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# The Perils of PFAS


Linda S. Birnbaum, Ph.D., D.A.B.T., A.T.S.

Scholar in Residence, Duke University

Scientist Emeritus and Former Director, NIEHS and NTP

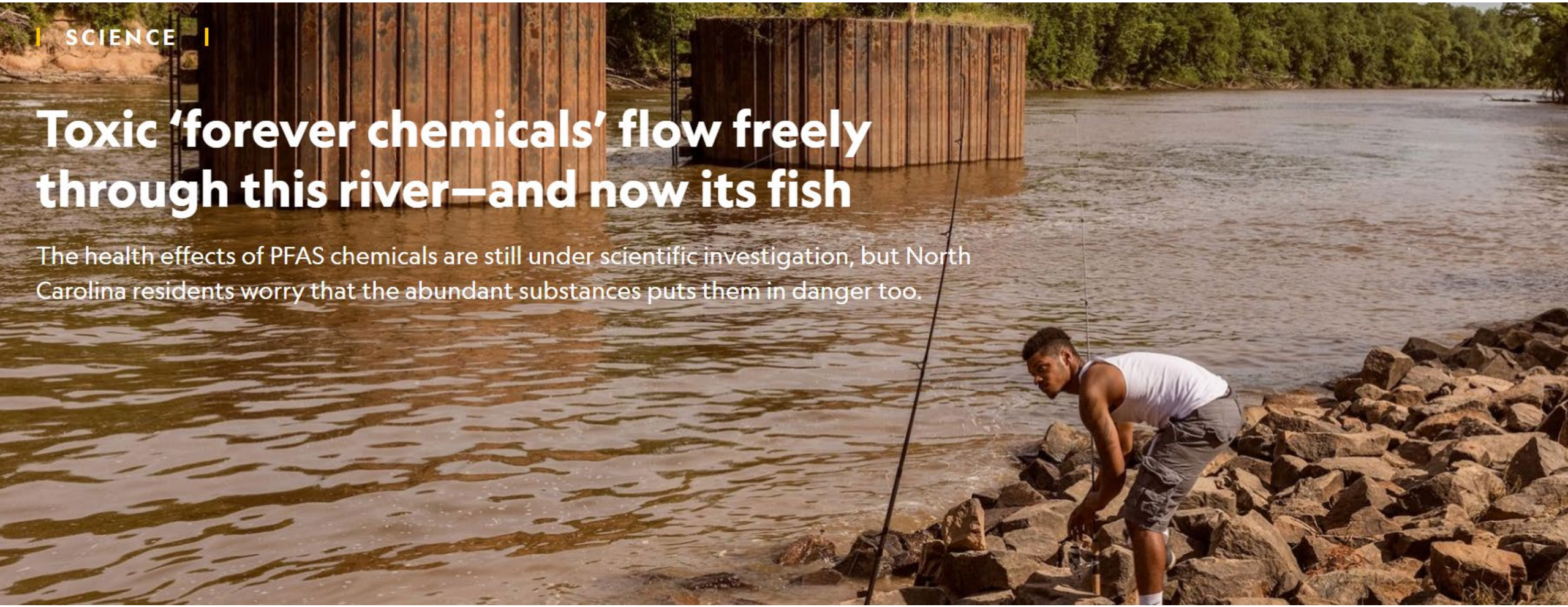

**Environmental Sciences and Engineering Centennial**
**Gillings School of Public Health, UNC**

**February 12, 2021**


**The PFAS in ski wax helps athletes slide faster down the hill.** Dmitry Molchanov/Shutterstock

NATIONAL GEOGRAPHIC

MARCH 24, 2020



SCIENCE

# Toxic ‘forever chemicals’ flow freely through this river—and now its fish

The health effects of PFAS chemicals are still under scientific investigation, but North Carolina residents worry that the abundant substances puts them in danger too.

In May 2018 in Fayetteville, North Carolina, D'Anthony Brown sets up fishing poles at the William O Huske Dam. This is the dam closest to the Chemours plant, which manufactures products containing PFAS chemicals. Chemours has been accused of polluting the water supplies of cities downriver.

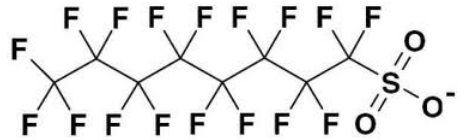
PHOTOGRAPH BY JEREMY M. LANGE

# Burlington, Haw River Assembly reach agreement on PFAS contamination (NC Policy Watch, Oct. 23, 2020)

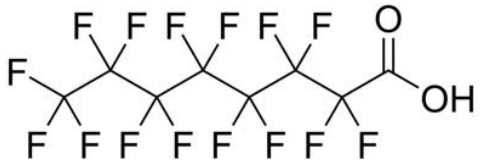
*The Haw River, drinking water supply for the Town of Pittsboro, as seen from the Bynum Bridge (File photo: Lisa Sorg)*

# What are Per- and Polyfluoroalkyl Substances (PFAS)?

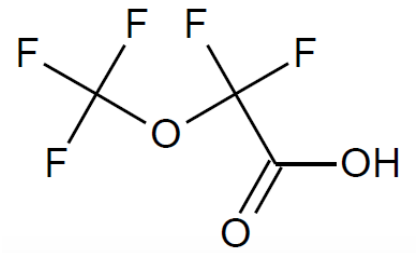
- **Total number of PFAS**
  **>9,000 chemicals**
  - Includes products, impurities and degradants
    - Teflon
    - Scotchguard
    - Aqueous Film Forming Foams (AFFFs)
  - Many unknown formulation
- Resistant to grease, water & oil
  - Surfactants, stain repellants
  - Fire suppression - AFFF
- Persistent, mobile and bioaccumulative
- Emergence of short-chain alternatives - less well studied
  - Few studied – same effects as long chains



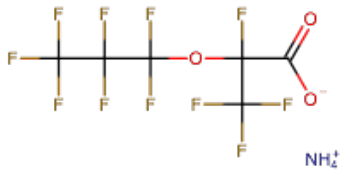
PFOS



PFOA



PFMOAA



GenX

# Per- and Polyfluoroalkyl Substances (PFAS)

**Perfluoroalkyl acids and perfluoroalkylether acids (PFAA), e.g.**

**perfluoroalkyl carboxylic acids (PFCA)**, $C_nF_{2n+1}$-COOH, e.g. PFOA

**perfluoroalkane sulfonic acids (PFSA)**, $C_nF_{2n+1}$-$SO_3H$, e.g. PFOS

**perfluoroalkyl phosphonic acids (PFPA)**, $C_nF_{2n+1}$-$PO_3H_2$

**perfluoroalkyl phosphinic acids (PFPiA)**, $(C_nF_{2n+1})(C_mF_{2m+1})$-$PO_2H$

**perfluoroalkylether carboxylic acids (PFECA)**, e.g. $C_2F_5OC_2F_4OCF_2COOH$

**perfluoroalkylether sulfonic acids (PFESA)**, e.g. $C_6F_{13}OCF_2CF_2SO_3H$

**Precursors to PFAA, e.g.**

**perfluoroalkane sulfonyl fluorides (PASF)**
**perfluoroalkanoyl fluorides (PACF) and their derivatives,** $C_nF_{2n+1}SO_2$-R / $C_nF_{2n+1}CO_2$-R

**n:2 fluorotelomer-based substances**
$C_nF_{2n+1}CH_2CH_2$-R

**per- and polyfluoroalkylether-based substances**
e.g. $C_nF_{2n+1}OC_mF_{2m+1}$-R

→ **side-chain fluorinated polymers**
e.g. (meth)acrylate, urethane, or oxetane polymers with non-fluorinated backbones and fluorinated side-chains

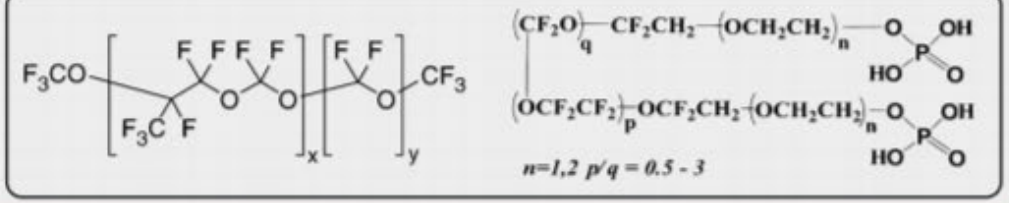
→ **non-polymers**
R = NH, $NHCH_2CH_2OH$, etc.

**some hydrofluorocarbons (HFCs**, e.g. $C_nF_{2n+1}$-$C_mH_{2m+1}$), **hydrofluoroethers (HFEs**, e.g. $C_nF_{2n+1}OC_mH_{2m+1}$) and **hydrofluoroolefins (HFOs**, e.g. $C_nF_{2n+1}$-$CH=CH_2$);
**perfluoroalkyl** ($C_nF_{2n+1}C(O)C_mF_{2m+1}$) and **semi-fluorinated** ($C_nF_{2n+1}C(O)C_mH_{2m+1}$) **ketones;**
**perfluoroalkyl alcohols** ($C_nF_{2n+1}OH$)

**Fluoropolymers, e.g.**

polytetrafluoroethylene (**PTFE**), -$(CF_2CF_2)_n$-
polychlortrifluorethylen (**PCTFE**), -$(CF_2CFCl)_n$-
polyvinylidene fluoride (**PVDF**), -$(CF_2CH_2)_n$-
fluorinated ethylene propylene (**FEP**), -$(CF_2CF_2)_n$-$(CF_2C(CF_3)F)_m$-

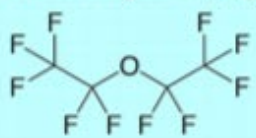
**Perfluoropolyethers, e.g.**



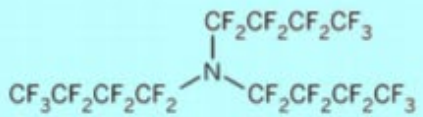

**Other PFAS*, e.g.**

**Perfluoroalkanes,** e.g.

**Perfluoroalkylethers,** e.g.



**Perfluoroalkylamines,** e.g.




Kwiatkowski et al., ES&T Lett., 2020

# “NEW” PFAS found all the time!

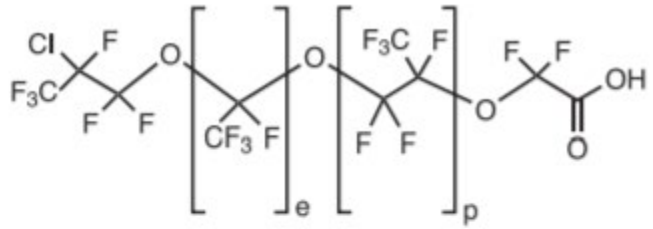



**Fig. 1. A chloroperfluoropolyether carboxylate (ClPFPECA) identified by nontargeted MS analyses in soil samples from New Jersey.** In the New Jersey samples, perfluoroethyl (e) plus perfluoropropyl (p) groups were observed to range in sum from one to four. The example congener depicted here would be designated (e,p) = 1,1. Isomers likely include an alternative terminal structure of $ClCF_2CF(CF_3)O$– (*13*, *14*) as well as relative positions for the perflluoroethyl and perfluoropropyl groups.

SOLVAY

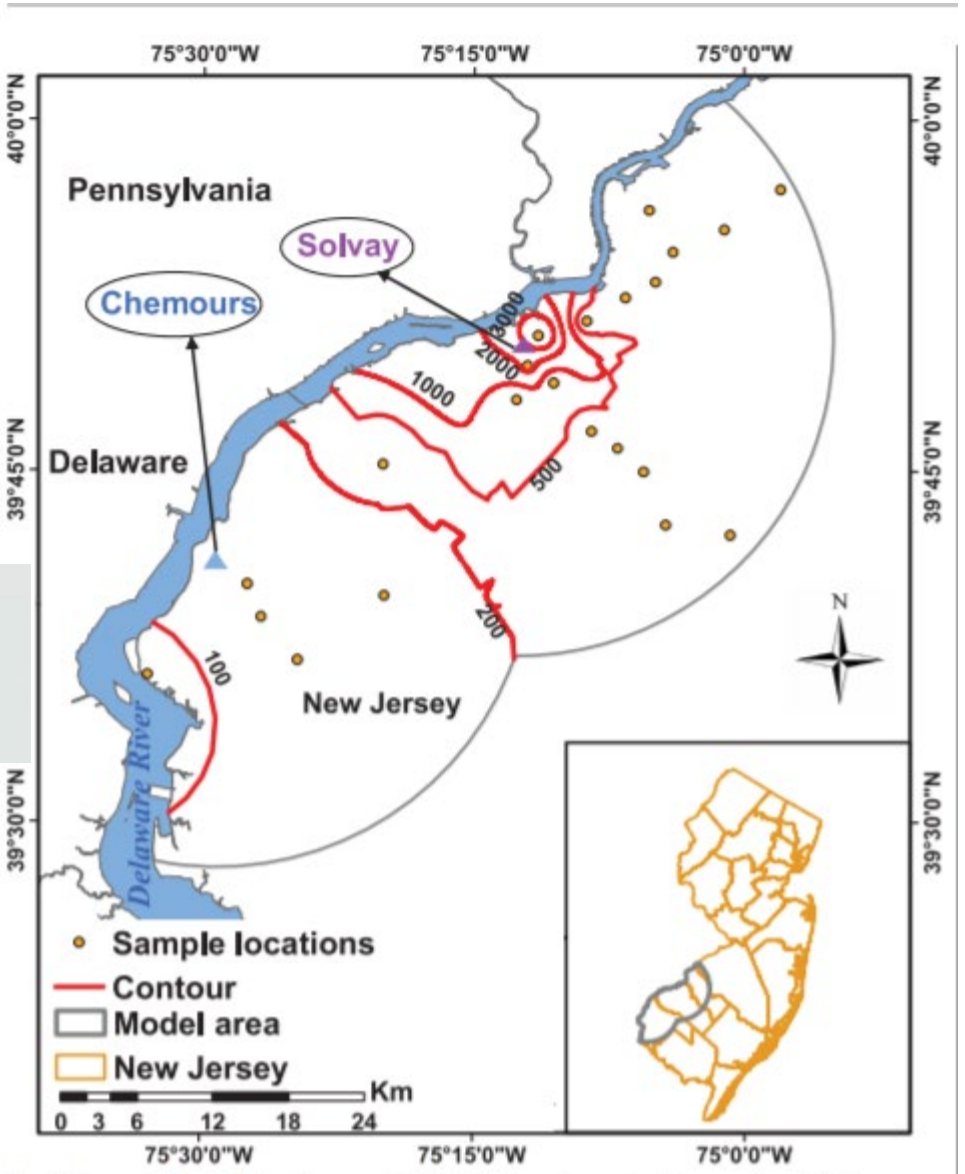
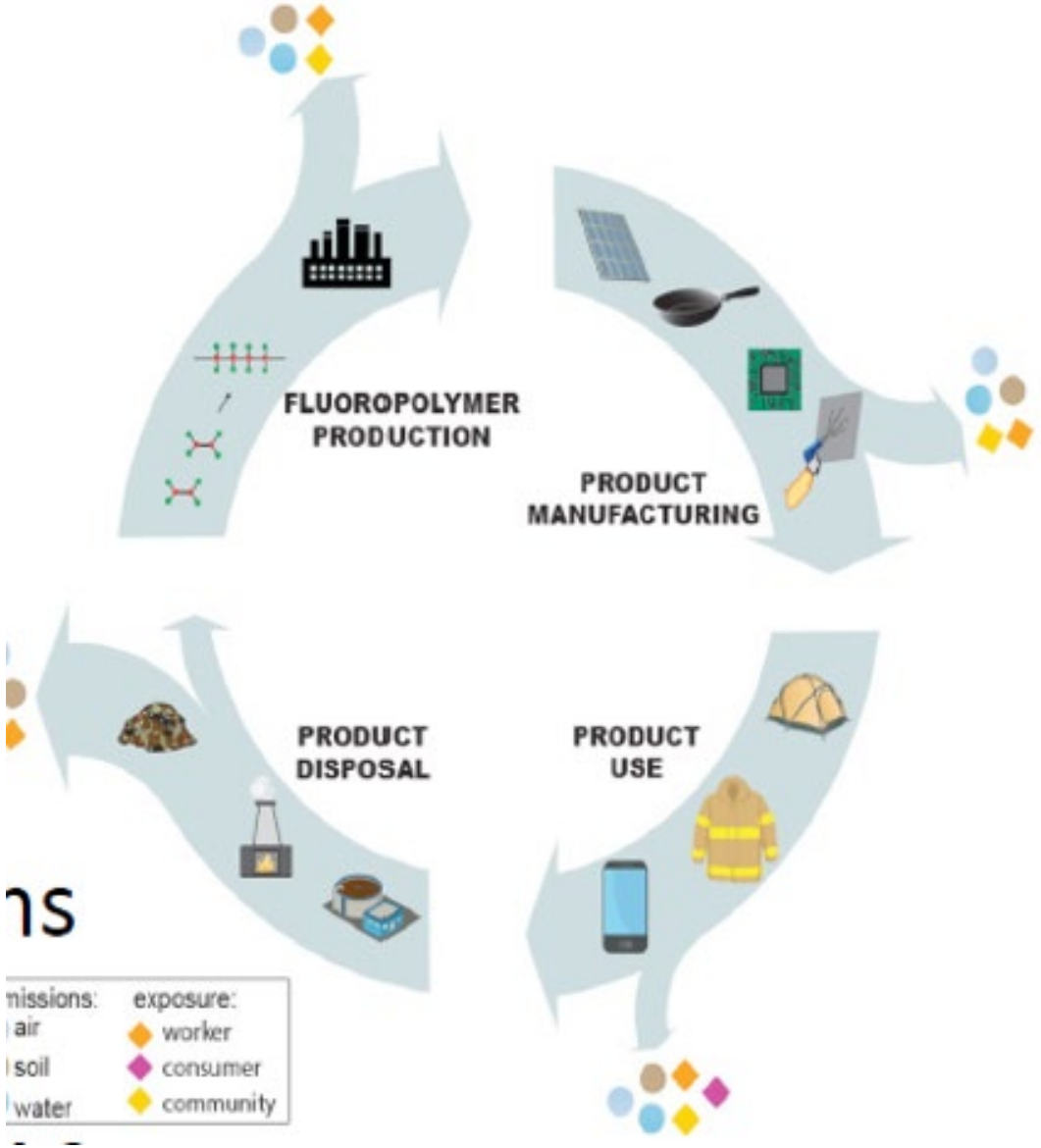



**Fig. 4. Geographic distribution.** Shown are ΣClPFPECAs in surface soils (picograms/gram). Contour lines were generated by using an algorthim in ArcMAP 10.6.1 that weighted the five nearest data points according to inverse-square distance. Despite some geographic sporadicity in the data and numerical artifacts where data are sparsely spaced, taken as a group the contours depict a clear pattern of increasing ΣClPFPECAs with proximity to Solvay.

