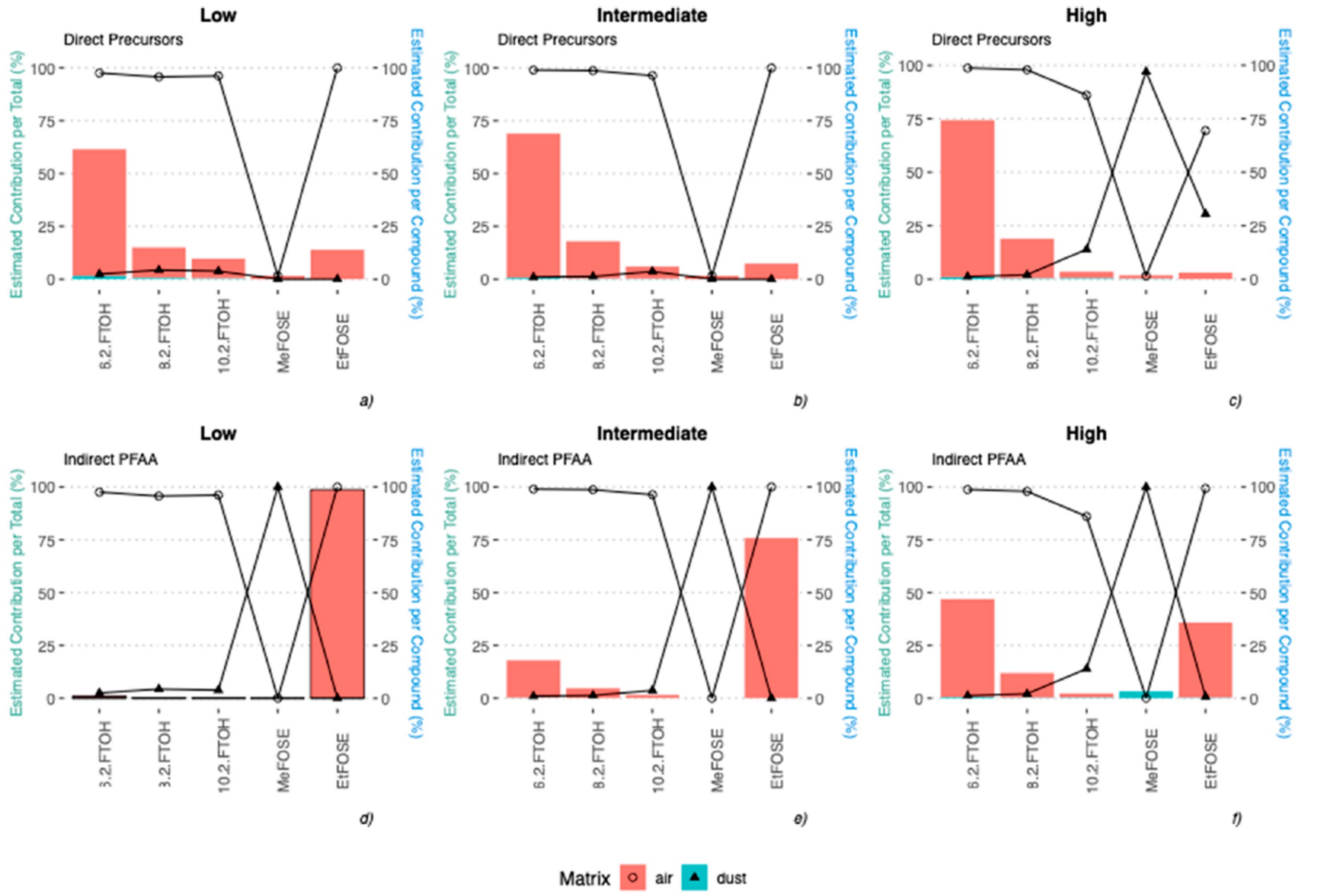
