PFAS: Health Effects & Exposure Sources

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Department of Environmental Health

Biogeochemistry of Global Contaminants HARVARD

STEEP

Sources, Transport, Exposure & Effects of PFASs

UNIVERSITY OF RHODE ISLAND SUPERFUND RESEARCH PROGRAM

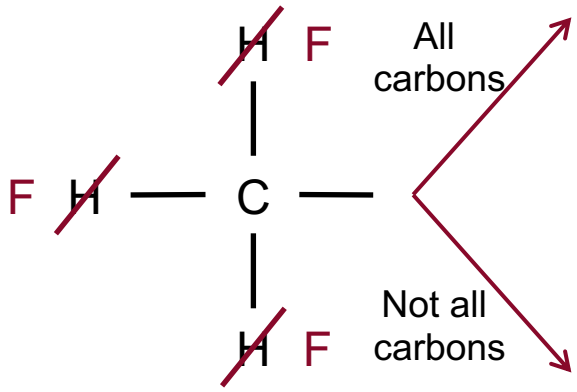
SERDP

DOD ▪ EPA ▪ DOE

NIEHS

National Institute of Environmental Health Sciences

F-C backbone of “Forever Chemicals”: Most research on a subset of PFAS known as PFAA



All carbons

Not all carbons

Perfluoroalkyl substances
(C_nF_{2n+1}-R)

Polyfluoroalkyl substances
(C_nF_m-R)

PFCAs
(C_nF_{2n+1}-COOH) → C4 – C14:
buta-, penta-, hexa-, hepta-, ***octa- (PFOA)****, nona-, deca-, etc.*

PFSAs
(C_nF_{2n+1}-SO_3H) → C4 – C10:
buta-, hexa-, ***octa- (PFOS)****, deca-*

Long-chain PFAS:
PFCAs, n ≥ 7
PFSAs, n ≥ 6

More bioaccumulative

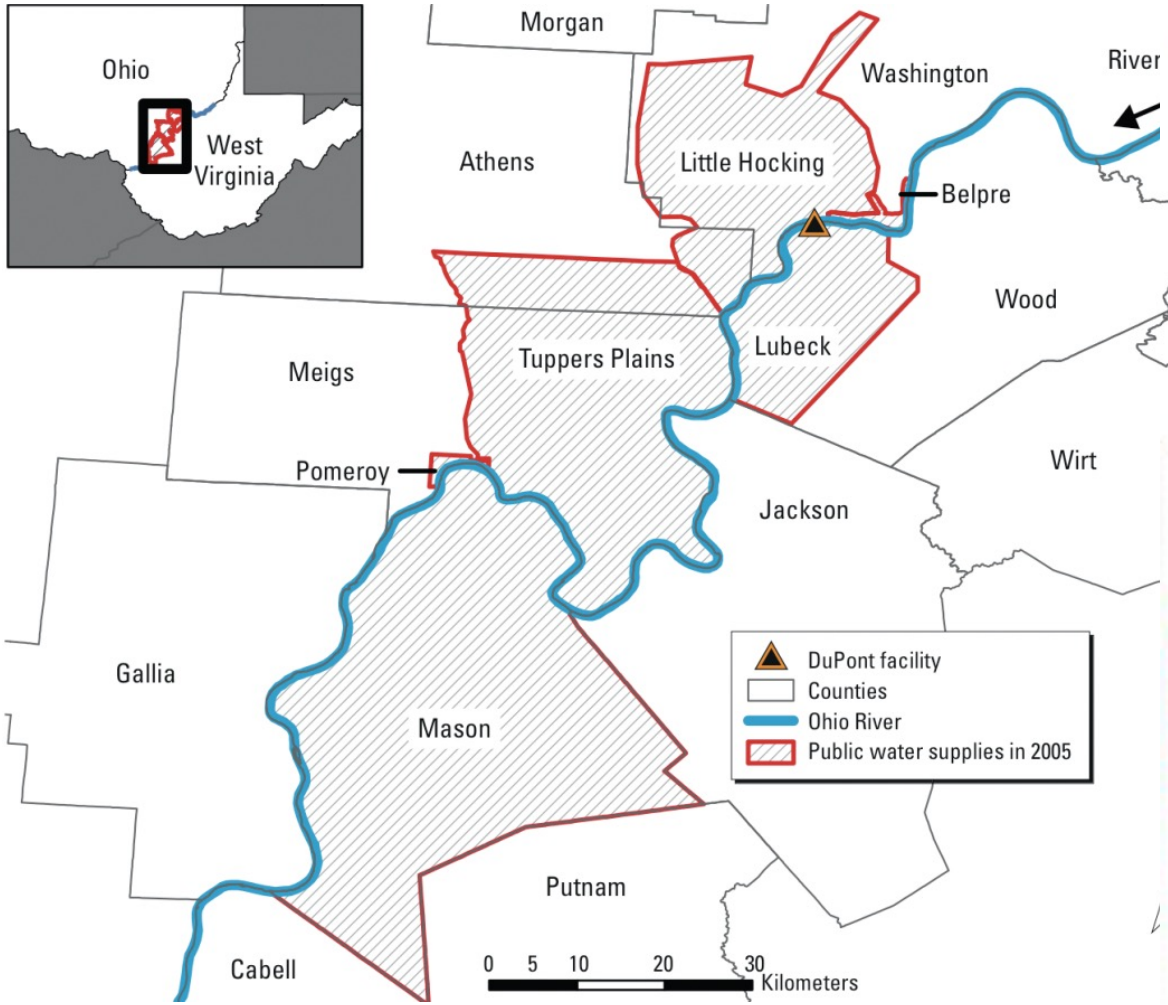
Certain classes of PFAS are **volatile or semi-volatile** and can be transported long distances

Some known as **precursors** can degrade into terminal PFAA (**PFOS, PFOA** etc.)

(Buck et al. 2011; Wang et al. 2017)

Health Effects Associated with PFAS Exposure

PFAS exposure is associated with diverse adverse health effects



C8 Science Panel

http://www.c8sciencepanel.org

cross-sectional study ~ 70,000 people (2005-2013)

Probable links for <u>PFOA</u> in this community included:

Cancer - kidney and testicular

Diagnosed elevated cholesterol

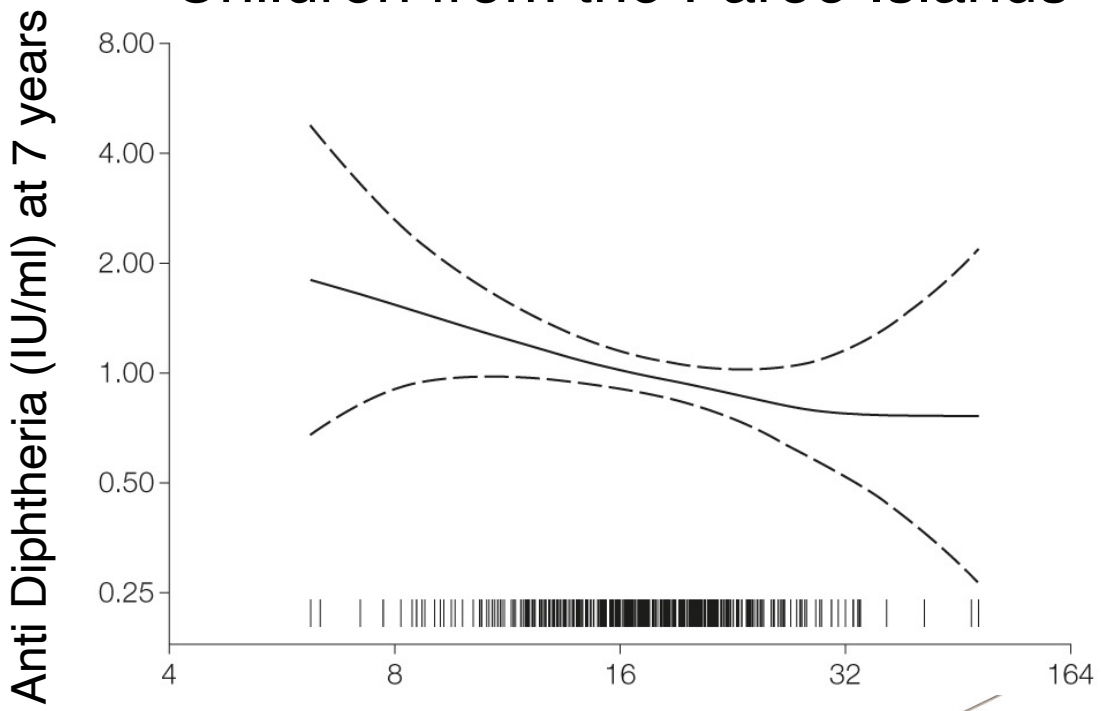
Pregnancy-induced hypertension and preeclampsia

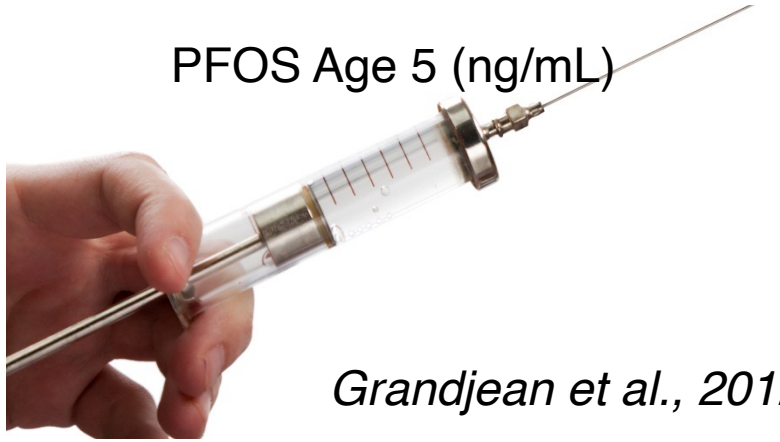
Thyroid Disease

Ulcerative colitis

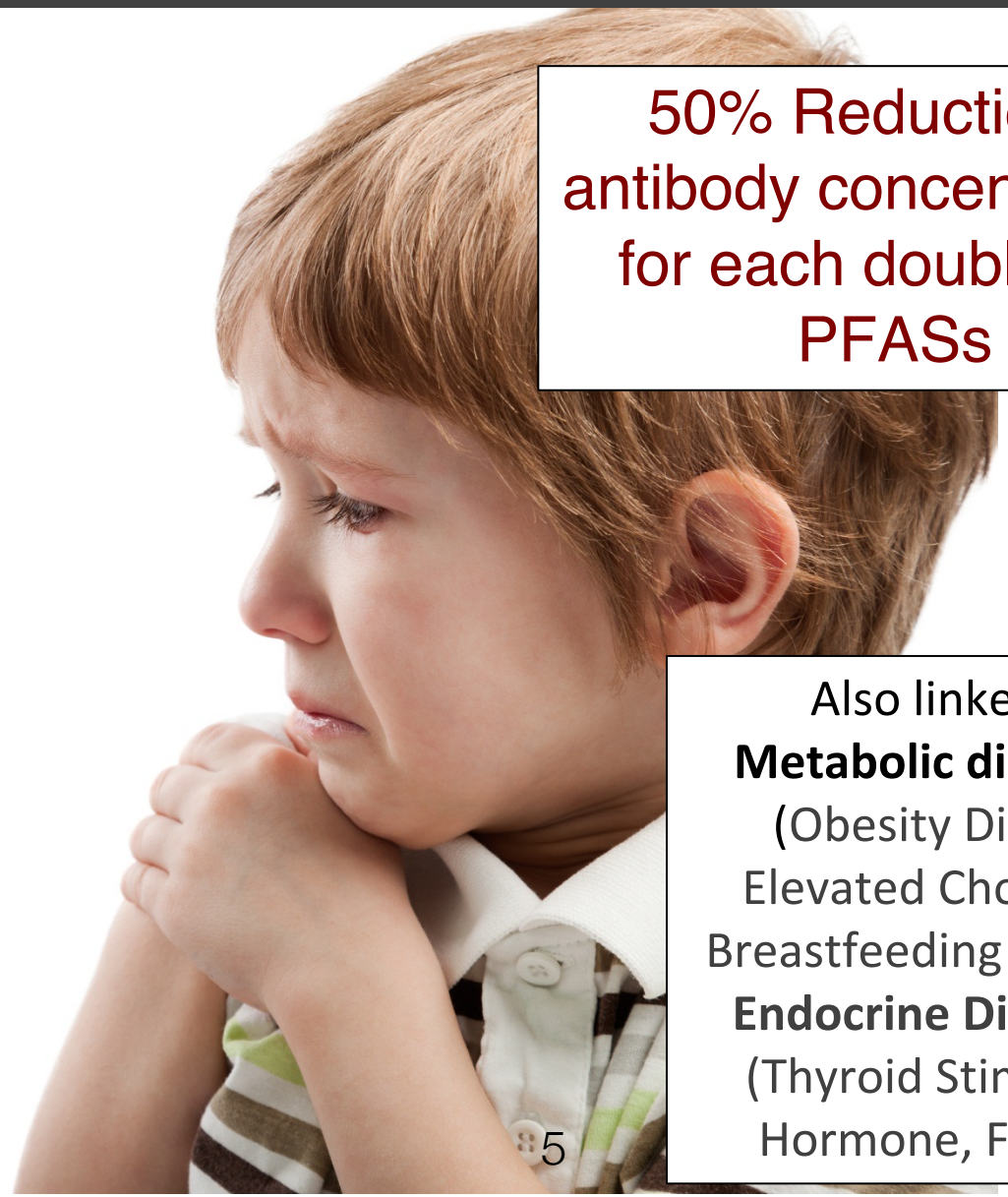
Potent immunotoxic response following vaccination in Faroese birth cohort