Washington et al., Science 2020.

# Stable PFAS from Precursors and Polymers

- FTOH--→ PFAS
- Fluorinated Polymers
  - Side chains can break down to release PFAS with half lives on the order of decades
  - Production may involve PFAS additives (e.g., PFOA, GenX)
  - Polymers = mixtures, containing residual monomers, oligomers, etc.
  - Emission occurs during fluoropolumer lifecycle:
    - Production, use, disposal



# Uses of PFAS?

Environmental Science Processes & Impacts

ROYAL SOCIETY OF CHEMISTRY

PAPER

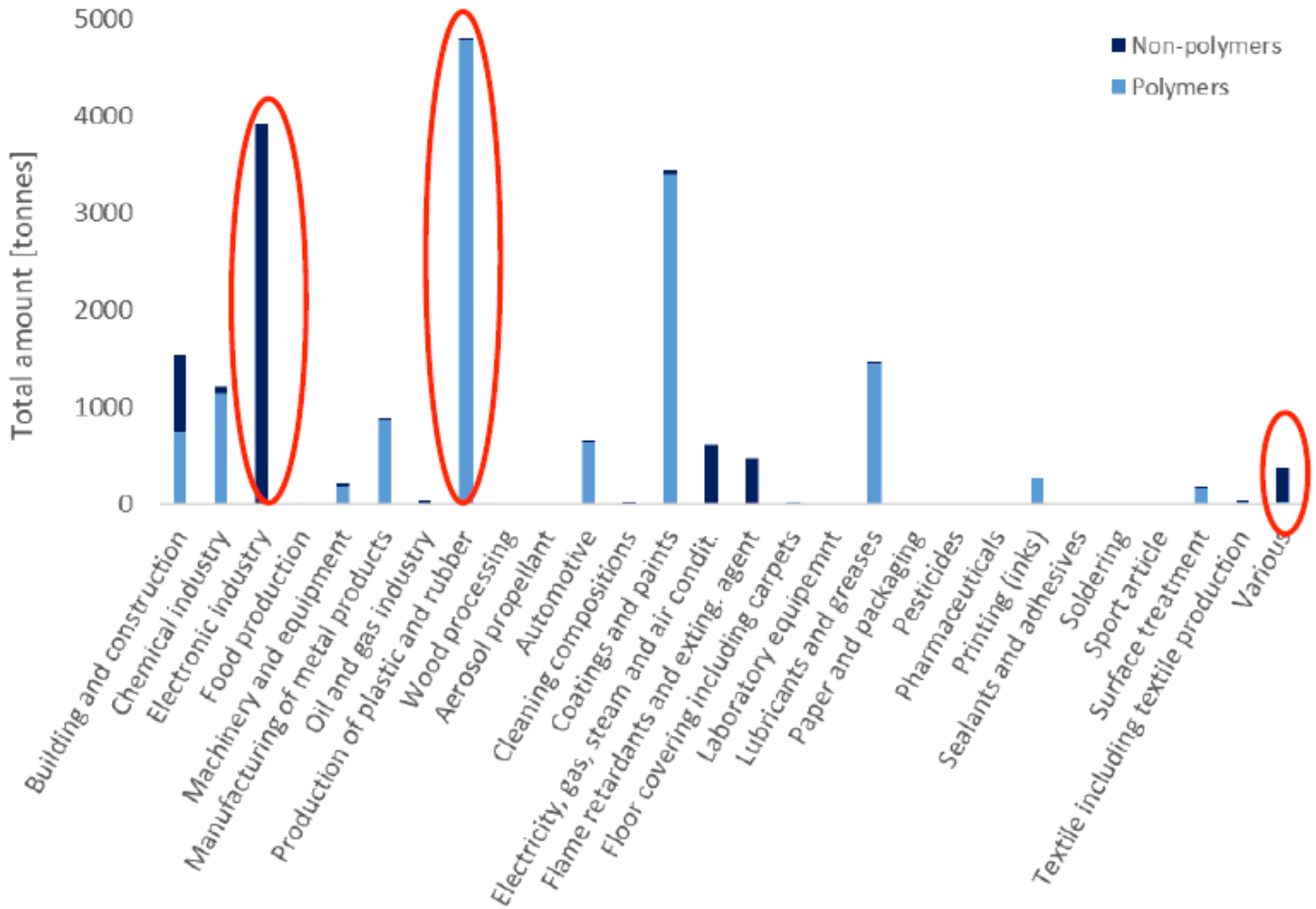
View Article Online

Check for updates

Cite this: Environ. Sci.: Processes Impacts, 2020, 22, 2345

**An overview of the uses of per- and polyfluoroalkyl substances (PFAS)†**

Juliane Glüge,[a] Martin Scheringer,[a] Ian T. Cousins,[b] Jamie C. DeWitt,[c] Gretta Goldenman,[d] Dorte Herzke,[e] Rainer Lohmann,[g] Carla A. Ng,[h] Xenia Trier[i] and Zhanyun Wang[j]

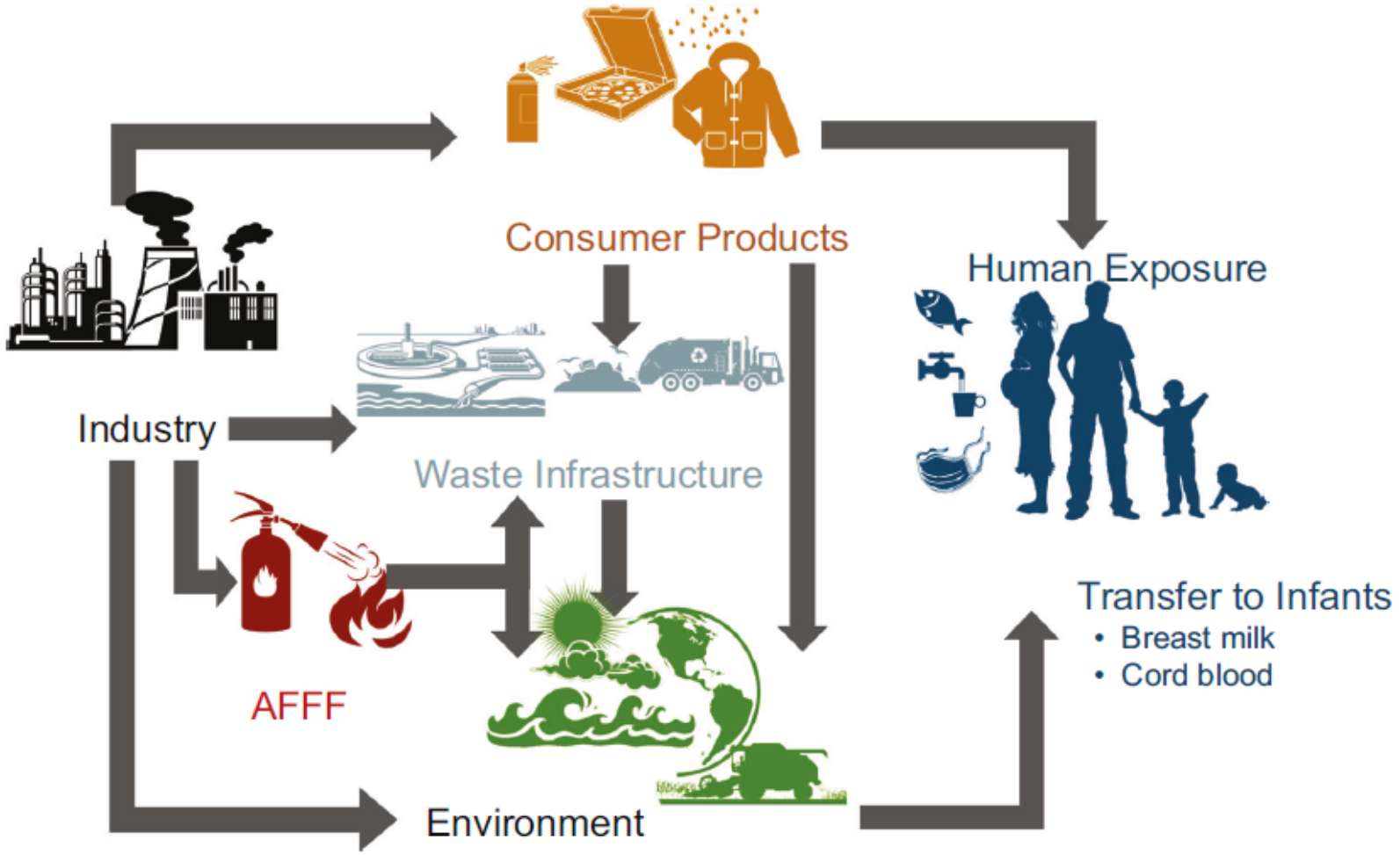



- More than 200 uses identified for more than 1400 PFAS

- Less well known uses:
  - ammunition,
  - climbing ropes,
  - guitar strings,
  - artificial turf,
  - soil remediation