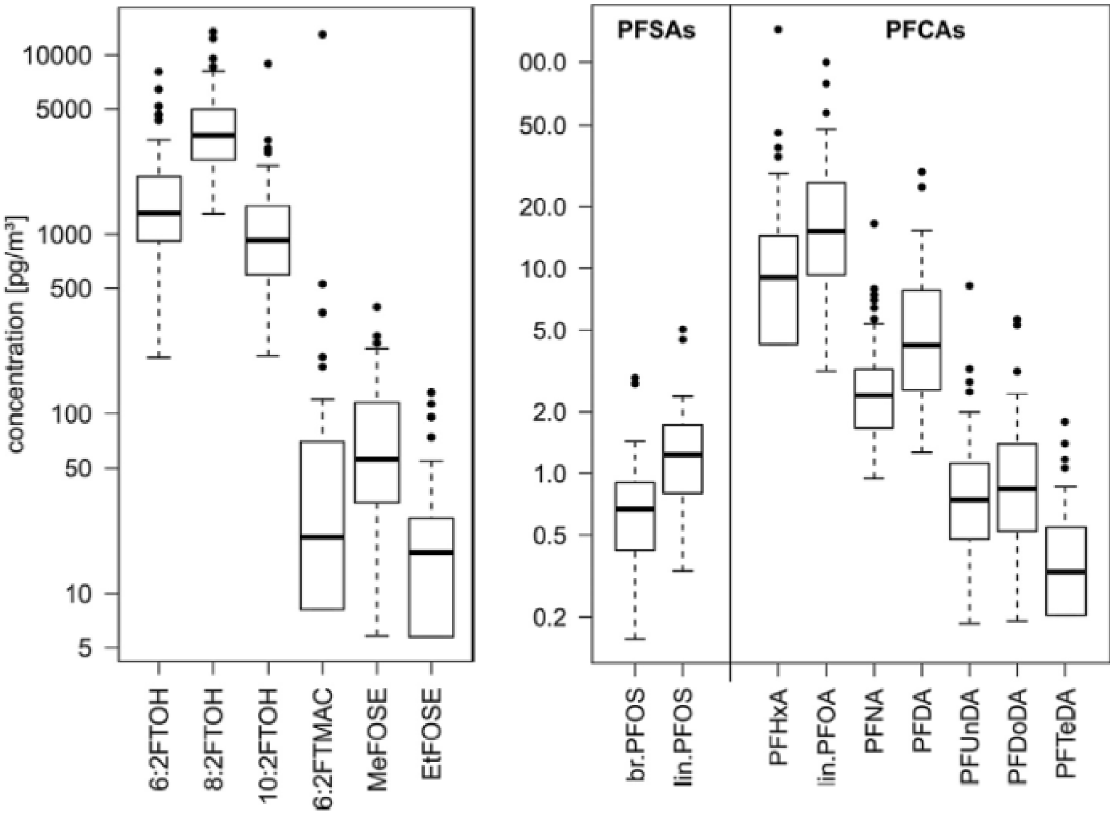