Children from the Faroe Islands





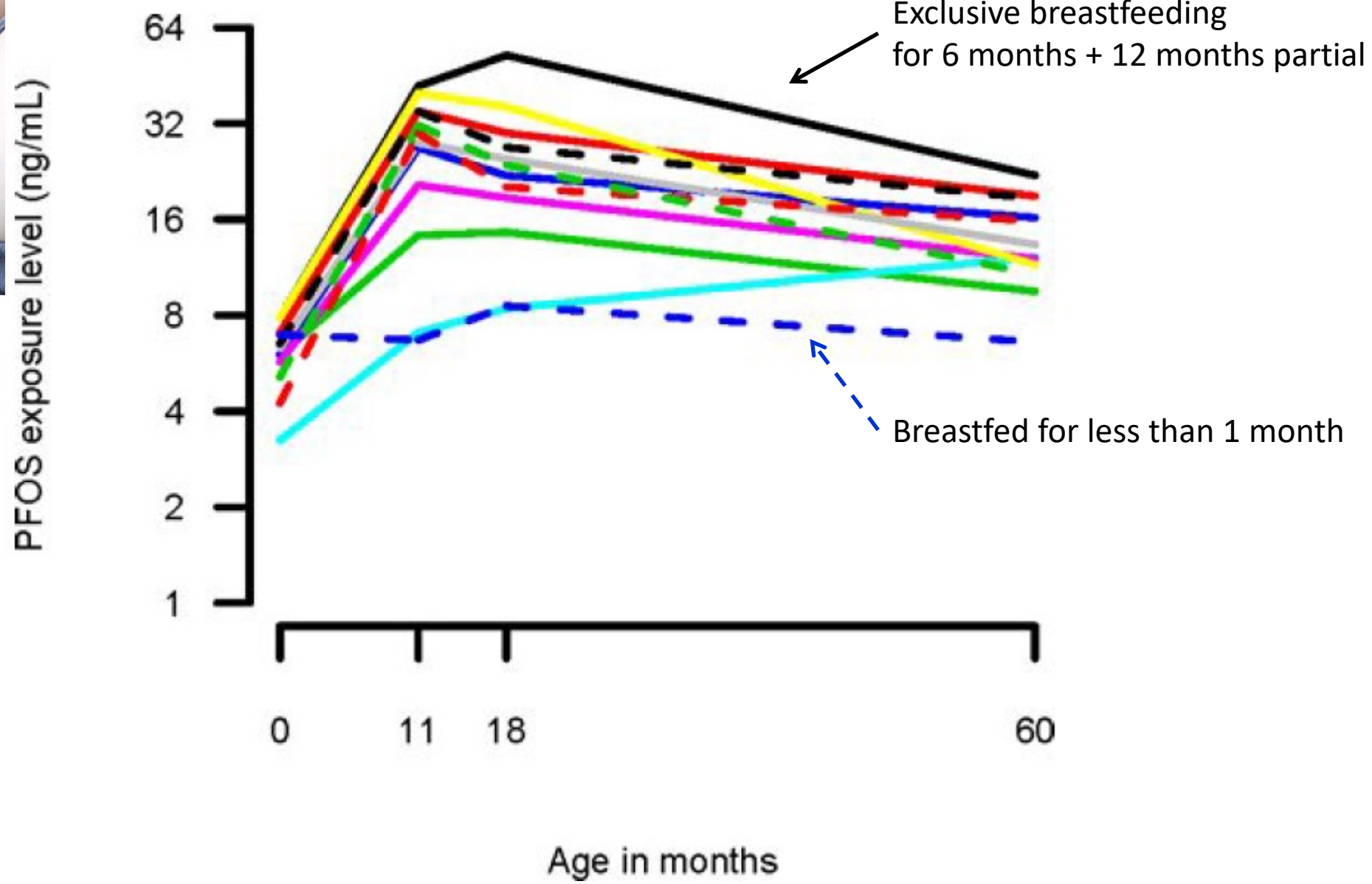
Grandjean et al., 2012



50% Reduction in antibody concentrations for each doubling of PFASs

Also linked to:
Metabolic disruption
(Obesity Diabetes Elevated Cholesterol Breastfeeding Duration)
Endocrine Disruption
(Thyroid Stimulating Hormone, Fertility)

Infancy is critical for risk assessment due to peak PFAS exposure and crucial development of the adaptive immune system



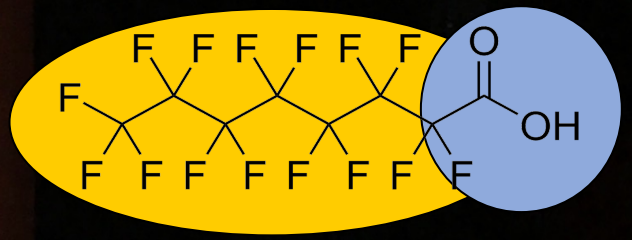
Mogensen et al., ES&T, 2015

PFAS: Delayed insight or delayed public access

Research finding	*First*	*Public*
PFASs in general population	1976	2001
PFASs in cord blood	1981	2004
PFAS transfer into milk (goats)	1993	2008
PFOS immunotoxicity (monkeys)	1978	2000
Immune cell changes in workers	1992	2018

22 years lag

Water-loving



Repels water
Repels fat

F-C
FOREVER CHEMICALS

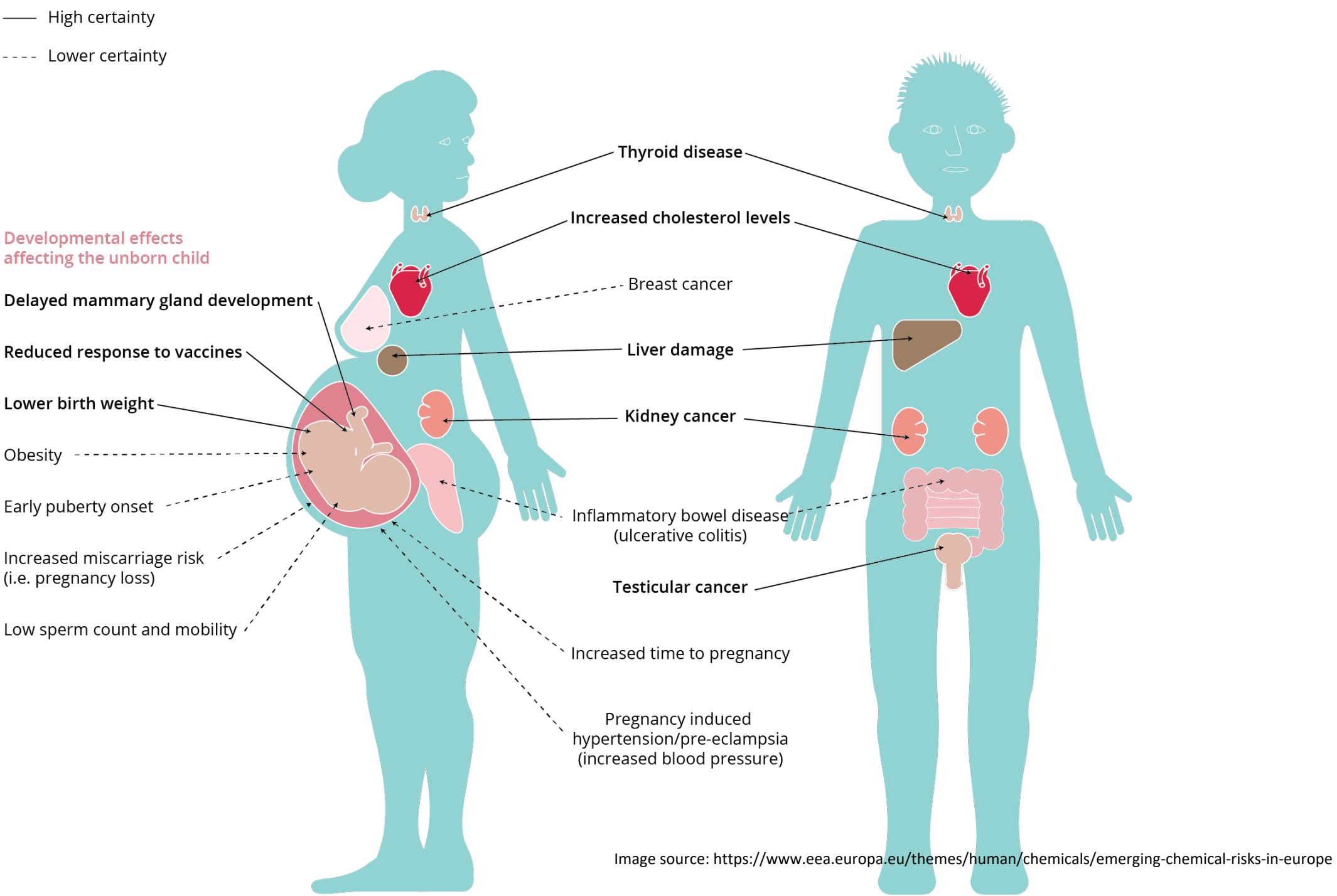


Image source: https://www.eea.europa.eu/themes/human/chemicals/emerging-chemical-risks-in-europe

Animal studies suggest PFAS exposure is linked to...

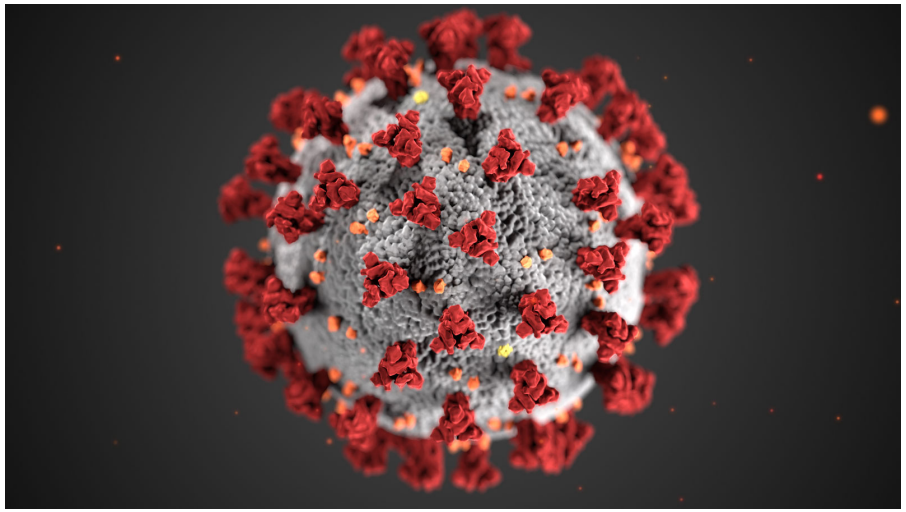
- damage to the immune system
- liver damage
- birth defects, delayed development, and newborn deaths