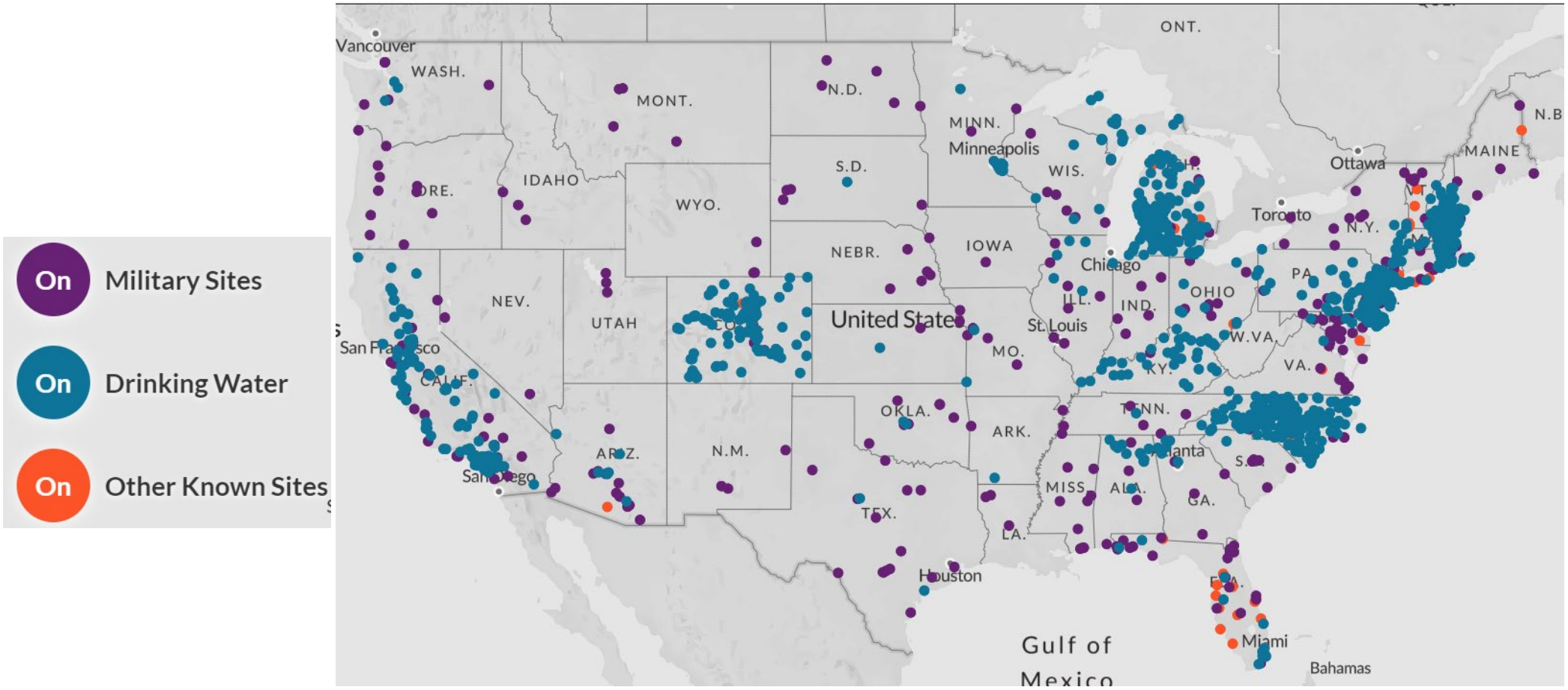
*Thx to Ian Cousins*

# PFAS Exposure



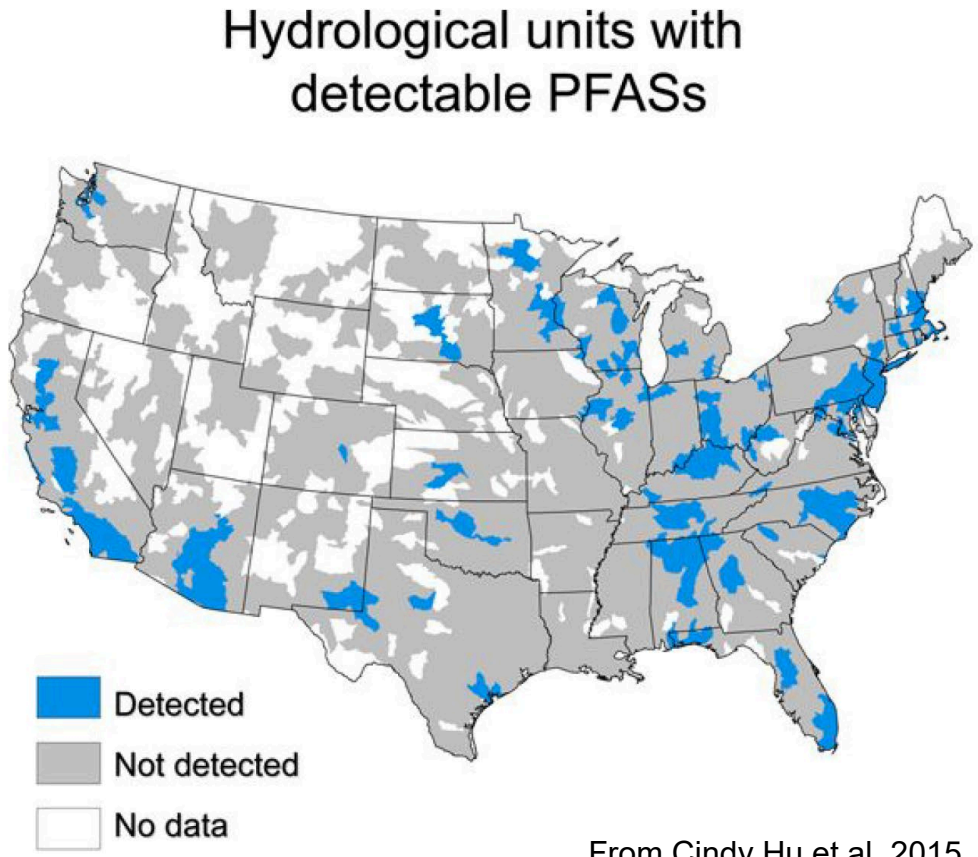

Sunderland et al., J Expos Sci & Epidemiol, 2019

# PFAS Water Contamination in the United States
# July 20,2020 (EWG)

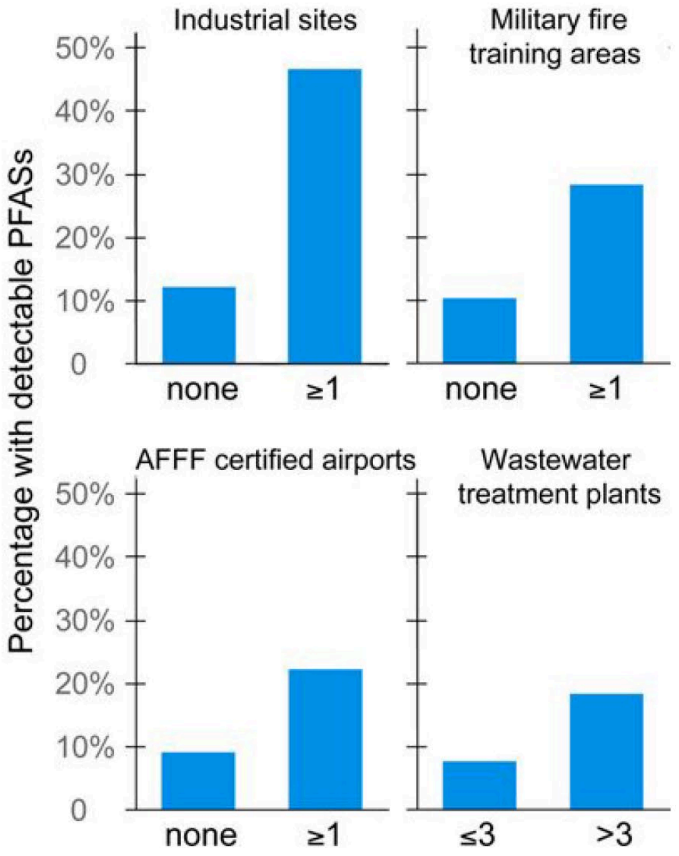



2,230 locations in 49 states are known to have PFAS contamination

# Watersheds with point sources have higher detection frequencies for PFAS




From Cindy Hu et al, 2015




Cindy Hu et al, ES&T Letters, 2016

# PFAS Exposure associated with AFFF

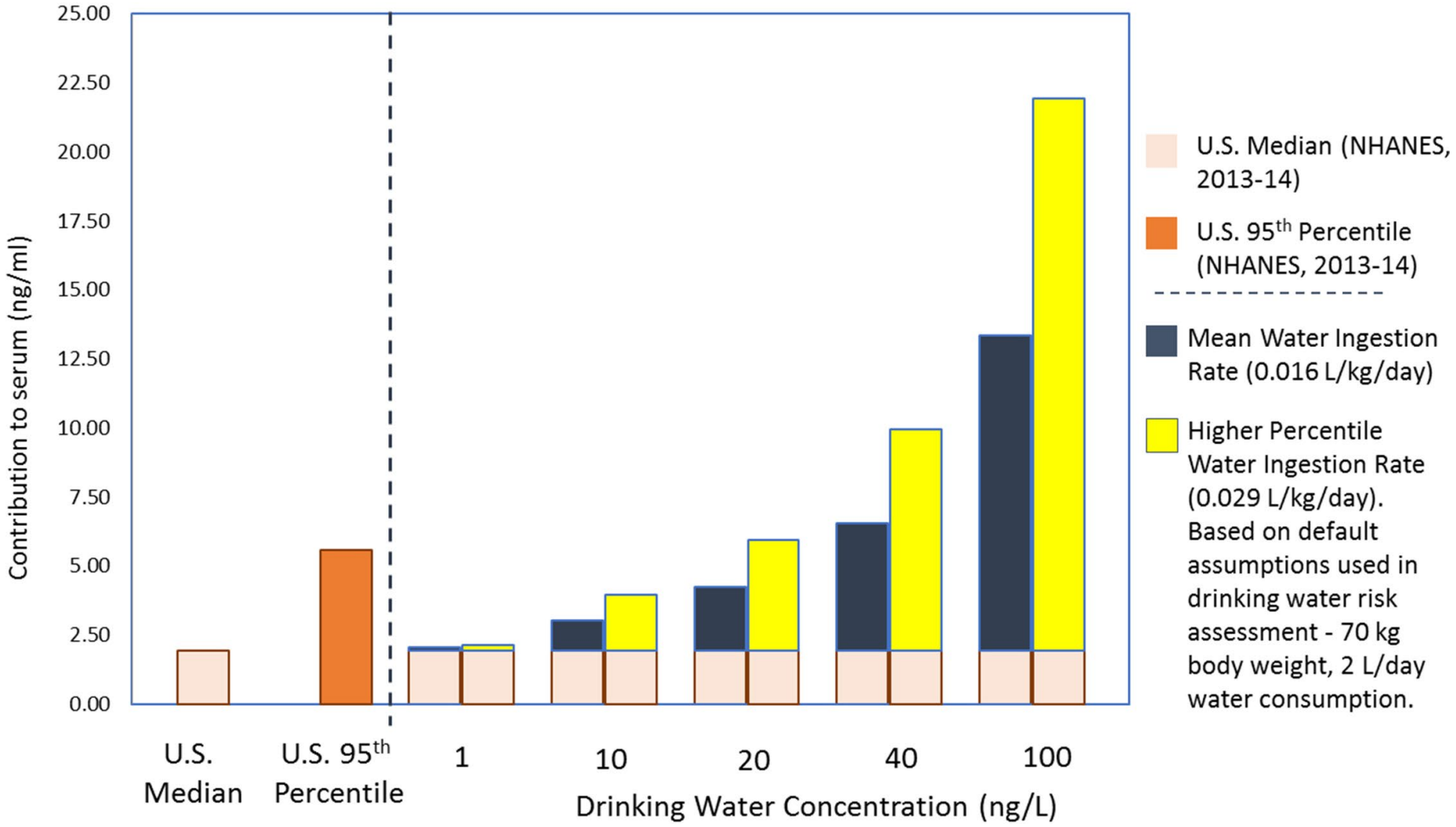
- Cross-sectional and longitudinal study of residents in Fountain, Security, and Widefield, CO (n=220)
  - Total PFASs in untreated well water ranged from 18 – 2300 ppt (ng/L)
    - PFAS detected are typical of fire-fighting foam-impacted groundwater

| Chemical in Blood Sample | Local Med. (ng/ml) | US Ref. Med. (ng/ml) | % Difference |
|---|---|---|---|
| PFHxS | 14.8 | 1.4 | + 1,000% |
| PFOS | 9.7 | 5.2 | + 80% |
| PFOA | 3.0 | 2.1 | + 43% |
| PFNA | 0.4 | 0.7 | - 43% |

John Adgate, 2019

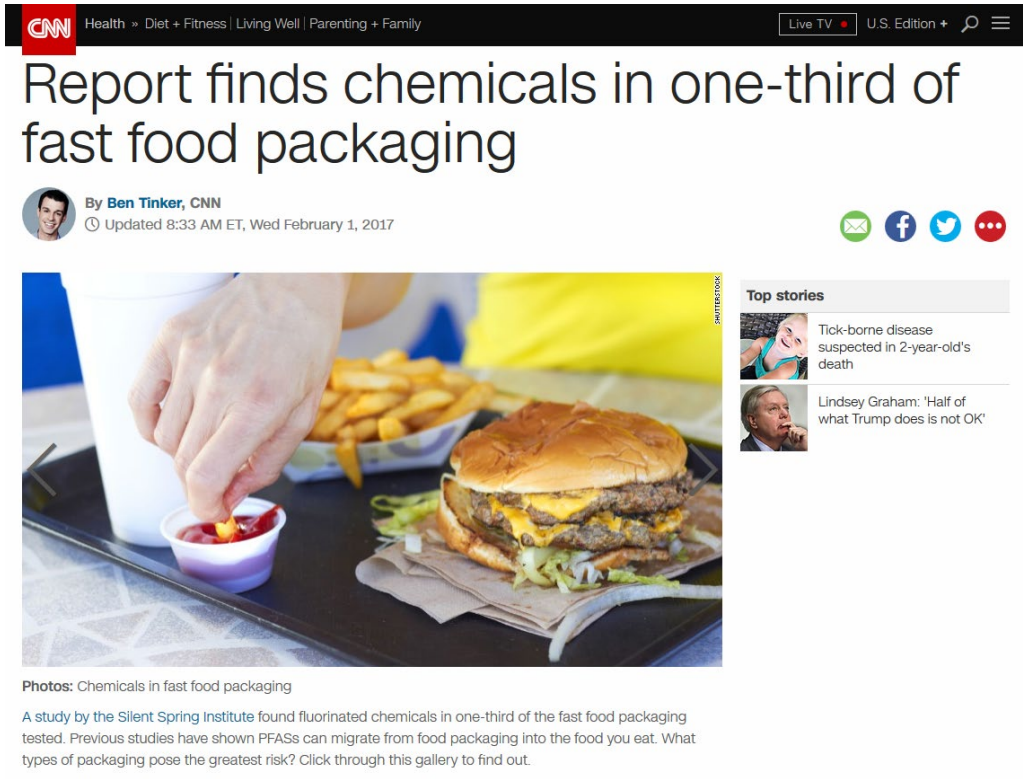
University of Colorado Denver

# PFOA blood levels rise with increased contamination of drinking water




-- Post et al., PLoS Biol 10(12): e2002855.

# PFAS in Fast Food Packaging



CNN Health » Diet + Fitness | Living Well | Parenting + Family — Live TV — U.S. Edition +

## Report finds chemicals in one-third of fast food packaging

By Ben Tinker, CNN
Updated 8:33 AM ET, Wed February 1, 2017

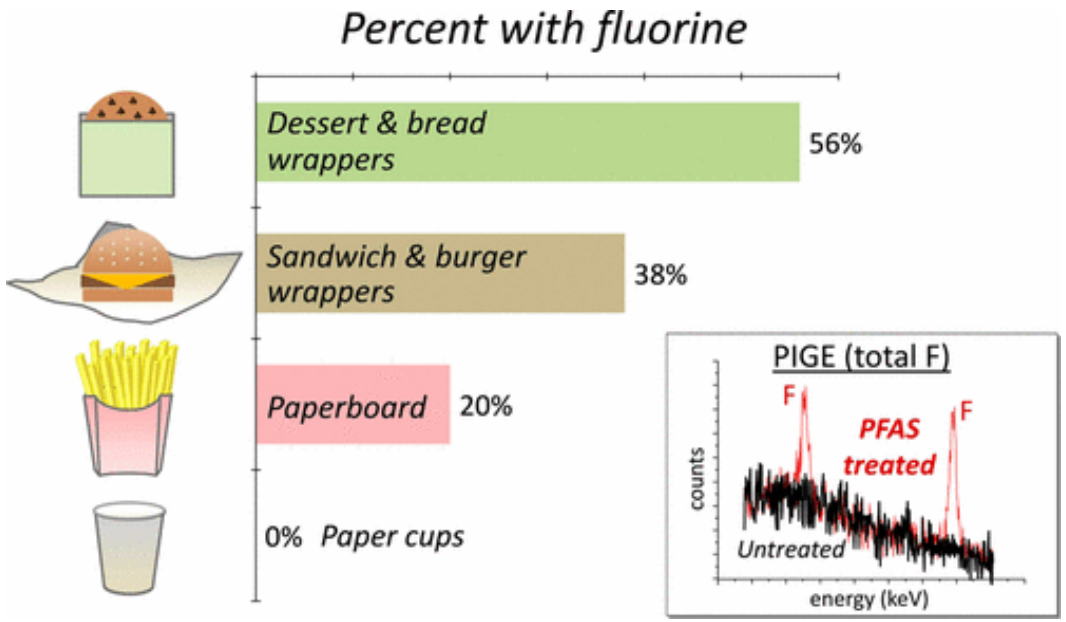
Top stories

Tick-borne disease suspected in 2-year-old's death

Lindsey Graham: 'Half of what Trump does is not OK'

**Photos:** Chemicals in fast food packaging

A study by the Silent Spring Institute found fluorinated chemicals in one-third of the fast food packaging tested. Previous studies have shown PFASs can migrate from food packaging into the food you eat. What types of packaging pose the greatest risk? Click through this gallery to find out.




***Most common PFAS in samples: PFOA, PFHxA, PFBS, and 6:2 FTS***


Environmental Science & Technology Letters

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Letter

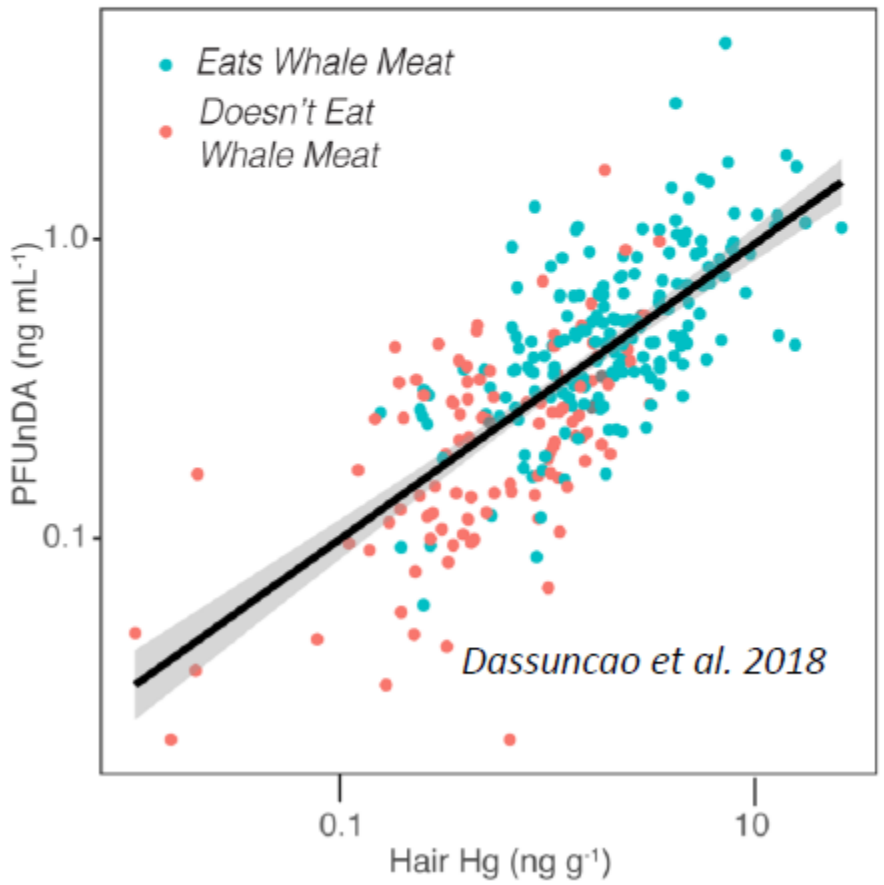
pubs.acs.org/journal/estlcu


**Fluorinated Compounds in U.S. Fast Food Packaging**

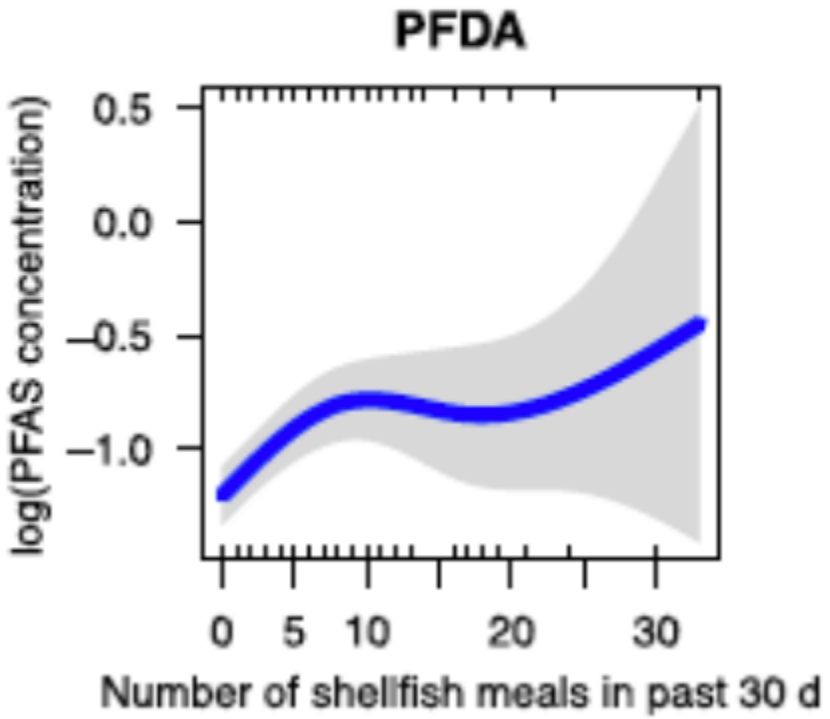

Laurel A. Schaider,[*,†] Simona A. Balan,[‡] Arlene Blum,[§,∥] David Q. Andrews,[⊥] Mark J. Strynar,[#] Margaret E. Dickinson,[▽] David M. Lunderberg,[▽] Johnsie R. Lang,[○] and Graham F. Peaslee[@]

