



GREEN SCIENCE  
POLICY INSTITUTE

# PFAS: What It is, What It Comes From, Where It's Found, & Its Dangers

Arlene Blum PhD

Research Associate in Chemistry, UC Berkeley  
Executive Director, Green Science Policy Institute

October 2020





# Brominated Tris Flame Retardant

*Tris (2,3-dibromopropyl) phosphate*

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- In children's sleepwear 1975 to 1977
- Up to 10% of the weight of fabric
- In children's urine
- Mutagen and possible carcinogen













Science, January 7, 1977

# **Flame-Retardant Additives as Possible Cancer Hazards**

The main flame retardant in children's pajamas is a  
mutagen and should not be used.

Arlene Blum and Bruce N. Ames



**U.S. Consumer Product  
Safety Commission**

# TRIS-Treated Children's Garments Banned

April , 1977

**Chlorinated Tris replaced Brominated Tris**

- Removed from pajamas in 1978
- Used in furniture until 2012

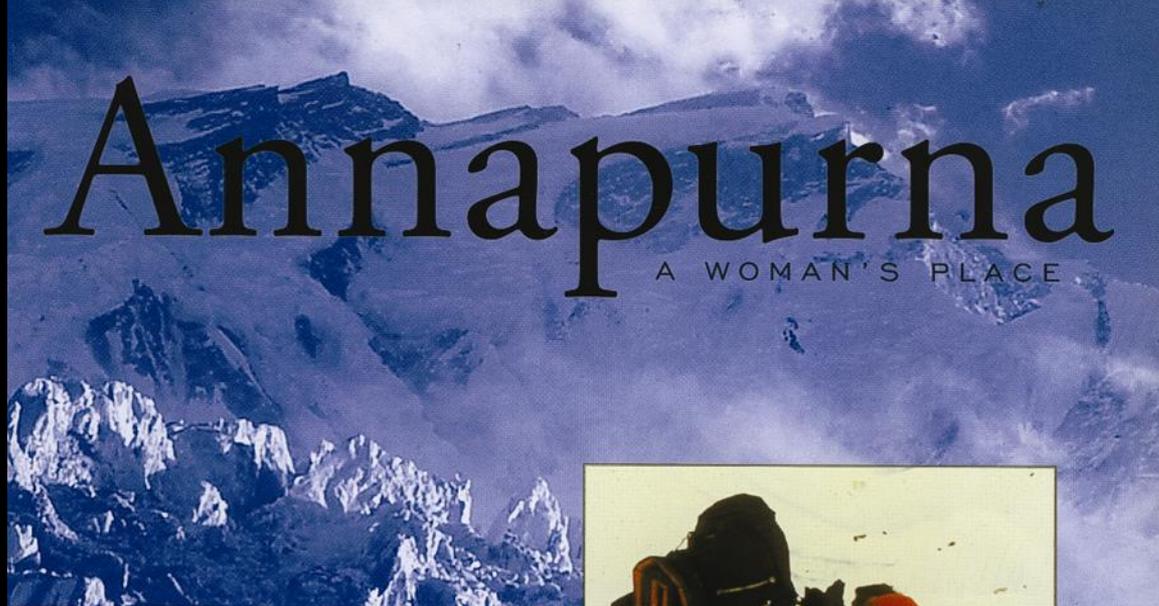






# Annapurna

A WOMAN'S PLACE



The dramatic  
story of the first  
American ascent of  
one of the world's  
highest peaks



ARLENE BLUM

20TH ANNIVERSARY EDITION

With a new Preface and Afterword by the author

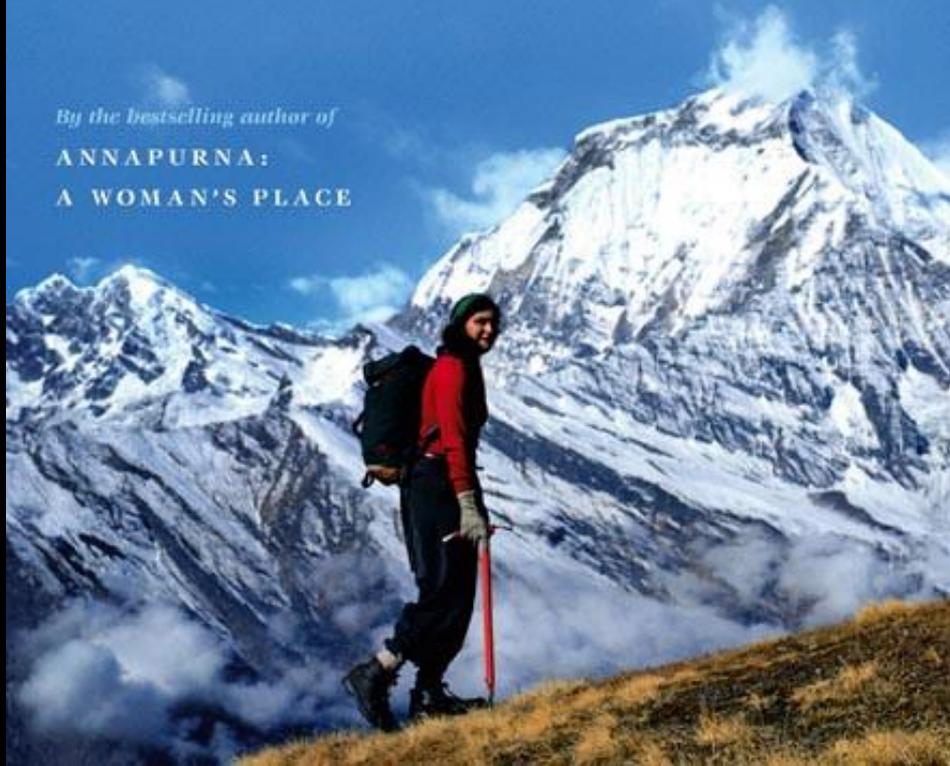
Arlene Blum

# BREAKING TRAIL

*A Climbing Life*

*By the bestselling author of*

**ANNAPURNA:  
A WOMAN'S PLACE**





# GREEN SCIENCE POLICY INSTITUTE

**ENVIRONMENTAL SCIENCE & TECHNOLOGY**  
**ENVIRONMENTAL LETTERS**

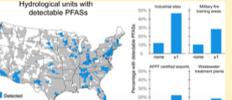
**Building insulation: ...ing codes**

**Novel and High Volume Use Flame Retardants in US Couches**  
 Heather M. Thomas F., P. Lee Ferguson, Michelle Gabriel

**Fluorinated Polyethylene Glycol in U.S. Fast Food Packaging**  
 Laurel A. Margaret, David Q. Andrews, Mark J. Strynar, ...

**Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants**  
 Xindi C. Hu, David Q. Andrews, Andrew B. Lindstrom, Thomas A. Bruton, Laurel A. Schaidler, Philippe Grandjean, Rainer Lohmann, Courtney C. Carignan, Arlene Blum, Simona A. Balan, Christopher P. Higgins, and Elsie M. Sunderland

**ABSTRACT:** Drinking water contamination with poly- and perfluoroalkyl substances (PFASs) poses risks to the developmental, immune, metabolic, and endocrine health of consumers. We present a spatial analysis of 2013–2015 national drinking water PFAS concentrations from the U.S. Environmental Protection Agency's (U.S. EPA) third Unregulated Contaminant Monitoring Rule (UCMR3) program. The number of industrial sites that manufacture or use these compounds, the number of military fire training areas, and the number of wastewater treatment plants are all significant




## Education



## Retreats

## Research

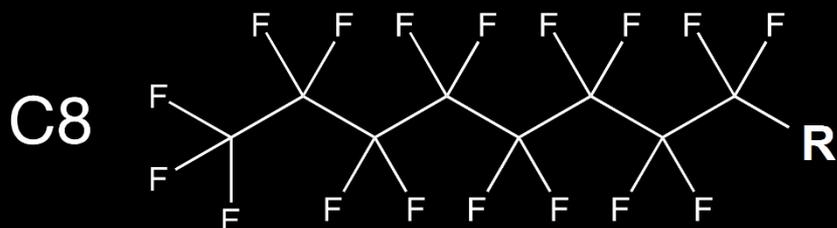
# Policy & Purchasing Change

# U.S. Toxic Substances Control Act (1976)

- 62,000 previous chemicals “grandfathered”
- 23,000 new chemicals
  - 85% have no health data
  - 67% have no data at all

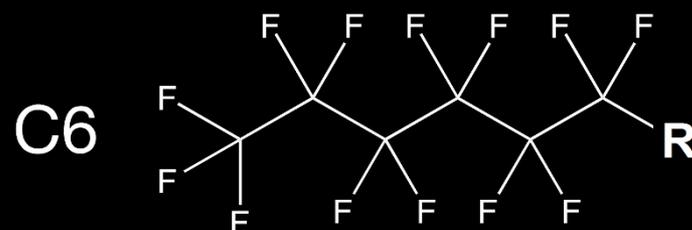


# “Regrettable” Substitution



## Long chain:

- Extreme persistence
- Bioaccumulation
- Toxicity



## Short chain:

- Extreme persistence
- Build-up in plants
- Suspected toxicity
- More mobile
- Clean up more difficult
- Harder to measure & monitor



**EVALUATING TENS OF THOUSANDS OF  
INDIVIDUAL CHEMICALS IS UNWORKABLE**



BUT ADDRESSING **SIX GROUPS** OF  
CHEMICALS OF CONCERN IS MANAGEABLE



# Six Classes Videos

1  
PFAS

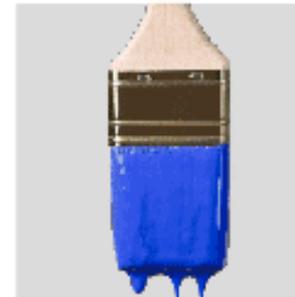
2  
Anti-  
microbials

3  
Flame  
Retardants

4  
Bisphenols  
+  
Phthalates

5  
Some  
Solvents

6  
Certain  
Metals



[www.SixClasses.org](http://www.SixClasses.org)

Healthier products, healthier people in four minutes!

