PFAS IN THE INDOOR ENVIRONMENT AND DRINKING WATER: RELEVANCE FOR HUMAN EXPOSURE

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Disclosure and Disclaimer

I have no financial disclosure or conflict of interest with the materials included in this presentation.

I will be discussing the CDC and ATSDR Multi-Site Study and the work of my colleagues related to that study. The views expressed are completely my own.

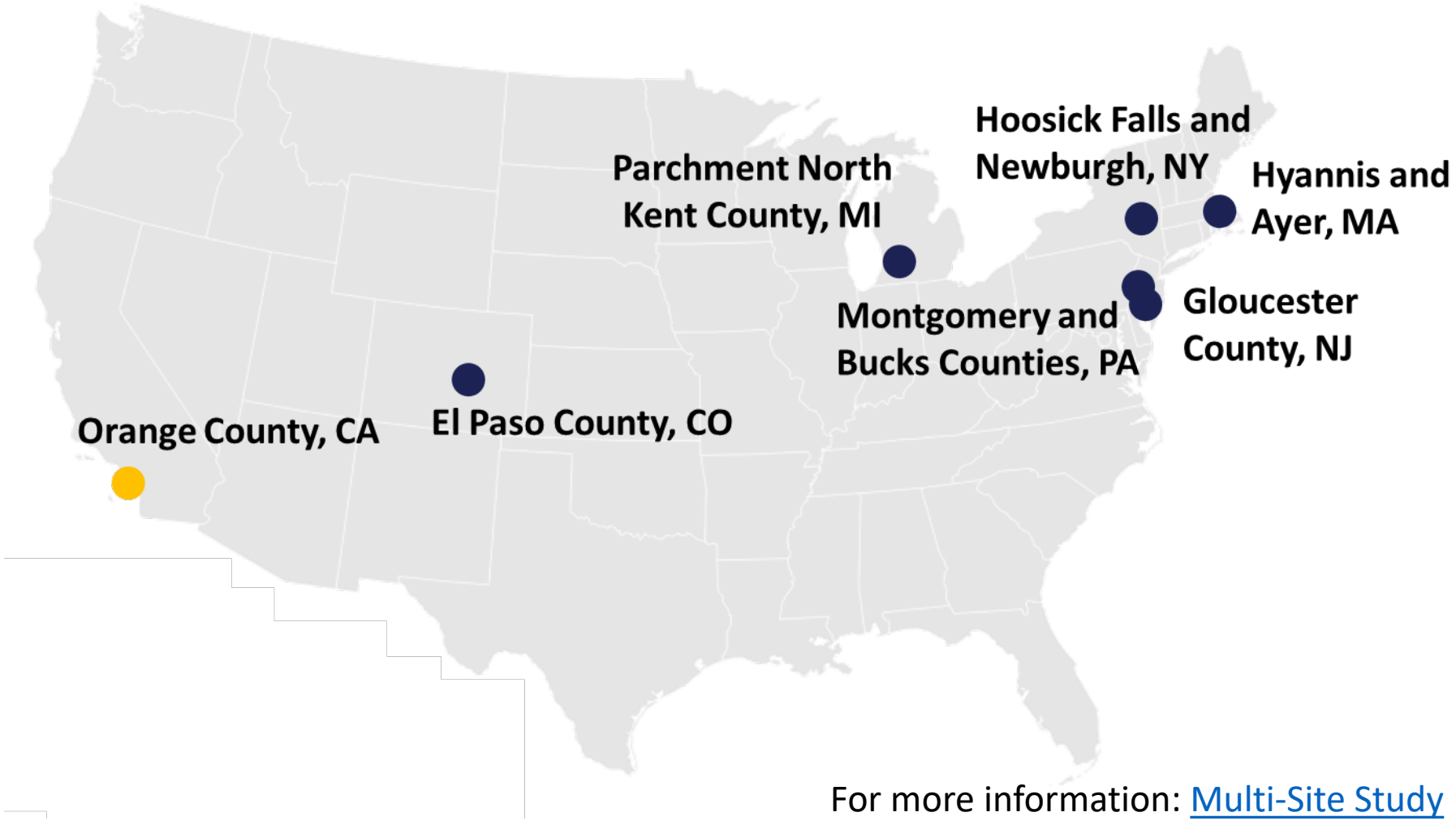
CDC/ATSDR Multi-Site Study (MSS)

- **Goal:** Investigate human health effects of PFAS exposures through drinking water
  - The study will compare different levels of PFAS exposure from different sites across the US
  - Health parameters include immune response, lipid metabolism, kidney function, thyroid disease, liver disease, glycemic parameters, and diabetes
- 5-year study, beginning in late-2019
- Building on the Pease Study in Portsmouth, New Hampshire