# Long-Chained PFCAs strongly associated with seafood consumption

Faroese Children



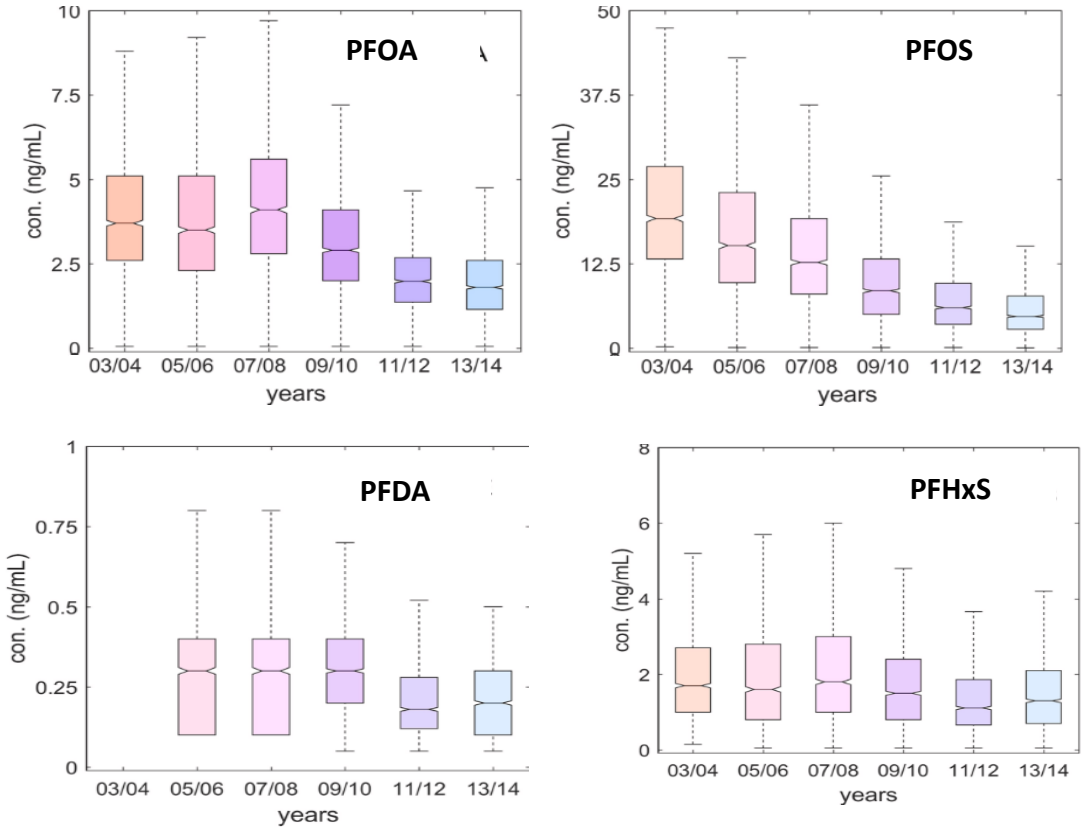

NHANES 2005-2006




*Hu et al. 2018*

# We All Have PFAS in Our Bodies

- Detected in humans globally
- >98% of people in the U.S. have measurable amounts of PFAS
- Levels of PFOA and PFOS have declined following phase-outs
- Changes in exposure to other PFAS are less pronounced

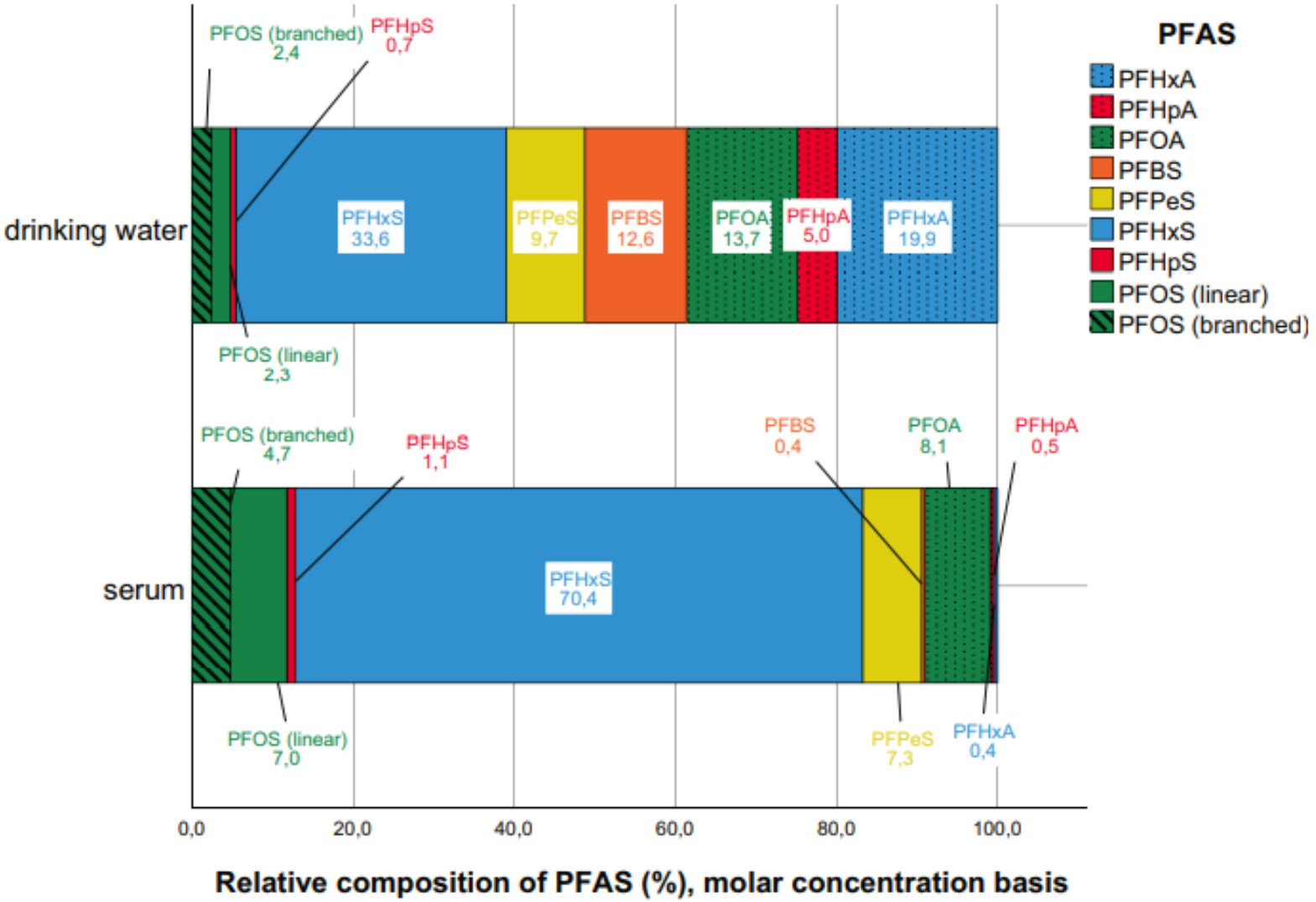



PFAS exposure trends in NHANES 2003 – 2014

Sunderland et al., J Expos Sci & Epidemiol, 2019
Dong et al., Ecotox and Environ Safety, 2019

# Swedish Airport Water and Workers Blood

Y Xu, T Fletcher, et al. EHP 2020




Serum Half-lives after Cessation of Exposure in Airport Workers

| PFAS | Half-Life |
|---|---|
| PFHpA | 62 d |
| PFOA | 1.8 y |
| PFBS | 44 d |
| PFPeS | 230d |
| PFHxS | 2.9 y |
| PFOS | 2.9 y |

# PFAS Concentration (ng/g) in Cadavers (n=20)

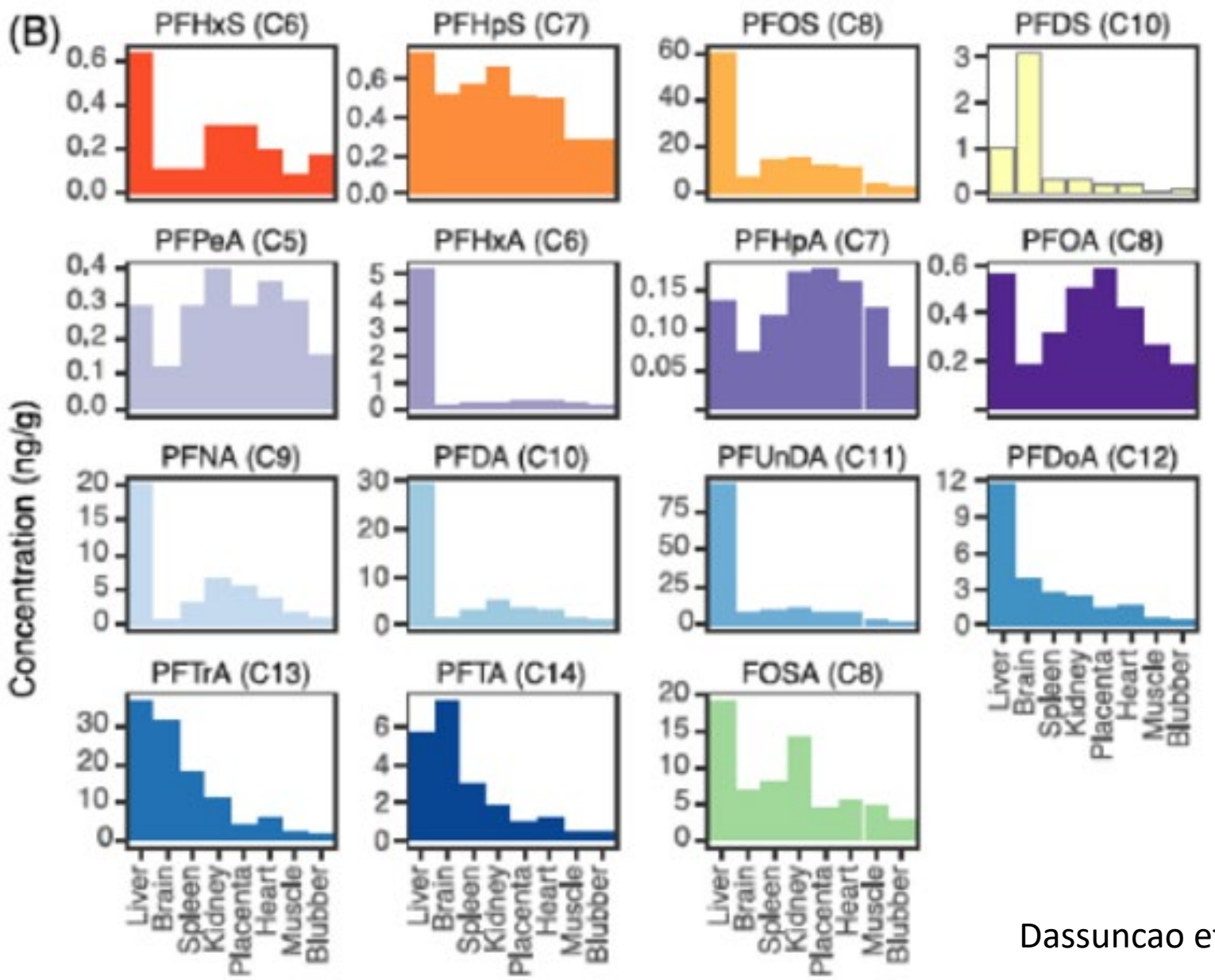
| PFAS | Liver | Bone | Brain | Lung | Kidney |
|---|---|---|---|---|---|
| PFBA | 3.0 | --- | 1.4 | 807 | 263 |
| PFHxA | 68.3 | 1.5 | 141.0 | 207 | 2.7 |
| **PFOA** | 4.0 | 20.9 | --- | 12.1 | 1.5 |
| **PFOS** | 41.9 | --- | 1.9 | 28.4 | 55 |
| PFHpA | 1.5 | 2.5 | --- | 1.6 | 2.6 |
| **PFNA** | 1.0 | --- | 13.5 | 3.5 | 10.9 |

PFDA, PFDS, PFDoA- also in brain

PFPeA, PFBS, **PFHxS**, PFDA, PFDS – also in lung

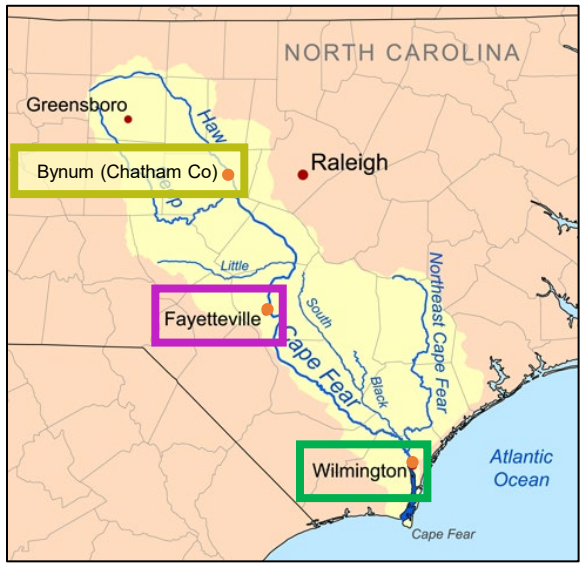
Perez et al., 2013

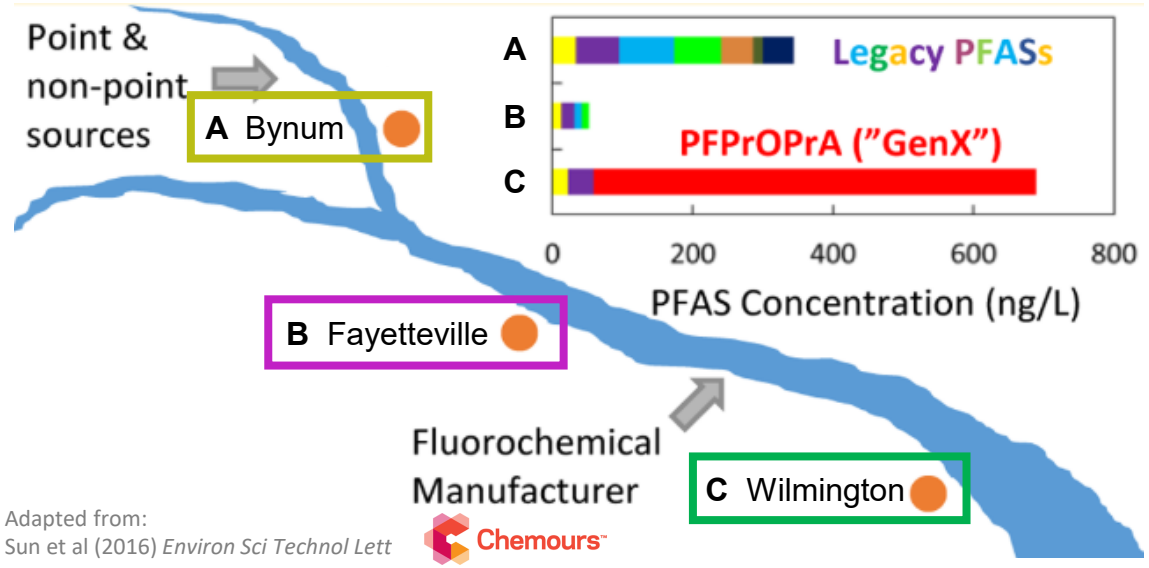
# Tissue Burdens in Pilot Whales




Dassuncao et al., ES&T 2019

# PFAS contamination in NC: Regrettable replacements




Adapted from:
Sun et al (2016) *Environ Sci Technol Lett*

1980s: GenX is formed as unknown byproduct during fluoropolymer production at Chemours/DuPont plant

2007: Nakamaya et al. publish first paper on PFAS in the Cape Fear River (CFR)

2016: Sun et al. publish report on GenX levels in CFR and finished drinking water (631 ppt)

1980s → 2002 → 2007 → 2009 → 2016 → 2017

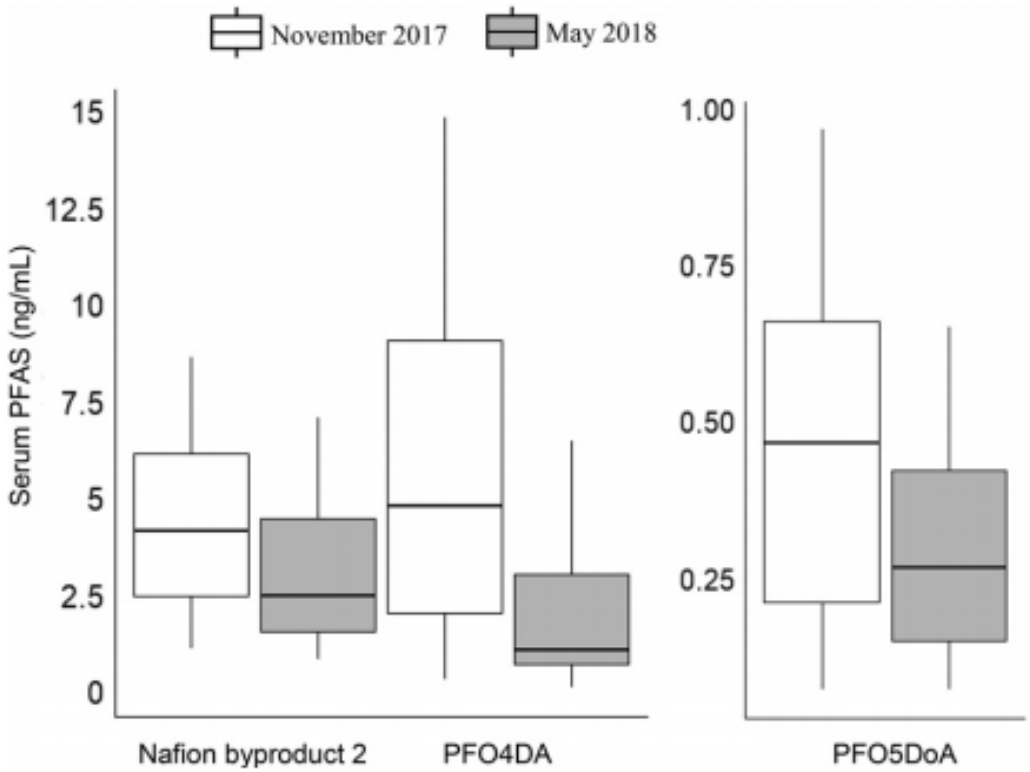
2002: Production of PFOA at plant begins