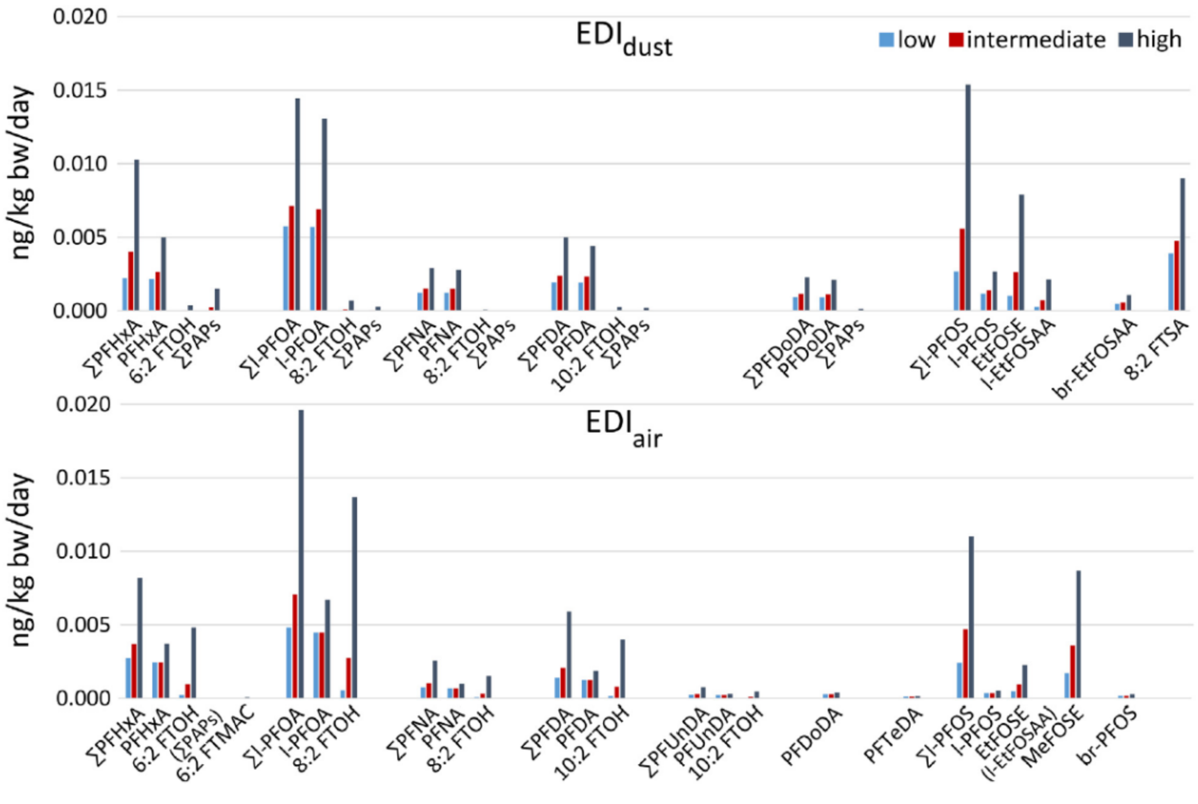
Figure 2. Percent of volatile and neutral PFAS (top panels) and indirect or biotransformed PFAA (bottom panels) intake via air inhalation (pink) and dust ingestion (blue) for 2–6-year-old children. Bars represent the relative contribution of individual precursors to total PFAS (left axes); bars are differentiated by color for both matrices. Lines represent the percent estimated contribution for each compound in air and dust (right axes). MeFOSE was detected at low concentrations in dust and <MDL in air.