Is it necessary?

Is it worth it?

Is there a safer alternative?

# From Surfer Shorts to Surgical Drapes:

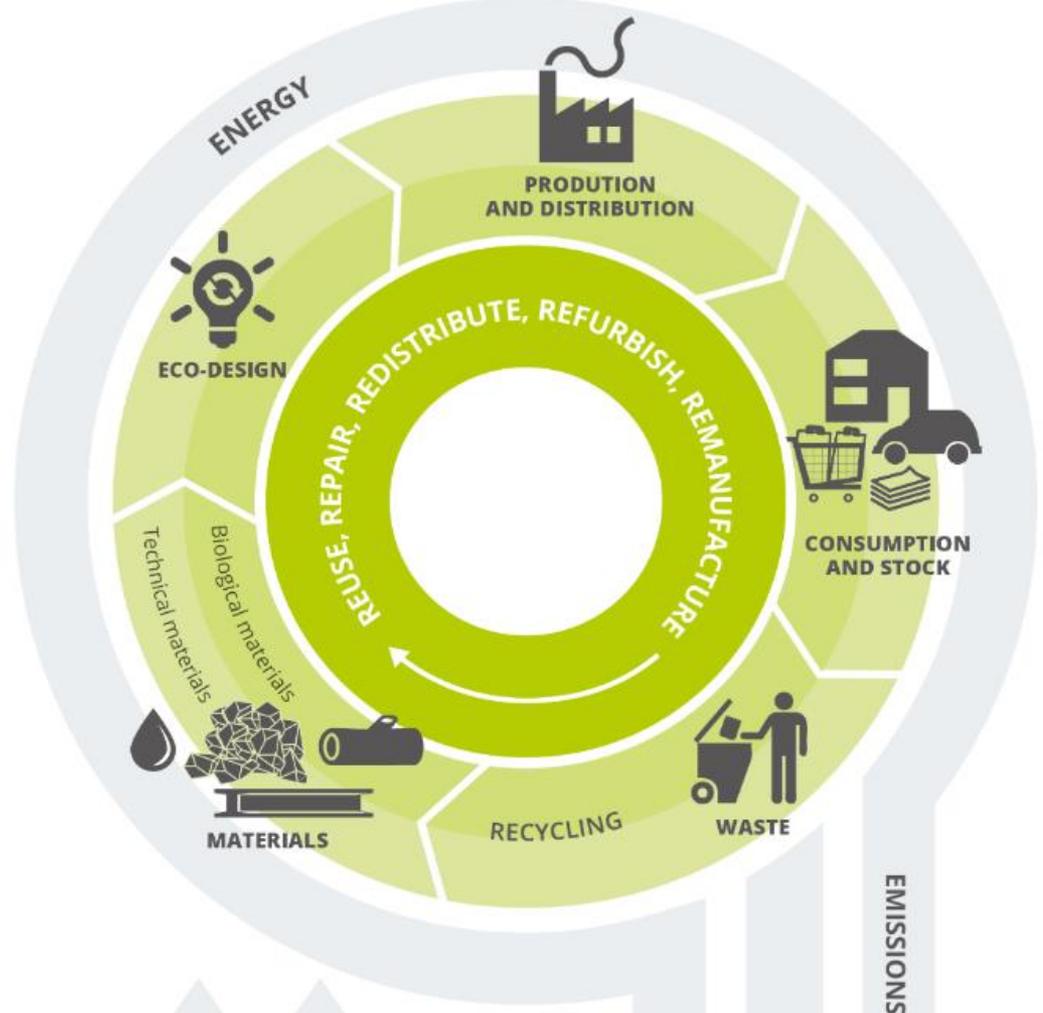
## The concept of essential use

Ian Cousins, Gretta Goldenman, et al., June 17, 2019



Category	Definition	PFAS examples
1	Uses that are not essential for health and safety, and the functioning of society. The use of substances is driven by market opportunity.	Dental floss, water repellent surfer shorts, ski waxes
2	Uses regarded as essential by society because they perform important functions, but where alternatives have now been developed that have equivalent functionality.	Most uses of AFFFs, certain water-resistant textiles
3	Uses considered essential for health or safety or for important purposes <i>and</i> for which alternatives are not yet established. There should be a constant search for alternatives to move these uses into Category 2	Certain medical devices, occupational protective clothing

# For a Circular Economy, Avoid Hazardous Substances



Minimise



EXTRACTION AND IMPORT OF NATURAL RESOURCES, INCLUDING ENERGY CARRIERS



INCINERATION LANDFILL

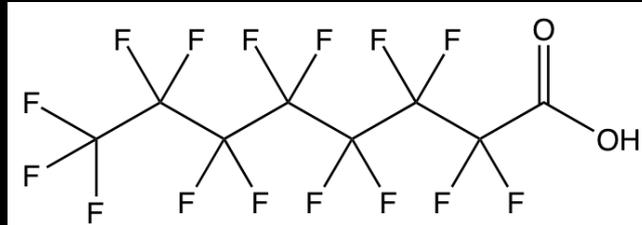
EMISSIONS

Products with toxics should be land filled or destroyed.

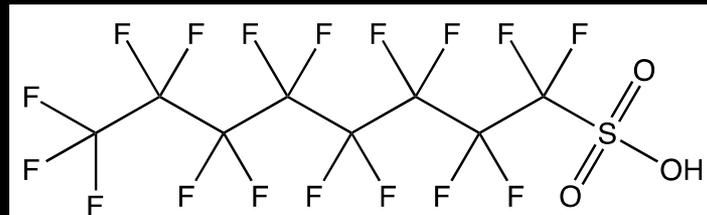
# PFAS

(Per- and polyfluoroalkyl substances)

PFOA  
(C8)



