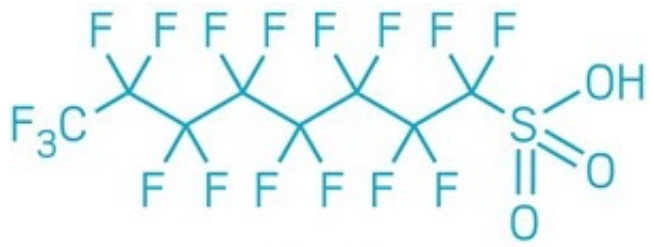
The Case for Managing PFAS as a Chemical Class to Protect Health

David Andrews, Ph.D., Senior Scientist

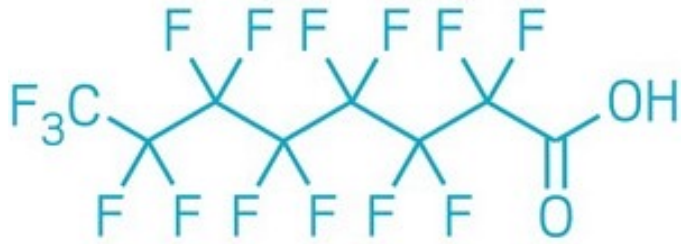
Environmental Working Group

March 24, 2021

How it started:

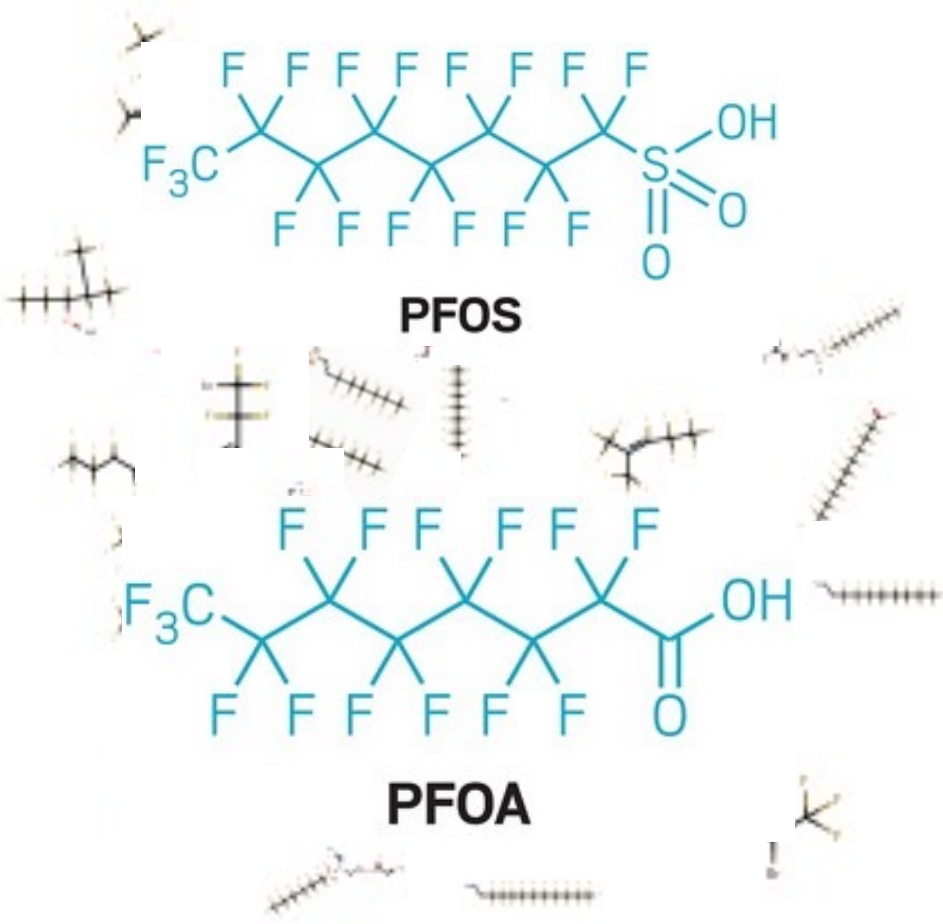


PFOS



PFOA

How it's going:



Images: https://cen.acs.org/environment/persistent-pollutants/US-EPA-recommends-cleanup-level/97/web/2019/04

Outline

- EWG and the PFAS timeline
- PFAS in food
- PFAS in drinking water
  - EPA testing
- PFAS health concerns, looking past PFOA/PFOS
- PFAS as a class


11:59
Welcome to
EWG's Healthy Living App
We've combined our most popular online resources, including the **Skin Deep® cosmetics database,** into one easy-to-use mobile app. Our app makes Healthy Living easy.

For Decades, Polluters Knew PFAS Chemicals Were Dangerous But Hid Risks From Public

As far back as 1950, studies conducted by 3M showed that the family of toxic fluorinated chemicals now known as PFAS could build up in our blood. By the 1960s, animal studies conducted by 3M and DuPont revealed that PFAS chemicals could pose health risks. But the companies kept the studies secret from their employees and the public for decades. **Here is a timeline of internal memos, studies and other company documents detailing the two companies' history of deception.**

DOWNLOAD ALL DOCUMENTS

1950

3M mice study reveals that PFAS builds up in blood.

DOWNLOAD DOCUMENT

1956

Stanford University study finds that PFAS binds to proteins in human blood.

DOWNLOAD DOCUMENT

https://www.ewg.org/pfastimeline/

ewg

Fountain Valley Clean Water Coalition

For Decades, The Department of Defense Knew Fire Fighting Foams With PFAS Chemicals Were Dangerous But Continued Their Use

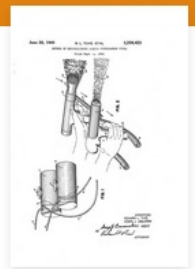
As far back as 1970s, studies conducted by the Department of Defense showed that the firefighting foam used on military bases and ships known as Aqueous Film Forming Foam (AFFF) that contain fluorinated chemicals now known as PFAS were toxic. By the 1980s, animal studies conducted by the Air Force revealed that PFAS chemicals could pose environmental and health risks. **Here is a timeline of internal DoD studies and reports detailing just how much they knew about the dangers of using AFFF.**

DOWNLOAD ALL DOCUMENTS

1963

Navy scientists seek patent for AFFF.

DOWNLOAD DOCUMENT



1966

Navy granted patent for AFFF.

DOWNLOAD DOCUMENT

https://www.ewg.org/dodpfastimeline/

Chemical Industry Archives

a project of Environmental Working Group

Search the archives

Select a Collection

GO refine your search

Type in a word or phrase in the box above to search 37,000 pages of internal company documents, or start from **here** for more search options, including searching by decade, or by the subcommittee of the Chemical Manufacturers Association that produced the document.

About the Archives

Chemical companies say that their products are rigorously tested for health and safety, their facilities are safe for workers and nearby communities, and their industry is tightly regulated. Can we believe their claims?

Not based on their own internal documents, thousands of which we are publishing on this site for the first time.

Take Action!

Please join Coming Clean's effort to get the chemical industry to come clean. Tell Congress what you think.
(**take action**)

DuPont Hid Teflon Pollution For Decades

Company Kept 1984 Tap Water Tests Secret After Finding C8 Contamination in Ohio Town

Secret tests conducted in 1984 by the DuPont chemical company found a Teflon-related contaminant (C8) in the tap water of the Little Hocking Water Association in Ohio, just across the river from the company's Teflon plant in Parkersburg, West Virginia. But the company never told the community, its water utility or state regulators about the tap water testing program, which continued through at least 1989, or about the positive findings.