For more information: Multi-Site Study

Multi-Site Study Sites

- 7 sites with past PFAS detections in drinking water throughout the United States are included in the MSS



For more information: [Multi-Site Study]

Multi-Site Study Protocol

- Each MSS site will recruit at least **1000 adults** and **300 children**
- **Shared core protocol**, common IRB, and centralized data management
- Each site performs local groundwater modeling and **historical exposure reconstruction** for each participant
- Site-specific **community engagement** and additional research activities are conducted

For more information: Multi-Site Study

Core Protocol Measurements

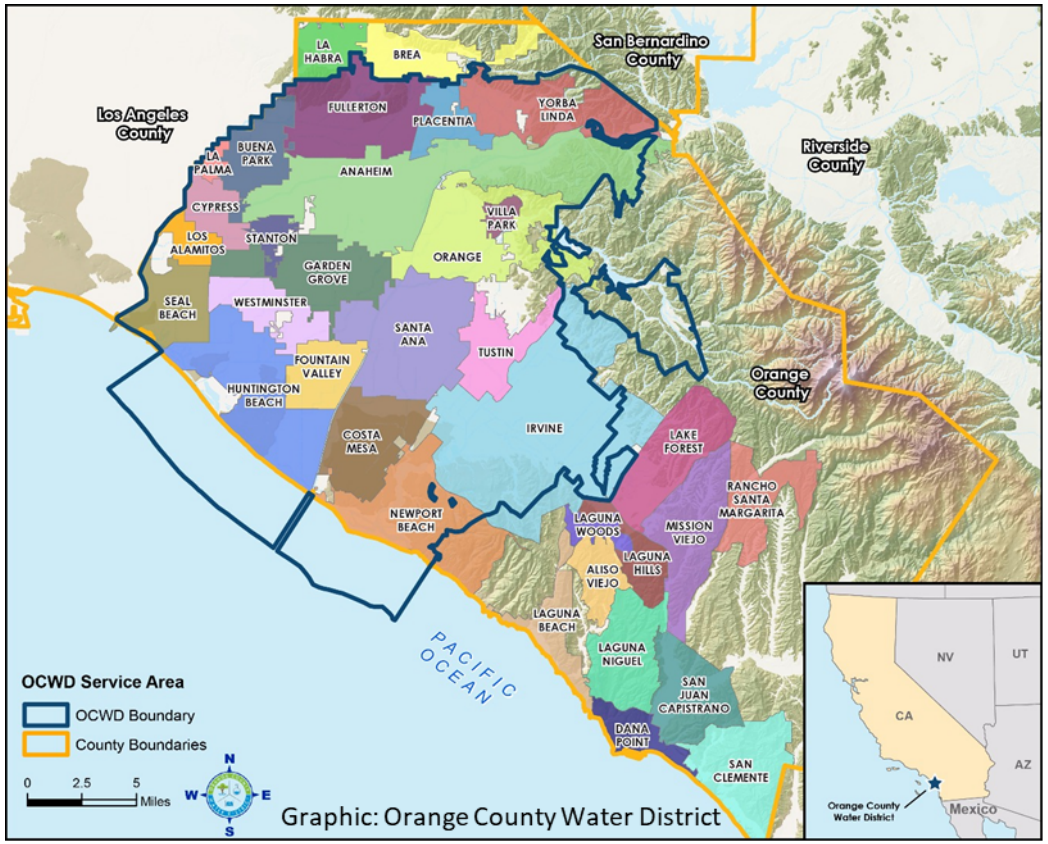
- Questionnaire
  - Including residential histories and water consumption
  - self-reported disease histories, validated by medical records
- Body measurements and blood pressure
- Neurobehavioral testing
- Educational records
- Medication list

- Fasting blood and urine samples, shipped to CDC
  - PFAS concentrations
  - Biomarkers of immune response, lipid metabolism, kidney function, thyroid function, liver function, and glycemic parameters