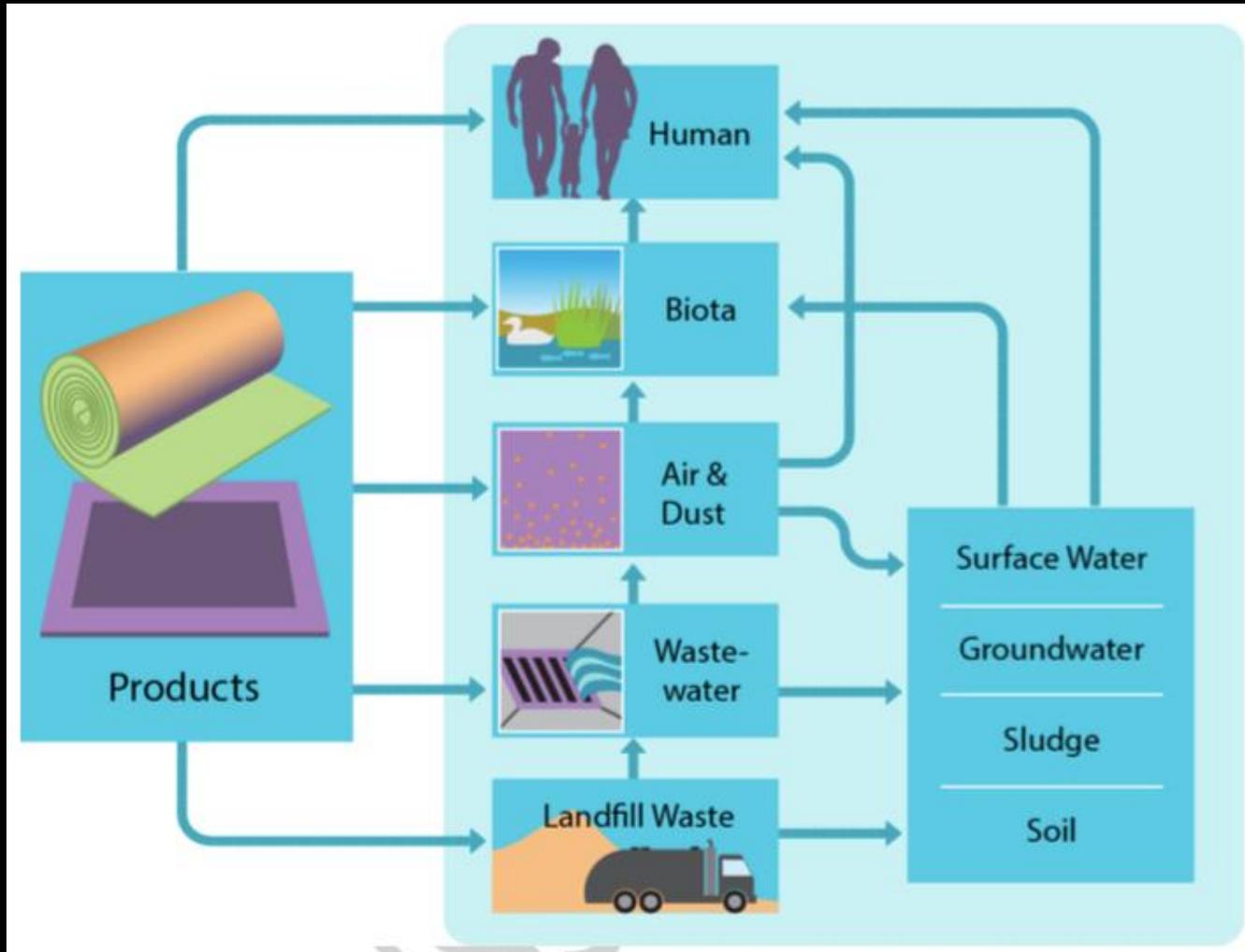
PFOS  
(C8)



Carbon-Fluorine bond strength:

- Leads to oil and water repellency
- “Forever chemicals” -- last for geologic time!

# Pathways to the Environment

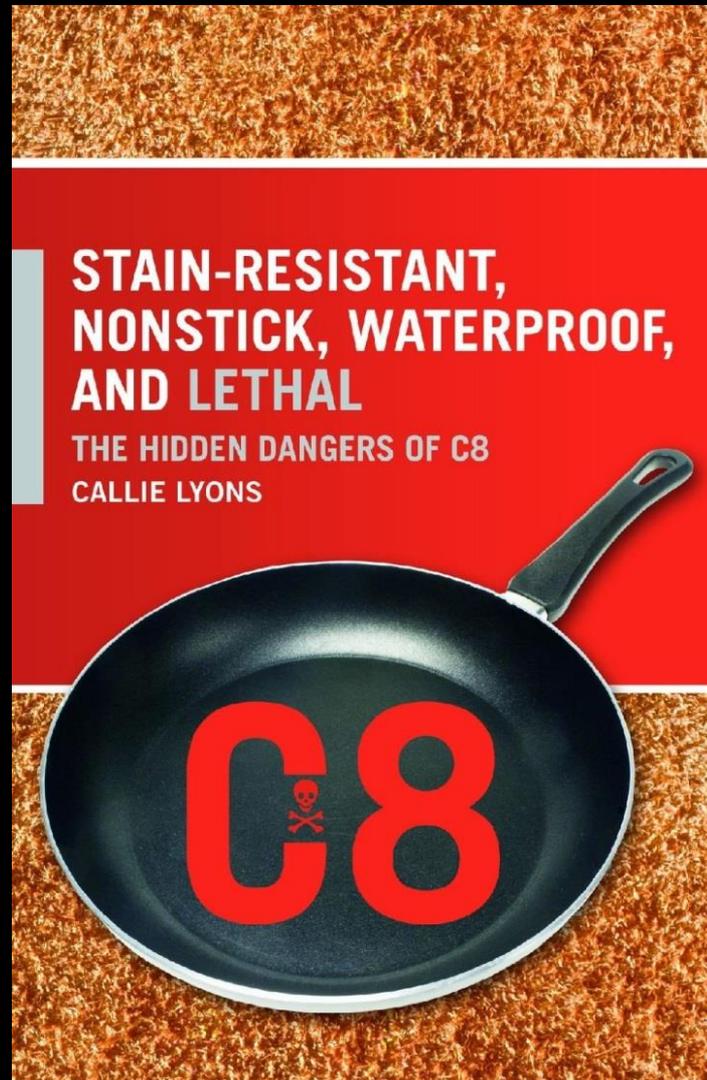


From California DTSC: Product-Chemical Profile for PFAS in Carpets and Rugs





Published 2007



# May 2000

## 3M Employee Bulletin

Date: 05/16/2000

### 3M Phasing Out Some of its Specialty Materials

3M will phase out of the perfluorooctanyl chemistry in certain repellents and surfactant products by the end of this year. We thank the people in these business units for their hard work. They have consistently given the company and our customers their best efforts. For more information, below is a news release issued this morning:

-----  
**ST. PAUL, Minn -- May 16, 2000** -- 3M today announced it is phasing out of the perfluorooctanyl chemistry used to produce certain repellents and surfactant products.



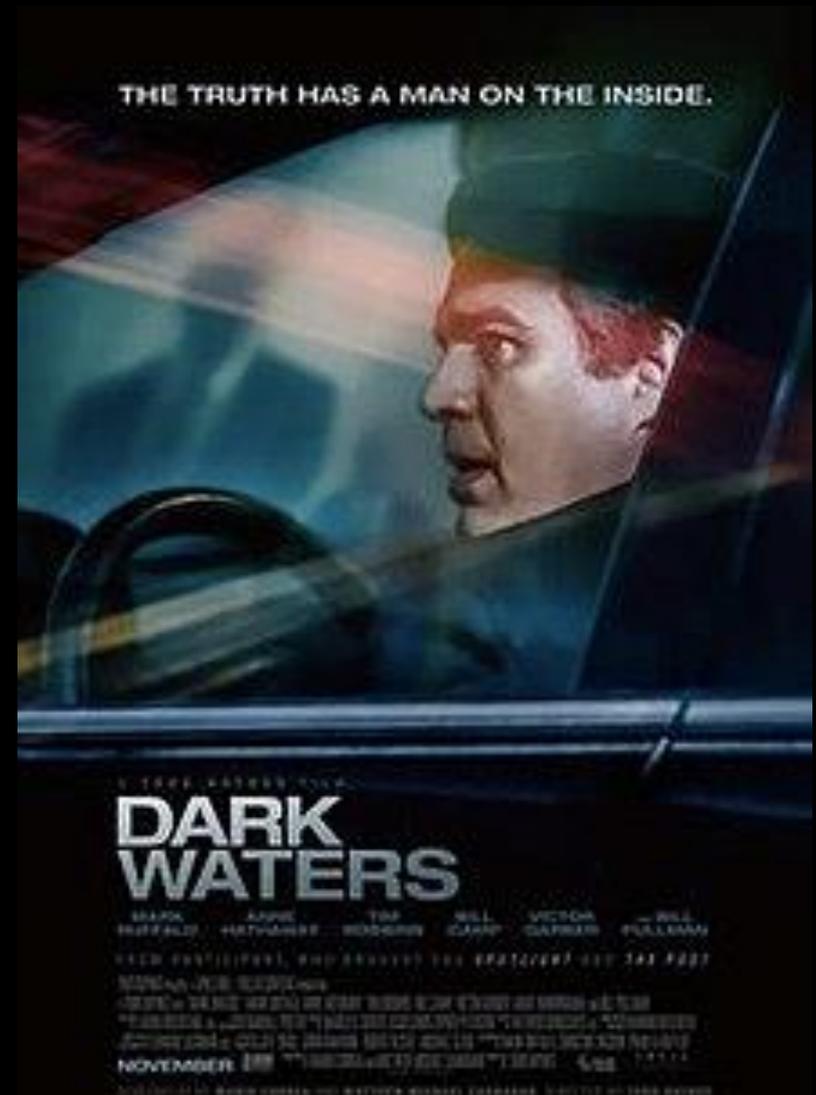
# Ohio River Valley: West Virginia Manufacturing Plant

- PFOA used to manufacture Teflon
- Releases to water & air
- 70,000 + residents with contaminated drinking water
- C8 Health Study