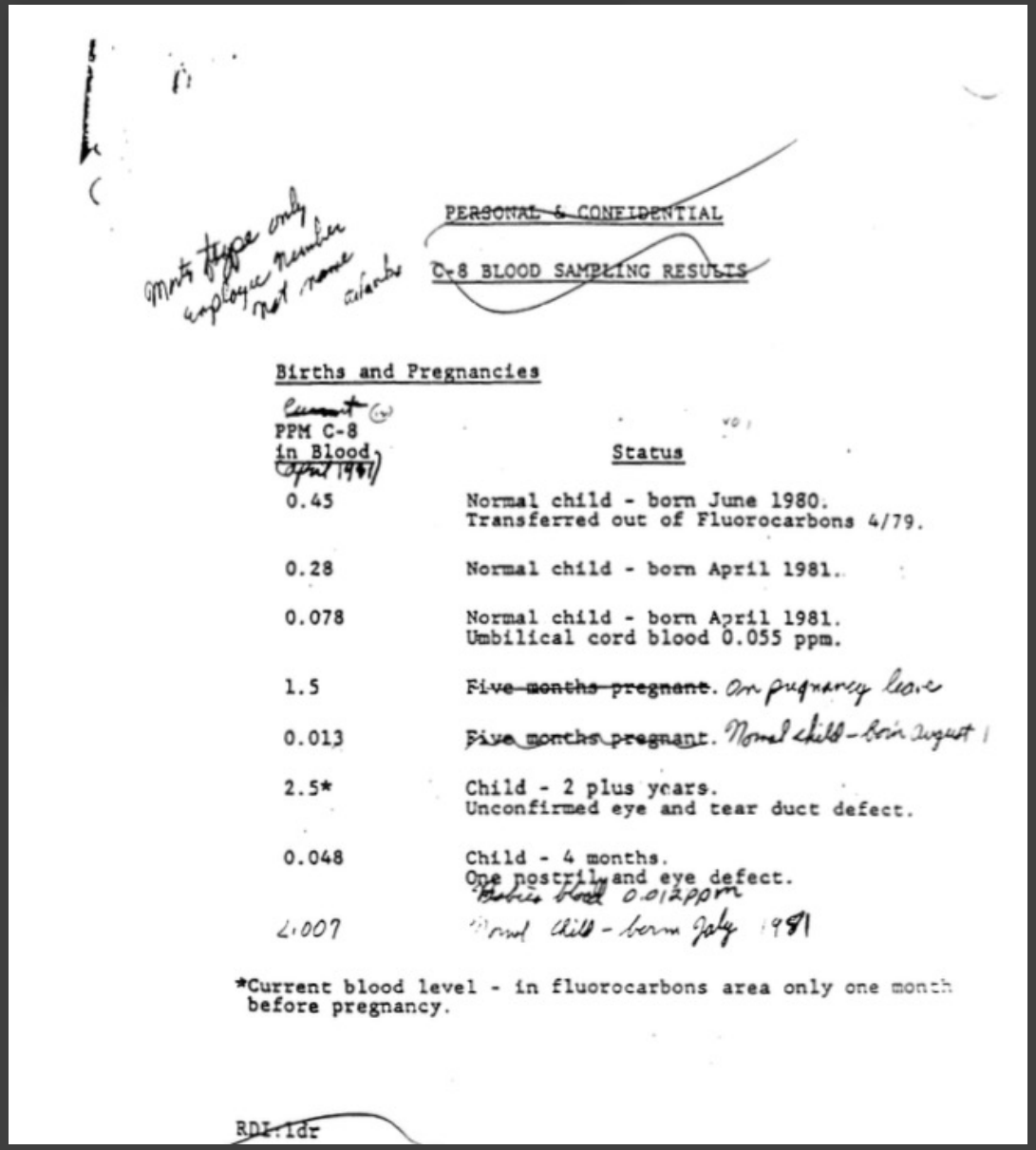
(**Read more**) 12/5/2002.

BHOPAL: 18th Anniversary of Bhopal disaster

December 3, 2002 marks the 18th anniversary of the worst disaster in the chemical industry's history. A toxic release in the middle of the night of December 3, 1984 at a Union Carbide pesticide factory in Bhopal, India sent a cloud of Methyl Isocyanate into the air over the city. An estimated 6,000 people died in the immediate aftermath, most suffocating from the cloud's toxic chemicals. Since 1984, over 20,000 people have died as a result of the disaster, according to survivor groups in Bhopal. Hundreds of thousands of Indians have claimed health effects from exposure to the chemical cloud.

Documents recently uncovered in litigation [Bano et al v. Union Carbide Corp & Warren Anderson, 99cv11329 SDNY, filed 11/15/99)] and obtained by EWG demonstrate that Union Carbide cut corners and employed untested technologies when building the Bhopal plant.

(Read more) 12/5/2002



PERSONAL & CONFIDENTIAL

C-8 BLOOD SAMPLING RESULTS

Births and Pregnancies

PPM C-8 in Blood	Status
0.45	Normal child - born June 1980. Transferred out of Fluorocarbons 4/79.
0.28	Normal child - born April 1981.
0.078	Normal child - born April 1981. Umbilical cord blood 0.055 ppm.
1.5	Five months pregnant. On pregnancy leave
0.013	Five months pregnant. Normal child - born August
2.5*	Child - 2 plus years. Unconfirmed eye and tear duct defect.
0.048	Child - 4 months. One nostril and eye defect. Cord blood 0.012ppm
2.007	Normal child - born July 1981

*Current blood level - in fluorocarbons area only one month before pregnancy.

RDL:ldr

- DuPont 1981
- PERSONAL & CONFIDENTIAL
- C-8 BLOOD SAMPLING RESULTS

ENVIRONMENTAL WORKING GROUP

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Washington, DC 200C
T: 202.667.698
F: 202.232.259

December 6, 2002

Ms. Dorothy Sussman
Centers for Disease Control and Prevention
National Center for Environmental Health
Division of Laboratory Sciences
Mail Stop F-20
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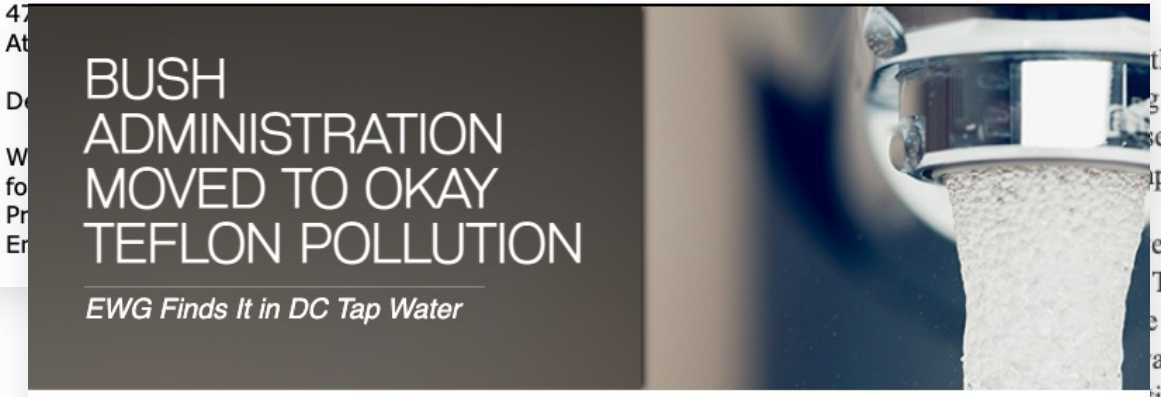

WEDNESDAY, JANUARY 14, 2009

BUSH ADMINISTRATION MOVED TO OKAY TEFLON POLLUTION

EWG Finds It in DC Tap Water

In its final days, the Bush administration appears poised to issue an emergency health advisory for tap water polluted with the toxic Teflon chemical PFOA (perfluorooctanoic acid) effectively allowing a significant level of pollution and discouraging cleanup of PFOA contamination in tap water in at least 9 states.

The level of permissible PFOA contamination under the administration's guidance would be 10 times higher than that allowed by the New Jersey Department of Environmental Protection, whose commissioner, Lisa Jackson has been tapped by incoming President Obama to run the U.S. Environmental Protection Agency. If the Bush administration advisory is allowed to stand, it could result in blood levels of PFOA in people nearly 10 times higher than the current average amounts.

THURSDAY, APRIL 3, 2003

PFCS: GLOBAL CONTAMINANTS

Consumers instantly recognize them as household miracles of modern chemistry — Teflon, Scotchgard, Stainmaster, Gore-Tex.

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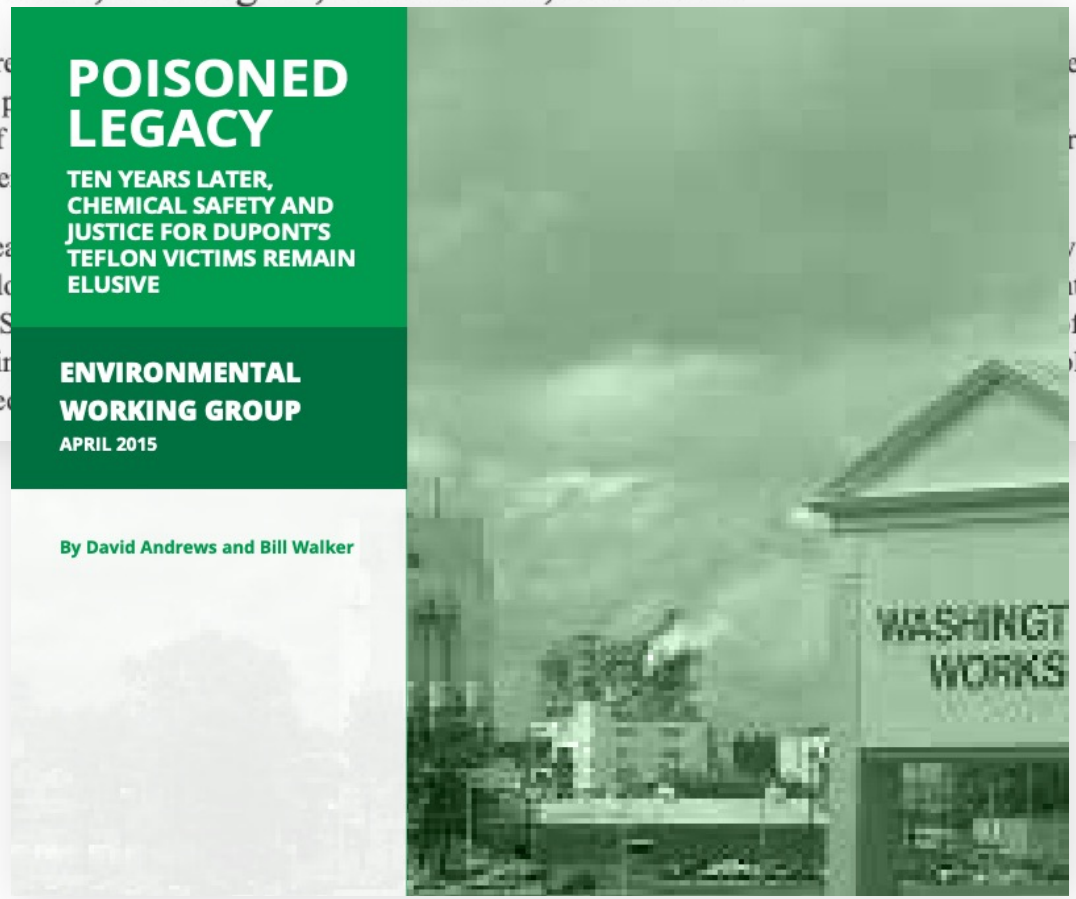
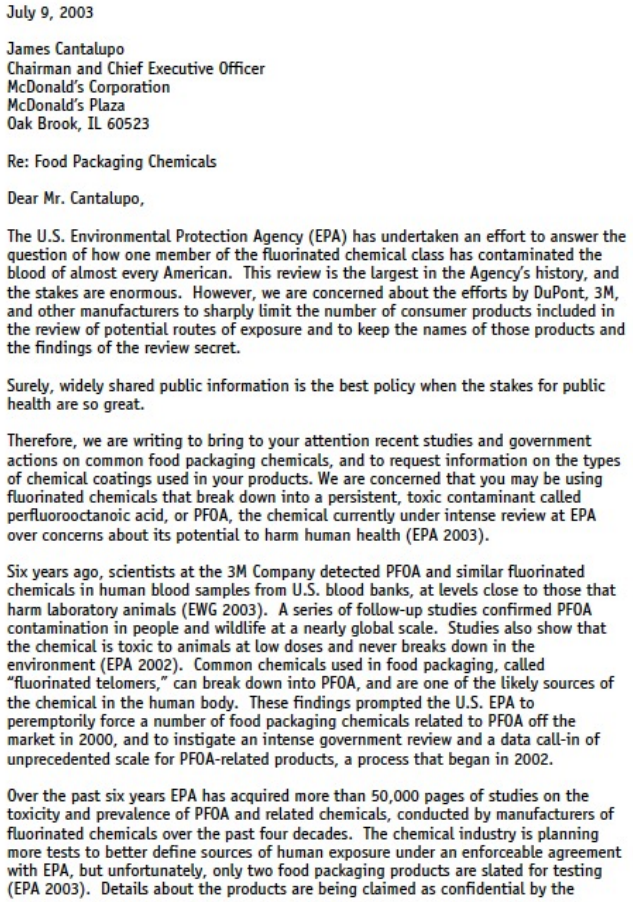