Draft Protocol Available Here

UCI PFAS Health Study - Orange County, CA

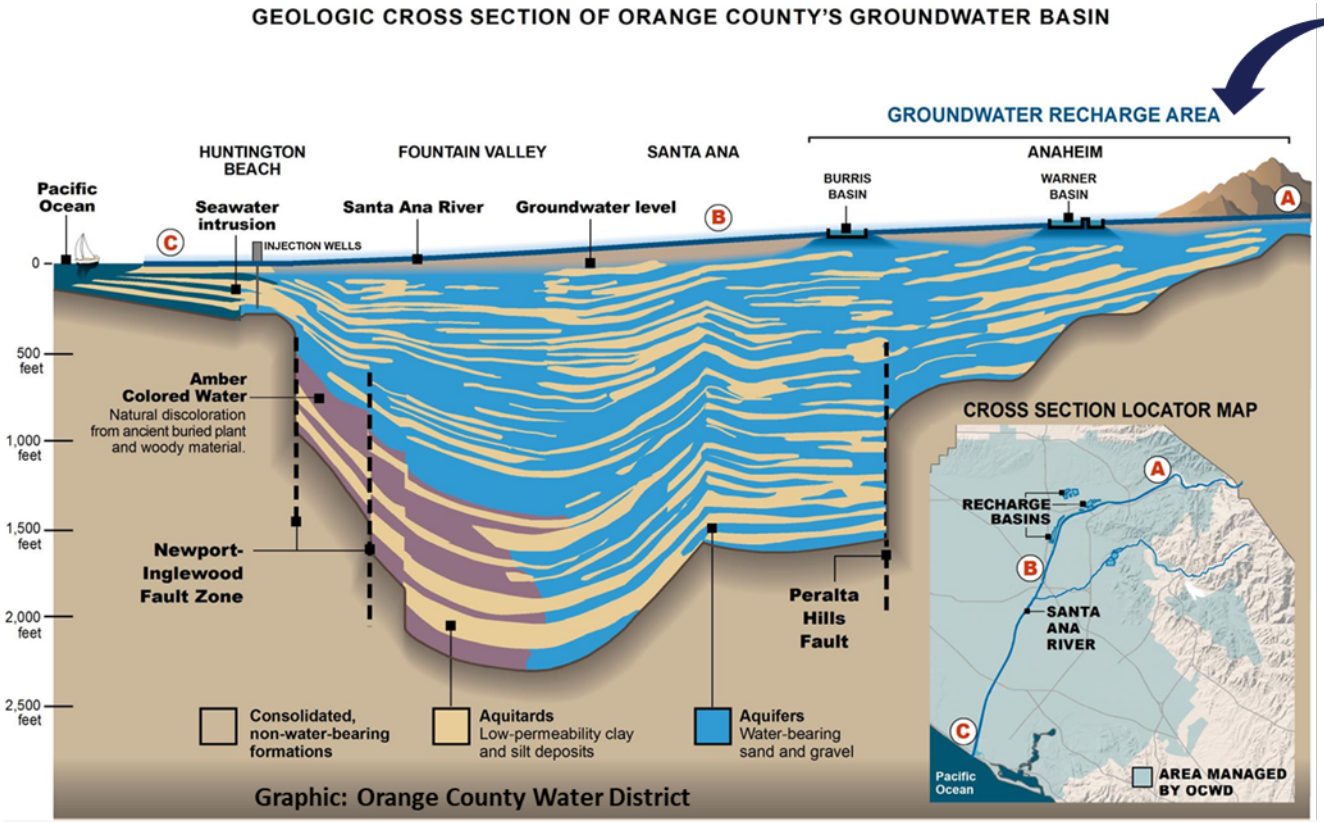
- Over 500,000 people are served by water systems within 10 miles of UC Irvine Medical Center that had at least one water measurement exceeding 70 parts per trillion PFOA + PFOS in UCMR3 (2013-2015)
  - Anaheim and Orange
  - Very diverse; nearly 50% speak a language other than English at home



Multi-site Health Study

Orange County's Drinking Water

- Local water utilities use seasonally varying combinations of groundwater, surface water, and/or imported water
- Groundwater supply and quality carefully managed by Orange County Water District (OCWD)



Recharge from Santa Ana River (**mostly WWTP effluent**), advanced treatment local recycled water, and imported surface water from northern California and the Colorado River.

Orange County and PFAS

- PFAS and OCWD
  - Wells with highest PFAS concentrations taken offline after 2013-2015 UCMR detections
  - 38 wells taken off-line by July 2020, in response to new stricter state health guidelines and additional PFAS water sampling
  - OCWD is currently testing advanced treatment systems to remove PFAS

- **Will other exposure sources be more significant contributors to overall exposure?**

The average American spends more than 90% of their time indoors. For communities with low-level PFAS in drinking water, indoor exposures may be important contributors to overall exposure.