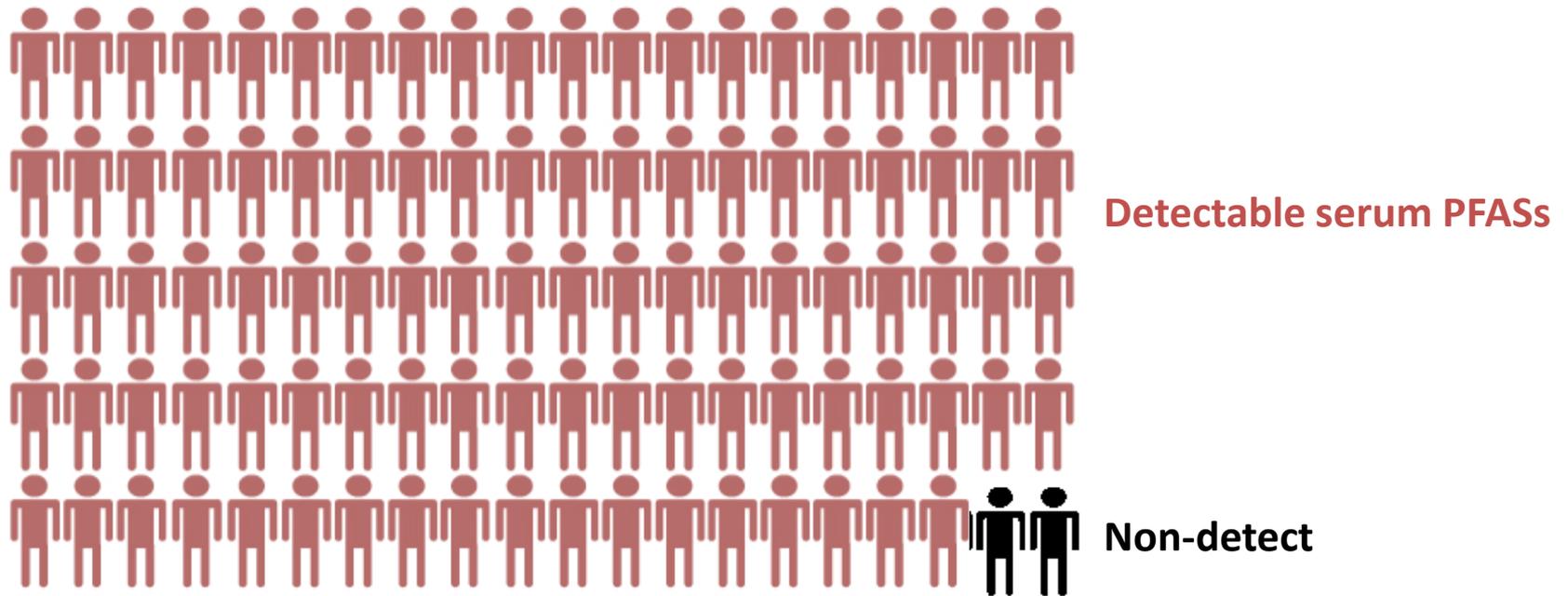
# See the film *Dark Waters*

- The story of attorney Rob Bilott, who uncovered massive PFOA contamination from a DuPont factory in WV



# PFAS exposure is a health concern

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Exposure linked to health risks:

Cancer, elevated cholesterol, obesity, immune suppression, and endocrine disruption

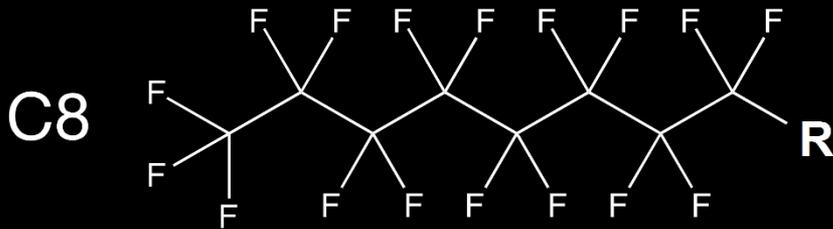
Courtesy, Cindy Hu, Harvard University

(Ref: Lewis et al., 2015; Grandjean et al., 2012; Braun et al., 2016; Barry et al., 2013)

# A Health History of PFOA & PFOS

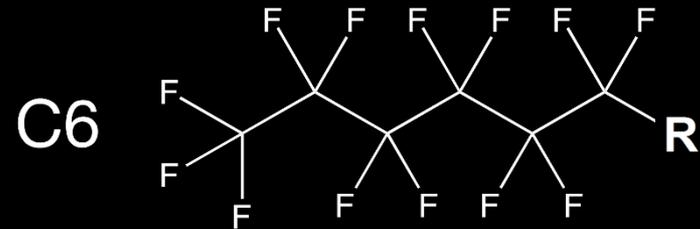
- 1961: DuPont toxicologist warns PFOA is toxic to animals and worker contact should be avoided
- 1975-1976: PFOA discovered in blood of general population and production workers;
- 1978: Immunotoxicity of PFOA & PFOS observed in monkeys
- 1981: PFOA found in umbilical cord blood of infants of female worker
- 1992: Leukocyte cell count changes in PFOA production workers
- 1998: PFOS found in blood from the general population
- 2000: 3M announces voluntary phase out of PFOS
- 2010-2015: DuPont & others finish phase out of PFOA

# “Regrettable” Substitution?



## Long chain:

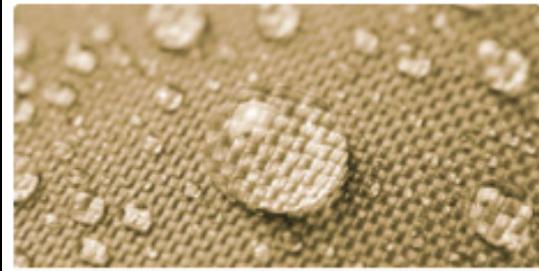
- Extreme persistence
- Bioaccumulation
- Toxicity



## Short chain:

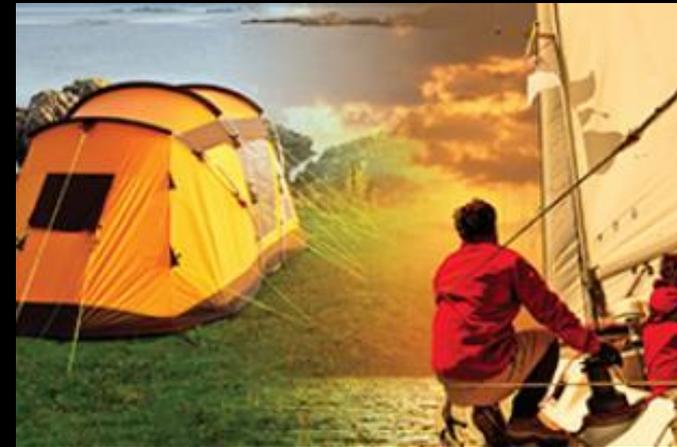
- Extreme persistence
- Build-up in plants
- Suspected toxicity
- More mobile
- Clean up more difficult
- Harder to measure & monitor

# AGC – THE FIRST COMPANY TO FULLY CONVERT TO PFOA-FREE\* WATER AND OIL REPELLENT



AsahiGuard® E Series is a fluorinated water and oil repellent providing sustainable alternatives for many applications, including paper packaging, textiles, apparel, non-wovens, natural and synthetic leathers and home furnishings based on proven AGC C6 chemistry. AsahiGuard E-Series offers high performance

C6 chemistry.



- “C6 polymers are proven safe for their intended use”
- “Evaluated by regulators, showing they are safe and effective”
- “C6 polymers cannot break down to C8”

# May 2015 The 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.”

Signed by 230 scientists from 40 countries

2015: Environmental Health Perspectives

# 2015-16

The Opinion Pages | OP-ED COLUMNIST

The New York Times

## Chemicals in Your Popcorn?

JUNE 4, 2015



Nicholas Kristof

What do a pizza box, a polar bear and you have in common?

All carry a kind of industrial toxicant called poly- and perfluoroalkyl substances, or PFASs, that do two things: They make life convenient, and they also appear to increase the risk of cancer.

## These Chemicals in Pizza Boxes and Carpeting Last Forever

More than 200 scientists around the world document the threats of perfluorinated compounds and call for more government control.

By Lindsey Konkel, National Geographic  
PUBLISHED MAY 01, 2015



The Intercept

## THE TEFLON TOXIN

DuPont and the Chemistry of Deception



Sharon Lezner

Aug. 11 2015, 3:35 p.m.



133

Home

The New York Times Magazine

## The Lawyer Who Became DuPont's Worst Nightmare

Rob Bilott was a corporate defense attorney for eight years. Then he took on an environmental suit that would upend his entire career — and expose a brazen, decades-long history of chemical pollution.