Information sourced from Agency for Toxic Substances and Disease Registry

NORTH CAROLINA PFAS Testing Network

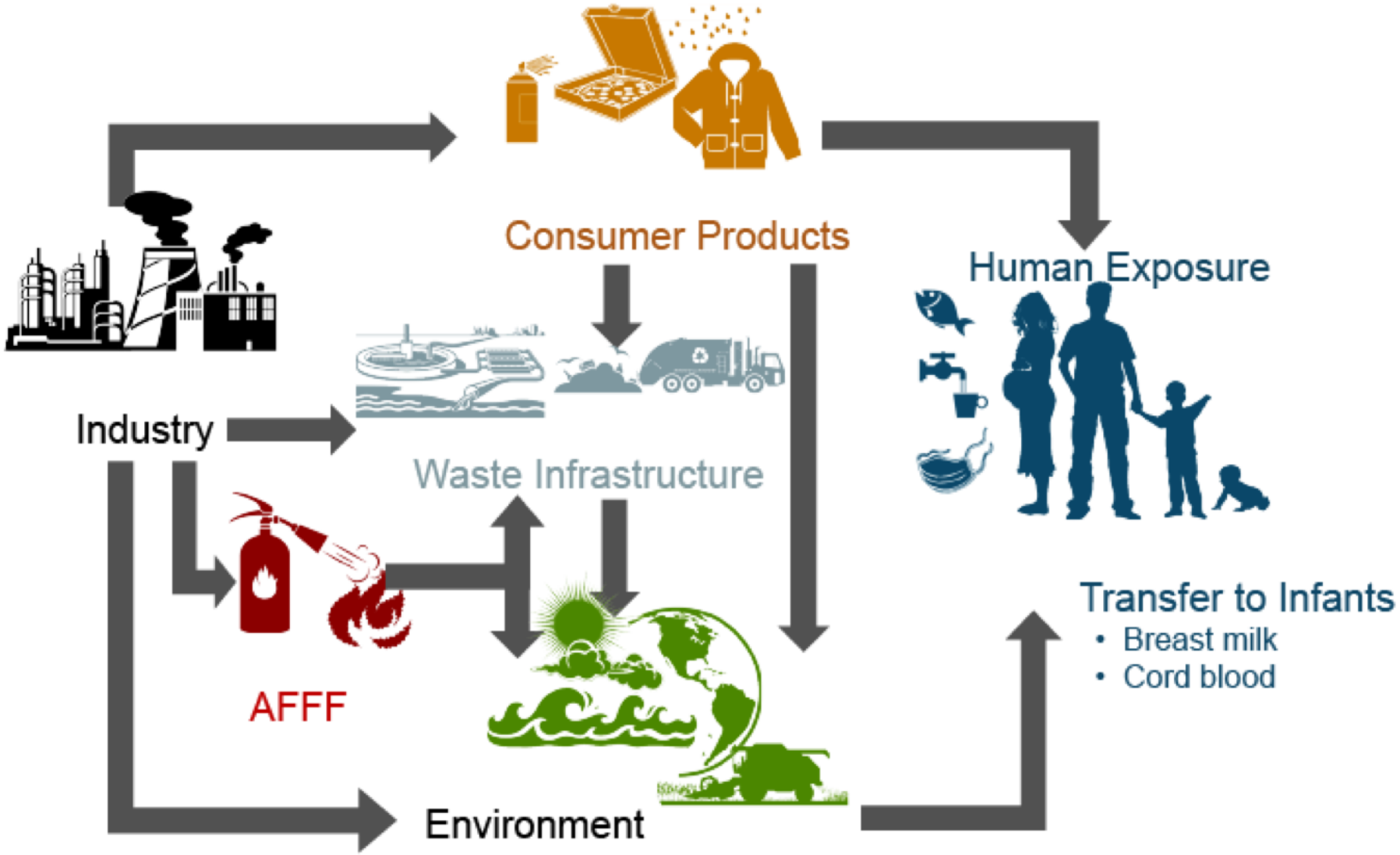
PFBA exposure linked to COVID-19 severity

- Grandjean et al., 2020
- https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0244815



PFAS Exposure Sources

Human exposures to PFAS are diverse: Some can be addressed/mitigated faster than others



Sunderland et al., 2019, JESEE

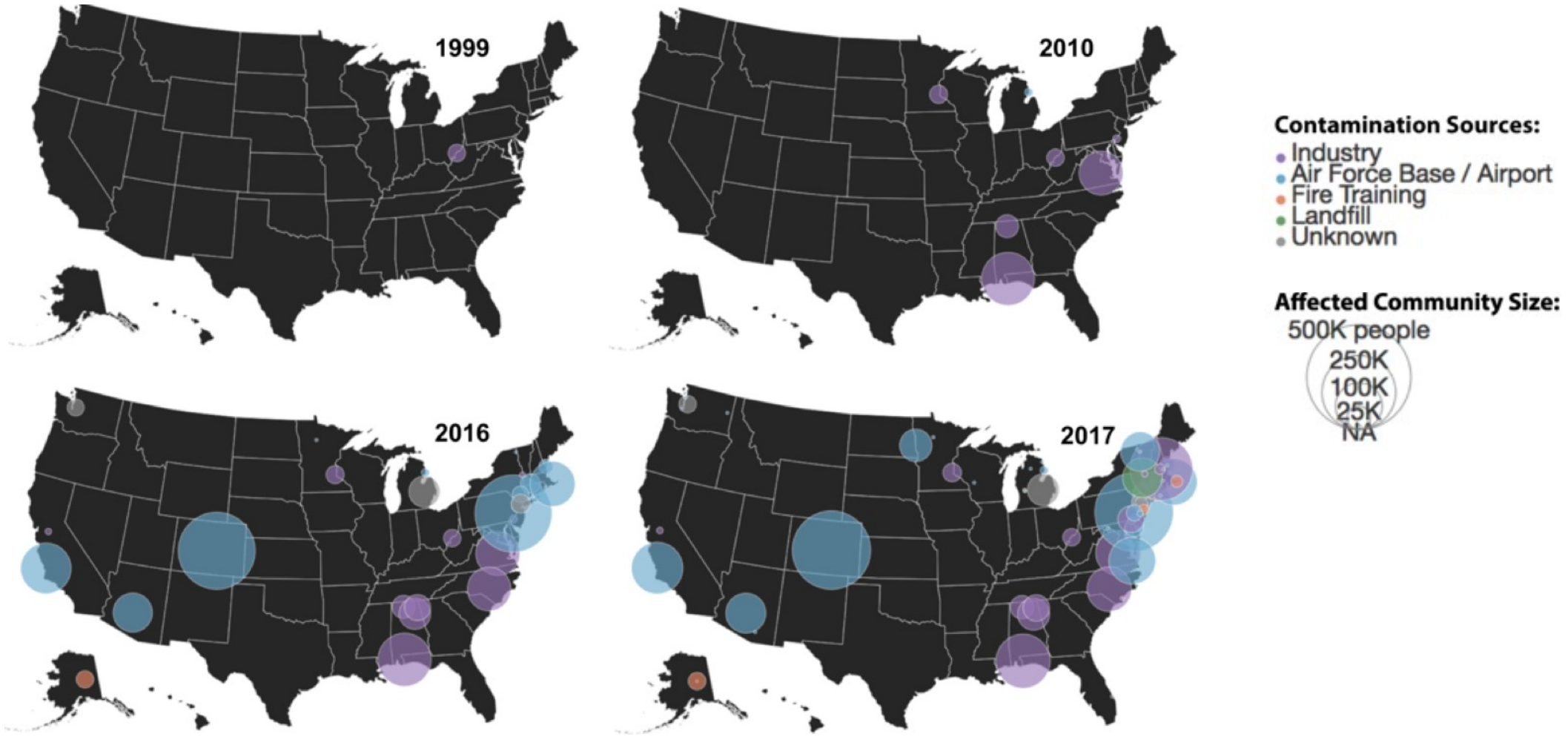
Our focus so far:

1. **Drinking water**
2. **Seafood**
3. **Consumer products**

Others needing attention:

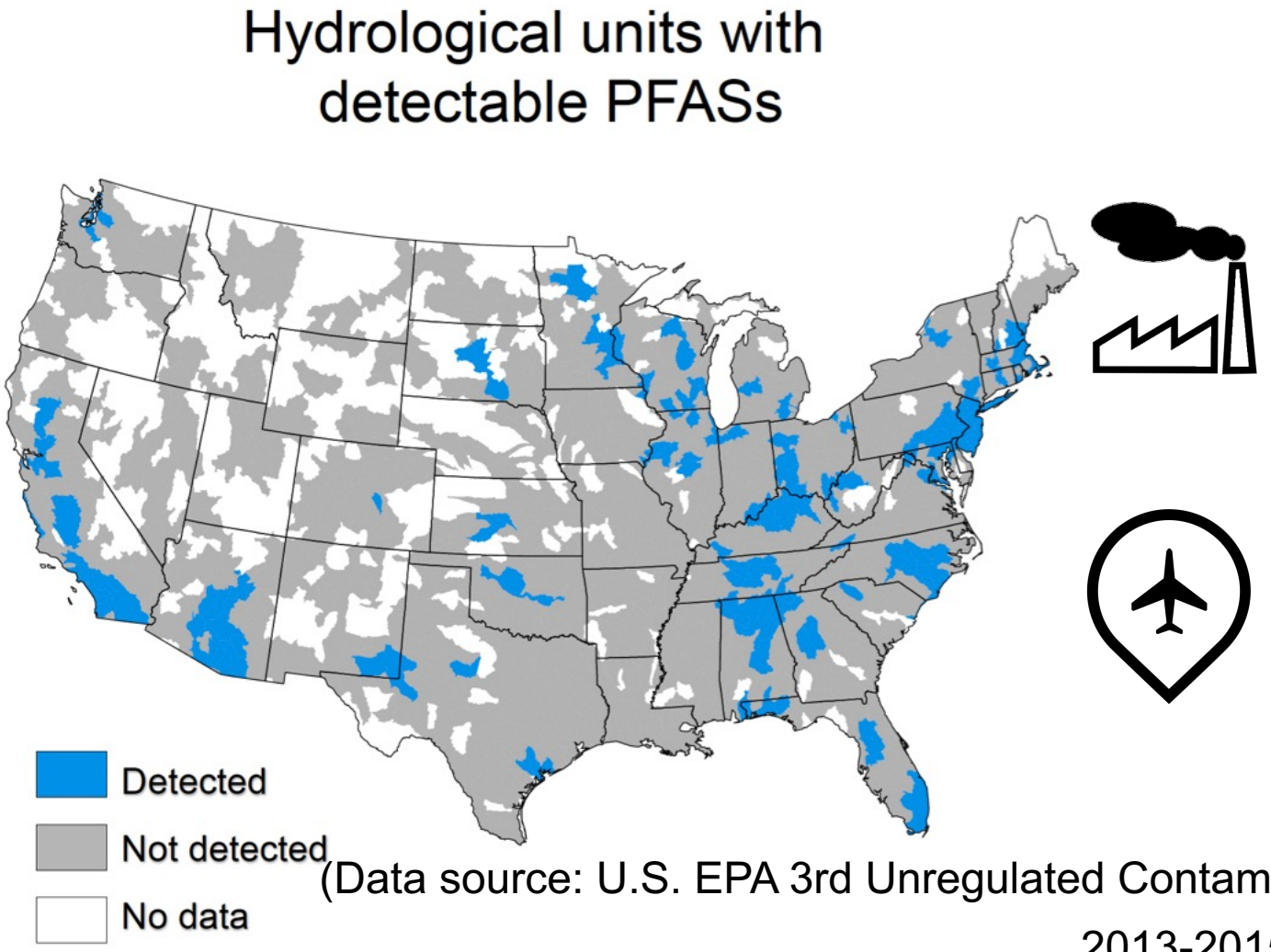
a. **Other foods**
b. **Dust/indoor**
c. **PCPs**

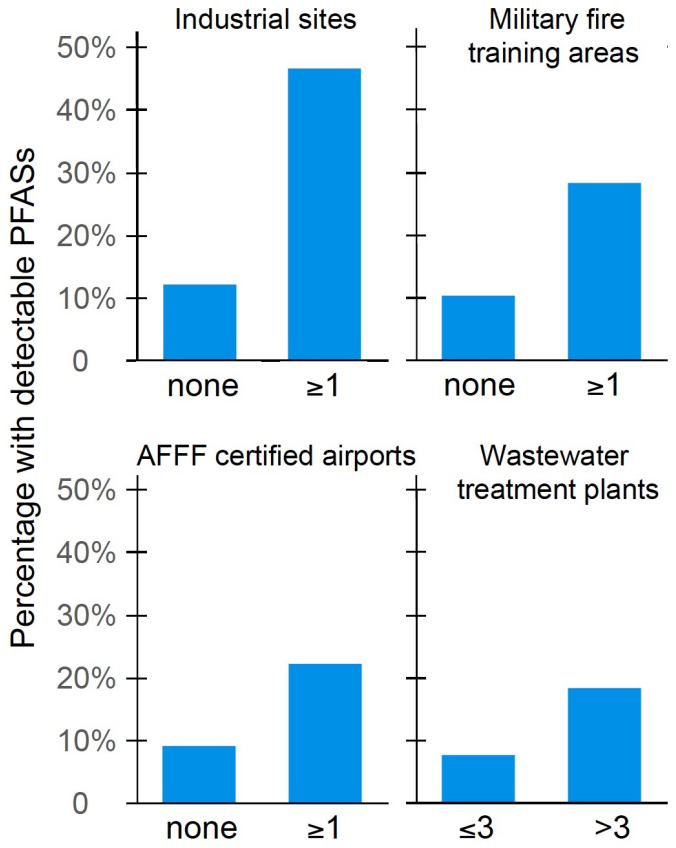
Drinking water is the primary pathway of PFAS exposure next to many contaminated sites