Estimated Daily Intake

- *FTOHs had significantly larger contributions in air*
- *FOSE had larger contributions in dust*

FTOHs dominate, in Europe, too





Air and dust equally important for uptake.
EFSA set TWI for PFHxS, PFOS, PFOA & PFNA at 4.4 ng/kg/wk.

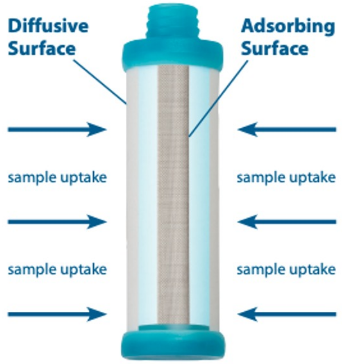
(Winkens et al., 2017, 18)

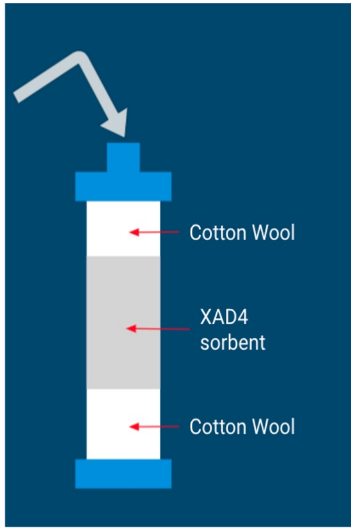
Our on-going work with PFAS in indoor air

- On-going validation of radiello-type air samplers for ionic and neutral PFAS

	6:2 FTOH	8:2 FTAcr	8:2 FTOH	10:2 FTAcr	10:2 FTOH
Sampling Rate (m3/day)	1.591922599	1.186799345	1.165878863	0.8918843599	0.6697831993

- Both in high-exposure and domestic settings





Some concluding thoughts

- PFAS are everywhere, indoors and outdoors
- PE sheets and radiellos work as detection tools for neutral PFAS
- Dust and carpets are likely sources of (neutral) PFAS to air
- In Europe, air and dust exposure < TWI. In the US?
- Detection and removal as major challenges

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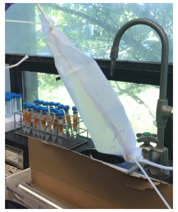
STEEP
Sources, Transport, Exposure & Effects of PFASs
UNIVERSITY OF RHODE ISLAND SUPERFUND RESEARCH PROGRAM

STEEP is funded by the Superfund Research Program, National Institute of Environmental Health Sciences under award number P42ES027706.

QUESTIONS?

Something in the air..

… and in your blood



Environmental Science & Technology

Article

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Airborne Precursors Predict Maternal Serum Perfluoroalkyl Acid Concentrations