By NATHANIEL RICH JAN. 6, 2016



# Letter from NY Department of Health to US EPA



Department of  
Environmental  
Conservation

Department  
of Health

January 14, 2016

The Honorable Gina McCarthy  
Administrator  
USEPA Headquarters  
William Jefferson Clinton Building  
1200 Pennsylvania Avenue, N. W.  
Mail Code: 1101A  
Washington, DC 20460

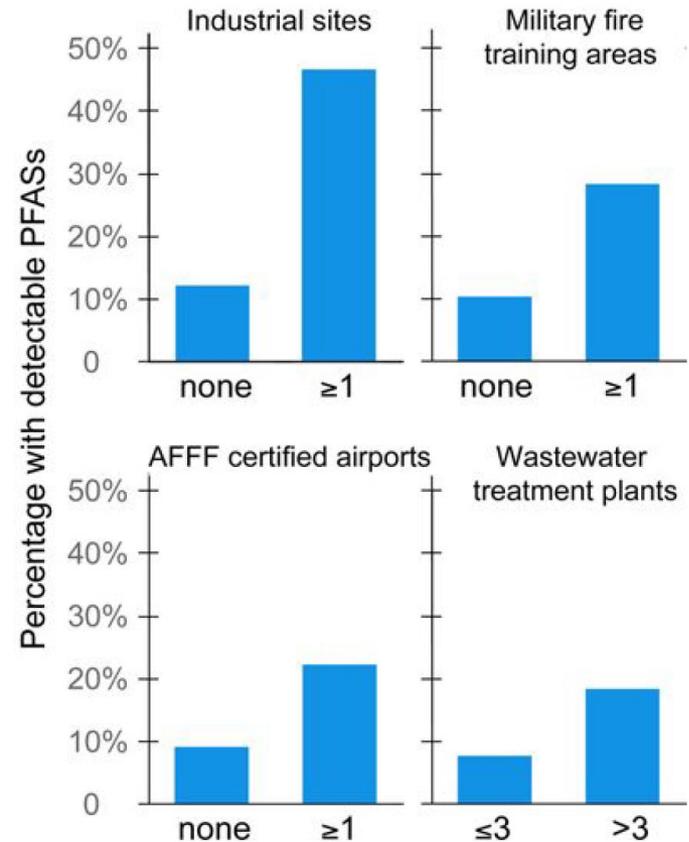
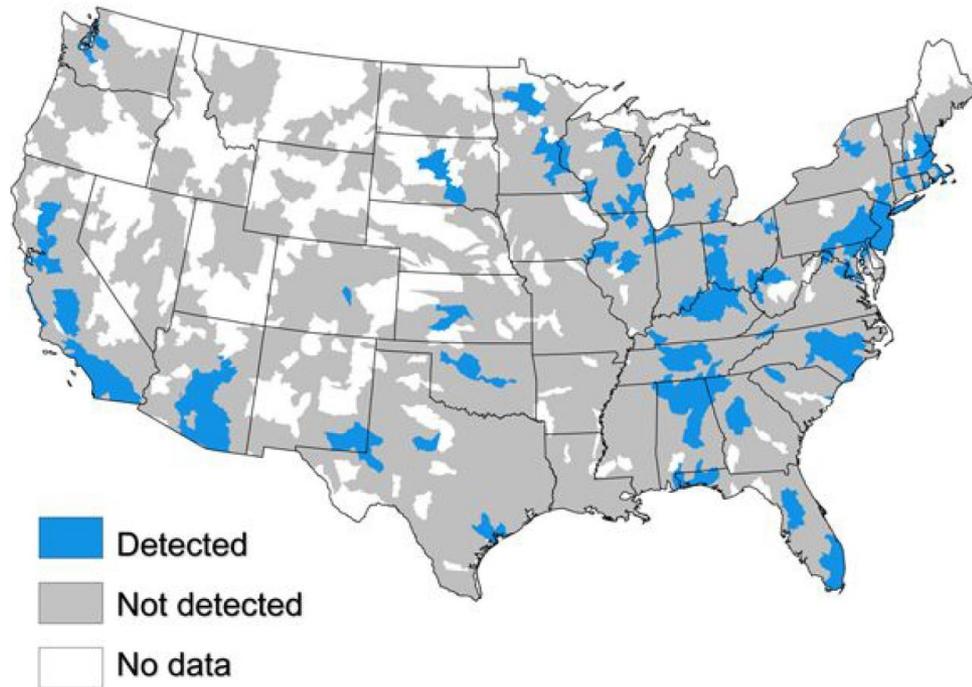
Dear Administrator McCarthy:

We write to you to request that EPA take vigorous action to address the presence of perfluorooctanoic acid (PFOA) in drinking water and groundwater. Respectfully, we ask that EPA:

- lower its provisional health advisory of 400 parts per trillion (ppt) for PFOA drinking water to take into account the most current scientific evidence;
- act expeditiously to adopt a protective maximum contaminant level for PFOA;
- expeditiously list PFOA as a hazardous substance under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) to facilitate the cleanup of contaminated groundwater and other media; and
- review the remaining uses of PFOA under the Toxic Substances Control Act and curtail it whenever less toxic alternatives are available.

# EPA Lifetime Health Advisory Level: 70 ng/L PFOA + PFOS

## Hydrological units with detectable PFASs



# Drinking Water Health Guidelines for PFOA

(parts per trillion)

DuPont  
5000

DuPont  
1000

U.S. EPA  
400

U.S. EPA  
70

NJ: 14  
MN: 35

MI, NH, WA  
Ranging 8-20

1987

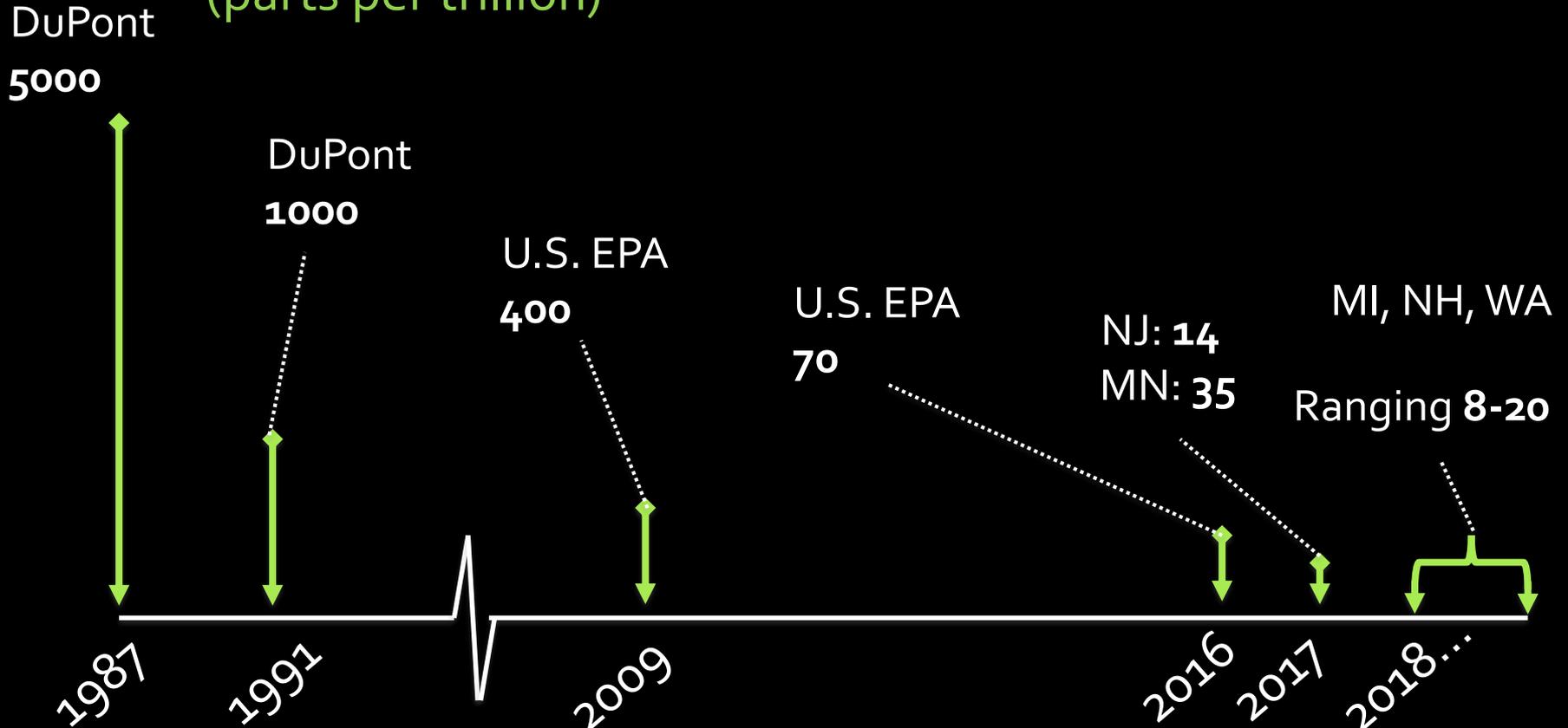
1991

2009

2016

2017

2018...