Data adapted from Northeastern SEERHI

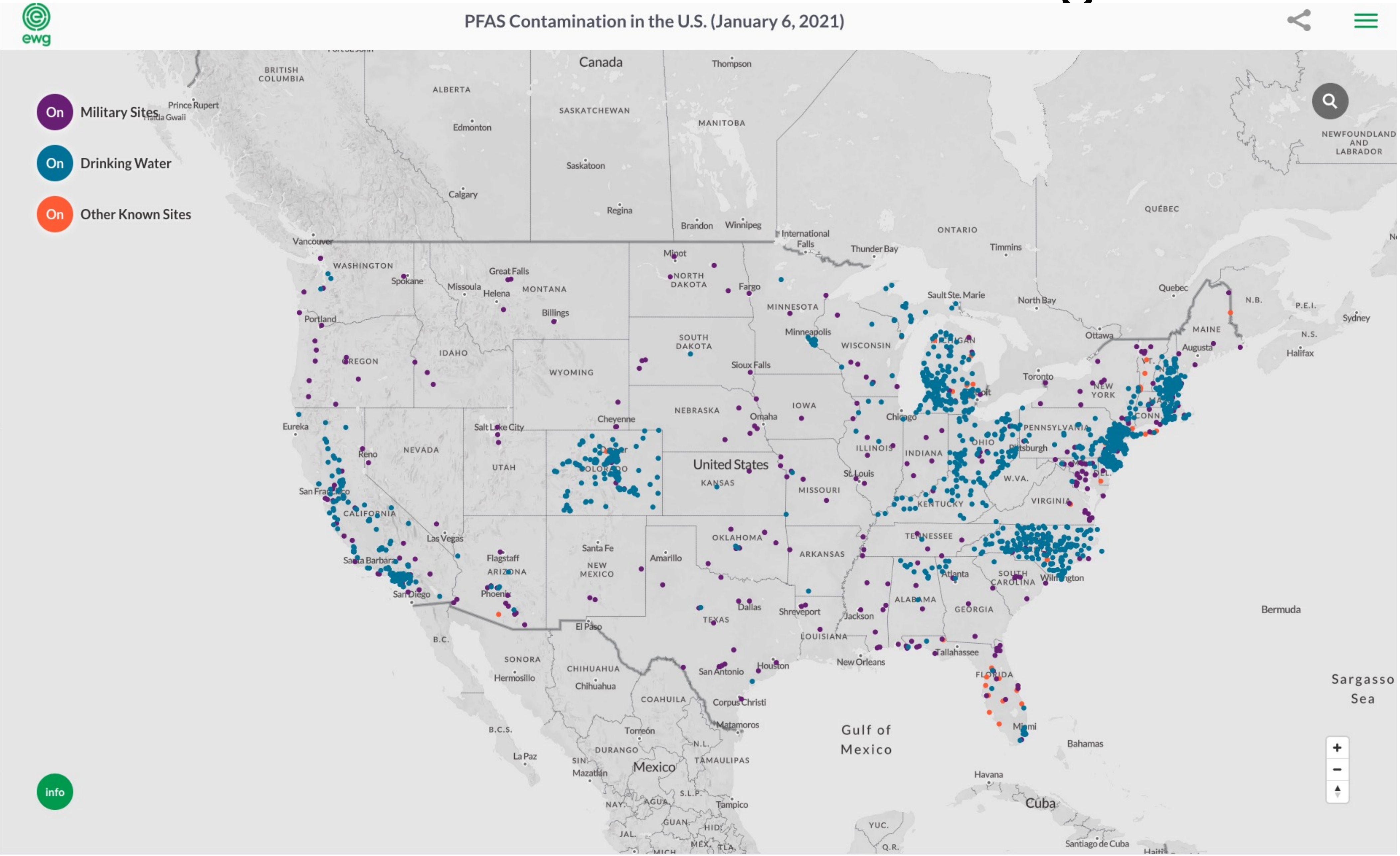
Drinking water best studied exposure source for general U.S. population at this time: Still gaps in data



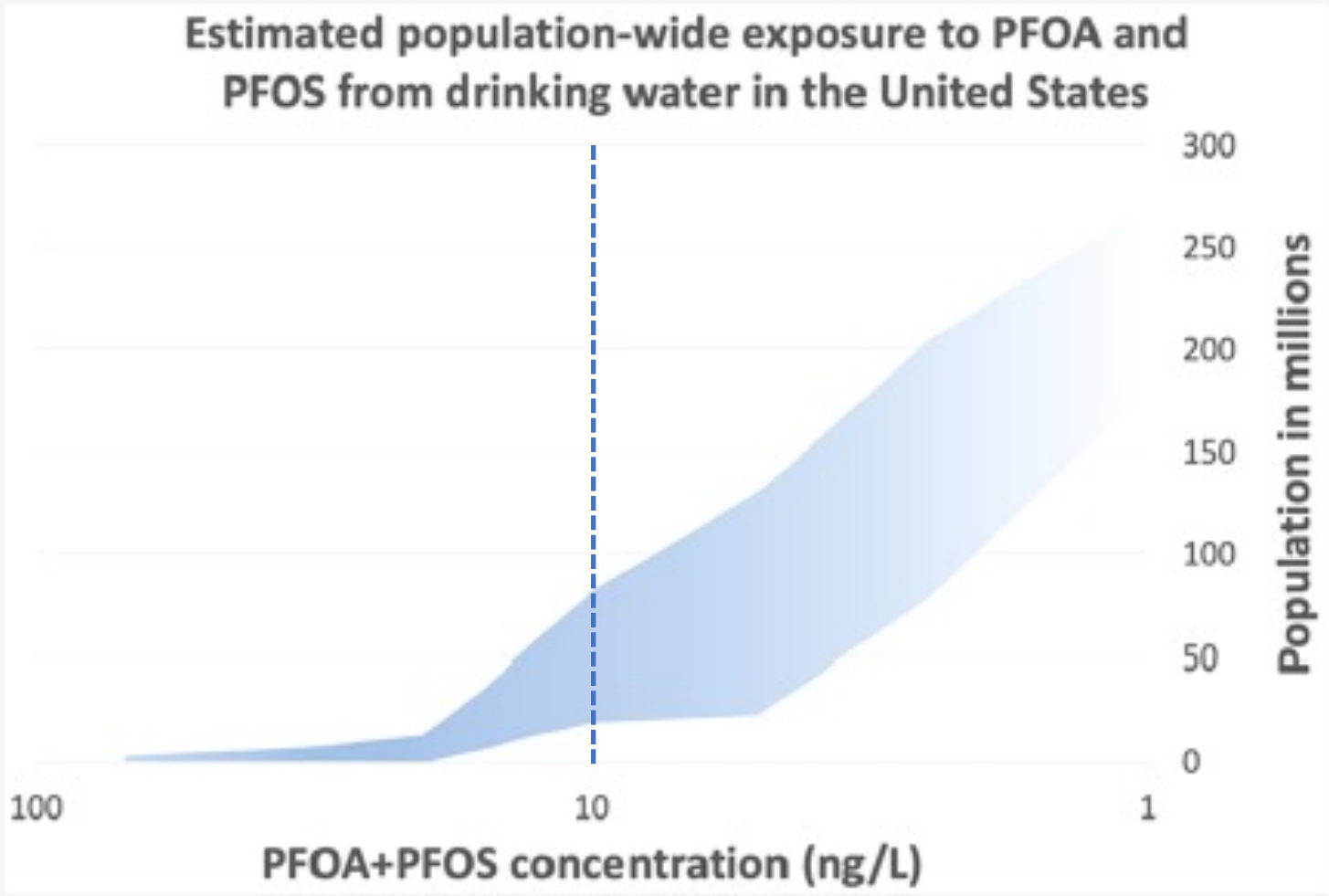


(Data source: U.S. EPA 3rd Unregulated Contaminants Monitoring Rule (UCMR3), 2013-2015) (Hu et al., *ES&T Letters*, 2016)

More and more contaminated sites are being discovered…



18-80 Million U.S. Residents have >10 ng/L PFAS in their tap water

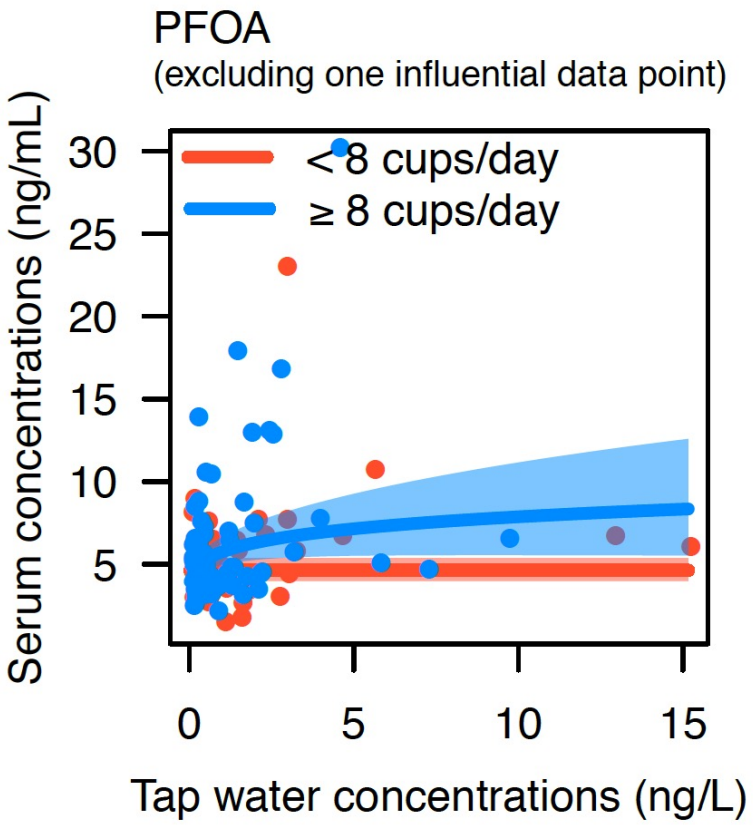


Andrews and Naidenko, 2020, EST Letters

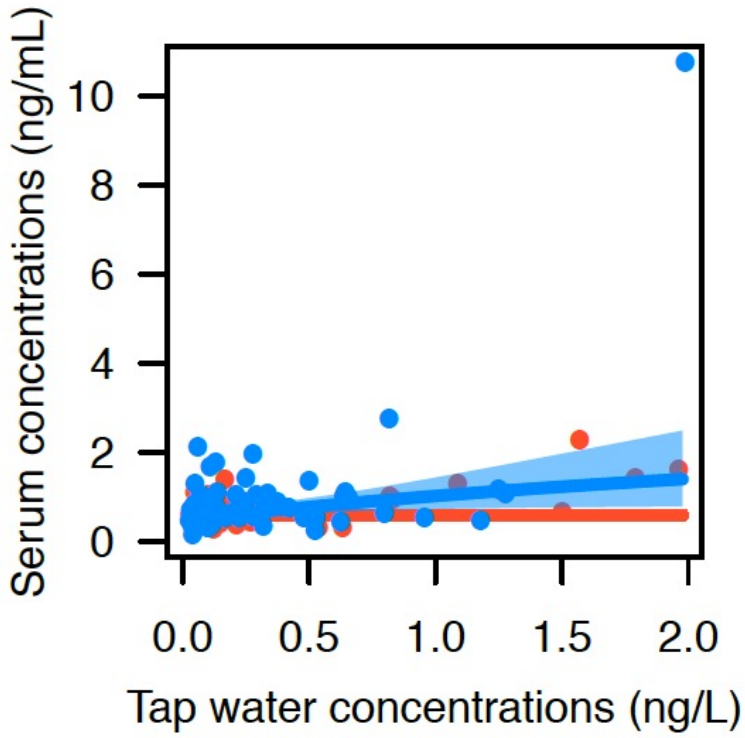
For much of the general U.S. population drinking water may only account for ~20% total PFAS exposure

Tap water PFOA and PFNA are statistically significant predictors of serum in 1990 for the NHS cohort