PFAS in Food

Fast Food Companies Asked to Disclose Use of Toxic Chemicals in Food Packaging

2003 EWG wrote letters to 9 fast food chains

Wendy's, Subway, Taco Bell, Burger King, McDonald's, KFC, Pizza Hut, Starbucks, Krispy Kreme



July 9, 2003

James Cantalupo
Chairman and Chief Executive Officer
McDonald's Corporation
McDonald's Plaza
Oak Brook, IL 60523

Re: Food Packaging Chemicals

Dear Mr. Cantalupo,

The U.S. Environmental Protection Agency (EPA) has undertaken an effort to answer the question of how one member of the fluorinated chemical class has contaminated the blood of almost every American. This review is the largest in the Agency's history, and the stakes are enormous. However, we are concerned about the efforts by DuPont, 3M, and other manufacturers to sharply limit the number of consumer products included in the review of potential routes of exposure and to keep the names of those products and the findings of the review secret.

Surely, widely shared public information is the best policy when the stakes for public health are so great.

Therefore, we are writing to bring to your attention recent studies and government actions on common food packaging chemicals, and to request information on the types of chemical coatings used in your products. We are concerned that you may be using fluorinated chemicals that break down into a persistent, toxic contaminant called perfluorooctanoic acid, or PFOA, the chemical currently under intense review at EPA over concerns about its potential to harm human health (EPA 2003).

Six years ago, scientists at the 3M Company detected PFOA and similar fluorinated chemicals in human blood samples from U.S. blood banks, at levels close to those that harm laboratory animals (EWG 2003). A series of follow-up studies confirmed PFOA contamination in people and wildlife at a nearly global scale. Studies also show that the chemical is toxic to animals at low doses and never breaks down in the environment (EPA 2002). Common chemicals used in food packaging, called "fluorinated telomers," can break down into PFOA, and are one of the likely sources of the chemical in the human body. These findings prompted the U.S. EPA to peremptorily force a number of food packaging chemicals related to PFOA off the market in 2000, and to instigate an intense government review and a data call-in of unprecedented scale for PFOA-related products, a process that began in 2002.

Over the past six years EPA has acquired more than 50,000 pages of studies on the toxicity and prevalence of PFOA and related chemicals, conducted by manufacturers of fluorinated chemicals over the past four decades. The chemical industry is planning more tests to better define sources of human exposure under an enforceable agreement with EPA, but unfortunately, only two food packaging products are slated for testing (EPA 2003). Details about the products are being claimed as confidential by the

If you are using fluorinated chemicals in food packaging, as many companies are, we look forward to hearing your plans for eliminating their use in the future as a proactive way to protect the health of your customers and reduce contamination of the biosphere with these toxic, indestructible pollutants.

https://www.ewg.org/news/news-releases/2003/07/10/fast-food-companies-asked-disclose-use-toxic-chemicals-food-packaging

MONDAY, JUNE 9, 2008

CREDIBILITY GAP: TOXIC CHEMICALS IN FOOD PACKAGING

How Green is DuPont's Alternative?

Study authors: Olga Naidenko, PhD, Senior Scientist; Renee Sharp, MS, Senior Scientist; Jane Houlihan, MSCE, Vice President for Research; Bill Walker, Vice President West Coast

In 2006, under pressure from the U.S. EPA, DuPont and 7 other companies promised to phase out by 2015 a cancer-causing chemical called PFOA, used to make Teflon and also found in grease-resistant coatings for food packaging. In its place, the chemical industry is pushing new, supposedly "green" food package coatings.

But an investigation by Environmental Working Group (EWG) finds no evidence that the industry-touted replacement chemicals being rushed to market are safer -- and plenty of evidence that DuPont and other manufacturers are continuing a decades-long pattern of deception about the health risks of PFOA and related chemicals.

Credibility Gap: Toxic Chemicals in Food Packaging

Credibility Gap: Are New Food Packaging Chemicals Any Safer?

News Release

FDA Bans Three Toxic Chemicals From Food Wrapping – Too Little, Too Late

LATEST NEWS

Fluorinated Compounds in U.S. Fast Food Packaging

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

View Author Information

Cite this: *Environ. Sci. Technol. Lett.* 2017, 4, 3, 105–111
Publication Date: February 1, 2017
https://doi.org/10.1021/acs.estlett.6b00435