# February 2020 California Drinking water

PFOA 10 ppt,

PFOS 40 ppt

OEHHA is currently developing Public Health Goals

September 24, 2020

## Massachusetts adopts drinking water standard for 6 PFAS

- 20 ppt limit for sum of PFOA, PFOS, PFDA, PFNA, PFHpA, PFHxS
- Public water supplies required to test beginning 2021
- State providing grants to impacted water systems



<https://www.mass.gov/news/baker-polito-administration-establishes-strict-standards-for-pfas-in-drinking-water-to-protect>

## Scientific Basis for Managing PFAS as a Chemical Class

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

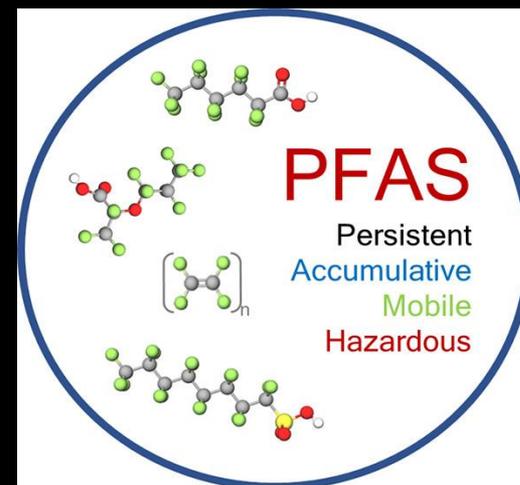


Cite This: <https://dx.doi.org/10.1021/acs.estlett.0c00255>



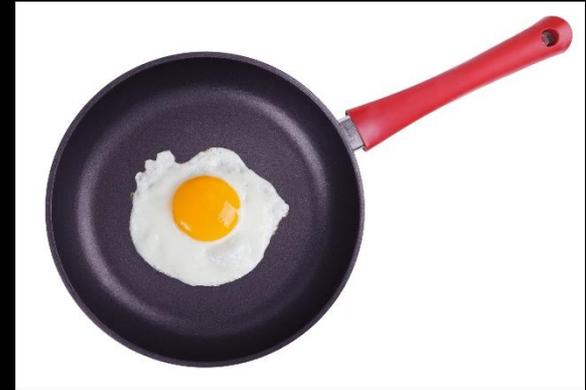
Read Online

- Extreme persistence and potential toxicity make all PFAS suspect
- Not enough time to study them all
- Avoid their use when possible

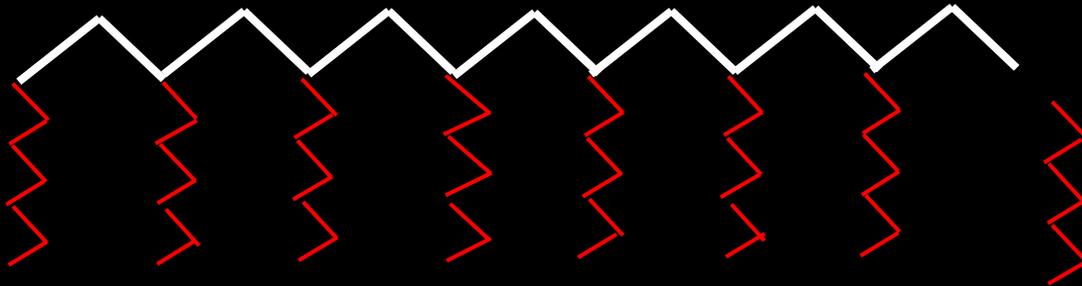


# Polymer Problems

1. Polymer production (Teflon, Gortex etc.) is a major source of air & water contamination.



2. Side chain polymers can break off and cause harm.



# PFAS Polymers Breakdown

**ENVIRONMENTAL**  
Science & Technology

Article

[pubs.acs.org/est](https://pubs.acs.org/est)

## Abiotic Hydrolysis of Fluorotelomer-Based Polymers as a Source of Perfluorocarboxylates at the Global Scale

John W. Washington<sup>\*,†</sup> and Thomas M. Jenkins<sup>‡</sup>

<sup>†</sup>USEPA, National Exposure Research Laboratory, 960 College Station Road, Athens, Georgia 30605-2700, United States

<sup>‡</sup>USEPA, Senior Environmental Employment Program, Athens, Georgia 30605-2700, United States

**S** Supporting Information

Fluoropolymer breakdown leads to PFAS in the environment.

# New Mexico

- Cannon Air Force Base
  - Firefighting foam entered groundwater
  - PFAS migrated from base to dairy wells to cows to milk



- PFOS level up to 12,000 ppt
  - 171 times EPA health advisory level!
- Feb. 10, 2020: discovered in Clovis drinking water

# Michigan

- Wolverine treated leather with Scotchguard (PFOS)
  - Leather scrap dumped
  - Sludge applied to fields
- PFOA + PFOS up to 58,000 ppt  
842 times EPA health advisory level!

Feb. 2020:

- Wolverine to pay Michigan \$69.5 million
- 3M to pay Wolverine \$55 million

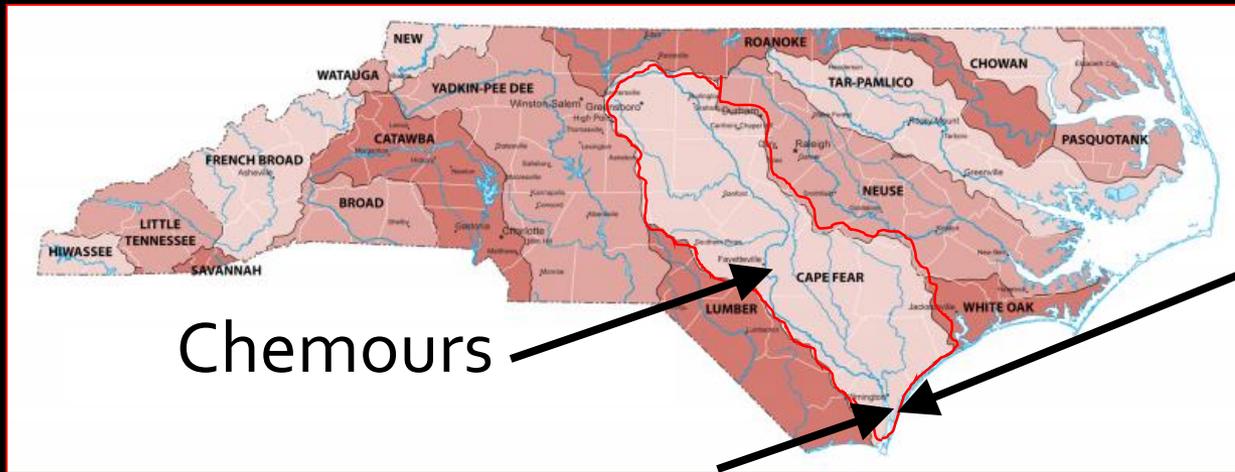


# What to do with PFAS-contaminated soil?



- “Cannot be disposed of at a landfill, cannot be re-located, so the soil pile just sits there waiting for ...a treatment technology...very expensive.”

# Water Treatment Costs: North Carolina



Chemours

Brunswick County:  
reverse osmosis  
filtration for 25,000  
customers:  
-\$99M to build  
-\$2.9M to operate

Cape Fear Public Utility Authority activated  
carbon filtration plant:

-\$46M to build

-\$2.7M to operate each year

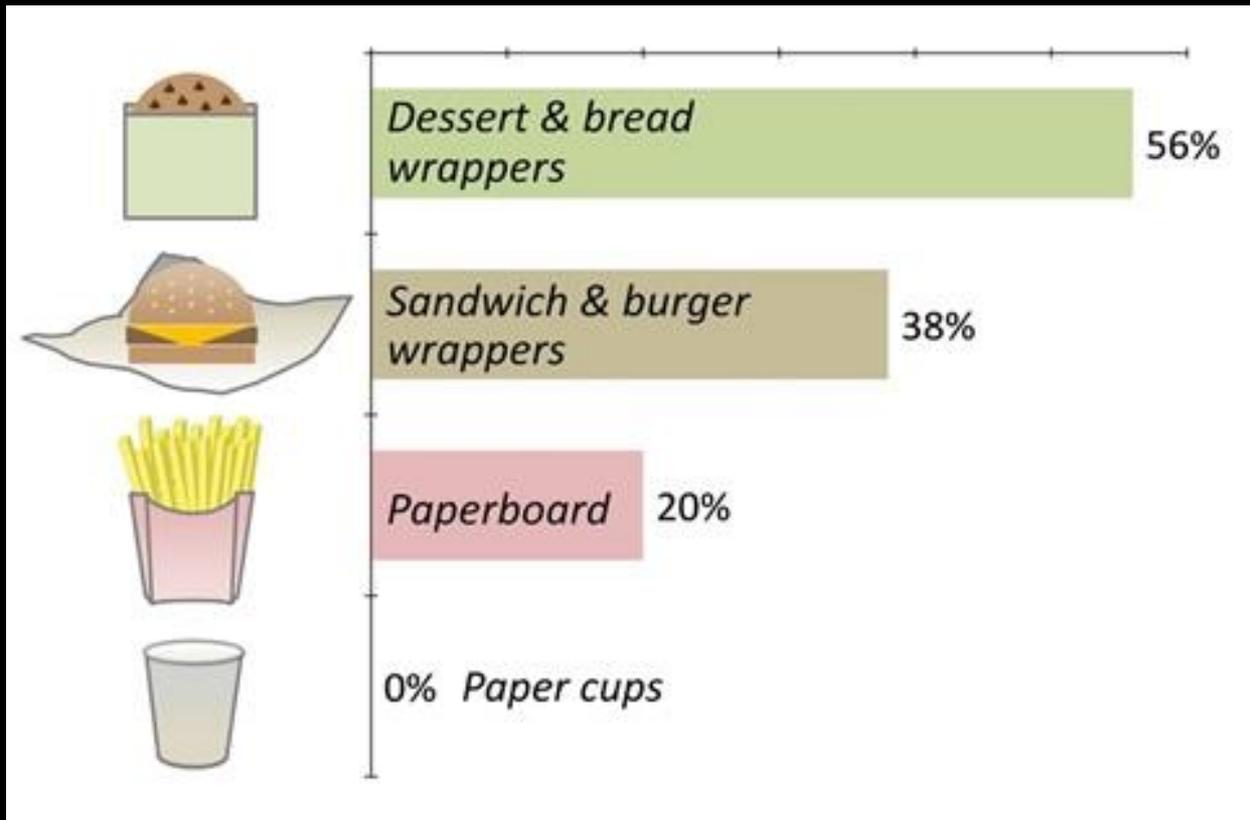
Wilmington Star News,  
May 9<sup>th</sup> and 10<sup>th</sup>, 2018

PFAS are Problematic  
& Difficult to Clean Up

Product Stewardship &  
Prevention is Preferable!

# Fluorine in U.S. fast food packaging paper

(percent positive; 400 products sampled)



Adopted from Schaidler L. 2016 *Fluorinated compounds in U.S. fast food packaging*.

Should these products be considered compostable?

**CNN** @CNN Follow

Researchers found fluorinated chemicals in one-third of the fast food packaging they tested, according to a report [cnn.it/2jWU6Rw](http://cnn.it/2jWU6Rw)



RETWEETS 237 LIKES 205

6:20 AM - 1 Feb 2017

47 237 205

**Washington Post** @washingtonpost Follow

Researchers find "another reason" to avoid fast food: Chemicals in the packaging



Researchers find 'another reason' to avoid fast food: Chemicals in the packa...  
Substances with links to health problems have been found in wrappers and containers, where they can leach into food.  
[washingtonpost.com](http://washingtonpost.com)

RETWEETS 141 LIKES 106

**Mother Jones** @MotherJones Follow

The Nasty Ingredient in Fast-Food Wrappers  
[mojo.ly/2jCPzA4](http://mojo.ly/2jCPzA4)



RETWEETS 19 LIKES 22

5:09 AM - 1 Feb 2017

19 22

**United States Senate**  
WASHINGTON, DC 20510

March 9, 2017

Mr. Daniel S. Schwartz  
Chief Executive Officer  
Restaurant Brands International Inc.  
226 Wycroft Road,  
Oakville, Ontario L6K 3X7,  
Canada

Dear Mr. Schwartz:

We write to inquire about Burger King's use of potentially harmful fluorinated chemicals in food wrappers, bags, boxes, or other kinds of food packaging. Per and polyfluoroalkyl substances (PFASs) represent a class of chemicals sometimes used in fast food packaging to prevent grease and sauces from seeping through packaging. These chemical compounds have been

# Microwave Popcorn Bags

- High PFAS concentrations <sup>1-4</sup>
- Coop Denmark - halted popcorn sales in 2015 due to PFAS
- RESULT: PFAS-free popcorn bags



1. Zabaleta, I., et al. *Talanta*. 152, 353-363. (2016)
2. Zafeiraki, E., et al. *Chemosphere*. 94, 169-176. (2014)
3. Dolman, S. and Pelzing, B. J. *Chrom. B.* 879:22, 2043-2050. (2011)
4. Begley, T. H., et al. *Food Add. and Cont.* 22:10, 1023-1031. (2005)

# Denmark bans all PFAS in paper and paperboard food packaging

- “I do not want to accept the risk of harmful [PFAS] migrating from the packaging and into our food. These substances represent such a health problem that we can no longer wait for the EU.”

- Danish Food Minister Mogens Jensen



• <https://www.cnn.com/2019/09/04/health/denmark-pfas-food-packaging-ban-intl/index.html>

# PFAS and Carpet

- PFAS-treated carpet linked to high PFAS blood levels

**ENVIRONMENTAL**  
Science & Technology

Article

[pubs.acs.org/est](https://pubs.acs.org/est)

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

Sanjay Beesoon,<sup>†</sup> Stephen J. Genuis,<sup>‡</sup> Jonathan P. Benskin,<sup>†,§</sup> and Jonathan W. Martin<sup>\*,†</sup>

<sup>†</sup>Division of Analytical and Environmental Toxicology, Department of Laboratory Medicine and Pathology, University of Alberta, Edmonton, AB, Canada

<sup>‡</sup>Department of Medicine, University of Alberta, Edmonton, AB, Canada

 Supporting Information

# Moving away from PFAS in carpet

- Major manufacturers phasing out PFAS
  - 2014 – Interface
  - 2017 – Tarkett
  - 2019 – Engineered Floors
  - 2019 – Shaw

## Home Depot plans to phase out selling rugs and carpets containing PFAS

By VIRGINIA GORDAN • SEP 17, 2019

[Share](#) [Tweet](#) [Email](#)



CREDIT ANDREI / ADOBE STOCK

The Home Depot announced Tuesday that it will stop buying from its suppliers any rugs and carpets that contain [PFAS chemicals](#).

"Excluding PFAS from the carpets and rugs we sell is another example of our shared commitment to building a better future for our customers and the planet,"

Ron Jarvis, The Home Depot's vice president for environmental innovation, said in a written statement.

Michigan Radio, Sept. 17, 2019

# BRANDS ARE ELIMINATING HIGHLY FLUORINATED CHEMICALS

IKEA

H&M

Crate&Barrel

LEVI STRAUSS & CO.

PUMA

benetton

ESPRIT

adidas

MARKS &  
SPENCER

MANGO

BURBERRY<sup>®</sup>  
LONDON

ZARA

# 2018 FAA Reauthorization

- Directs FAA to allow airports to use PFAS-free Class B firefighting foams
- Signed into law Oct. 5, 2018



# 2020 National Defense Authorization Act

- Require military to phase PFAS out of firefighting foams
- USGS nationwide water sampling
- Require reporting from PFAS manufacturers
- Authorize Air Force to compensate for contaminated agricultural lands
- Prohibit fluorinated packaging in meals ready to eat
- Continue funding health studies in impacted communities



# Europe to adopt total PFAS drinking water standard

- 2020: group standard for 20 PFAS
- Next 3 years: develop analytical method for total fluorine
- Testing to begin in 2021-2022



# Towards a PFAS Phase-out in Europe

- Proposal from Sweden, Netherlands, Germany, Denmark:
- Take action “on the EU-level to phase out PFASs at the latest by 2025, to be in effect by 2030.”



# Moving away from PFAS



CARPETS



CARPET CLEANING PRODUCTS



FOOD PACKAGING



FURNISHINGS



COSMETICS



OUTDOOR GEAR



CLOTHING



ADHESIVES AND SEALANTS



PROTECTIVE COATINGS



NON-STICK COOKWARE



CARSEATS



FIREFIGHTING FOAM



## PFAS Central: sharing notable news, scientific papers & events



NEWS

### PFAS Chemicals to be Banned in Firefighting Foam Used on Military Bases

U.S. Senator Kirsten Gillibrand today announced that a provision she cosponsored to prohibit the Department of Defense from procuring firefighting foam that contains per- and polyfluoroalkyl substances (PFAS) passed the Senate Armed Services Committee as part of the annual National Defense Authorization Act (NDAA).

[LEARN MORE](#)



SCIENCE

### Larval amphibians rapidly bioaccumulate poly- and perfluoroalkyl substances.

Toxic frogs lead to bioaccumulation in predator species.

[LEARN MORE](#)



POLICY

### The Cost of Inaction: A socioeconomic analysis of environmental and health impacts linked to exposure to PFAS

A recent Nordic Council study, The Cost of Inaction: A socioeconomic analysis of environmental and health impacts linked to exposure to PFAS, estimates the very high cost of harm to human health and the environment from PFAS exposure in Europe.