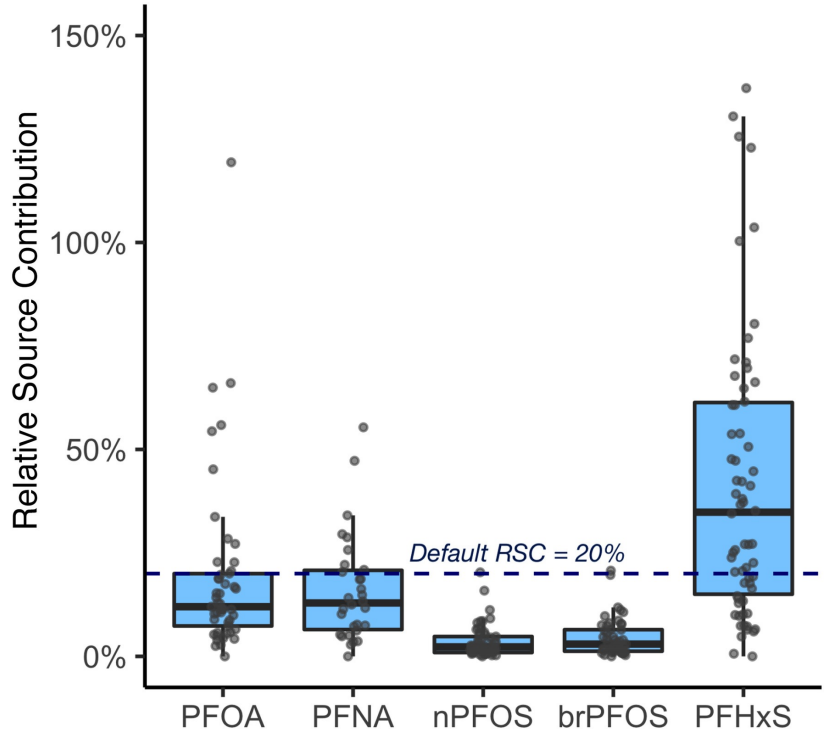
PFOA



PFNA



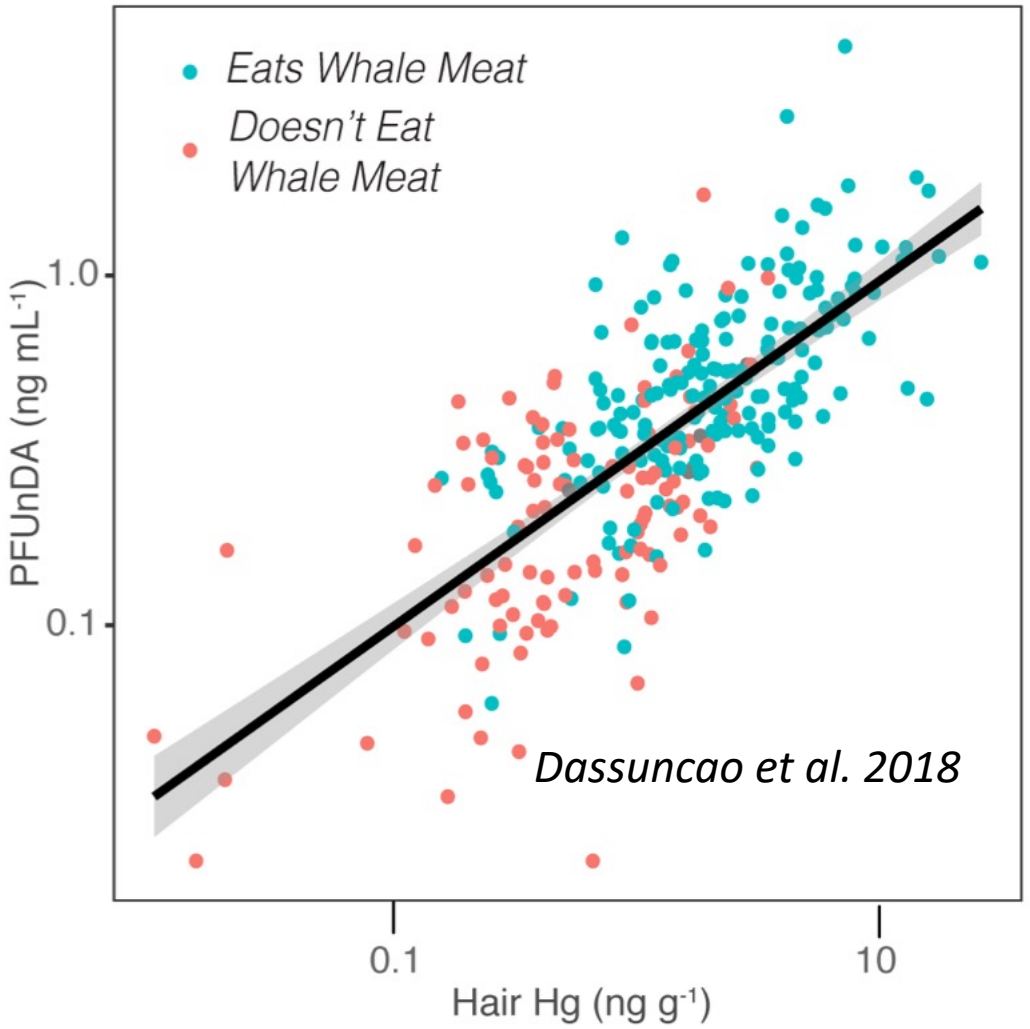
RSC = 2% - 34%



Hu et al., 2019, EHP

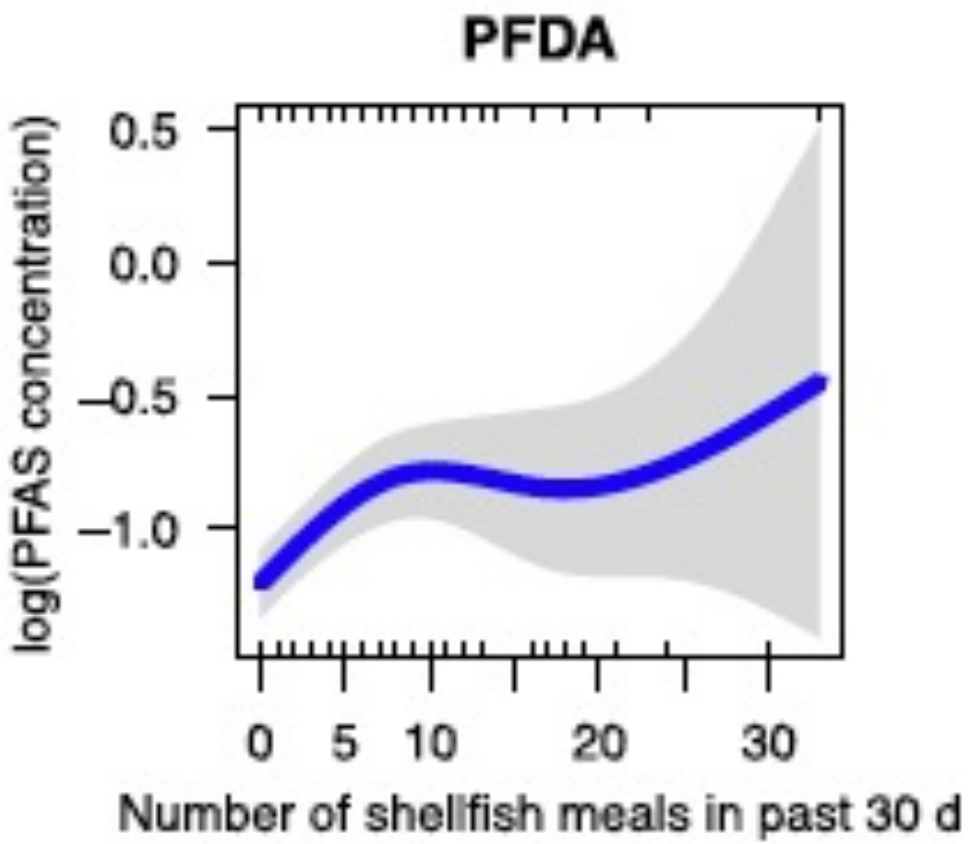
Long-Chained PFCA strongly associated with seafood consumption

Faroese Children

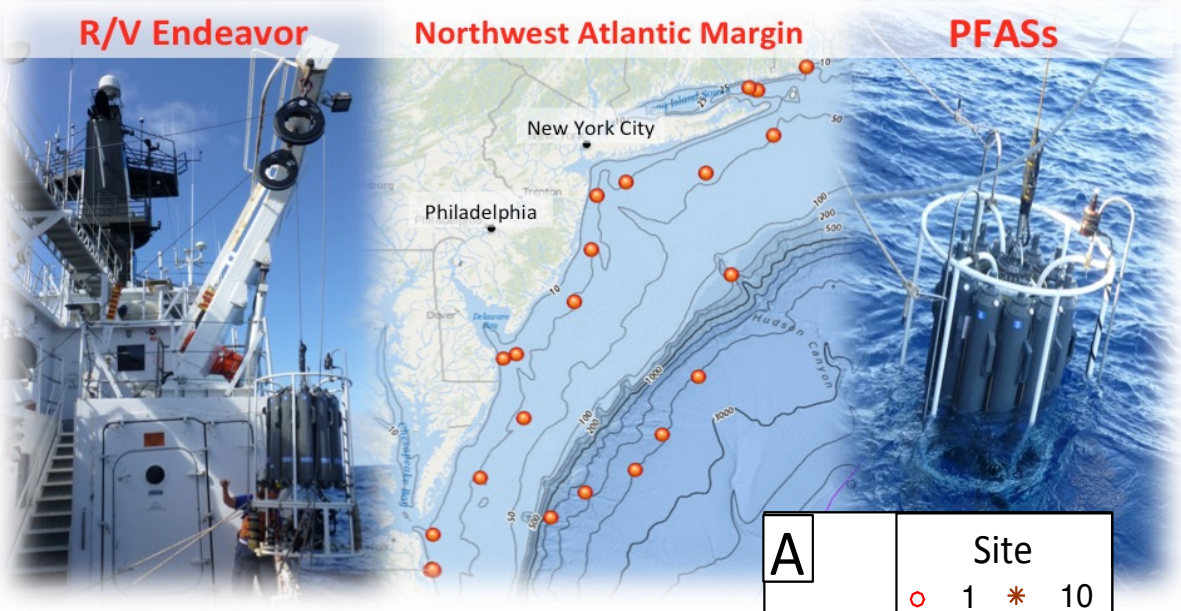


Dassuncao et al. 2018

NHANES 2005-2006

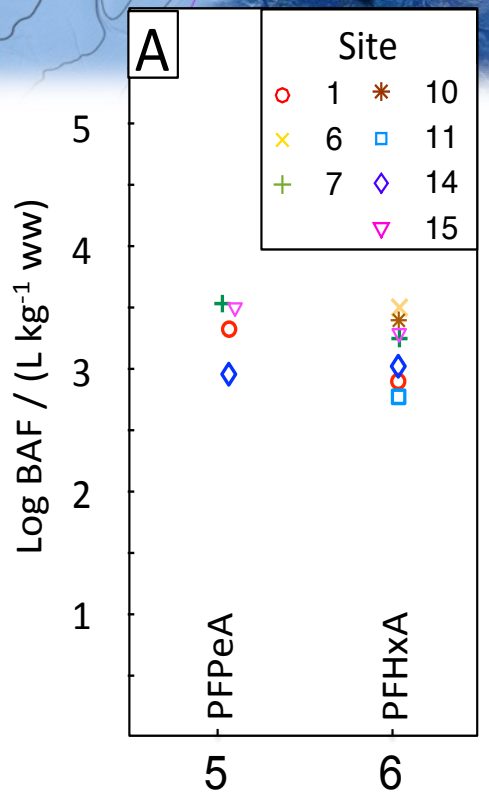


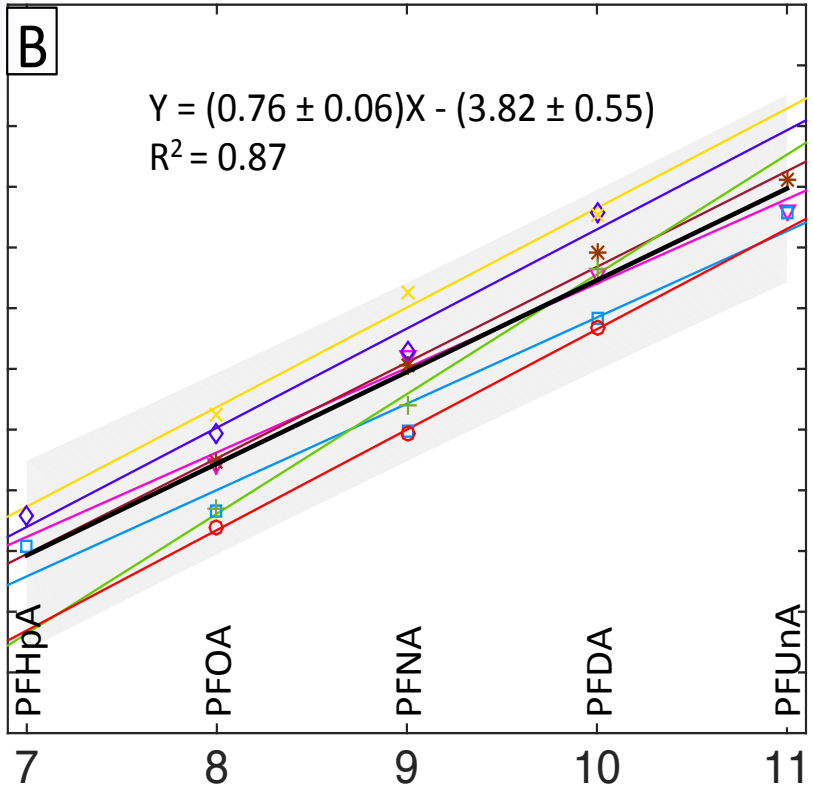
Hu et al. 2018

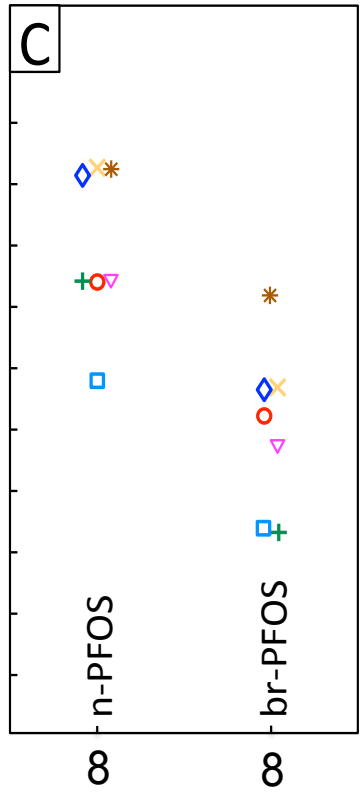


Longer chain PFAS have greater potential to bioaccumulate in food webs: Industry is switching to shorter chain PFAS

Higher than expected concentrations of C-5 and C-6 PFCAs in plankton potentially from degradation of polyfluorinated precursors