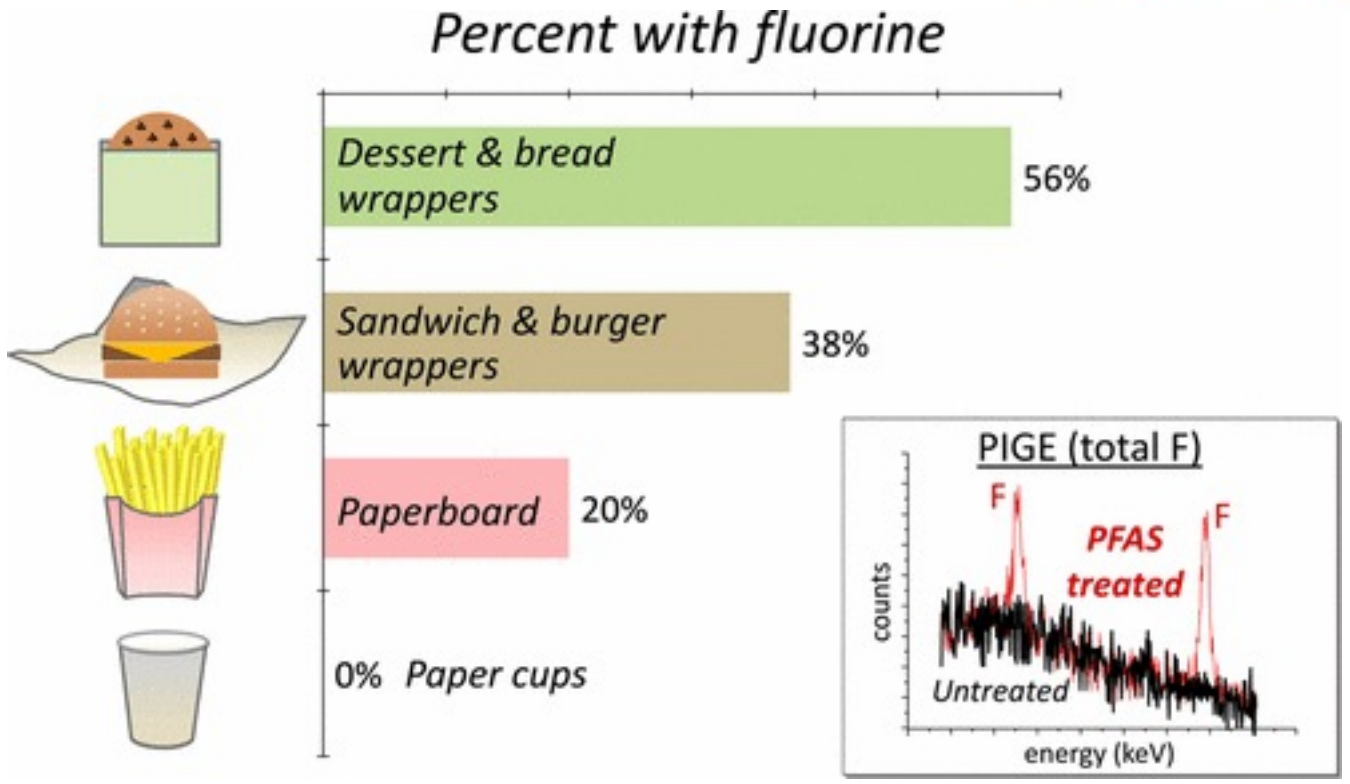


Figure S3 in supporting information

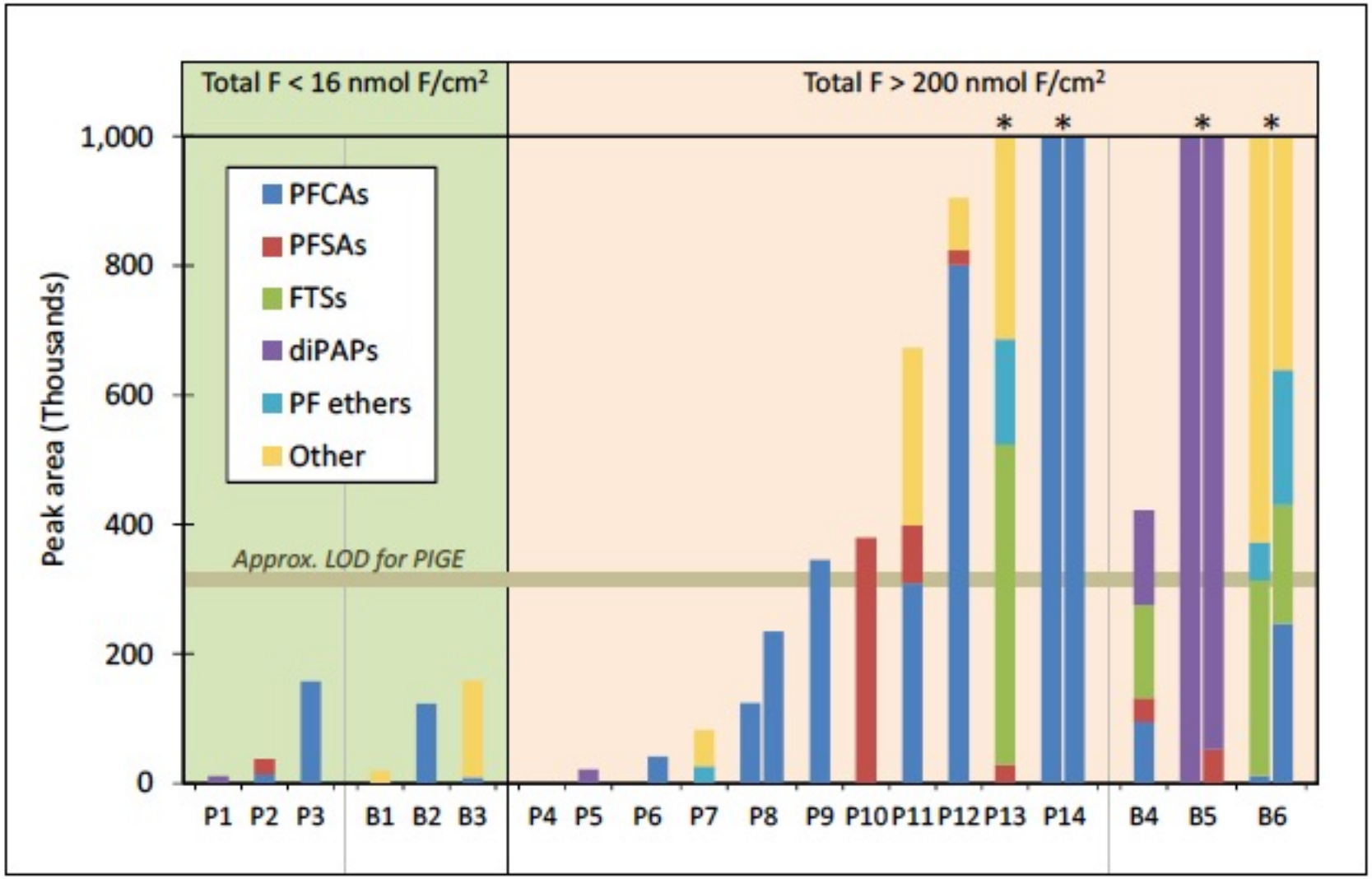
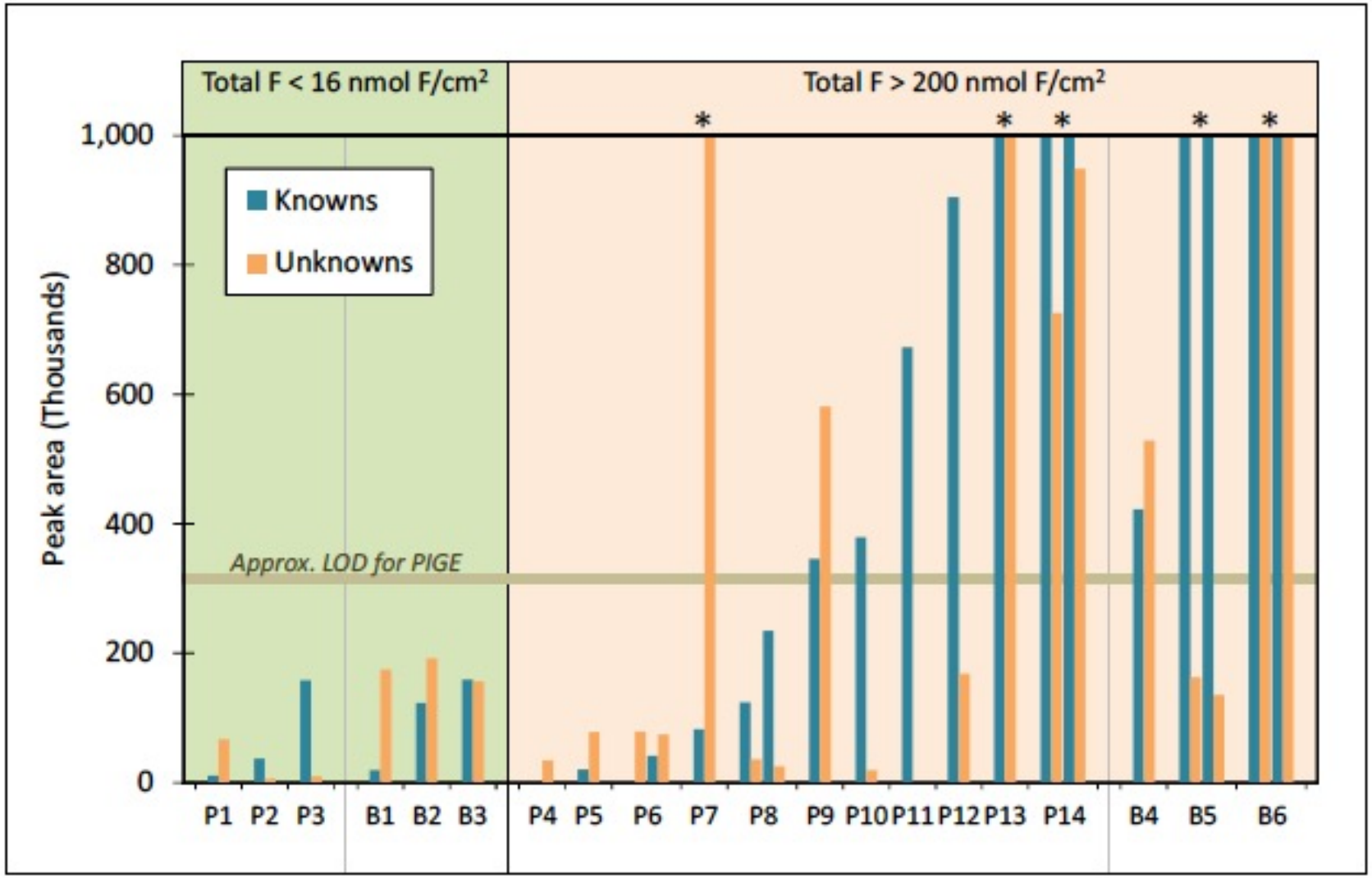


Figure S4 in supporting information



PFAS in Water

Testing for PFAS as a class started in the 60's

These findings suggest that there is widespread contamination of human tissues with trace amounts of organic fluorocompounds derived from commercial products.

Organic Fluorocompounds in Human Plasma: Prevalence and Characterization

W. S. GUY
Department of Basic Dental Sciences, University of Florida, Box J424, Gainsville, Fla. 32610

D. R. TAVES
Department of Pharmacology and Toxicology, University of Rochester, Rochester, N.Y. 14642

W. S. BREY, JR.
Department of Chemistry, University of Florida, Gainsville, Fla. 32611

Taves discovered that samples of his own blood serum contained two distinct forms of fluoride (1-4). Only one of these was exchangeable with radioactive fluoride. The other, non-exchangeable form was detectable as fluoride only when sample preparation included ashing. This paper is concerned with three aspects of this newly discovered, non-exchangeable form: 1) its prevalence in human plasma, 2) how its presence in human plasma affects the validity of certain earlier conclusions about the metabolic handling of the exchangeable form of fluoride, and 3) its chemical nature.