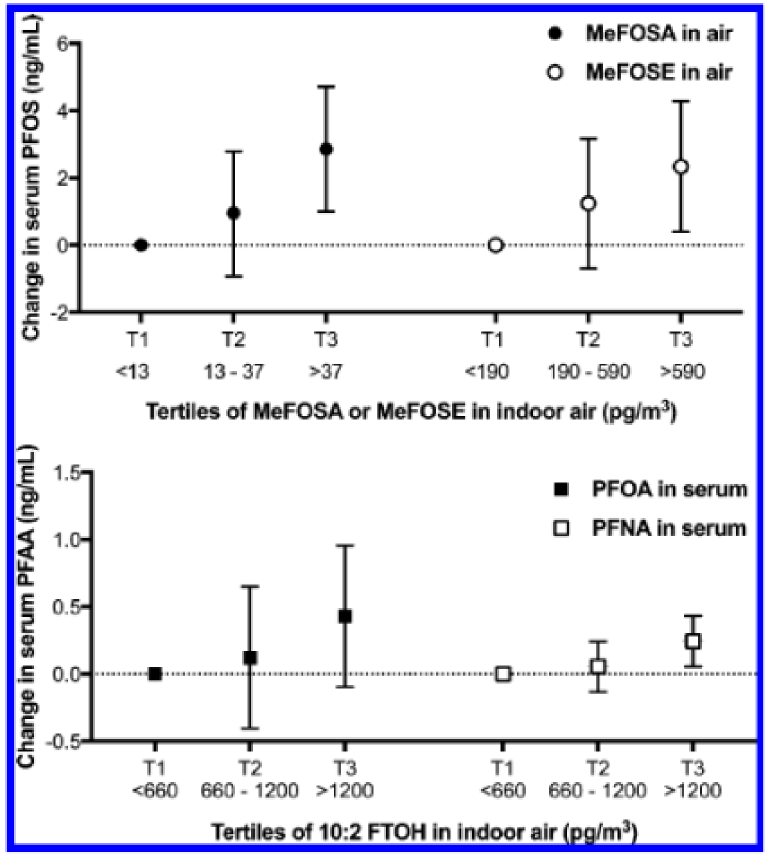
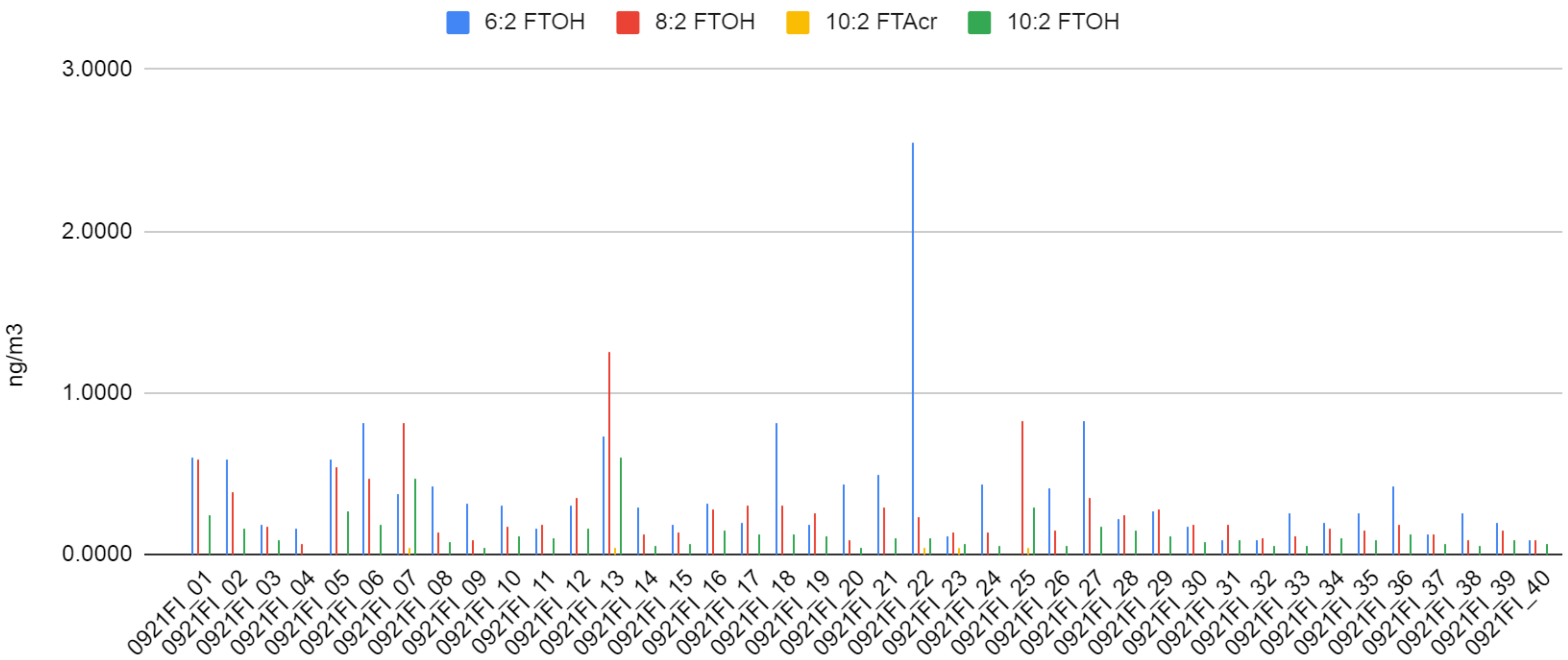


Figure 1. Exposure categories [low (n = 17), medium (n = 16), and high (n = 16)] of PreFAA in air predicting serum PFAA levels in 50 women.