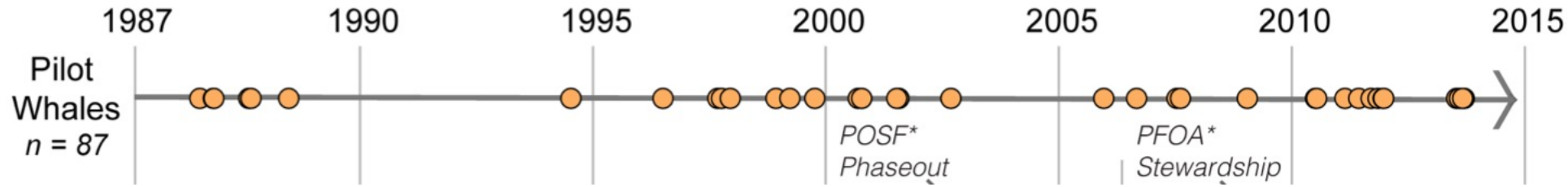




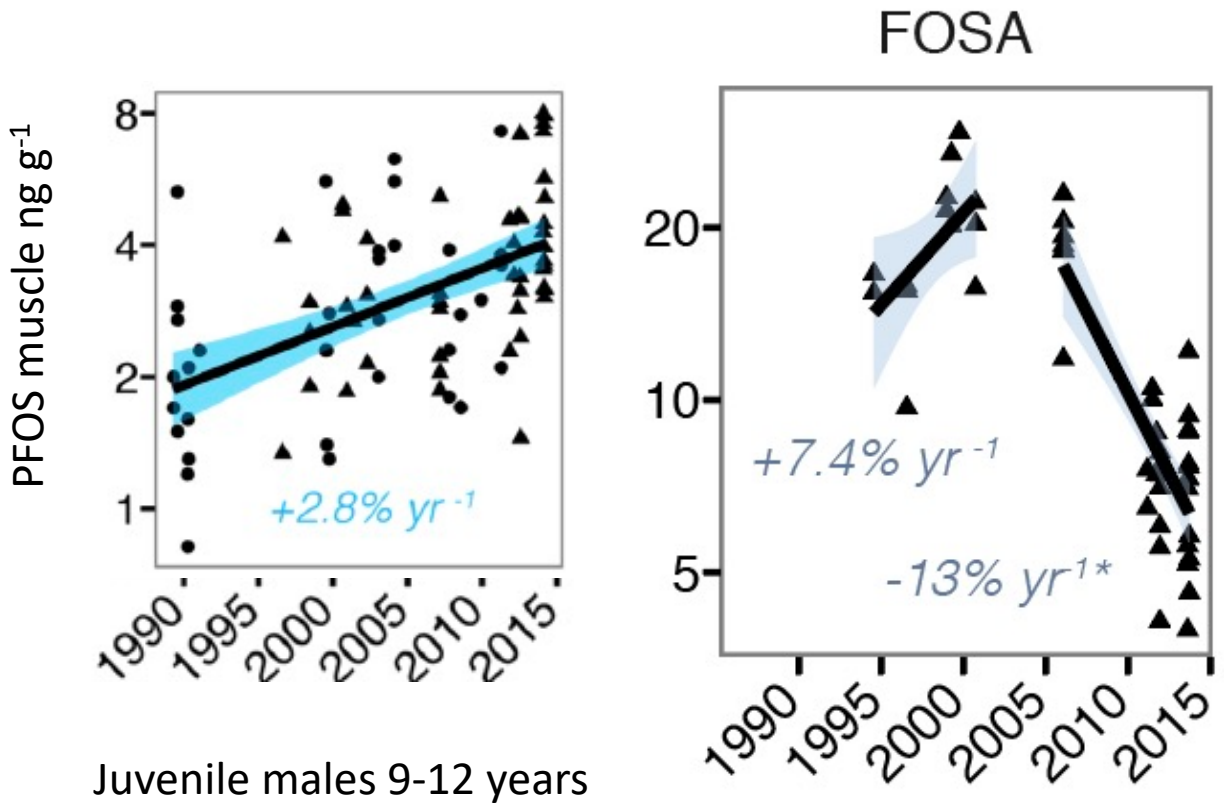


Zhang et al., 2019

Measured targeted PFAS concentrations in North Atlantic pilot whales shows a rapid decline in FOSA, a PFOS precursor since 2000



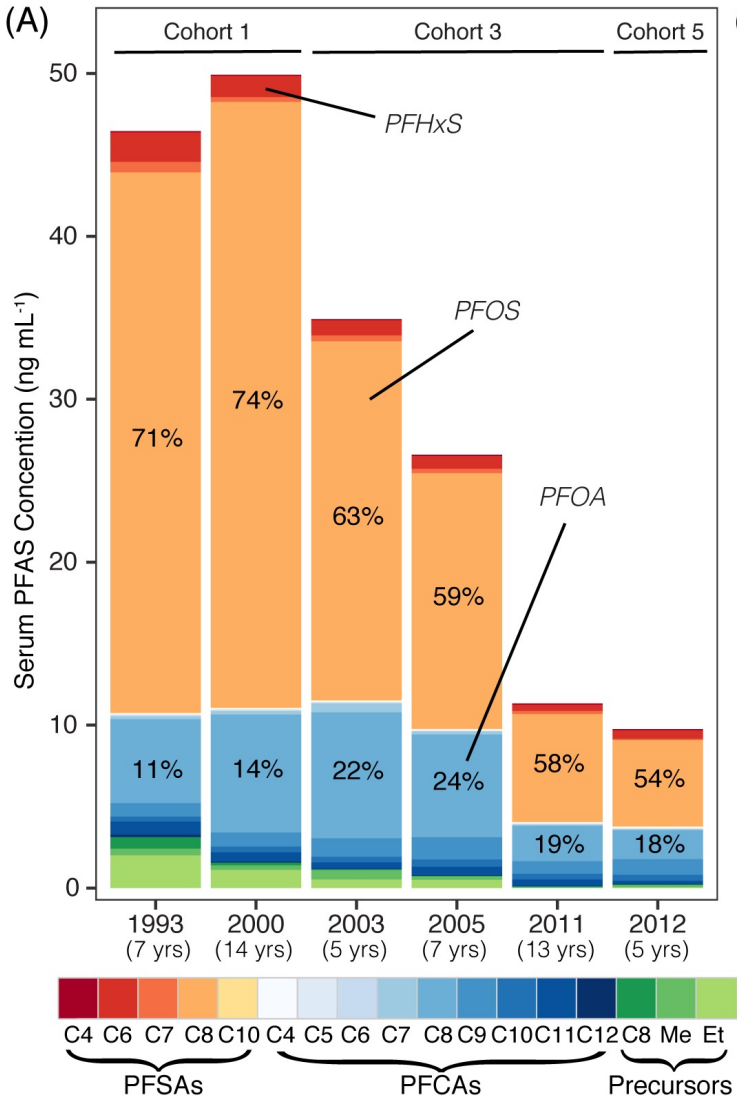
Dassuncao et al., 2017, ES&T

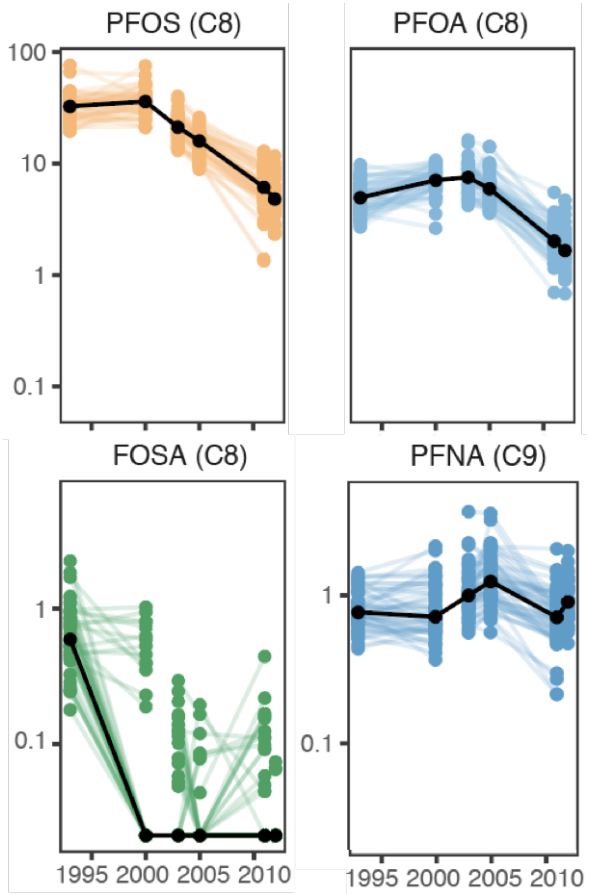


Juvenile males 9-12 years

Rapid declines in targeted PFAS in children's serum driven mainly by PFOS, PFOA, and FOSA

Some long chain PFAS (i.e., PFNA) stable or increasing

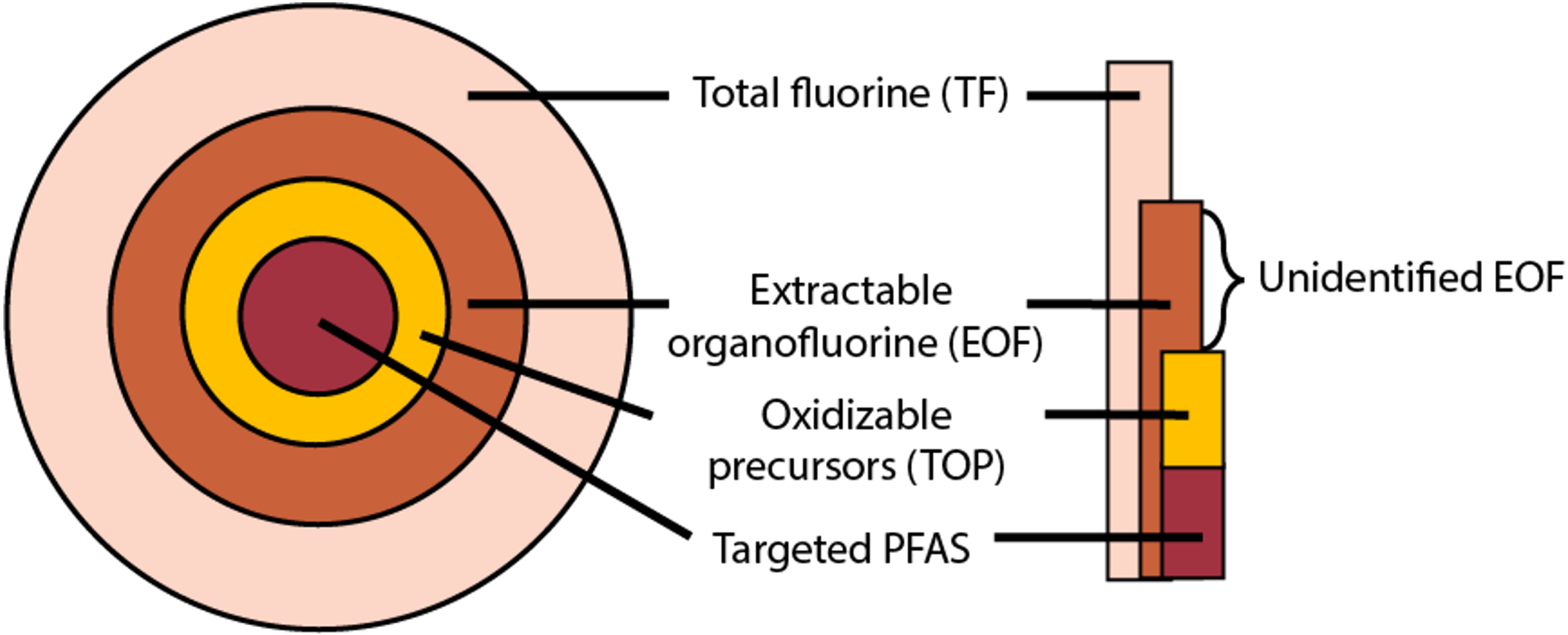




Dassuncao et al., 2018

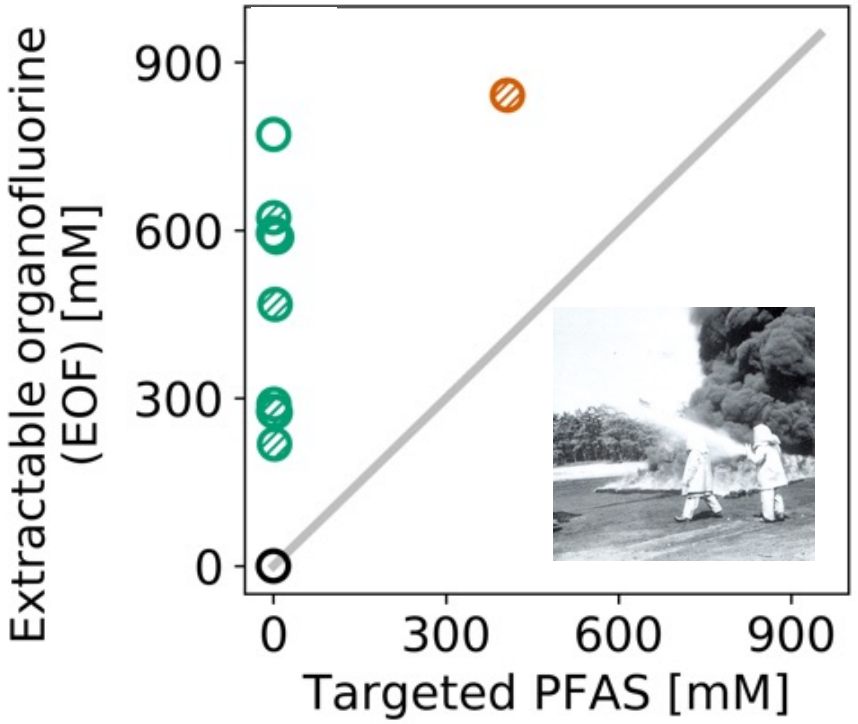
Most PFAS are not detected by targeted analysis (standard EPA methods)