Preliminary work in this laboratory suggested that the non-exchangeable form was widespread in human plasma but did not exist in the plasma of other animals. Ashing increased the amount of fluoride an average of 1.6 ± 0.25 SD μM (range 0.4 - 3.0) in samples of plasma from 35 blood donors in Rochester, N.Y. (5). No such fluoride was detectable (above 0.3 μM) in blood serum from eleven different species of animal including horse, cow, guinea pig, chicken, rabbit, sheep, pig, turkey, mule and two types of monkey (6).

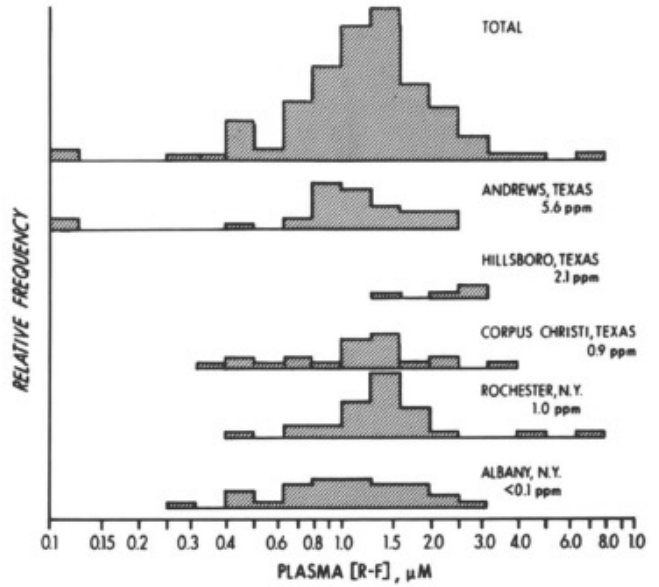
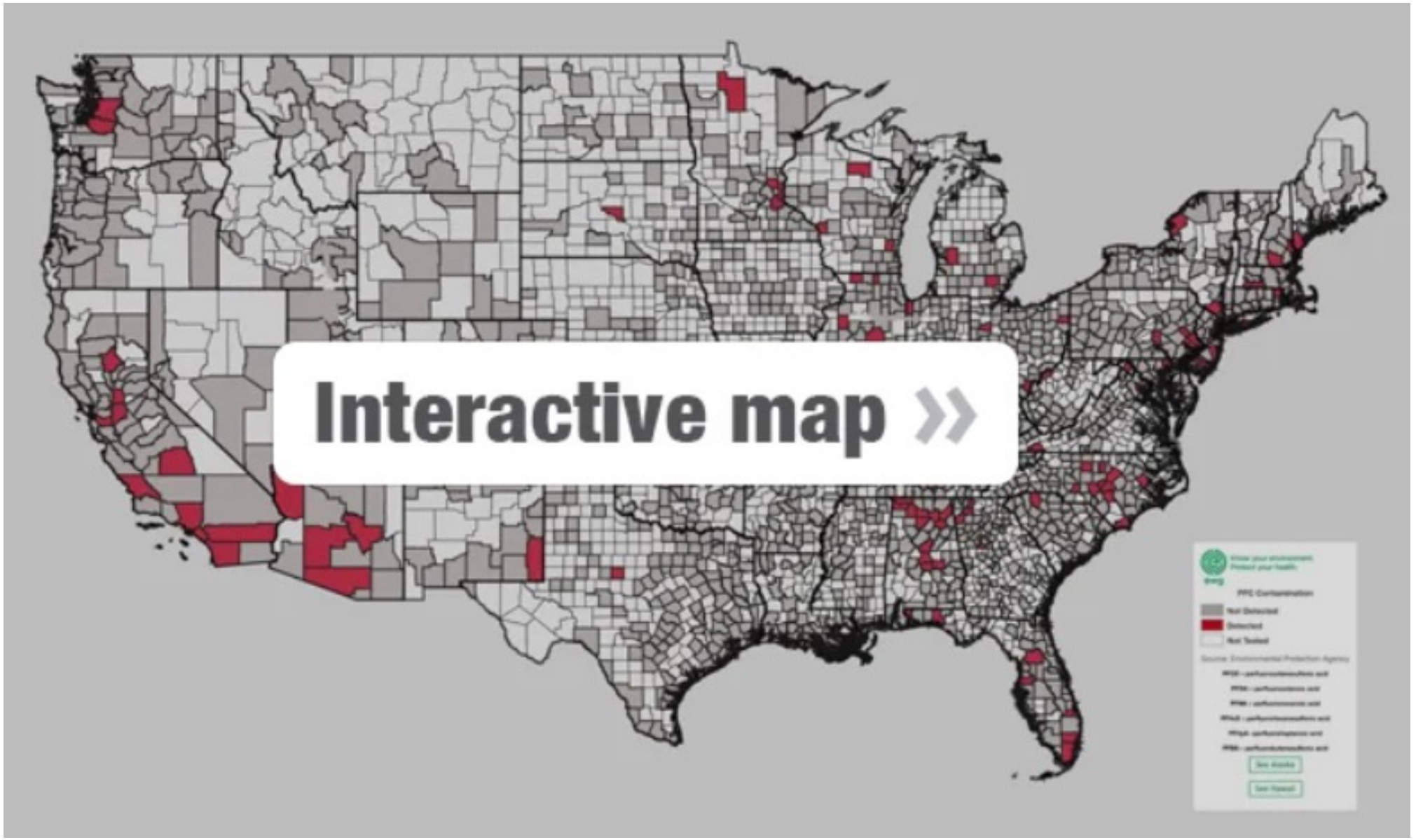
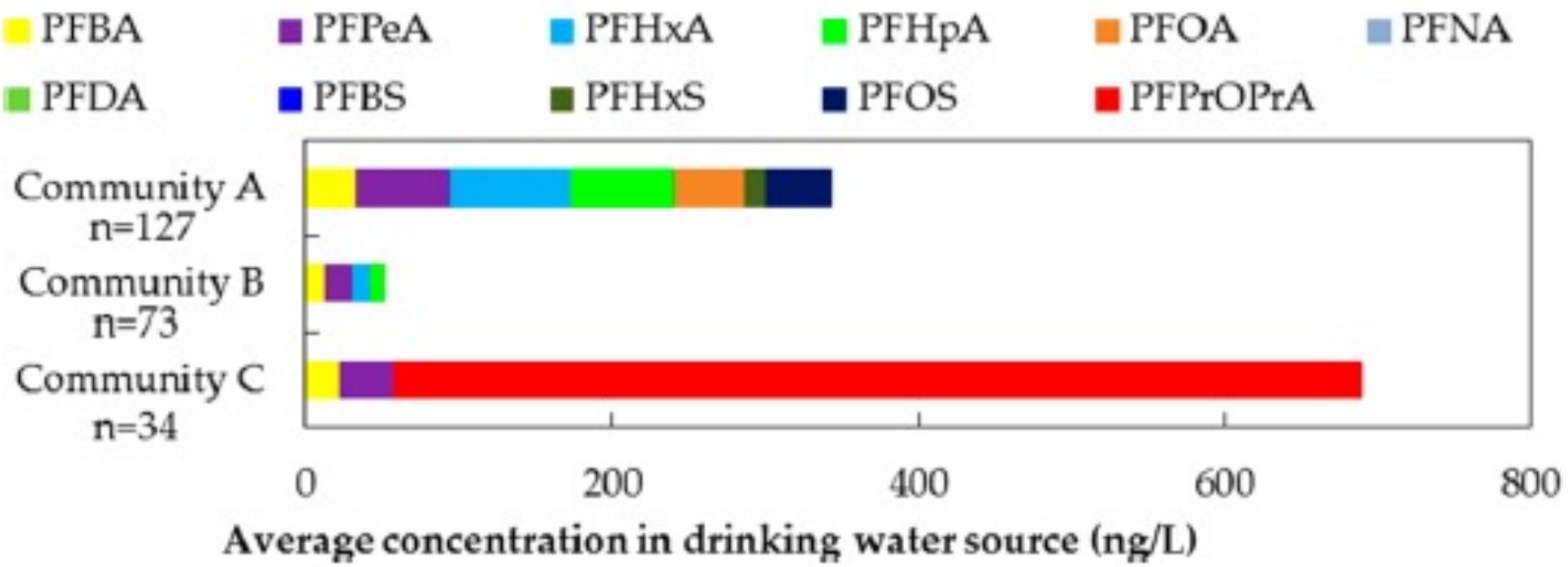


Figure 2. Relationship between the concentration of organic fluorine in human plasma and the concentration of fluoride in the drinking water