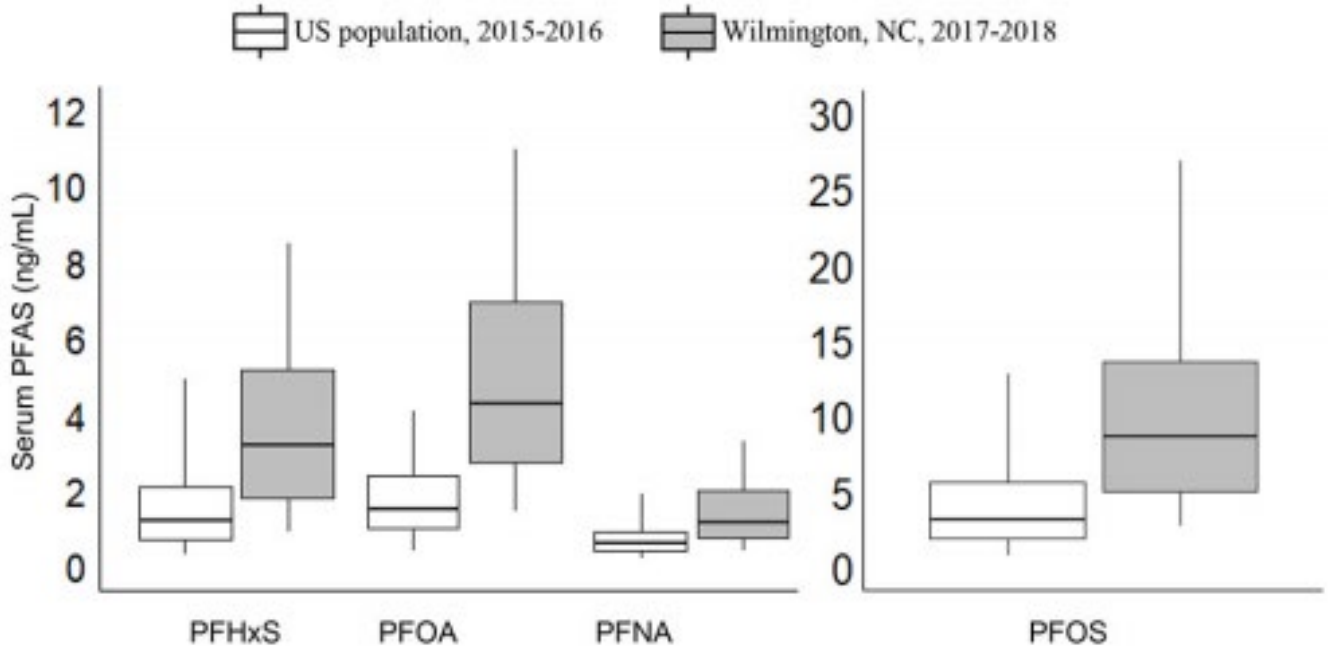
2009: DuPont/Chemours begins producing GenX as substitute for PFOA

2017: NCDEQ reports plant is no longer discharging GenX (07/13/17)

Adapted from:

# Serum Levels in Wilmington, NC



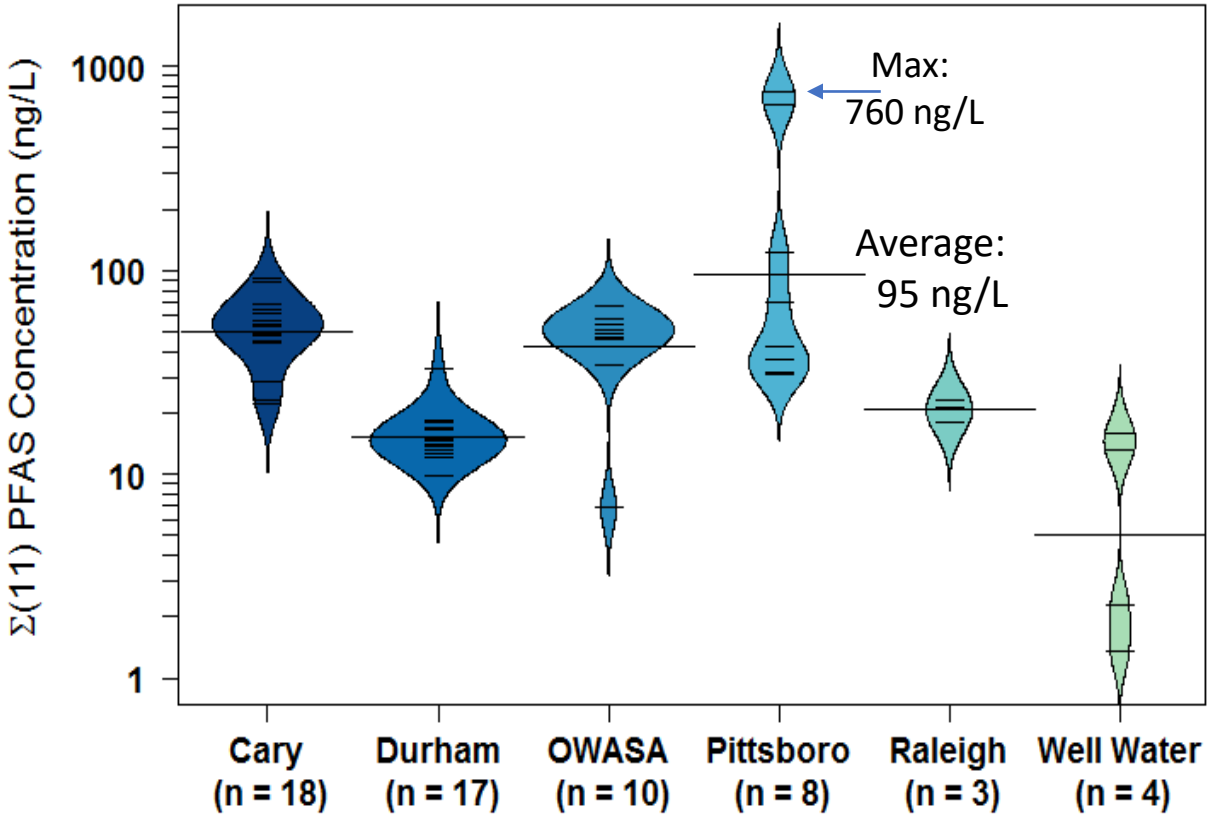




**GenX not detected (LOD> 2ng/ml)**
**6 /fluoroethers detected in serum: Nafion byproduct 2, PFO4DA, PFO5DA in >85% participants; PFO3DA and NVOHOS – infrequently detected; Hydro-EVE not quantifiable**
**~24% of total serum PFAS (median = 25.3 ng/ml)**

N. Kotlarz et al., EHP 2020

# *PFAS Concentrations in Triangle Drinking Water*

- In 2018, the sum concentration of 11 PFAS chemicals measured in Pittsboro drinking water ranged from 30 to 760 ng/L
- Pittsboro concentrations were higher than levels measured in Cary, Durham, Chapel Hill and Raleigh
- Concentrations varied considerably over time

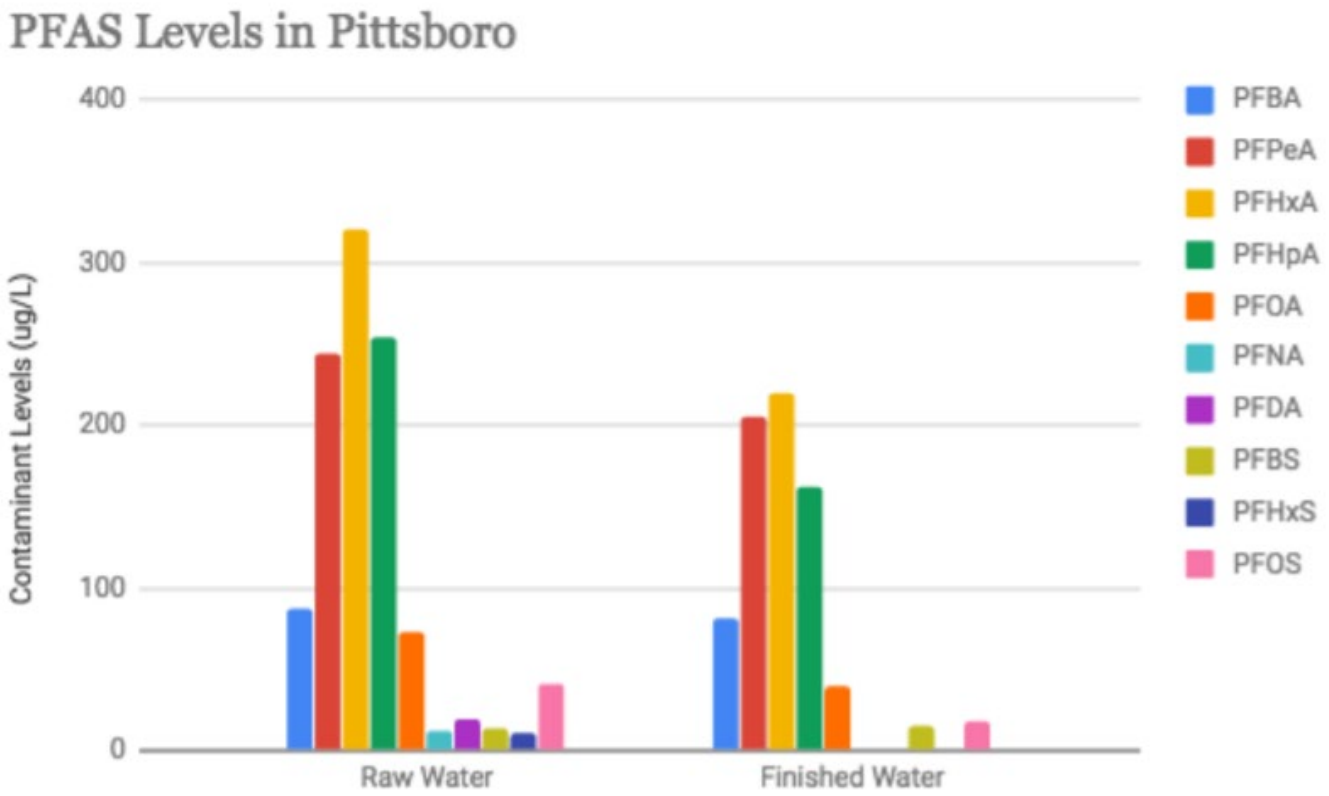



Herkert et al. 2020

# Haw River Contamination


*Pittsboro is home to nearly 4,000 residents. It's the only town to draw its drinking water from the Haw River.*

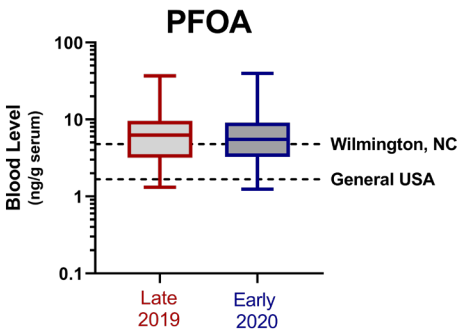
CREDIT 1NATIVETEXAN / FLICKR

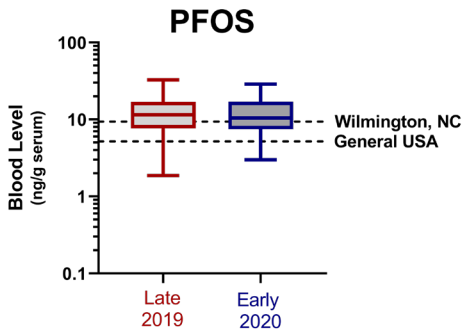


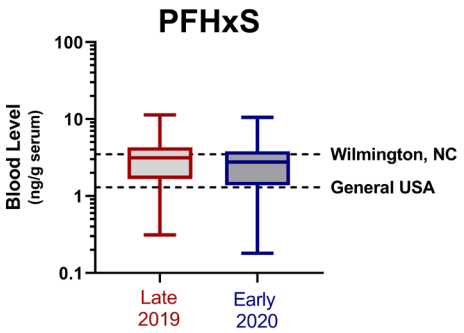

Σ=1076ppt

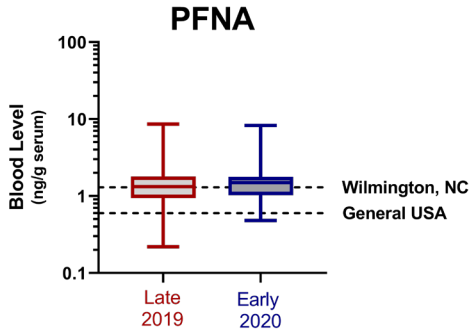
Haw River Assembly

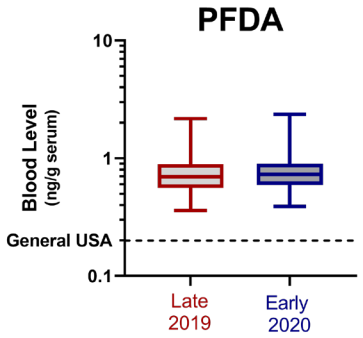
# *PFAS Blood Results*

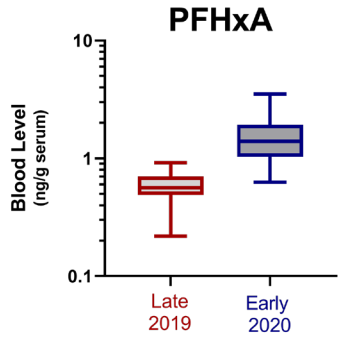


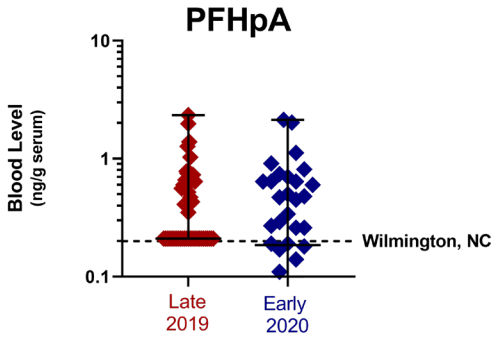




*Thx to Heather Stapleton, Duke*

Data for the general USA is from the national biomonitoring program run by the Centers for Disease Control and Prevention

Wilmington, NC references the GenX Study (Kotlarz, et al. 2020)

PFDA & PFHxA not measured in Wilmington, NC study

# PFAS-exposure related health concerns began in the 1960s

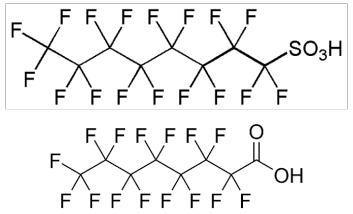
1930s

PTFE (Teflon) invented

1940s

1947: PFAS production begins at 3M plant in MN

PFOS & PFOA begin to be produced PTFE-based non-stick coatings produced




1950s

PFOS-based stain & water resistant products

1960s

PFOS-based fire fighting foam

PFOA-based protective coatings

1962: DuPont raises concerns re: health risks of PFAS in internal document

1970s

1978: Unpublished study shows adverse effects of PFOA in monkeys

1980: PFAS detected in serum of workers

1981: Concerns about birth defects in children born to women workers

PTFE-based waterproof fabrics PFNA & fluorotelomers begin to be produced

1980s

1987: PFOA causes cancer in rat study

1990s

1993: 3M begins to monitor PFOA in workers

2000s

2000-2002: DuPont begins producing PFOA at Chemours facility in Fayetteville, NC

2000: PFOA and PFOS detected in 100% of Americans in study; 3M announces phase-out of PFOA

1998: Samples from U.S. blood donors shown to contain PFAS

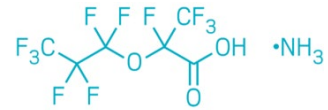
2001: DuPont sued in class action lawsuit

2004: DuPont settles class action suit ( >80,000 plaintiffs) for $343 million; settlement funds C8 Health Study

2006: EPA invites 8 major companies to phase out PFOA by 2015 (95% reduction by 2010)

2010s

2009: Chemours commercially manufactures GenX as PFOA substitute



2012: Immune system effects related to PFAS reported in children

Present

2015: Researchers publish report of novel PFAS (including GenX) in Cape Fear River

3M DUPONT Chemours™

B. Blake, 2020

# Studying PFAS exposure in human populations

## Disease Correlations

DuPont loses another 'bellwether' C8 lawsuit

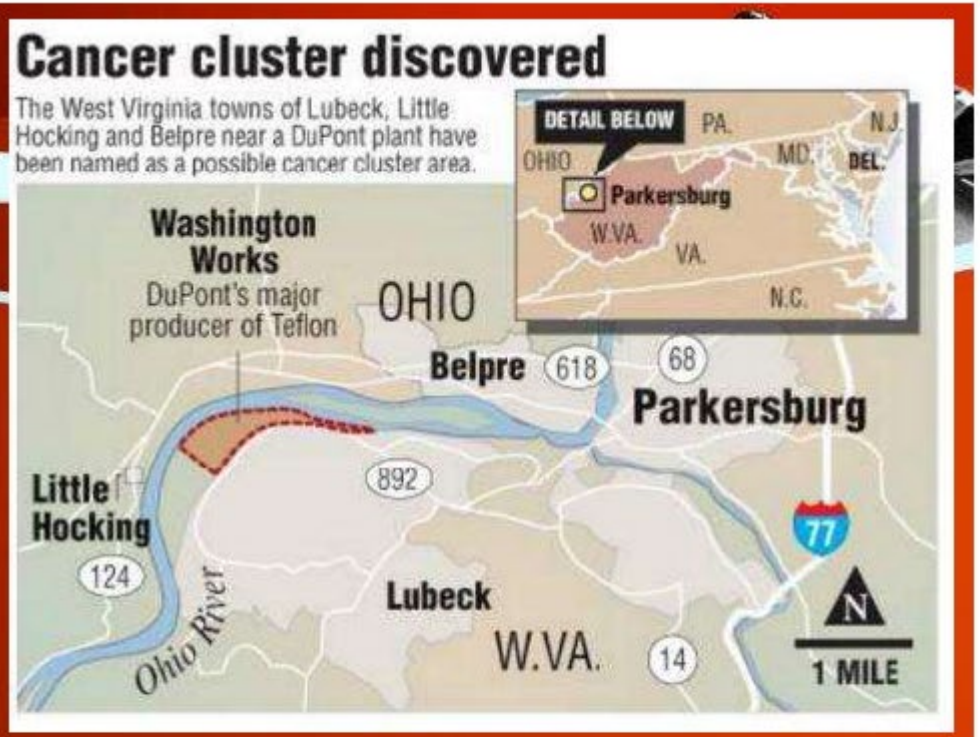
RELATED ITEMS
» DuPont faces fourth C8 trial
» DuPont's toxic C8 chemical still unchecked, group says
» DuPont settles one C8 case, loses bid for retrial in another

HEALTH HEADLINES
» Neuroscience experts in central Ohio say advances,

By Furl Rinehart
*The Columbus Dispatch* • Wednesday July 6, 2016 9:36 PM

David Freeman hugged Michael Papantonio after a federal court jury awarded him $5.1 million on Wednesday in his lawsuit against DuPont.