PFAS in Indoor Environments

- Diet and drinking water have been reported in the literature as major pathways for PFAS exposure and are the most well-studied
- Indoor exposures such as inhalation of airborne volatiles and ingestion of dust are less studied
- However, these pathways could contribute to PFAS exposure, particularly for the general population

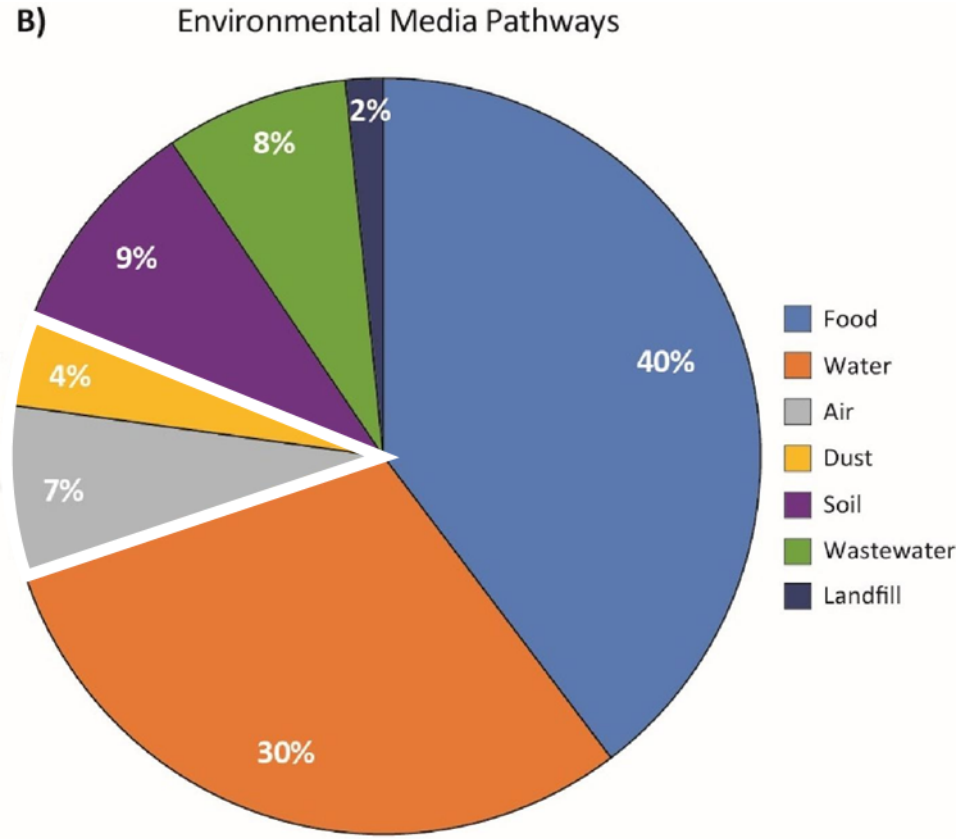
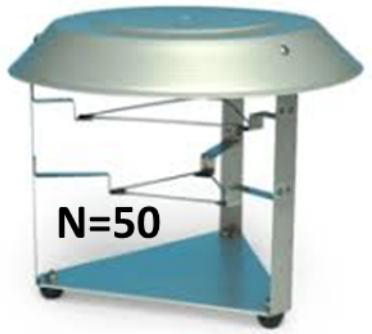


Figure Adapted from: DeLuca et al. 2021

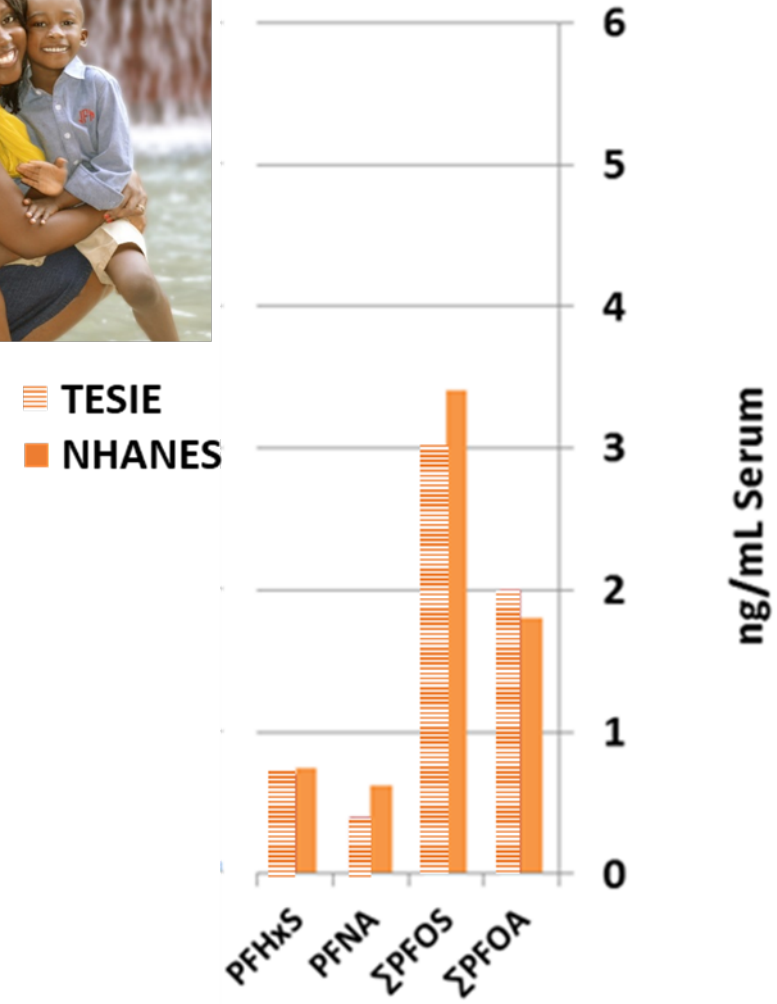
Children's Exposure to PFAS in Indoor Environments