2015 PFAS MAP



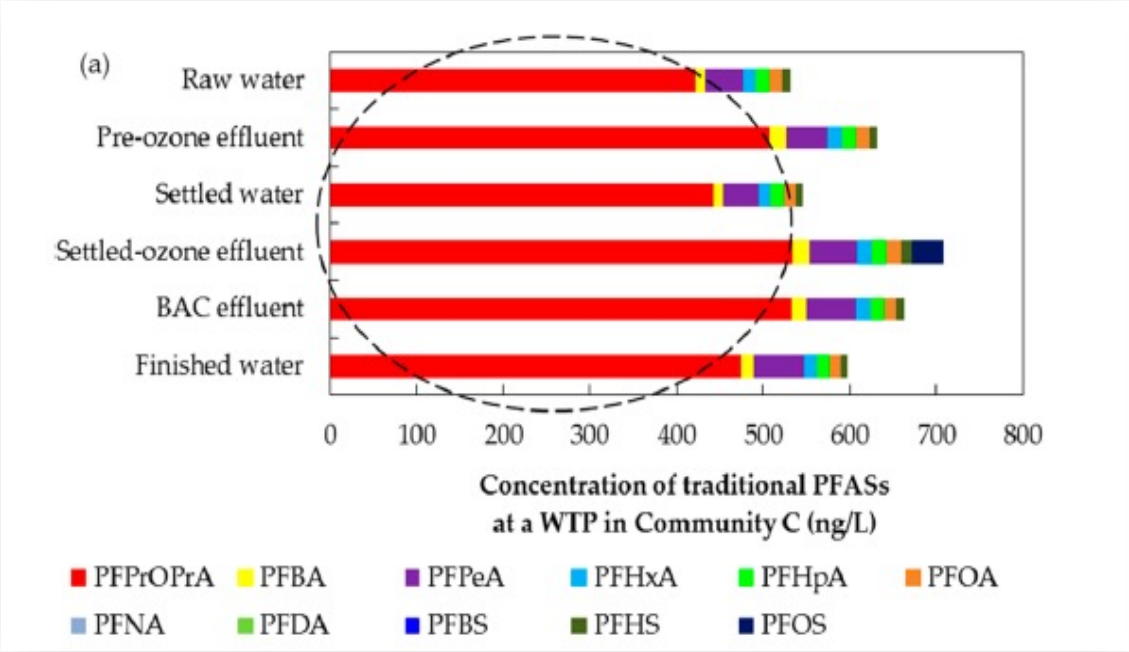
What is missed when you look at just PFOA & PFOS

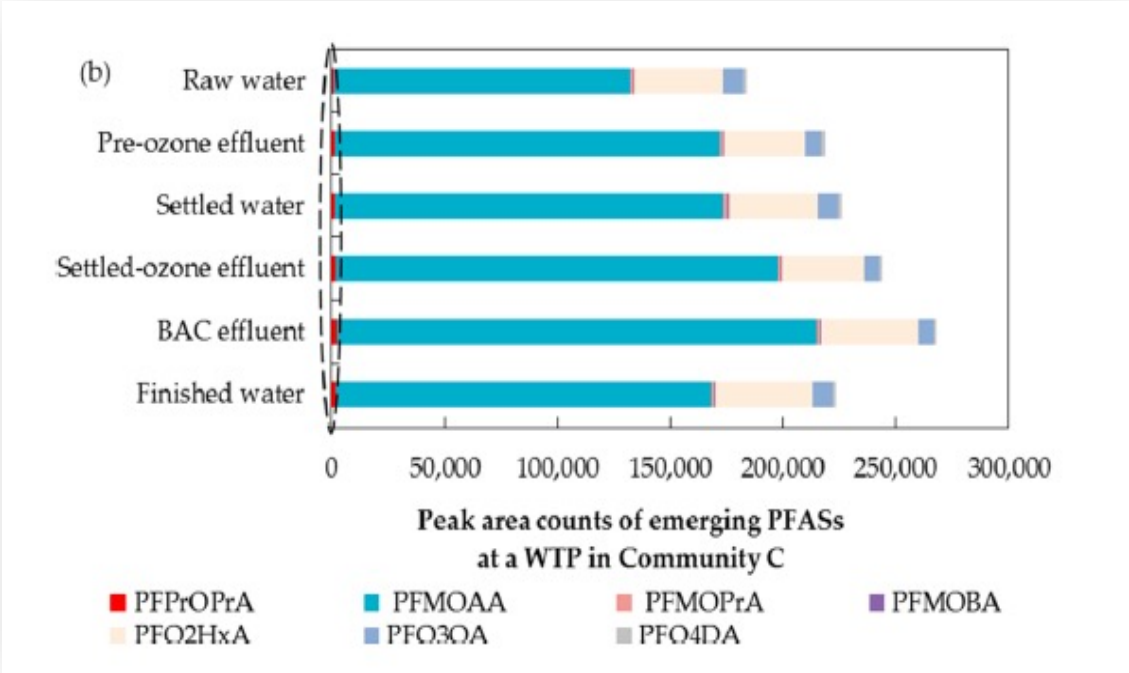


Legacy and Emerging Perfluoroalkyl Substances Are Important Drinking Water Contaminants in the Cape Fear River Watershed of North Carolina

Mei Sun, Elisa Arevalo, Mark Strynar, Andrew Lindstrom, Michael Richardson, Ben Kearns, Adam Pickett, Chris Smith, and Detlef R. U. Knappe

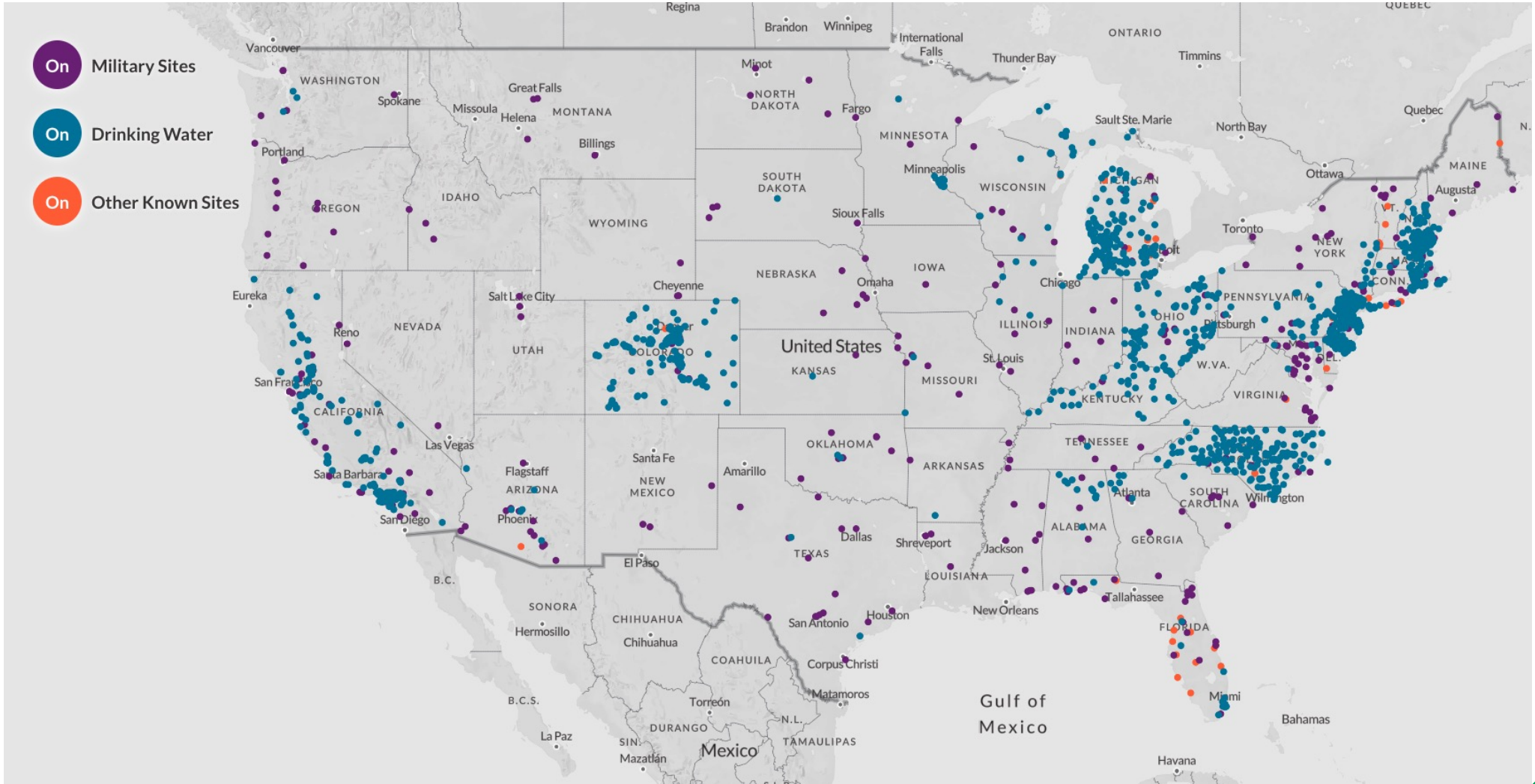
Environ. Sci. Technol. Lett. 2016, 3, 12, 415–419


(a)
Raw water
Pre-ozone effluent
Settled water
Settled-ozone effluent
BAC effluent
Finished water
0
100
200
300
400
500
600
700
800
Concentration of traditional PFASs
at a WTP in Community C (ng/L)
PFPrOPrA
PFBA
PFPeA
PFHxA
PFHpA
PFOA
PFNA
PFDA
PFBS
PFHS
PFOS