REQUEST TO BUY THIS PHOTO
CRAIG HOLMAN | DISPATCH FILE PHOTO




***3500+ lawsuits***
***$671M settlement***

**Testicular cancer**
**Kidney Cancer**
**Hypertension**
**Pre-eclampsia**
**Ulcerative colitis**
**High Cholesterol**

**http://www.c8sciencepanel.org/**

G. Peaslee, Norte Dame

# Immune-Related Health Effects of PFAS Exposure

**National Toxicology Program Systematic Review**

**Animal Studies**

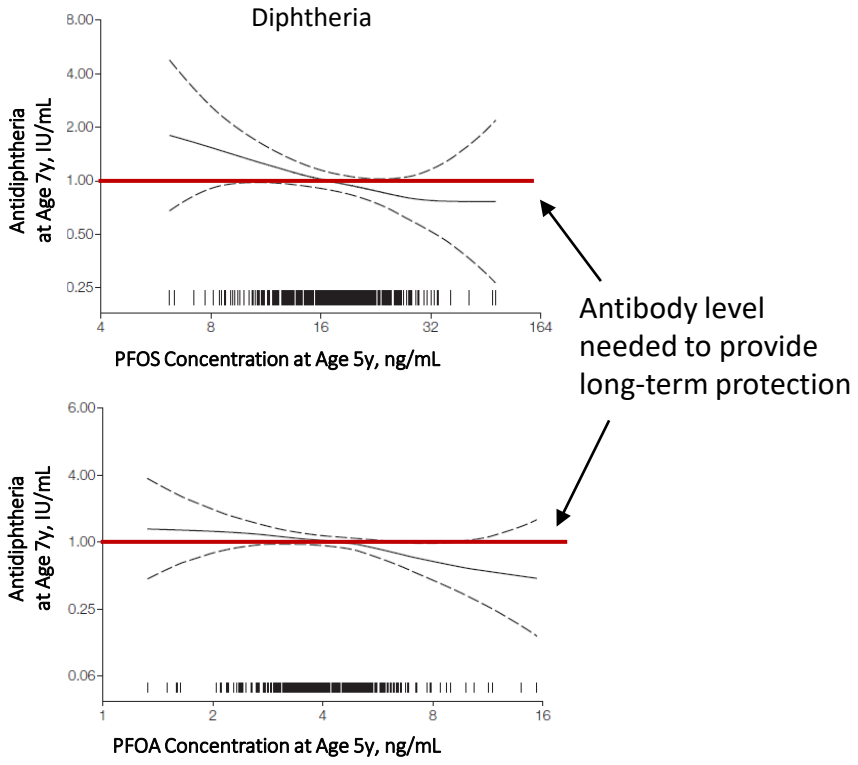
- Experimental studies:
  - **Immunosuppression**: Reduced antibody response, disease resistance, etc.
  - **Hypersensitivity**: Increased airway hypersensitivity
- Wildlife studies

**Human studies**

- **Immunosuppression**: Reduced antibody response to vaccines
- **Hypersensitivity**: Increased asthma in children
- **Autoimmunity**: Increased incidence of ulcerative colitis

Monograph on Immunotoxicity Associated with Exposure to PFOA and PFOS, National Toxicology Program, 2016

**Elevated PFAS exposure associated with reduced diphtheria and tetanus antibody concentrations at ages 5, 7, and 13**




Grandjean et al., JAMA, 2012; Grandjean et al., EHP, 2017

Increased lower respiratory infections in children (Impinen et al., Environ Res, 2017)

Decreased measles-specific antibody concentration after vaccination (Timmermann et al, EHP, 2020)

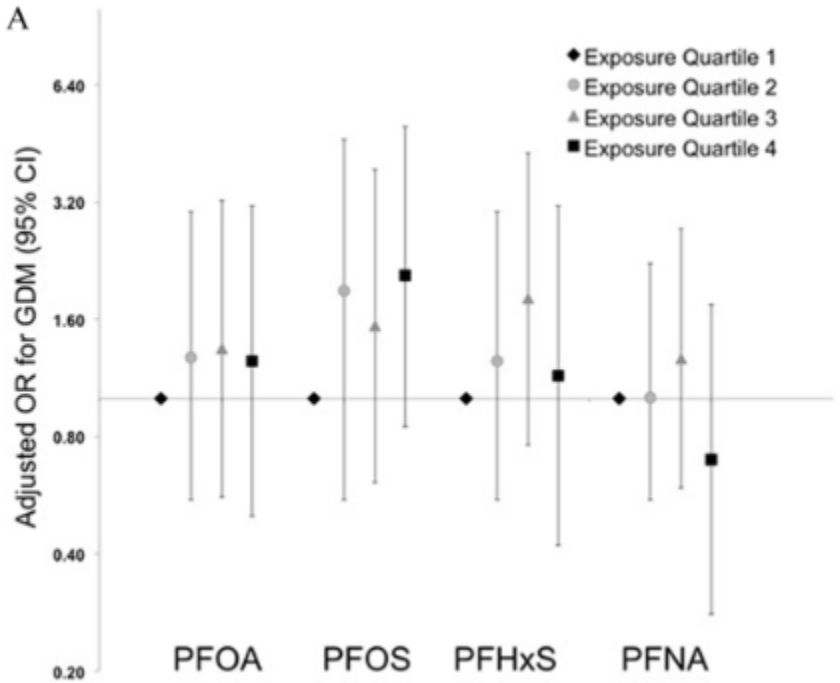
**Fig 1. Proportion of plasma samples with detectable PFBA concentrations at different disease severities.**


Grandjean P, Timmermann CAG, Kruse M, Nielsen F, Vinholt PJ, et al. (2020) Severity of COVID-19 at elevated exposure to perfluorinated alkylates. PLOS ONE 15(12): e0244815. https://doi.org/10.1371/journal.pone.0244815
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.024

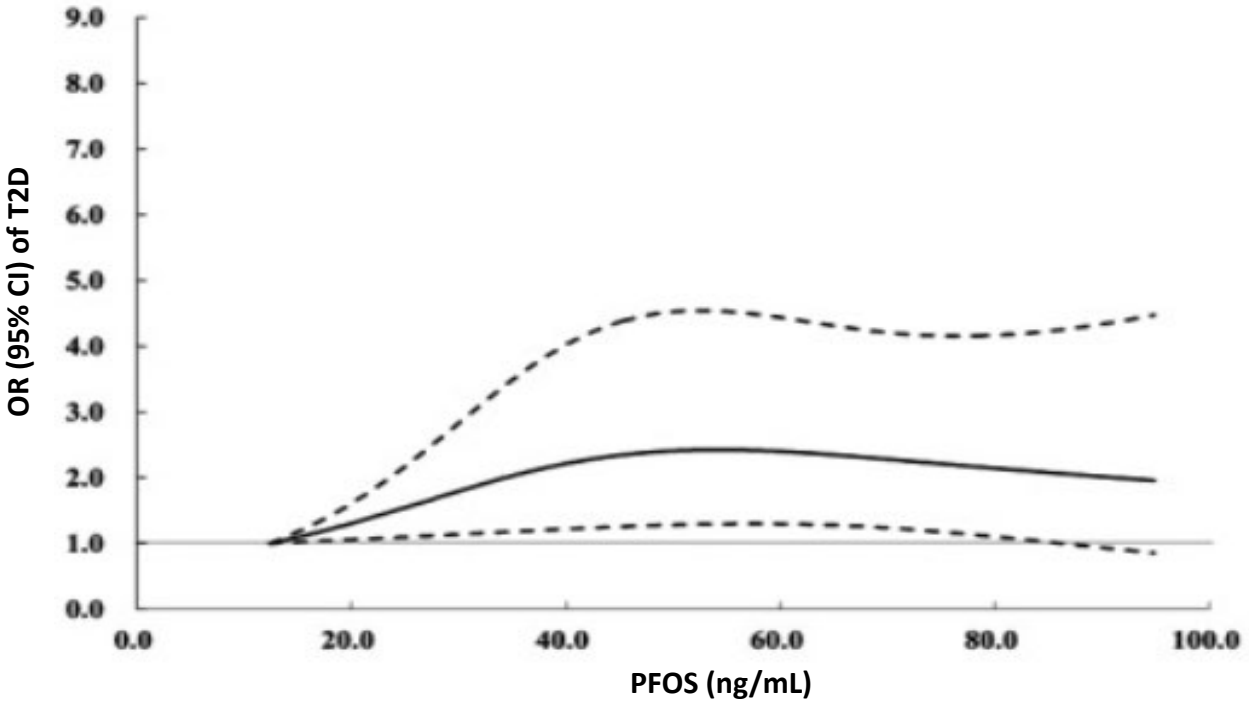
PLOS ONE

# PFAS and Diabetes

Gestational Diabetes



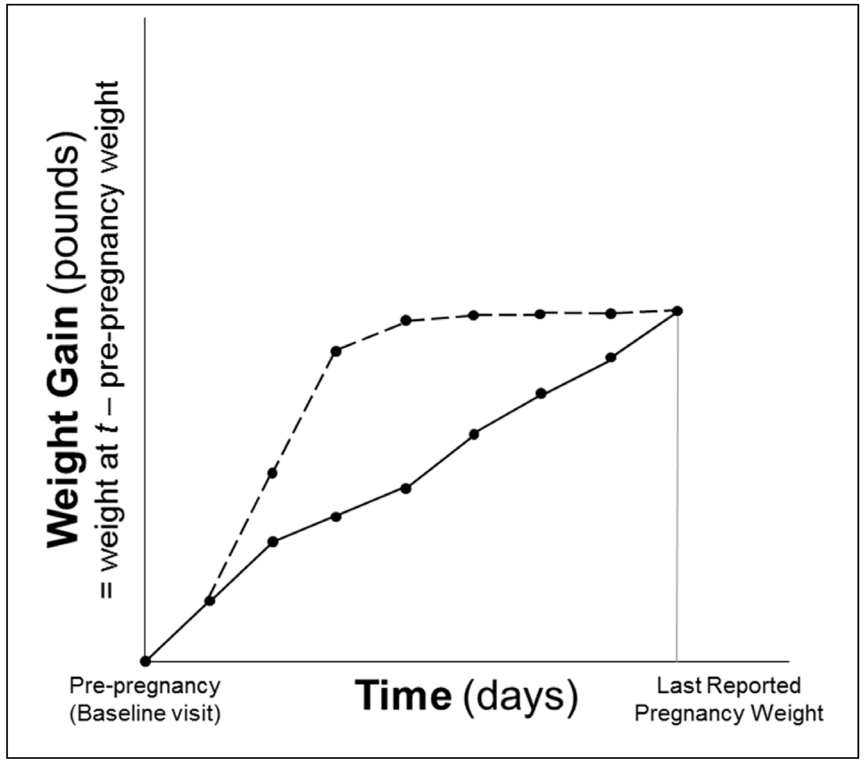

Type 2 Diabetes




***PFAS exposures during pregnancy may influence lipid metabolism and glucose tolerance and thus may impact the health of the mother and her child.*** Matilla-Santander et al., EHP 2017

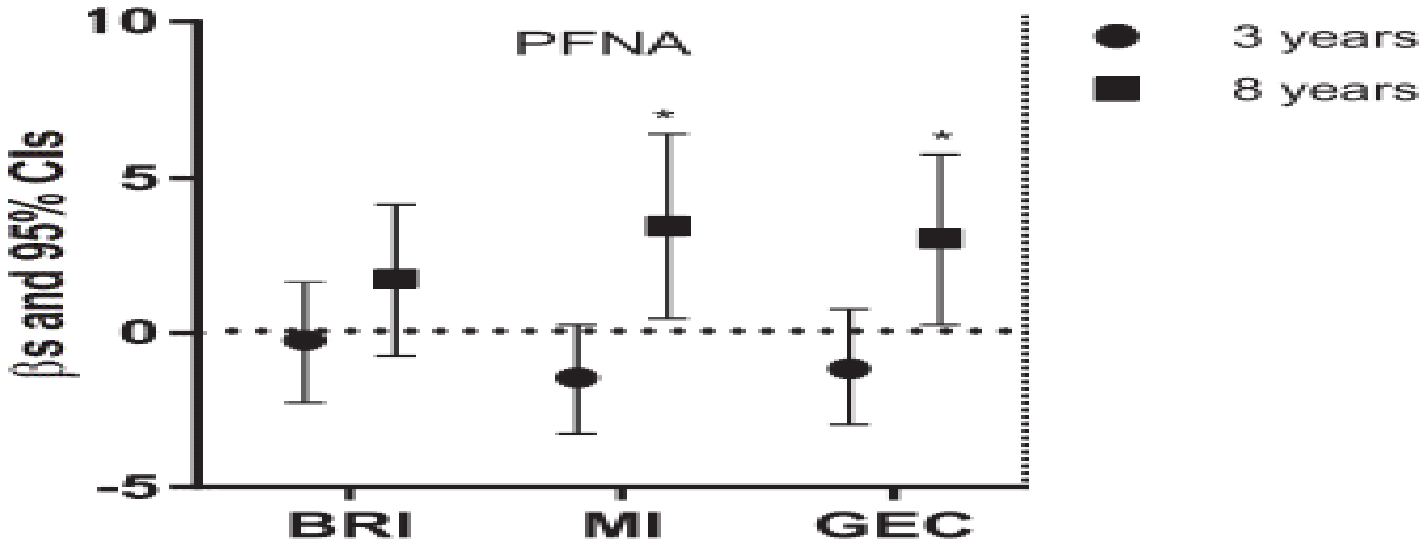
Sun et al., EHP 2018

# Ongoing PFOS exposures associated with abnormal gestational weight gain




Jaacks et al., Int. J. Environ. Res. Public Health. 2016.

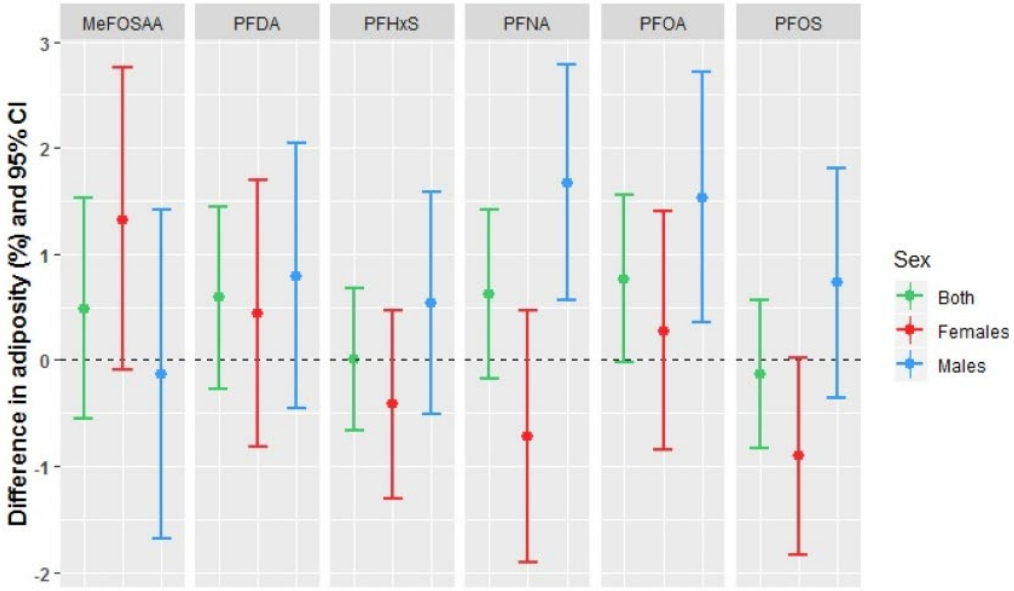
# Serum PFNA is Associated with Poorer Executive Functioning

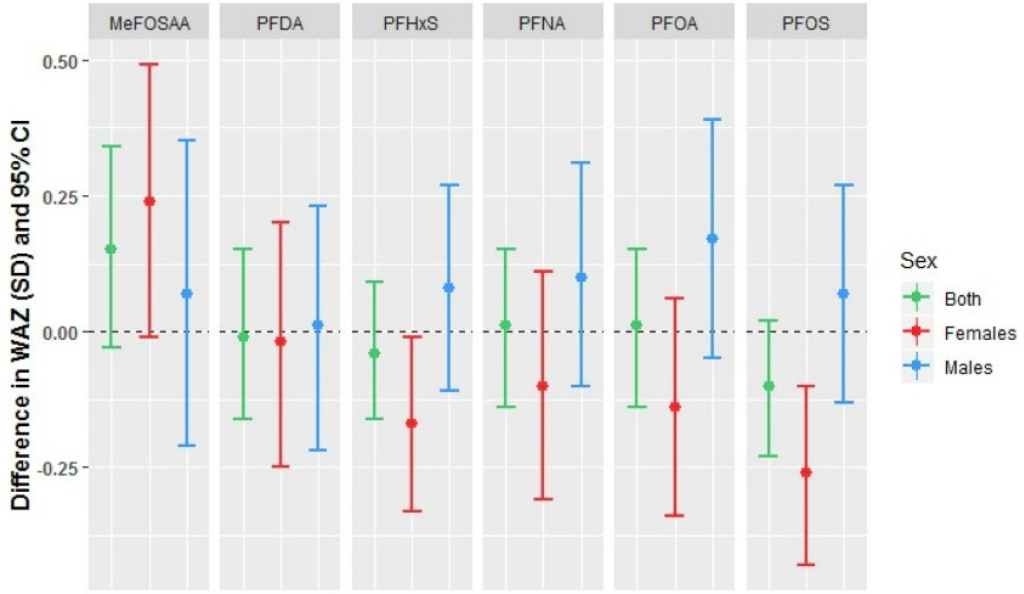



*Vuong et al., Environ. Int. 2018*

# Healthy Start Study:

"…maternal serum concentrations of certain PFAS …may influence infant growth and adiposity in a sex-specific manner."