- **The TESIE Study:** 203 children aged 3-6 years, 2014-2016
- Children provided a blood sample at a home visit; house dust samples were collected from the main living area and passive air samplers were deployed; a subset of children wore silicone wristbands
- PFAS were evaluated in dust, air (PUF), wristbands, and serum



Characteristics of TESIE Children n=203

Characteristic		N	%
Male child		113	55.7
Child age	38-47 months	34	16.7
	48-59 months	130	64.0
	60-73 months	39	19.2
Maternal race/ethnicity			
	non-Hispanic White	84	41.4
	non-Hispanic Black	75	36.9
	Hispanic White	41	20.2
	Other	3	1.5
Mother college graduate		113	55.7

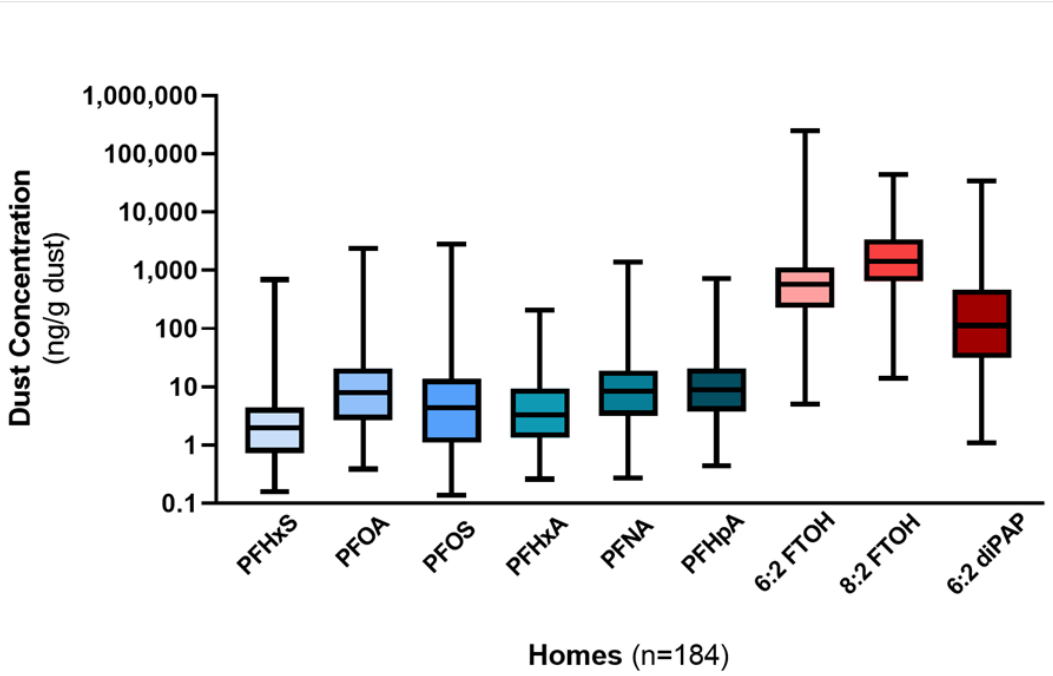


PFAS are commonly detected in indoor dust

Hall et al. 2020

Study team collecting household dust samples

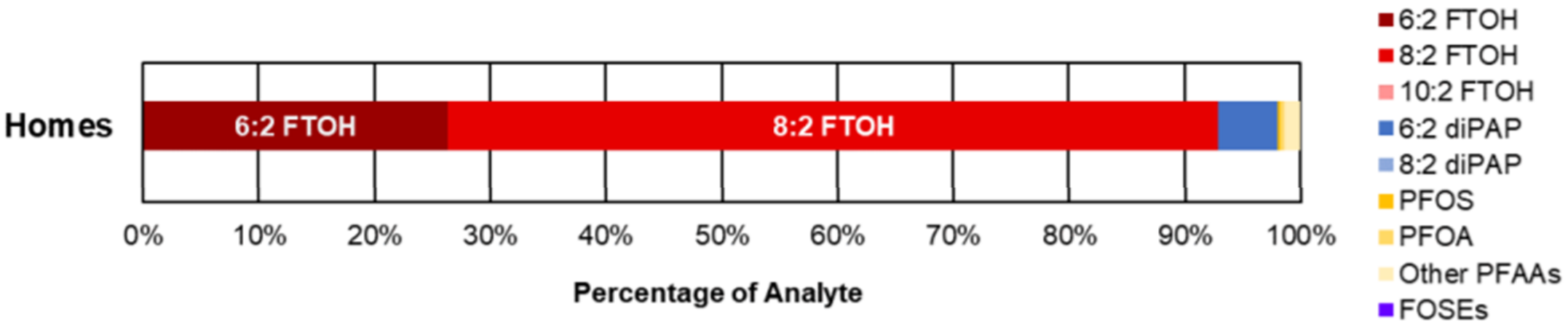
photo credit: Jared Lazarus Duke Photography



- In 2014-2016, we collected dust samples in 184 North Carolina homes
- Precursor PFAS were found at higher concentrations than legacy PFAAs
- FTOHs and diPAPs were the most prevalent PFAS in house dust samples, with medians of approximately 100 ng/g dust or greater.

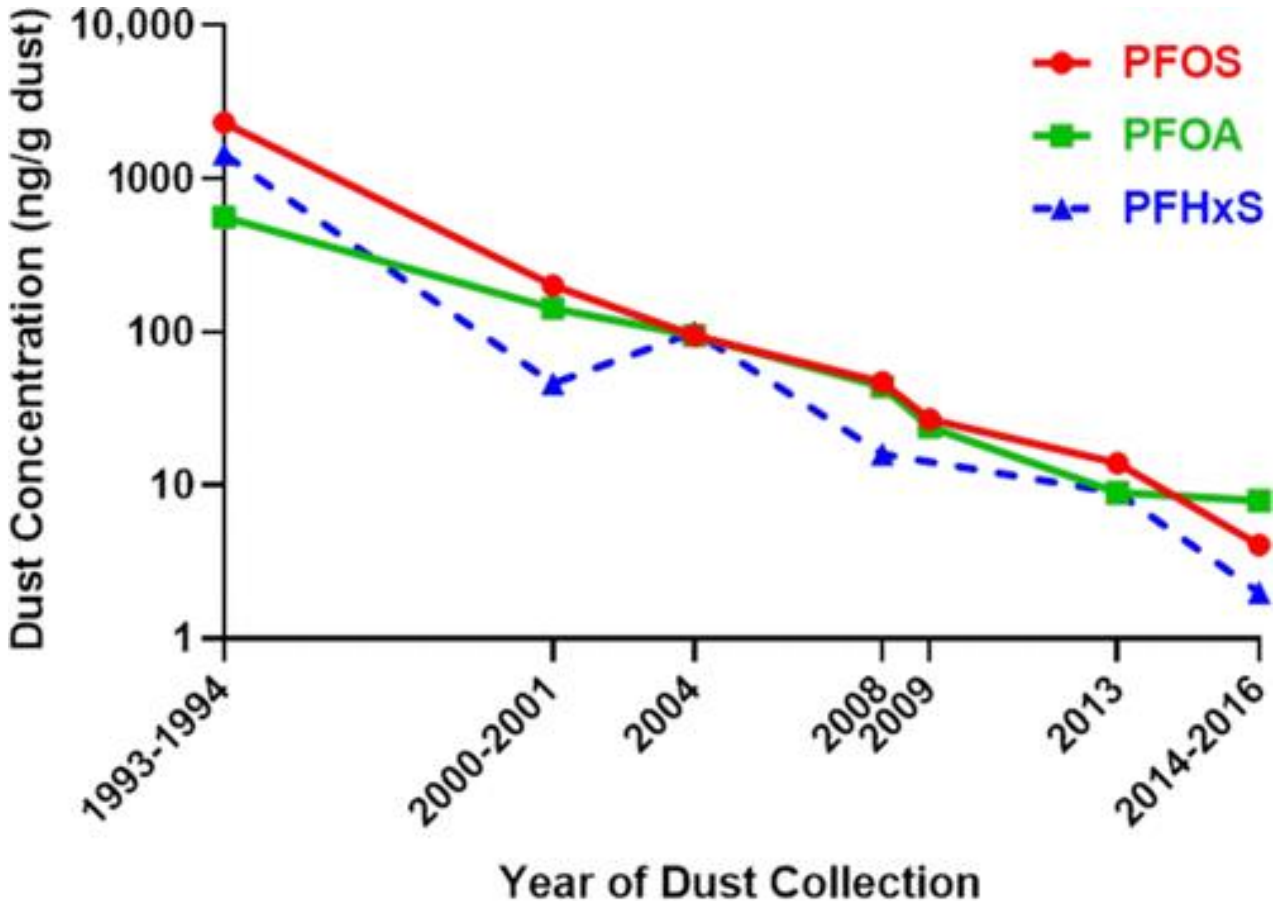
PFAS are commonly detected in indoor dust