[LEARN MORE](#)

Although useful, PFAS or highly fluorinated chemicals are associated with serious health harm and can remain in the environment forever.

[LEARN MORE](#)

# Six Classes Videos

1

Highly  
Fluorinated



2

Antimicrobials



3

Flame  
Retardants



4

Bisphenols  
+ Phthalates



5

Some  
Solvents



6

Certain Metals



[www.SixClasses.org](http://www.SixClasses.org)



For monthly e-newsletters:  
[PFASCentral.org/Newsletter](http://PFASCentral.org/Newsletter)

**Questions:**  
[Arlene@GreenSciencePolicy.org](mailto:Arlene@GreenSciencePolicy.org)

**By limiting use of the PFAS**

**We can have a healthier world.**

**[GreenSciencePolicy.org](https://www.GreenSciencePolicy.org)  
[PFASCentral.org](https://www.PFASCentral.org)**

Extra slides

# Drinking water: California



August 2019: Notification levels dropped

- PFOS: 13 ppt → 6.5 ppt
- PFOA: 14 ppt → 5.1 ppt

Feb. 2020: Response levels dropped

- Formerly: (PFOA + PFOS) 70 ppt
- Now: PFOA 10 ppt, PFOS 40 ppt

OEHHA developing Public Health Goals

# CA Water Board PFAS Investigation

Announced March 2019

- Phase 1: airports, landfills, and nearby drinking water wells
- Phase 2: Refineries, fuel terminals, fire training locations, urban wildfire areas
- Phase 3: Wastewater treatment plants

July 9, 2020:

- Investigative order to ~250 POTWs (> 1 mgd)
- 31 PFAS compounds
- Beginning Q4 2020, to last 1 year

# PFAS & Wastewater Treatment

- Are WWTPs sources of PFAS?



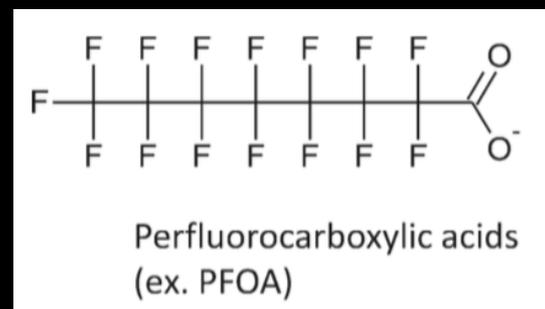
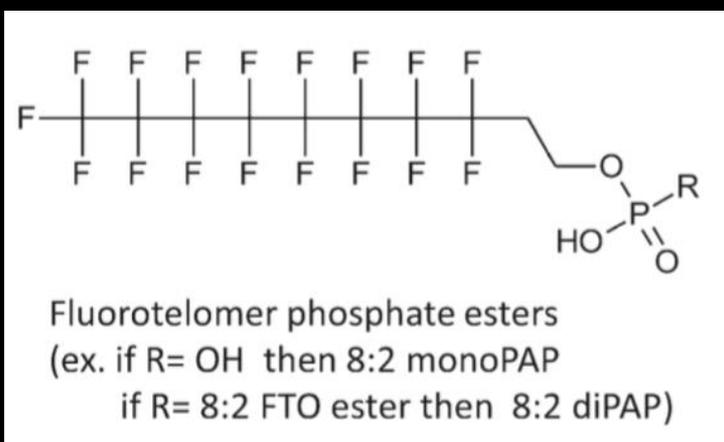
# Sources of PFAS Emissions

- Industrial
  - Plants that produce PFAS
  - Plants that use PFAS
- Firefighting foam
  - Military bases, airports, etc.
- Landfills
- Consumer products\* – carpets, apparel, food packaging, cosmetics, other

High input = high output.  
Industrial sources &  
firefighting foam are  
important.

# Conventional treatment trains not effective

- Perfluoroalkyl acids (PFOA, PFOS, etc.) resistant to biodegradation
- Aerobic treatment oxidizes precursor compounds, generating more perfluoroalkyl acids
- Effluent > Influent



# From WWTPs to the Environment: Biosolids

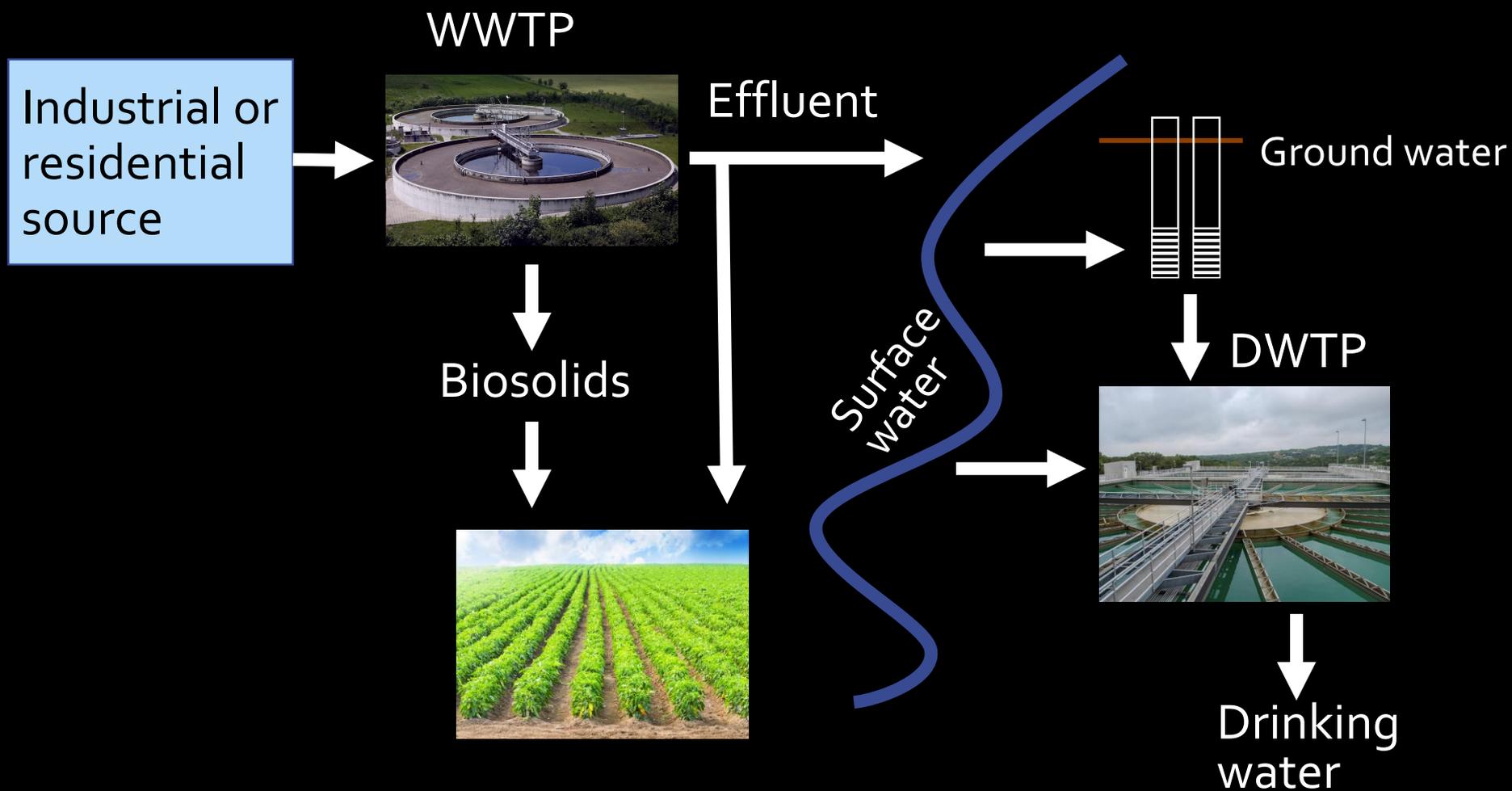
- Partitioning to biosolids
  - Long-chains > short-chains
- 2013 study: 10 out of 13 PFAS analyzed consistently detected in US municipal biosolids samples
- Potential for accumulation in agricultural soils & uptake to food crops

# From WWTTPs to the Environment: Effluent

- Can be Problematic for downstream users,  
example: Orange County has wells with PFAS
  - Possible source: treated wastewater from Inland Empire entering groundwater through Santa Ana River
  - OCWD expects to shut down 1/3 of its 200 wells this year due to PFOA & PFOS

See Orange County Register, Jan. 17, 2020

# PFAS Fate



# PFAS Treatment



## Drinking Water:

- Granular activated carbon
- Ion exchange
- Reverse osmosis



## Wastewater:

- Advanced treatment

## Biosolids:

- Industrial pretreatment