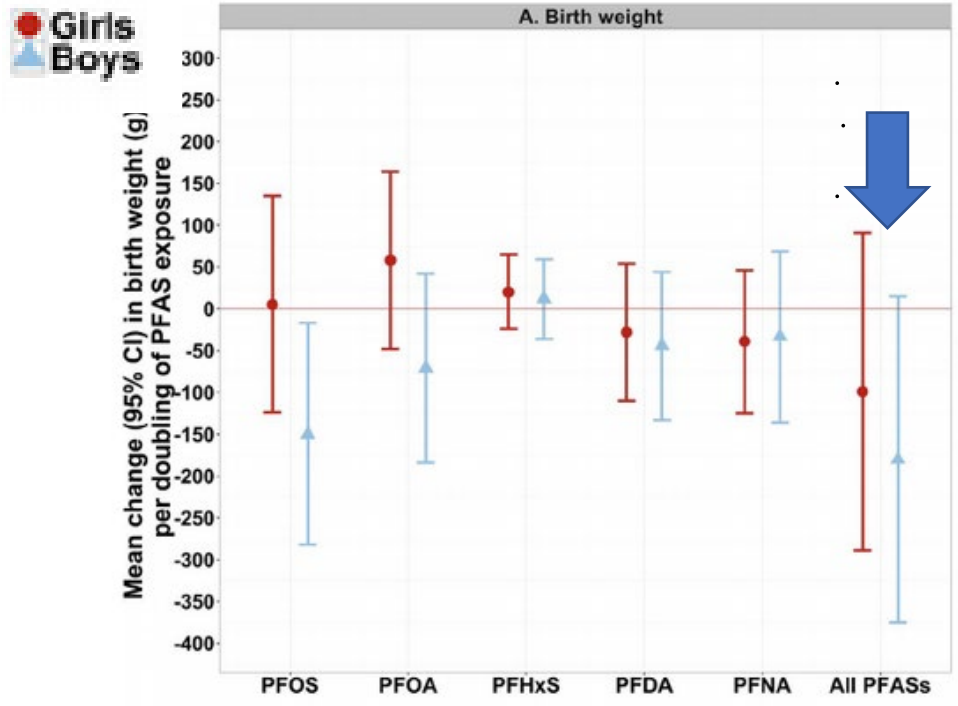

415 infant-mother pairs at 5 months

AP Starling et al., Environ. Intern. 131 (2019) 104983

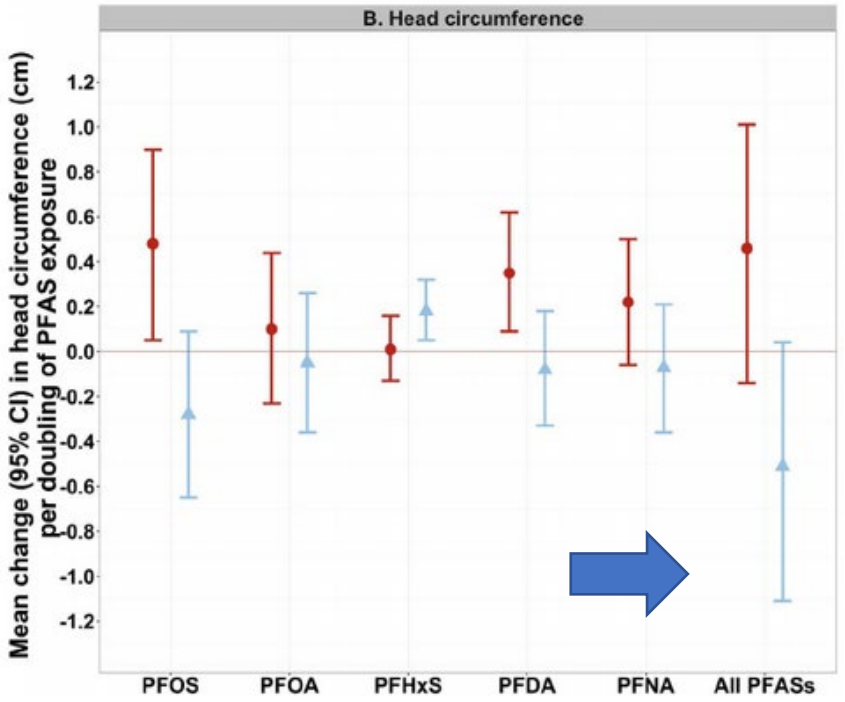
University of Colorado Denver

# *In utero* PFAS exposure concentrations result in lower birth weight and head size in newborn boys

**Birth Weight**



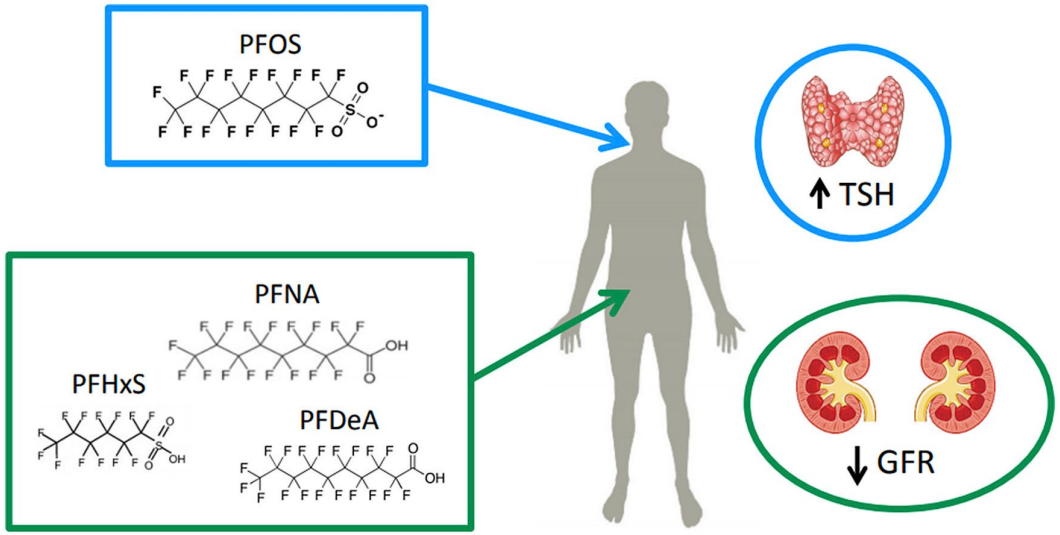

**Head Circumference**




-- Valvi et al., Environmental international, 2017, v. 107, pp. 205-215.

# PFAS Levels Associated with Altered Kidney and Thyroid Function in Adults

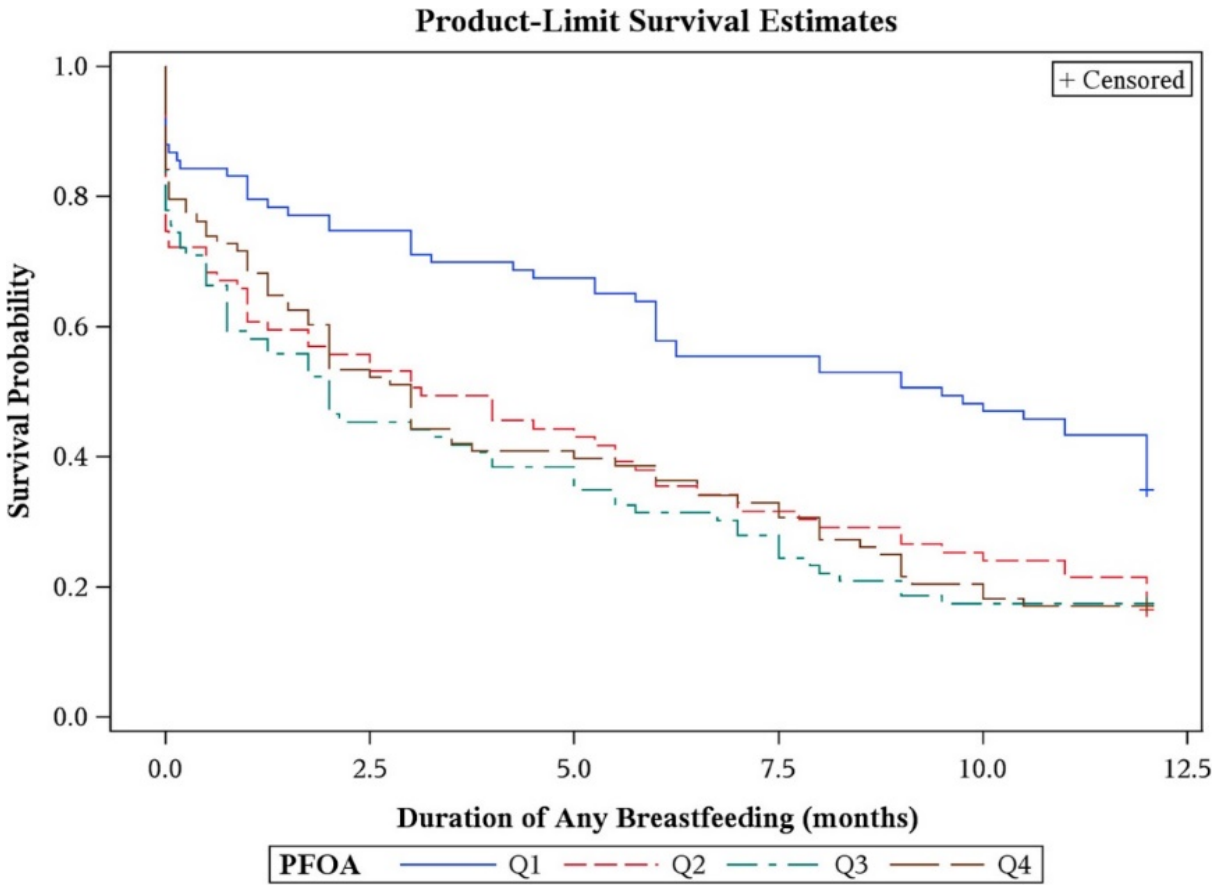
- Repeated measures of serum PFOS associated with increased thyroid stimulating hormone
- Repeated measures of serum PFNA, PFHxS, and PFDeA associated with decreased kidney function



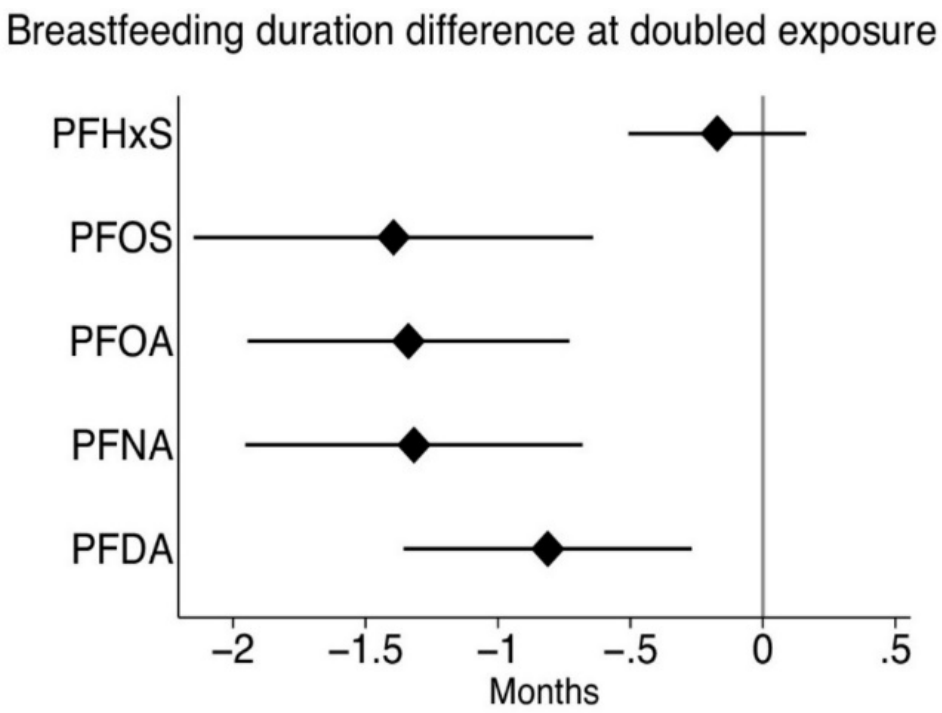

- PFHxS retained high stability between serum measurements over a period greater than 10 years

Blake et al., Environ Pollut, 2018

# PFAS Affect Breastfeeding Duration in Women




From Romano et al. 2016, *Environ Res*




From Timmermann et al. 2017, *Reprod Toxicol*

# Animal *and Human* Studies Show Wide Range of Health Effects

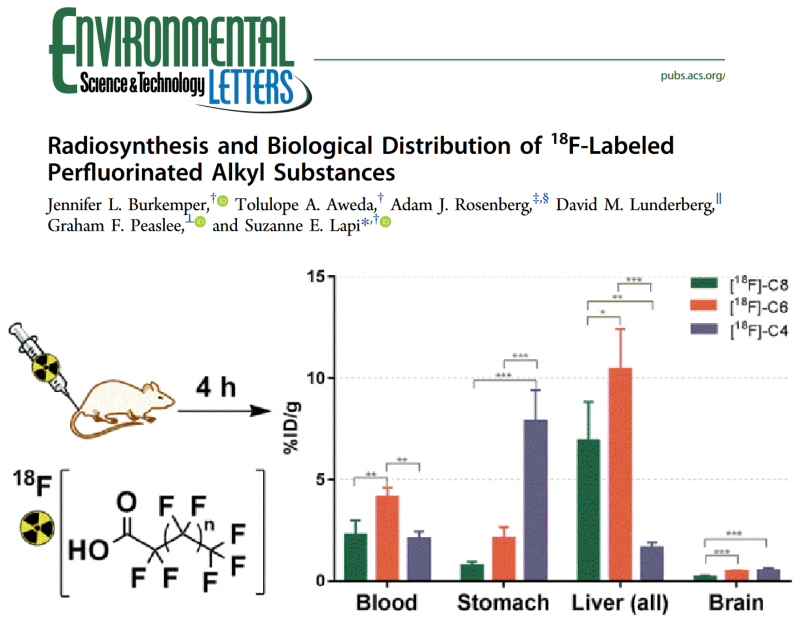
**PFOA and/or PFOS**

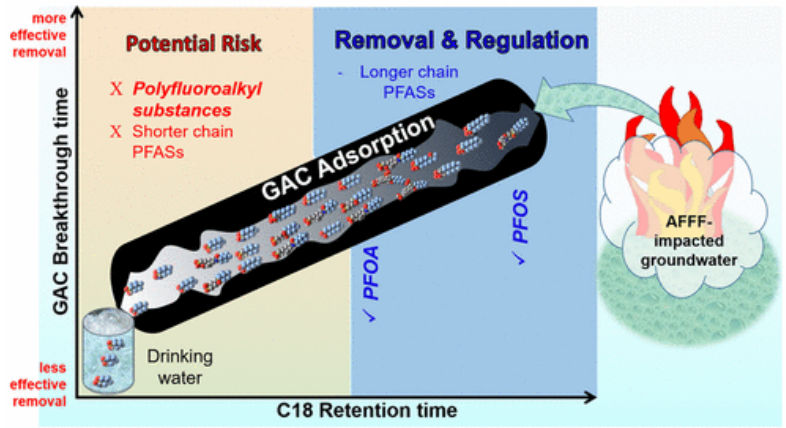
- Testicular cancer
- Kidney cancer
- Ulcerative colitis
- High cholesterol
- Pregnancy-induced hypertension
- Thyroid disruption
- Hormonal changes
- Liver malfunction
- Obesity
- Immunotoxicity, eg interference with child vaccine response
- Lower birth weight and size
- Delayed puberty, decreased fertility, early menopause
- Reduced testosterone
- Prostate cancer
- Ovarian cancer
- Bone density decrease

# *KEY QUESTION*

## PFOS/PFOA replacements – Are they safer?

- = Persistence
- ↓ Toxicity
- ? Uptake
- ? Target organs
- ↓ Water filtration&remediation




Environ Sci Technol. 2017 Jun 6;51(11):6342-6351. doi: 10.1021/acs.est.7b00970.

**Sorption of Poly- and Perfluoroalkyl Substances (PFASs) Relevant to Aqueous Film-Forming Foam (AFFF)-Impacted Groundwater by Biochars and Activated Carbon.**

Xiao X[1,2,3], Ulrich BA[2], Chen B[1,3], Higgins CP[2].