Hall et al. 2020



- FTOHs accounted for >90% of measured PFAS

Median concentrations of PFOA, PFOS, and PFHxS in US house dust may be decreasing



We expect to see concurrent increases in newer replacement PFAS as these compounds have been replaced.

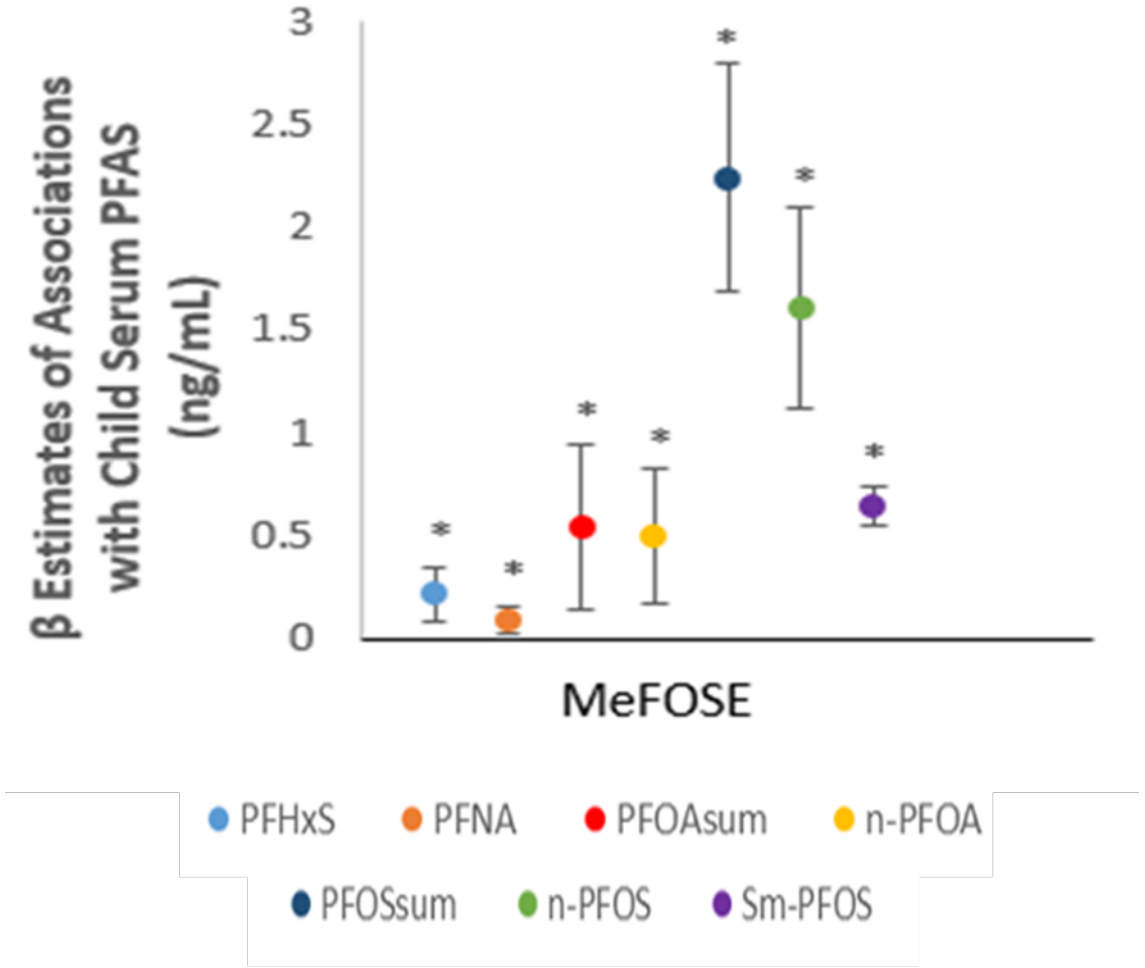
Data on PFAS precursors in US house dust are more limited.