(Makey et al. 2017)

Volatile PFAS in Faroese homes

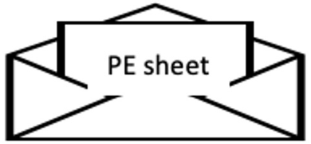


- 14 days (validation study)
- 21 days (kinetic study)
- 28 days (measurements)
- 2 PE sheets: 25 50 uM
- Radiellos: 6 samples
- PEs: 90 samplers

Lab Work II

- PEs cleaned, inserted in scintillation vials, spiked, extracted overnight with EA, blown down, spiked with Recov Std
- Radiellos placed in falcon tubes, spiked, extracted overnight with EA twice, blown down, centrifuged, concentrated, spiked with Recov Std

PEs & Radiellos



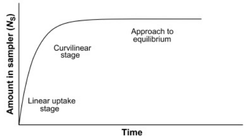
Samples precleaned, packed, individually wrapped, stored

Lab Work I

- Std Sol prep: QA/QC, Int Std, Recov Std
- Field blk, lab blk, lab spk
- 5 pt Calibration

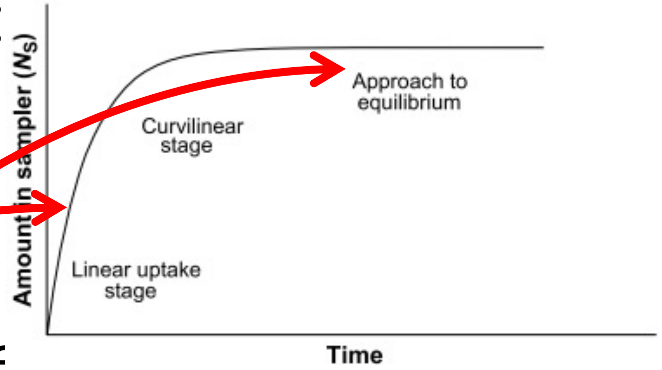
GC/MS

Samples analyzed using GC-MS on an Agilent 7890B chromatograph coupled to an Agilent 5977A MSD operating in positive chemical ionization mode using selected ion monitoring



Passive samplers

- Most passive samplers measure activity of pollutant *e.g.* the dissolved/gas phase



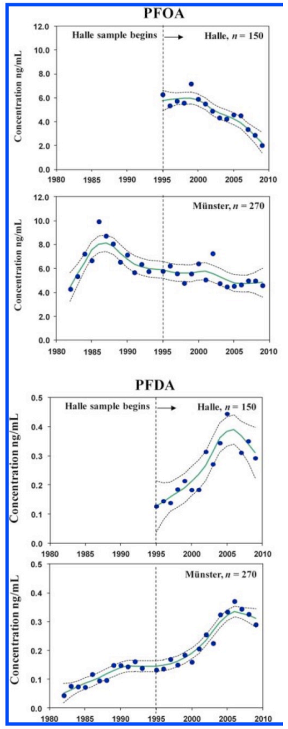
- uptake by diffusion
- advantage – no operational separation of particulate and dissolved phase*
- need to know $K_{passive\text{-}water}$ (T, sal) or Rs, sampling rate
- **C_{diss} = $n_{passive}$ /[Rs x t]** **(linear uptake)**

- **C_{diss} = $C_{passive}$ / $K_{passive\text{-}w}$** **(equilibrium sampler)**

PFASs: Challenging compounds

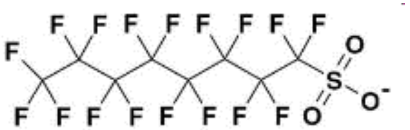
- Widespread human and environmental exposure
  - 100s of contaminated sites in U.S.
    - PFAS production sites, indus
    - Fire training sites, airports

- Everyday exposure for all
  - Contaminated drinking water; Consumer products/dust, diet



- Wide range of adverse effects (humans/animals)
  - Immunosuppression (Grandjean et al., 2013)
  - More PFOA, higher risk of being overweight (Haldersson et al., 2012)

- Unique physical-chemistry, unlike traditional hydrophobic POF
  - Amphiphilic compounds, ionized in solution; bind to proteins



- Regulatory action
  - PFOS withdrawal and PFOA action plan; novel chemistries (e.g., Gen X)