# NTP Guideline Rat Toxicity Studies

- 28-Day Toxicity Studies: Comparison of Seven PFAS
  - Data available here: https://ntp.niehs.nih.gov/results/areas/pfas/index.html
  - TOX Report 96: Sulfonates (2019) (PFBS, PFHxS, PFOS)
  - TOX Report 97: Carboxylates (2019) (PFHxA, PFOA, PFNA, PFDA)
    - **The shorter chained PFASs (perfluorohexanoic acid (PFHxA) and perfluorobutane sulfonic acid (PFBS)) induced similar toxicities as the longer chained analogues,**
    - **Shorter chained chemicals required higher doses.**
    - **There were similar effects within the liver and thyroid hormones that occurred for short-chain and long-chain PFAS.**
- PFOA Two Year Study: Comparison of PFOA perinatal and non-perinatal effects
  - Data available https://ntp.niehs.nih.gov/results/path/index.html
  - Technical Report draft (TR-598) peer reviewed Dec. 12, 2019 – Clear evidence of carcinogenic activity in male rats; some evidence in female rats

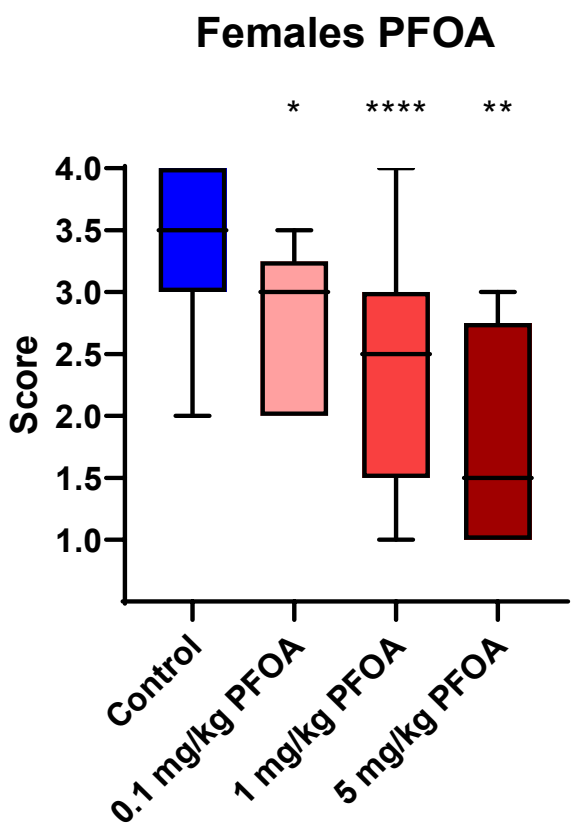
# Effects of “Short-Chain” Alternatives on the Liver

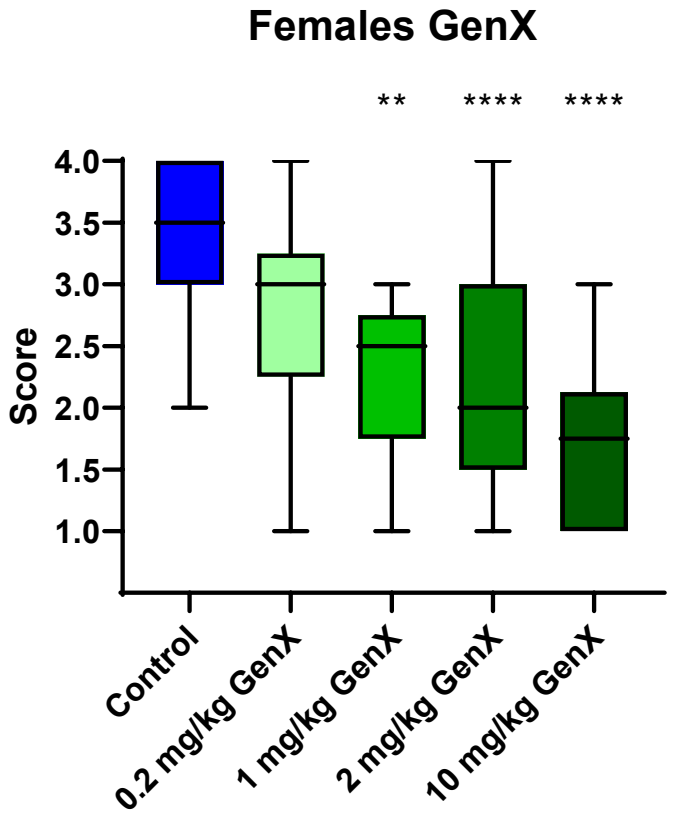
- 6:2 FTCA & 6:2 FTSA increased inflammation and cell death in mice
  - Sheng et al., Arch Toxicol, 2017
- PFBS &PFHxA  increased liver weights and enzymes caused liver lesions
  - Full data tables for all chemicals can be found at: https://ntp.niehs.nih.gov/results/path/index.html
- GenX induces similar constellation of adverse maternal liver alterations as PFOA at internal liver concentrations ~10x lower
  - Blake et al., Environ Health Perspect 2020

***When tested, ‘short chains’ cause the same effects at the ‘long chain” PFAS***

# Abnormal Female Mammary Gland Development

CD1 Mice

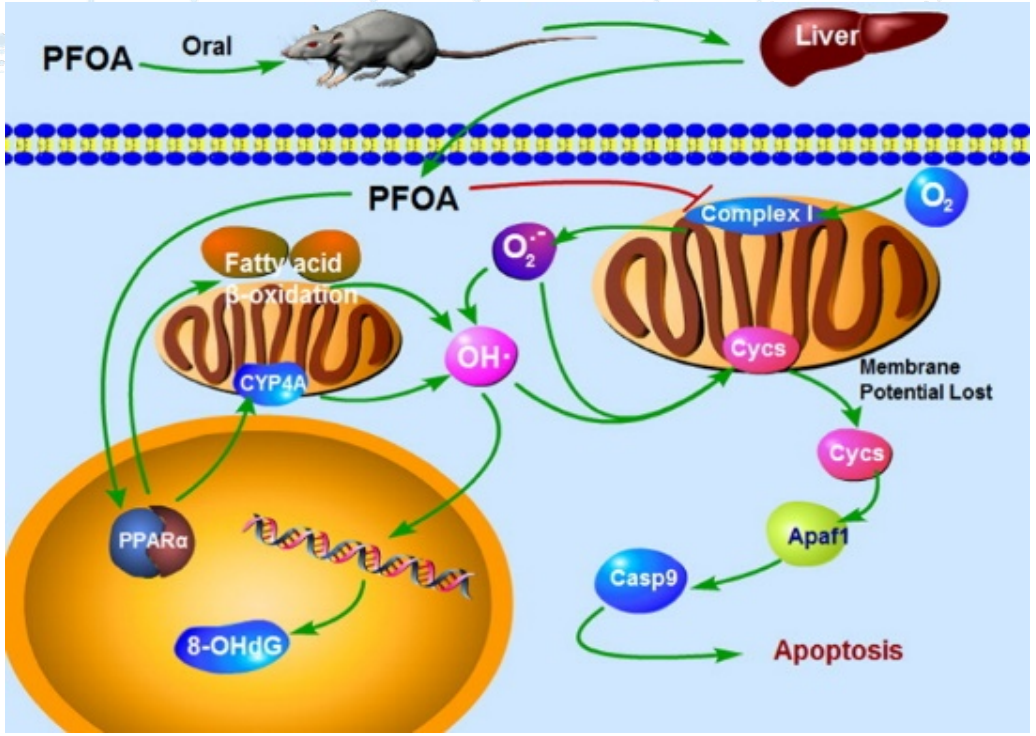



BE Blake et al., 2020

# Mechanisms of PFAS toxicity

- Activation of PPARs
- Alternate receptor: AhR, CAR, PXR, FXR
- Inhibiting fatty acid transport
- Interfering with mitochondrial function




Li et al., 2017

# Key Research Questions

- **Total organic fluorine analysis** – Are we measuring 90% or 10% of PFAS present in a sample?
- **Essentiality** – Where are chemicals really needed and where can we replace with safer alternatives? (*Cousins et al., 2019)*
- **Assessing alternatives** – Are our substitutes safer?
- **PFAS as a class** – One chemical group or subclasses? *(Kwiatkowski et al., ES&T Lett. 2020)*
  - Too many PFAS to do proper toxicity testing (including mixtures)
  - The National Academy of Sciences, Engineering, and Medicine (NASEM) recently addressed hazards to Organo-Halogen Flame retardants in a report to the Consumer Product Safety Commission (CPSC – 7/24/2019).
  - NASEM strongly endorsed the use of subclasses of organohalogens in hazard assessment along with the use of alternative toxicological approaches.
  - ***"….an approach that uses subclasses to assess the chemicals is scientifically justifiable…"*** **[NASEM]**

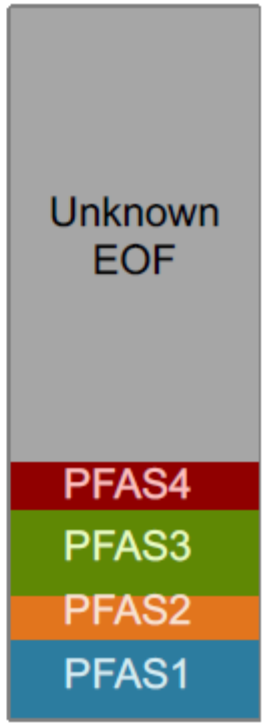
# Pilot data suggest large increase in unidentified PFAS in drinking water: Consistent with production trends

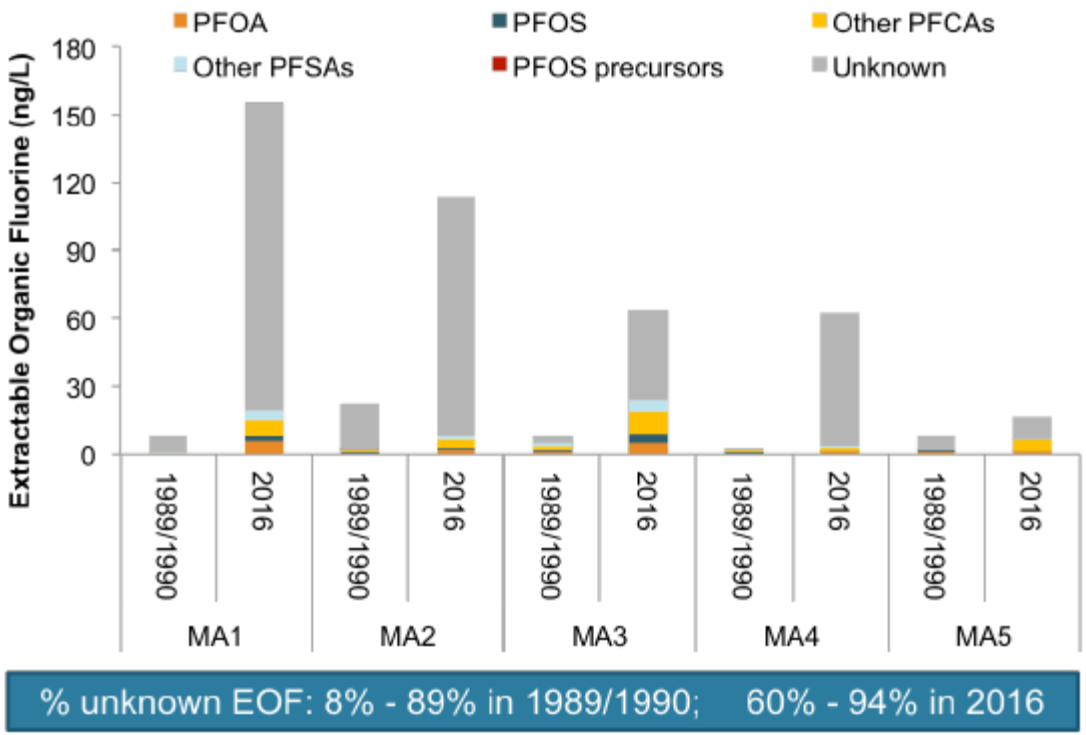
Extractable organic fluorine (EOF)

4700 PFASs

>200 detected

Toxicity of alternative PFASs not well understood




Hu et al., 2019, EHP



E. Sunderland, Harvard

# US Federal “Regulations” on PFAS

- **EPA**
  - **Lifetime Health Advisories for Drinking Water – 70 ppt PFOA+PFOS**
  - **NO regulation of ground water**
  - **NO determination of ‘Hazardous Substance’**
  - **172 PFAS added to TRI (in NDAA 2020 Bill)**
- **FDA**
  - **Food Contamination**
- **Department of Defense**
  - **No PFAS in AFFF in practice/training**
  - **No PFAS in Food Packaging**
- **Consumer Product Safety Commission**
- **FAA**
  - **No PFAS in AFFF in domestic airports**

# PFAS in Food Packaging

- NY State Ban  - Effective at the start of 2023.
  - No consideration of other PFAS alternatives as in Maine and WA laws
  - Governor Cuomo signed Dec. 3, 2020
- The effort to ban or restrict PFAS has gained steam after San Francisco restricted the chemicals in some foodware effective Jan. 1, 2020.
- Maine banned the intentional addition of PFAS in food packaging in 2019.
- Washington state will begin prohibiting PFAS in food packaging in 2022.
- Denmark is the first country to ban PFAS in food packaging as of July 2020
- FDA
  - 7 PFAS banned in 2012
  - July 31, 2020 – 6,2-FTOH  voluntarily phased out of 15 food contact materials by 6/2025
    - 6,2 – FTOH --→ 5,3 – PFOA – highly persistent and toxic (Kabadi et al, 2018; Rice and Kabadi, 2020)

# *USEPA & State PFAS Drinking Water Guidelines (ng/L; ppt)*

***(Includes Standards & Guidance Values - *Proposed, Recommended & Final*)***

| | PFOA | PFOS | PFNA | PFHxS | PFHpA | PFDA | *Total?* | PFBA | PFHxA | PFBS | GenX |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **EPA** | 70 | 70 | --- | --- | --- | --- | *Yes (2)* | --- | --- | --- | --- |
| **CA** | 10 | 40 | --- | --- | --- | --- | *No* | --- | --- | --- | --- |
| **CT** | 70 | 70 | 70 | 70 | 70 | --- | *Yes (5)* | --- | --- | --- | --- |
| **MA** | 20 | 20 | 20 | 20 | 20 | 20 | *Yes (6)* | --- | --- | 2000 | --- |
| **MI** | 8 | 16 | 6 | 51 | --- | --- | *No* | --- | 400,000 | 420 | 370 |
| **MN** | 35 | 15 | --- | 47 | --- | --- | *No* | 7000 | --- | 2000 | --- |
| **NH** | 12 | 15 | 11 | 18 | --- | --- | *No* | --- | --- | --- | --- |
| **NJ** | 14 | 13 | 13 | --- | --- | --- | *No* | --- | --- | --- | --- |
| **NY** | 10 | 10 | --- | --- | --- | --- | *No* | --- | --- | --- | --- |
| **NC** | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 140 |
| **OH** | 70 | 70 | | | | | | | | | |
| **VT** | 20 | 20 | 20 | 20 | 20 | --- | *Yes (5)* | --- | --- | --- | --- |
| **WA** | 10 | 15 | 14 | 70 | --- | --- | *No* | --- | --- | 1300 | --- |

**States not listed generally use USEPA Health Advisories of 70 ng/L for PFOA and PFOS as guidance.**

# NC attorney general sues DuPont, Chemours over PFAS contamination


Sharon Johnson – WITN *Oct. 13, 2020*

# DEQ cite Chemours for PFAS Treatment System Failures

January 28, 2021 by Greg Barnes

The bridge over the Cape Fear River at Elizabethtown downstream from the Chemours Fayetteville Works plant. Flickr Creative Commons, Gerry Dincher

North Carolina Health News

# Levels in Tap Water in Brunswick County, NC

- Levels in Tap Water in Brunswick County, NC
  - EWG, Samples taken from May-December, 2019
  - Sum of 30 PFAS = 185.9 ppt
  - Wilmington = 50.5 ppt
- Chemours slapped by DEQ with notice of violation for failing to abide by 2019 consent order requiring 99% removal of residual PFAS by 9/30/2020
  - Latest in series of Chemours violations of DEQ orders starting in 2017 to stop discharging its wastewaters into Cape Fear River

# Madrid Statement on Highly Fluorinated Chemicals

"We call on the international community to cooperate in limiting the production and use of PFASs and in developing safer non-fluorinated alternatives."

2015: Environmental Health Perspectives

# Chemicals Strategy for Sustainability Towards a Toxic Free Environment

**PFAS**[62]

The Commission will:

- ban **all PFAS** as a group **in fire-fighting foams** as well as in **other uses**, allowing their use only where they are essential for society;
- address PFAS with a **group approach**, under relevant legislation on water, sustainable products, food, industrial emissions, and waste;
- address PFAS **concerns on a global scale** through the relevant international fora[63] and in bilateral policy dialogues with third countries;
- establish an EU-wide approach and provide financial support under research and innovation programmes to identify and develop **innovative methodologies for remediating PFAS contamination** in the environment and in products;
- provide research and innovation funding for safe **innovations to substitute PFAS** under Horizon Europe.

European Commission – October 10, 2020

# WHY DO WE CONTINUE TO MAKE CHEMICALS THAT WILL NEVER GO AWAY?

*DIDN'T WE LEARN FROM DDE, DIOXINS, PCBS, BFRS….?????*

**Thank you to all**

*and Especially to all*
*by trainees, collaborators,*
*and colleagues*

***Questions???***