Figure from: Hall et al. 2020

PFAA precursors are commonly detected in indoor air

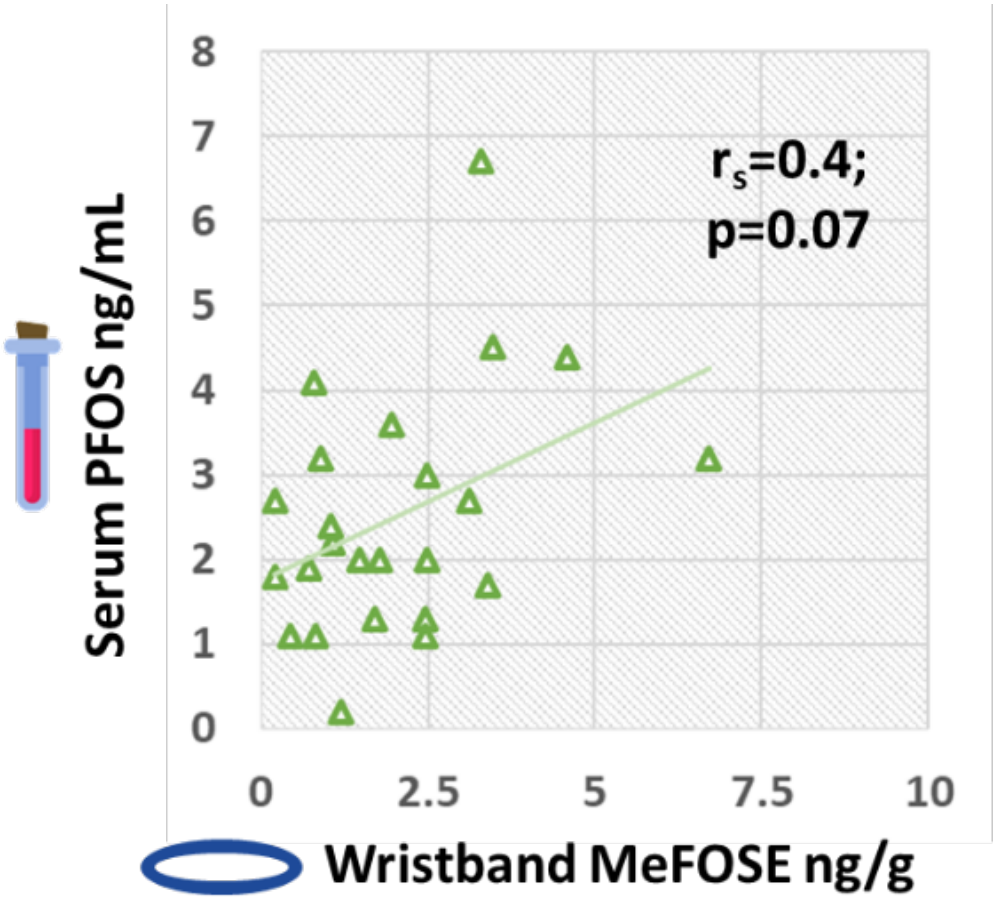
Matrix and Compound	(%) Detect	Median	Maximum
Air (ng/m³)			
6:2 FTOH	77	3.3	49.6
8:2 FTOH	100	3.3	13.2
10:2 FTOH	77	0.99	3.5
EtFOSE	77	0.03	0.67
MeFOSE	100	0.20	4.0

Airborne precursors predict serum PFAA concentrations among children



- Associations between precursors in air and PFAS in children's serum were observed, but little association observed for indoor dust.
- Overall results were consistent with two previous North American studies suggesting airborne precursors predict serum PFAS more strongly than dust: Fraser et al. 2012, 2013 and Makey et al. 2017

Silicone wristband precursors predict serum PFAA concentrations among children



- Silicone wristbands were worn by children for 7 days through all activities
- Patterns of association between precursors in wristbands and serum PFAA concentrations were similar to air
- Cumulatively, data suggest silicone wristbands capture information about exposure to PFAS in indoor environments and are a promising exposure assessment tool

Challenges Investigating and Regulating Indoor PFAS Exposures

- Methods of sampling the indoor environment are less standardized than biomonitoring approaches
  - Prior studies investigating indoor exposure have primarily been small and convenience samples
- Vast range of physical-chemical properties for PFAS
- The existence of precursors and polymers
- Wide range of source products making targeted exposure reduction strategies complicated
- Biomonitoring data are mainly from impacted communities

Summary

- The Multi-Site Study will provide information on PFAS exposure in communities with varying levels of contamination in drinking water
- When water PFAS concentrations are known, PK models provide information about the contribution of water consumption to overall exposure (for some PFAS)
- Exposures in Orange County, CA may become more like the 'general population' over time and other sources of exposure may be more important to evaluate
- Investigations of indoor exposure pathways remain limited; extensions of the Multi-Site Study could be helpful in assessing exposure pathways other than drinking water

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