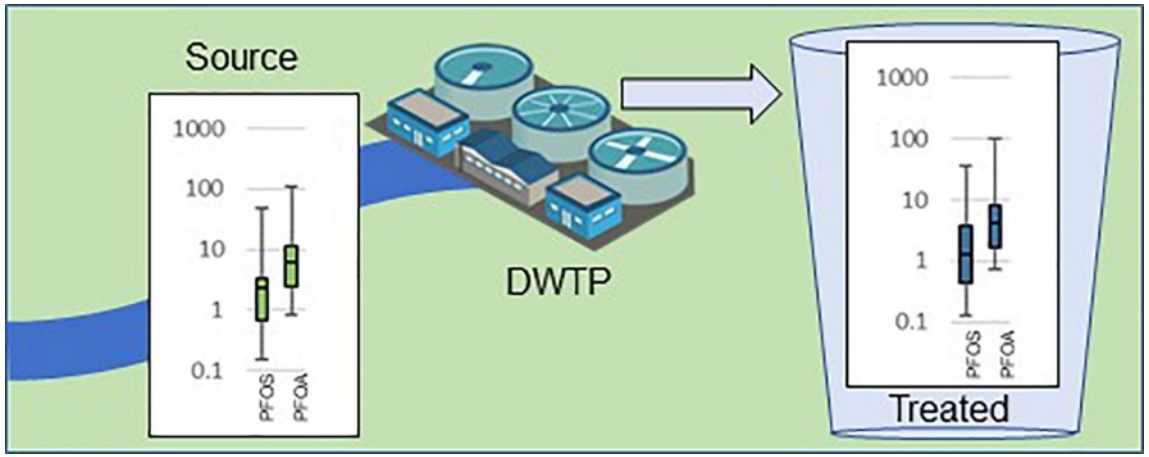

(b)
Raw water
Pre-ozone effluent
Settled water
Settled-ozone effluent
BAC effluent
Finished water
0
50,000
100,000
150,000
200,000
250,000
300,000
Peak area counts of emerging PFASs
at a WTP in Community C
PFPrOPrA
PFMOAA
PFMOPrA
PFMOBA
PFO2HxA
PFO3OA
PFO4DA

Mapping the PFAS Contamination Crisis: New Data Show 2,337 Sites in 49 States

(January 6, 2021)



Per- and polyfluoroalkyl substances in source and treated drinking waters of the United States

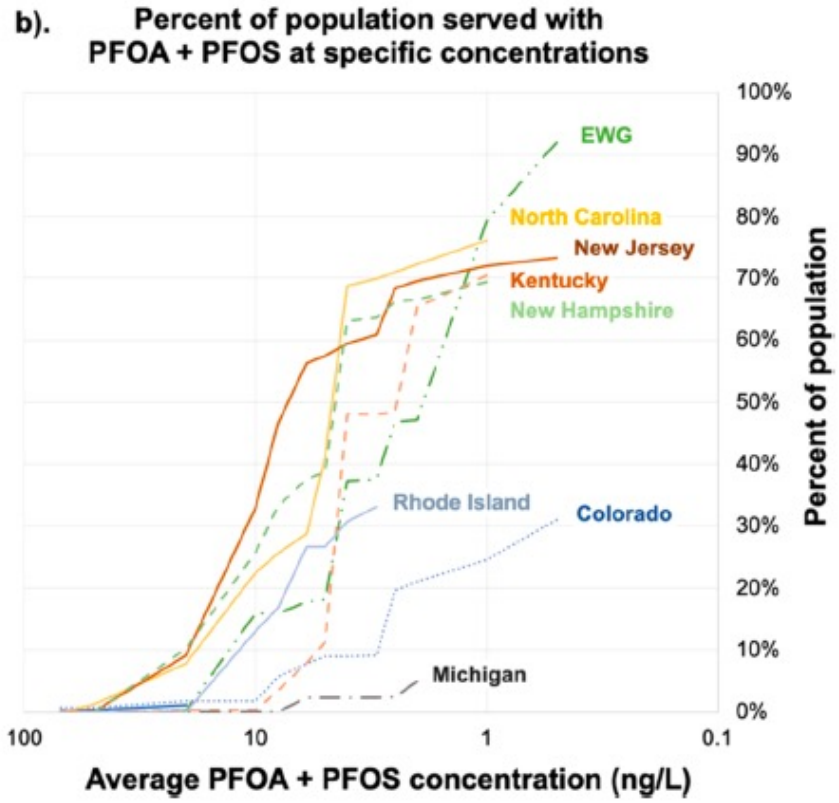


The median total ΣPFOS + PFOA concentration was 5.7 ng/L in the source water and 3.9 ng/L in the treated drinking water.

The median total PFAS concentration was 21.4 ng/L in the source water and 19.5 ng/L in the treated drinking water.

Boone JS, Vigo C, Boone T, Byrne C, Ferrario J, Benson R, Donohue J, Simmons JE, Kolpin DW, Furlong ET, Glassmeyer ST. Sci Total Environ. 2019 Feb 25;653:359-369. doi: 10.1016/j.scitotenv.2018.10.245.

Population-Wide Exposure to Per- and Polyfluoroalkyl Substances from Drinking Water in the United States



For the combined EPA/USGS and EWG data sets, 92% of the samples had detectable PFAS at 1 ng/L or higher, 51% at or above 10 ng/L total PFAS, and four systems were over 100 ng/L.

Andrews DQ, Naidenko NV. Environ. Sci. Technol. Lett. 2020, 7, 12, 931–936 doi:doi.org/10.1021/acs.estlett.0c00713

Tap Water Contributions to Plasma Concentrations of Poly- and Perfluoroalkyl Substances (PFAS) in a Nationwide Prospective Cohort of U.S. Women

Table 5

Extractable organic fluorine levels from tap water samples matched by city at five locations in Massachusetts (MA1 – MA5) in 1989–1990[a] and 2016[b]

Extractable organic fluorine (ng/L)	MA1		MA2		MA3		MA4		MA5	
	1989–1990	2016	1989–1990	2016	1989–1990	2016	1989–1990	2016	1989–1990	2016
PFOA	0.2	6.2	0.5	1.7	0.9	4.8	0.6	0.9	1.3	0.9
PFOS	0.4	1.6	0.4	0.8	1.2	4.2	0.5	0.3	0.6	0.3
Other PFCAs	0.1	7.4	0.8	4.2	1.3	9.6	0.6	1.7	0.0	5.1
Other PFSAs	0.3	4.3	0.3	1.7	1.5	5.6	0.2	0.7	0.4	0.1
PFOS precursors	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown	6.7	135.6	19.8	105.2	2.9	39.4	0.2	58.5	5.4	9.6

[a]1989–1990 tap water samples were collected from five participants' home addresses, one sample at each location.
[b]2016 tap water samples were collected in the cities from the same municipal water supplies as original participant's homes. Two samples were collected at each location.

Hu XC, Tokranov AK, Liddie J, Zhang X, Grandjean P, Hart JE, Laden F, Sun Q, Yeung LWY, Sunderland EM. Environ Health Perspect. 2019 Jun;127(6):67006. doi: 10.1289/EHP4093.

EWG TESTING OF CORD BLOOD SHOWS BABIES ARE PRE-POLLUTED WITH PFAS CHEMICALS.

C-8 Science panel findings

DATE	PROBABLE LINK	NOT A PROBABLE LINK
Dec. 5, 2011	Pregnancy-induced hypertension & preeclampsia	Birth defects Premature birth or low birth weight Miscarriage and stillbirths
April 16, 2012	Testicular cancer Kidney cancer	Adult-onset diabetes Other types of cancer
July 30, 2012	Thyroid disease Ulcerative colitis	Stroke Asthma or chronic obstructive airways Neurodevelopmental disorders in children Influenza Autoimmune diseases
Oct. 29, 2012	High cholesterol	Parkinson's disease Osteoarthritis Liver disease Chronic kidney disease High blood pressure Coronary heart disease

Source: Environmental Working Group, from C8 Science Panel Probable Link Reports
www.c8sciencepanel.org/prob_link.html

CHEMICAL	HARM TO THE IMMUNE SYSTEM	HARM TO DEVELOPMENT AND REPRODUCTION	HARM TO THE ENDOCRINE SYSTEM	METABOLIC CHANGES	CHANGES IN THE LIVER	INCREASED RISK OF CANCER
PFOA*#	■	■	■	■	■	■
PFOS*#	■	■	■	■	■	■
PFNA*#	■	■	■	■	■	●
PFHxS*#	■	■	■	●	■	●
PFDA*#	■	■	■	■	■	●
PFDoA#	●	●	●	▲	■	●
PFHxA*#	■	■	■	▲	■	●
GenX*	■	■	■	▲	■	■
PFBS*#	●	■	■	●	■	●
PFBA*#	●	■	●	▲	■	●
PFHpA*#	▲	▲	●	▲	■	●
PFUA#	●	■	●	▲	■	●