Targeted analysis is usually limited to <50 PFAS with analytical standards



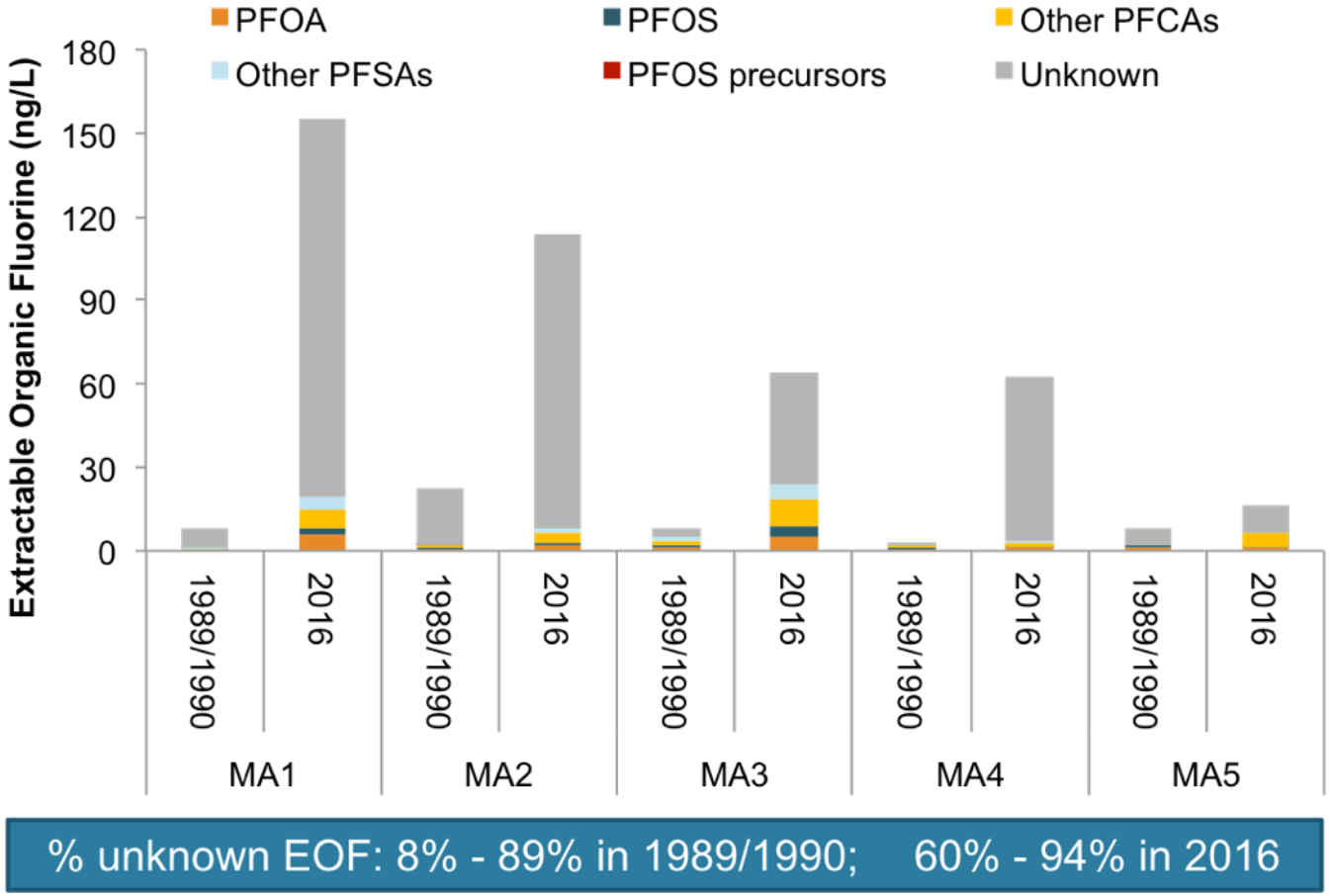
Large amounts of organofluorine in AFFF and drinking water

Fluorotelomer AFFF (2013-2017)



Ruyle et al. (2021)

Pilot Data on Drinking Water in MA

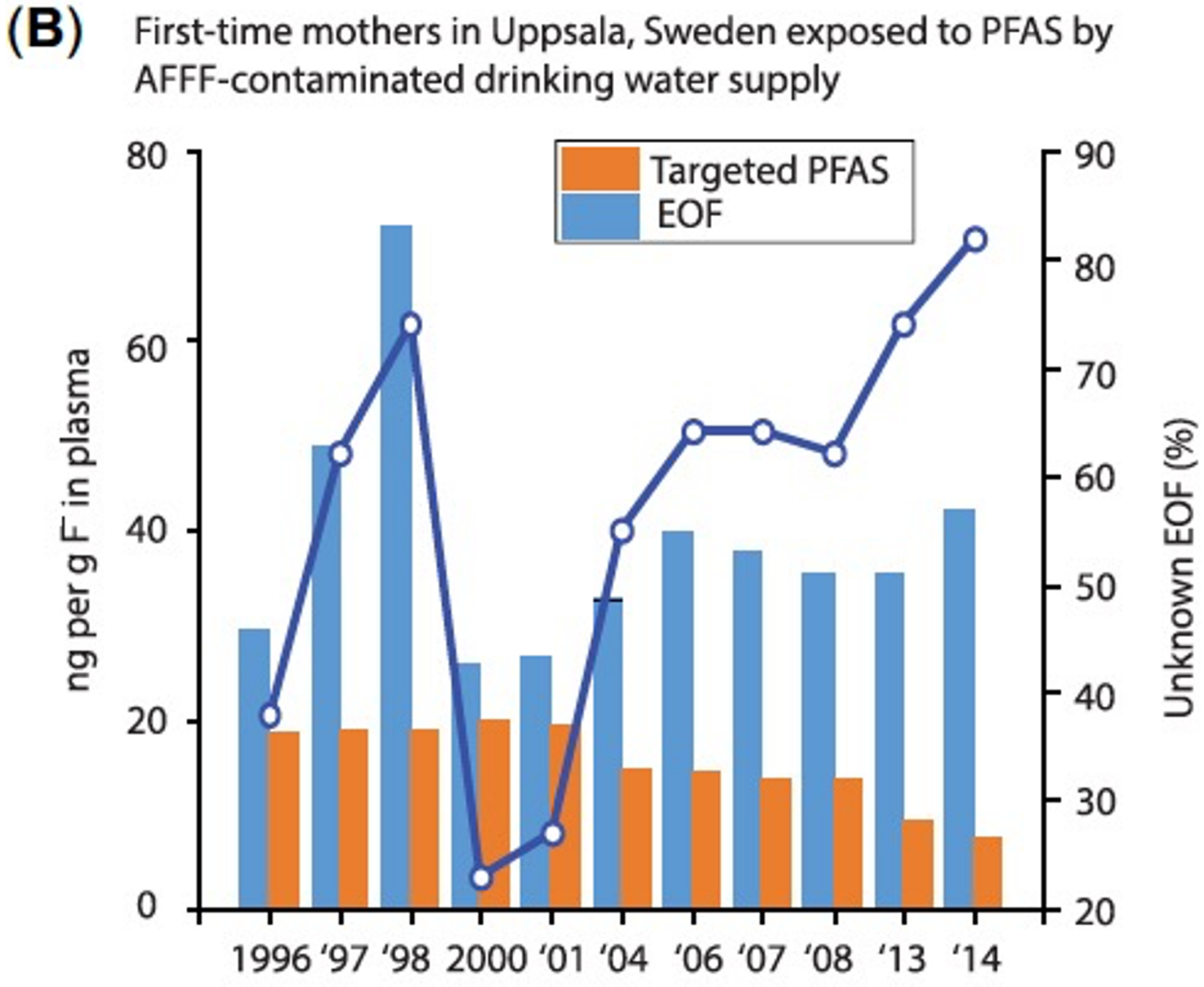


Hu et al. (2019)

NIH National Institute of Environmental Health Sciences

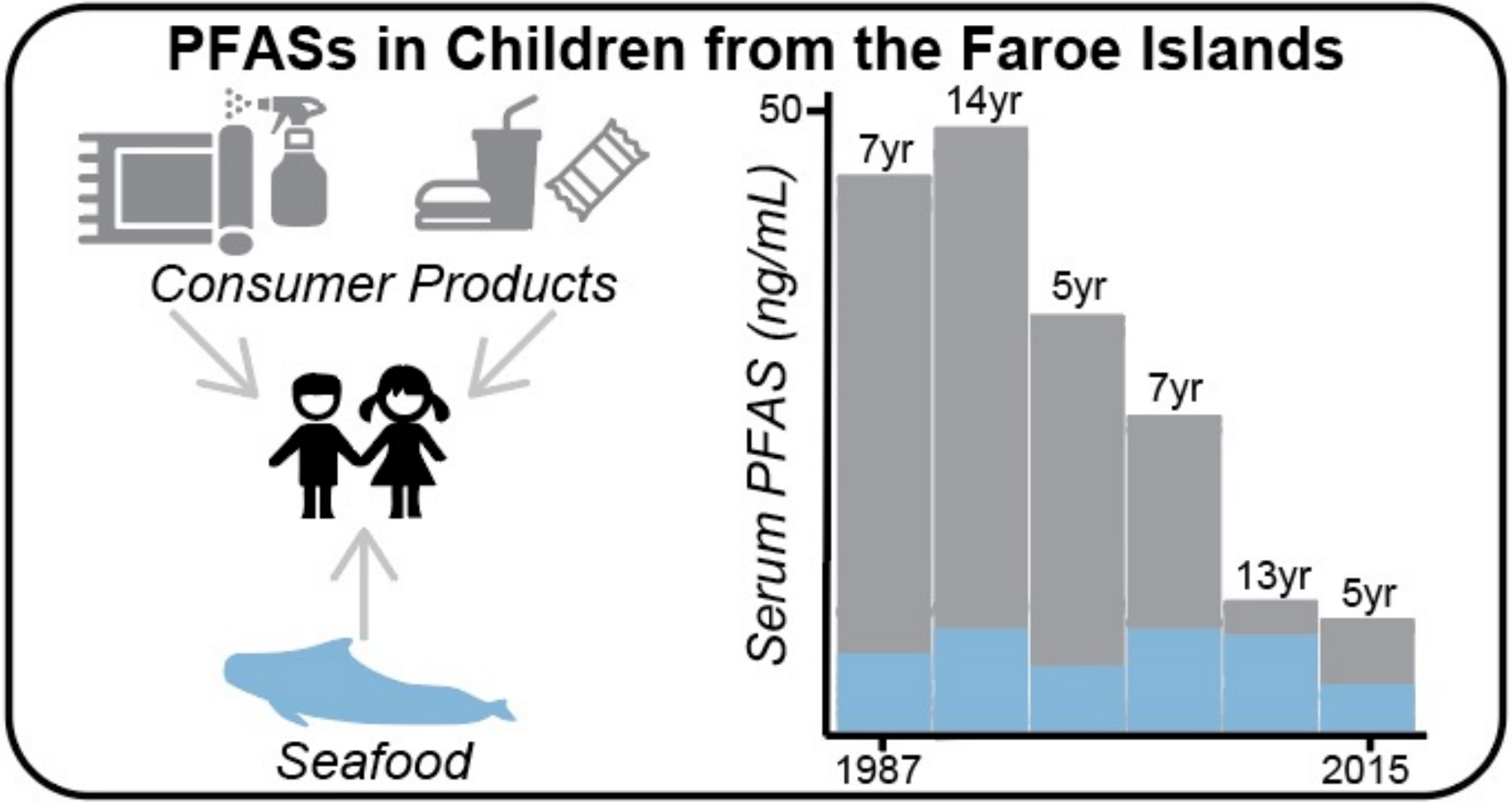
EPA United States Environmental Protection Agency

Large amounts of organofluorine in human populations



Data from Miaz et al., 2020

Decline in serum PFAS concentrations can not be explained by shifts exposure from seafood consumption



Even in the Faroe Islands (remote high seafood consuming population), diverse consumer products appear to have accounted for the majority of exposures for children in the 1990-2000s.