*PFAS chemicals detected by EWG in U.S. public drinking water supplies

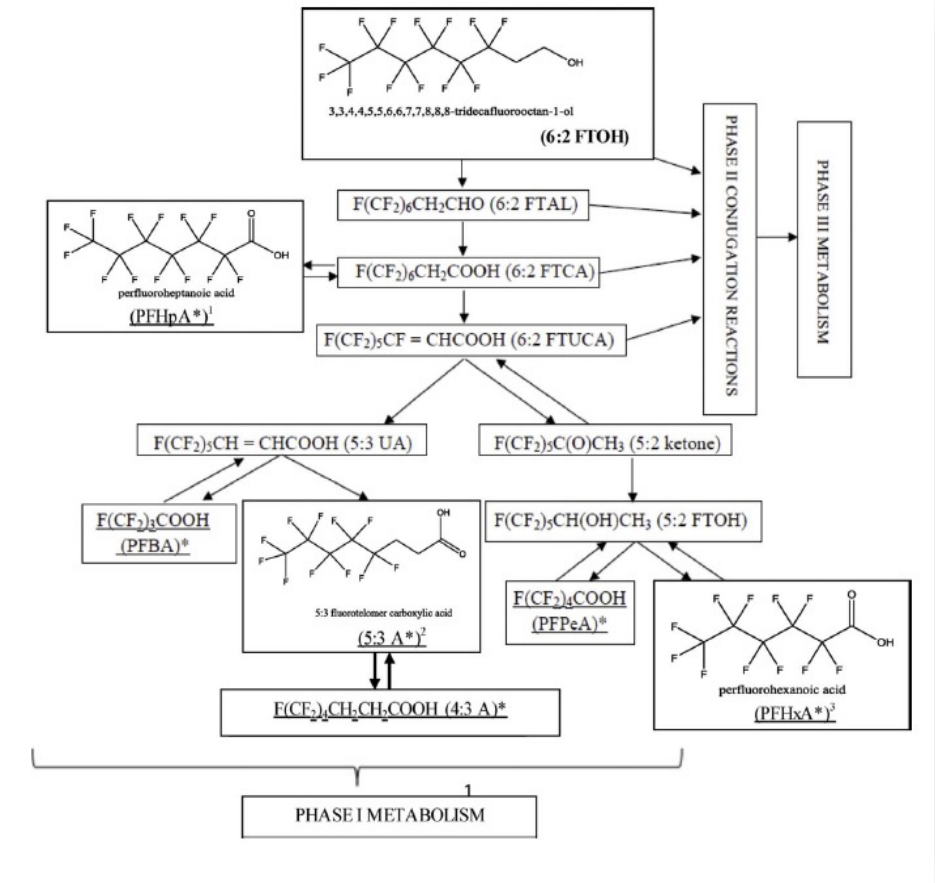
PFAS included in ATSDR toxicological profile

■ Strong evidence of health effect documented in people or in laboratory animal studies

● Moderate evidence of health effect documented in people or in laboratory animal studies

▲ Not studied or no reported association in available studies

https://www.ewg.org/news-and-analysis/2020/08/feeding-waste-cycle-how-pfas-disposal-perpetuates-contamination



Kabadi et al, Food and Chemical Toxicology 112 (2018) 375–382

FDA Announces the Voluntary Phase-Out by Industry of Certain PFAS Used in Food Packaging

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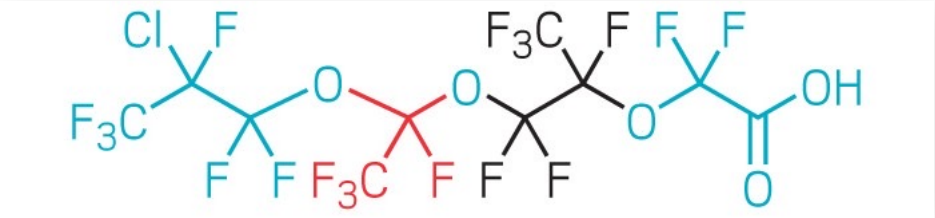
Constituent Update

July 31, 2020

The U.S. Food and Drug Administration (FDA) is announcing the voluntary phase-out of a certain type of short-chain per- and poly-fluoroalkyl substances (PFAS), that contain 6:2 fluorotelomer alcohol (6:2 FTOH), which may be found in certain food contact substances used as grease-proofing agents on paper and paperboard food packaging.

Today's announcement follows an FDA post-market scientific review and analysis of data from rodent studies finding biopersistence of 6:2 FTOH. While the findings were in rodents, the data point to the potential that 6:2 FTOH may also persist in humans following dietary exposure. Further scientific studies are needed to better understand the potential human health risks from dietary exposure resulting from authorized food contact substances for short-chain PFAS that contain 6:2 FTOH. This phased market removal balances uncertainty about the potential for public health risks with minimizing potential market disruptions during the COVID-19 public health emergency.



Positive statistical associations between the LVE Substances' level in the blood and triglycerides albumin, albumin/globulin ratio, and FT3, and negative statistical associations for alpha-2-globulins, IgG, IgM, and estradiol.

Structure from https://cen.acs.org/environment/persistent-pollutants/Solvay-withheld-PFAS-toxicity-data/99/web/2021/01

PFAS in a class

Bloomberg Law, May 2019

Environment & Energy

The Environmental Protection Agency building in Washington, D.C.

Photographer: Mark Wilson/Getty Images

INSIGHT: The Case for Regulating All PFAS Chemicals as a Class

May 20, 2019, 6:00 AM

Listen

The Environmental Working Group's David Andrews outlines why he believes chemicals called per- and polyfluoroalkyl compounds should be regulated as a class. This is part of a point-counterpoint series paired with one from the American Chemistry Council's Jessica Bowman.

In 1968, a scientist named Donald Taves discovered that samples of his own blood contained a distinct form of fluoride, which he later surmised was widespread in people because of the extensive use of organic fluoride-based compounds in consumer products. He was right: Today these fluorinated chemicals, or PFAS, are detected in nearly every person on Earth.

David Andrews
Environmental Working Group

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INSIGHT: With PFAS One-Size-Fits-All Isn't the Answer
May 20, 2019, 6:00 AM

Companies

Environment & Energy

An employee inspects machinery on the production line inside acoatings manufacturing facility in Buk, Poland, on July 5, 2016.

Photographer: Bartek Sadowski/Bloomberg via Getty Images

INSIGHT: With PFAS One-Size-Fits-All Isn't the Answer

May 20, 2019, 6:00 AM

Listen

The American Chemistry Council's Jessica Bowman explains why she believes chemicals called per- and polyfluoroalkyl compounds should not be regulated as a group. This is part of a point-counterpoint series paired with one from the Environmental Working Group's David Andrews, who argues for regulating the chemicals as a class.

The modern world is a marvel of innovation, ideas, and inventions that have transformed our daily lives and the course of history. When Thomas Edison said, "there's a way to do it better—find it," the world took note. Today, whether we are talking about technology, transportation, medicine, or science, our lives are better because of innovation. This is certainly true when it comes to chemistry, an essential building block for a healthier, safer, more sustainable, and more productive world.

Unfortunately, innovation in chemistry and the critical role it plays in our way of life are too often overshadowed by hyperbole in today's public discourse, most notably when it comes to the safety and use of chemicals. While scary sound bites might

Jessica Bowman
FluoroCouncil

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GLOBAL PERSPECTIVE

Scientific Basis for Managing PFAS as a Chemical Class

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 fluoridess (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

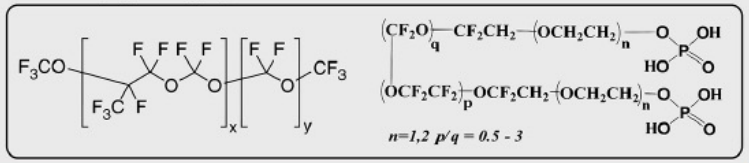
→ **non-polymers** R = NH, $NHCH_2CH_2OH$, etc.

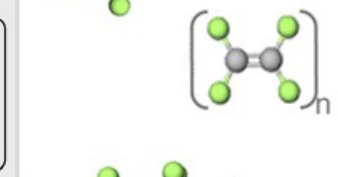
- some **hydrofluorocarbons** (**HFCs**, e.g. C_nF_{2n+1}-C_mH_{2m+1}), **hydrofluoroethers** (**HFEs**, e.g. $C_nF_{2n+1}OC_mH_{2m+1}$) and **hydrofluoroolefins** (**HFOs**, e.g. C_nF_{2n+1}-$CH=CH_2$);
- **perfluoroalkyl** ($C_nF_{2n+1}C(O)C_mF_{2m+1}$) and **semi-fluorinated** ($C_nF_{2n+1}C(O)C_mH_{2m+1}$)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

Fluoropolymers, e.g.

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

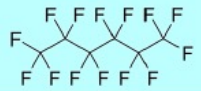
Perfluoropolyethers, e.g.



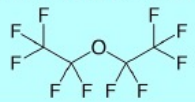


Other PFAS*, e.g.

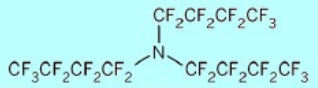
perfluoroalkanes, e.g.



perfluoroalkylethers, e.g.



perfluoroalkylamines, e.g.



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PFAS RISK MANAGEMENT

Regulatory

Marketplace

Essential use

GLOBAL PERSPECTIVE

Scientific Basis for Managing PFAS as a Chemical Class

- Extreme persistence & potential for harm
  - A more efficient approach is needed to address thousands of PFAS (per- and polyfluoroalkyl substances)

- Most consistent feature (persistence)
  - leads to – accumulation in the environment, including water, air, sediment, soil, plants, and living organisms including people
- High mobility

- PFAS chemical features lead to a broad range of adverse health outcomes associated with exposure

Carol F. Kwiatkowski, David Q. Andrews, Linda S. Birnbaum, Thomas A. Bruton, Jamie C. DeWitt, Detlef R. U. Knappe, Maricel V. Maffini, Mark F. Miller, Katherine E. Pelch, Anna Reade, Anna Soehl, Xenia Trier, Marta Venier, Charlotte C. Wagner, Zhanyun Wang, and Arlene Blum. **Environ. Sci. Technol. Lett. 2020, 7, 8, 532–543**