Dassuncao et al. 2018

Targeted LC-MS/MS measurements make up SMALL fraction of total PFAS in consumer products

ENVIRONMENTAL Science & Technology LETTERS

Letter

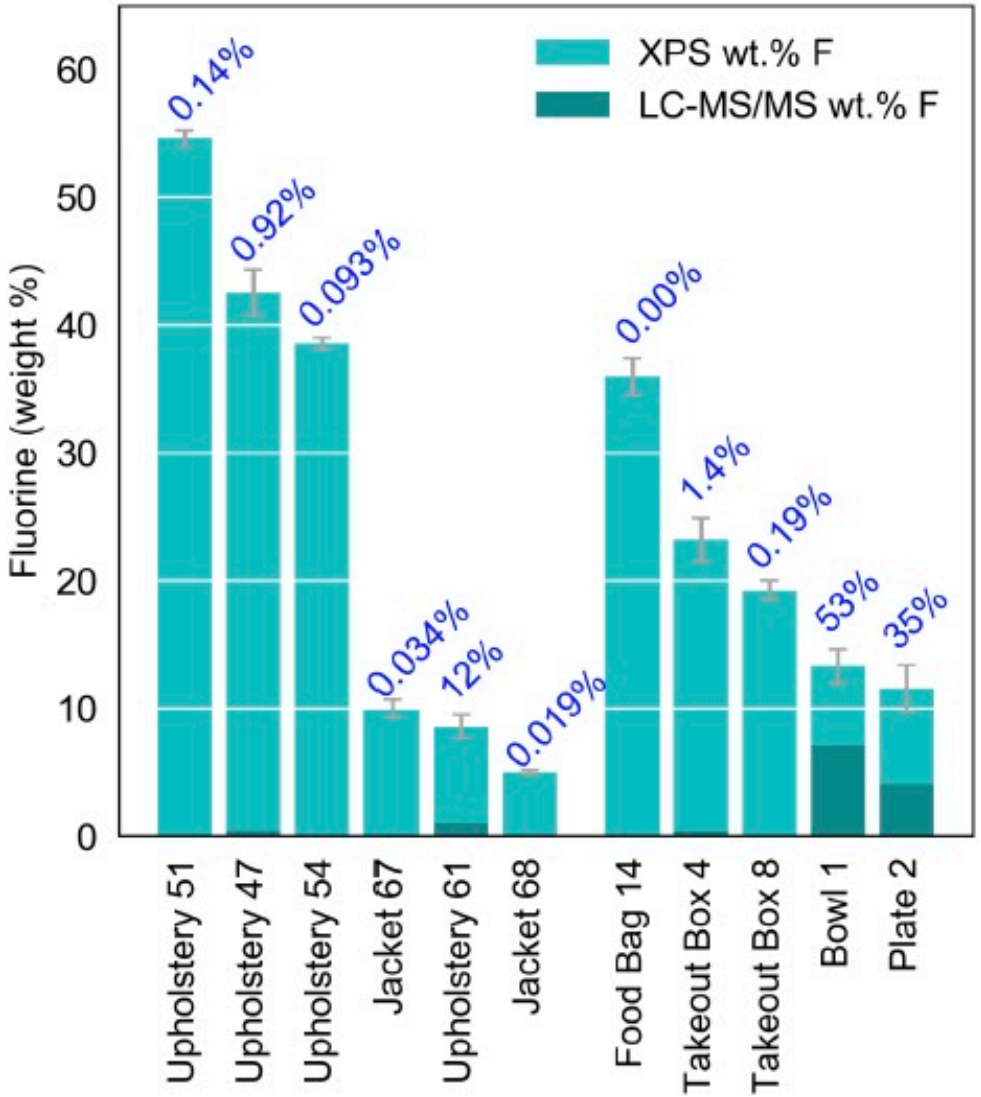
Cite This: *Environ. Sci. Technol. Lett.* 2019, 6, 38–43

pubs.acs.org/journal/estlcu

How Do We Measure Poly- and Perfluoroalkyl Substances (PFASs) at the Surface of Consumer Products?

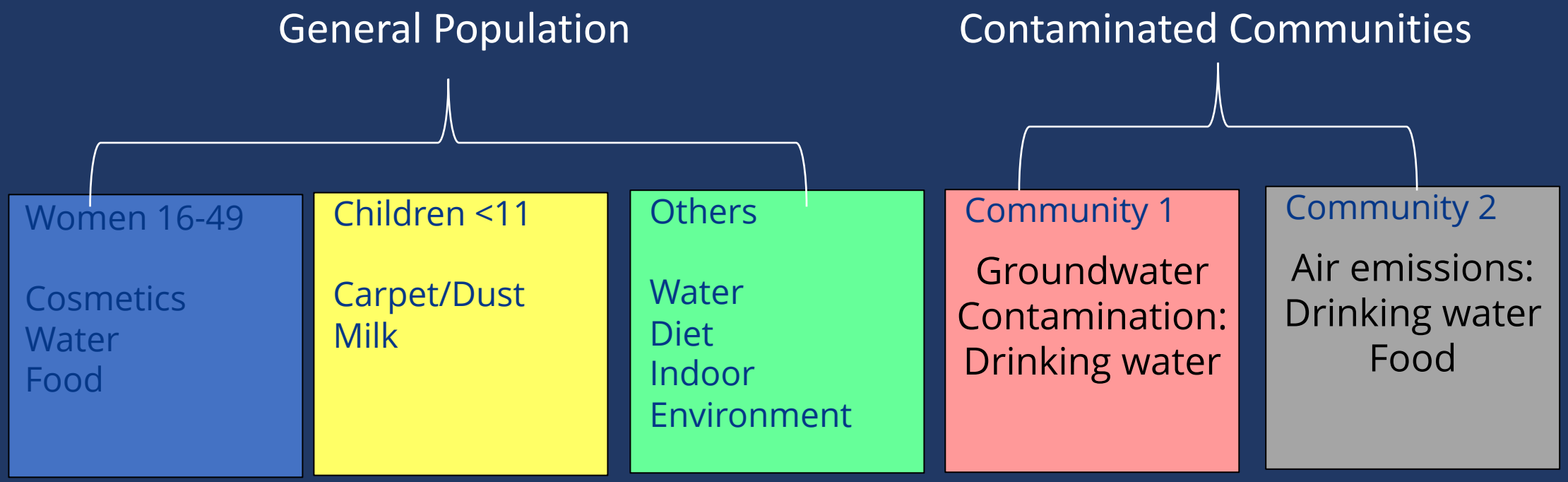
Andrea K. Tokranov,*[†] Nicole Nishizawa,[†] Carlo Alberto Amadei,[†] Jenny E. Zenobio,[‡] Heidi M. Pickard,[†] Joseph G. Allen,[§] Chad D. Vecitis,[†] and Elsie M. Sunderland[†,§]

Tokranov et al., 2019, ES&T



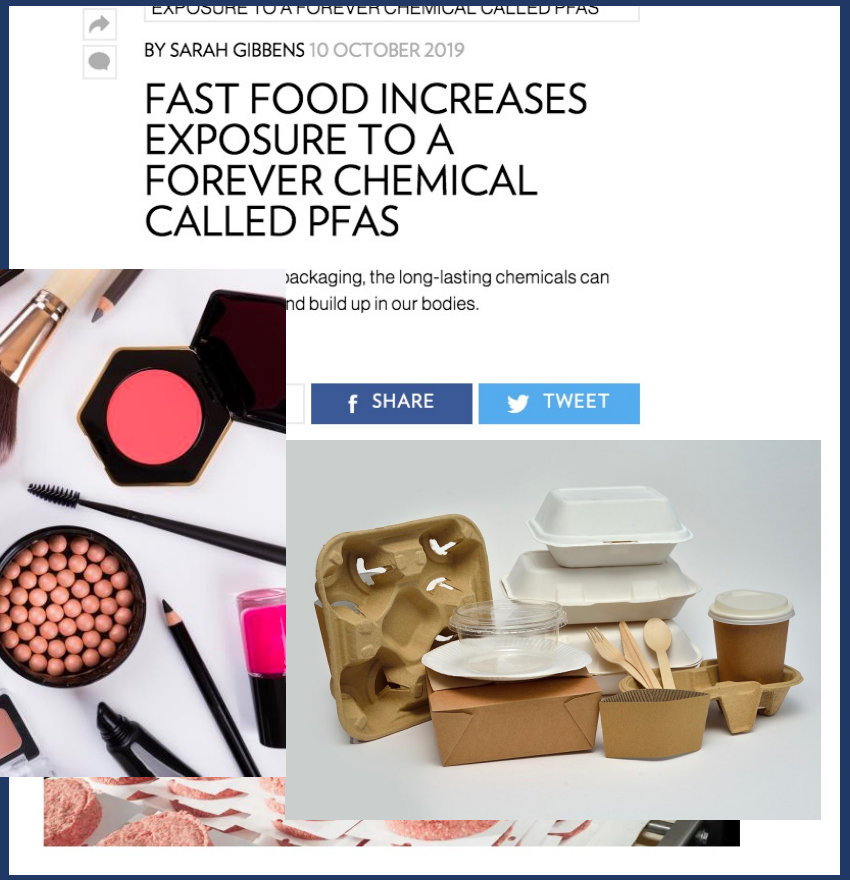
Limited understanding of the relative importance of exposure sources for the general population

Importance of different exposure sources varies across different demographic groups



Known Unknown Exposure Sources

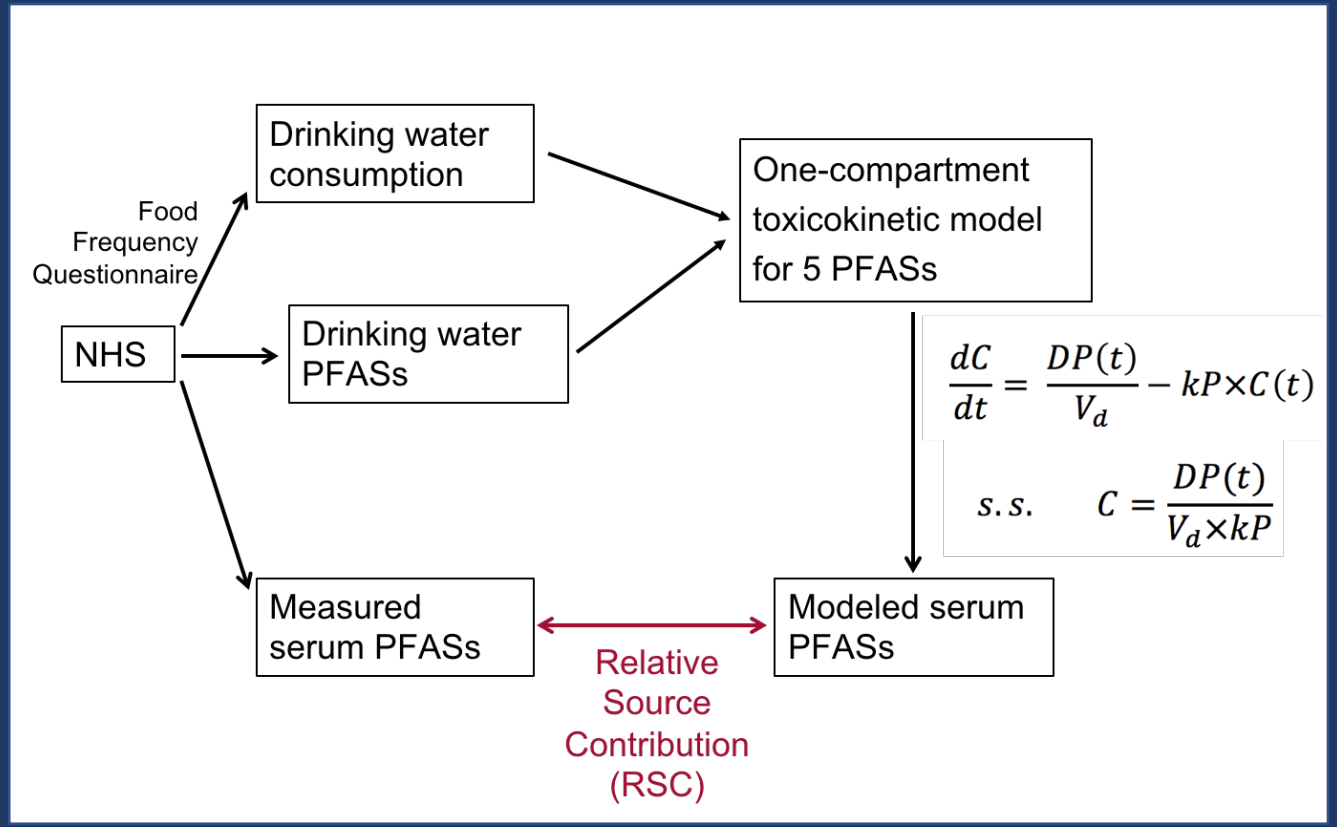
- Biosolids, FCM, Cosmetics



Schuiltes et al., 2018;
Susmann et al., 2019, EHP

Unknown Unknown Exposure Sources

- Likely we are still not aware of some sources
- Pairing environmental exposure measurements with human serum data is needed understand and rank their relative significance.
- Need to consider multiple sources simultaneously in the same population



Example for tap water from Hu et al., 2019, EHP

Summary

- **<u>Diverse adverse health effects associated with PFAS Exposure:</u> PFAS are particularly problematic because they affect every major organ system in the human body!**

- **<u>Many human exposure sources – some</u> : We have the most data on drinking water as an exposure source but the importance of others (diet, consumer products, seafood) is poorly understood.**

- **<u>The importance of PFAS precursors for human exposures needs to be better understood</u>: Our standard analytical techniques have been limited by commercially available standards and are not keeping pace with industrial production of new PFAS. Innovation is needed (HRMS + total fluorine metrics).**