THE Water Research FOUNDATION

The Science of Per- and Polyfluoroalkyl Substances (PFAS)

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FATE AND EFFECTS OF PER- AND POLYFLUORINATED ALKYL SUBSTANCES

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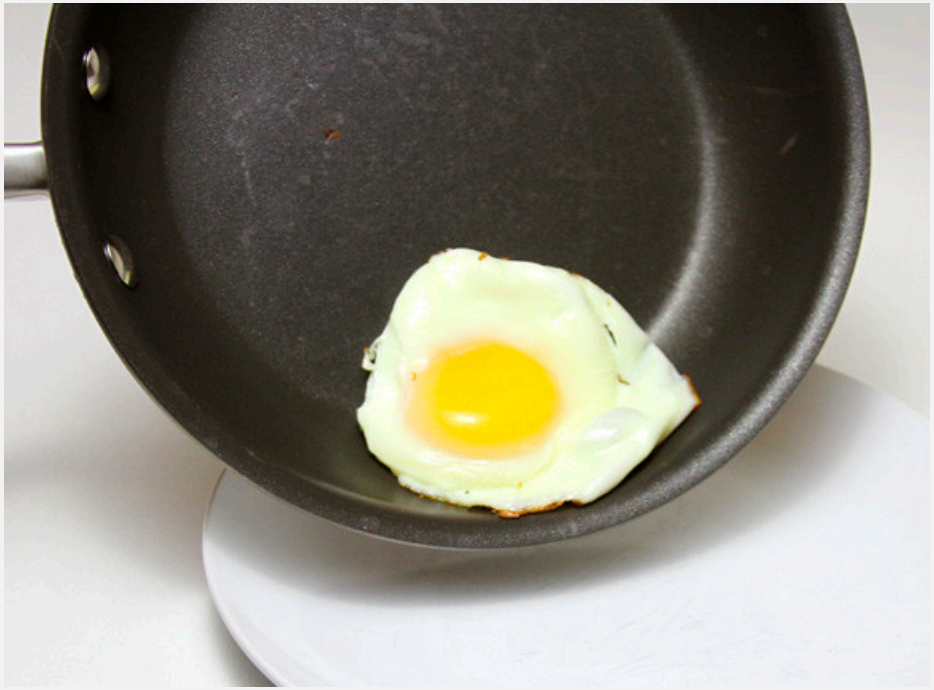
WRF Congressional briefing on the Science of PFAS

Thursday, September 26, 2019

PFAS: PER AND POLYFLUOROALKYL SUBSTANCES



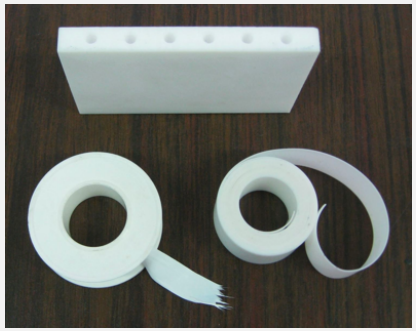
"nonstick chemicals"

PFAS ARE EVERYWHERE

As part of regular national biomonitoring surveys, CDC scientists found four PFAS (PFOS, PFOA, PFHxS, and PFNA) in the serum of nearly everyone tested nationwide, indicating the U.S. population has been widely exposed. You can view the report and all the results collected since 1999 at: https://www.cdc.gov/exposurereport/

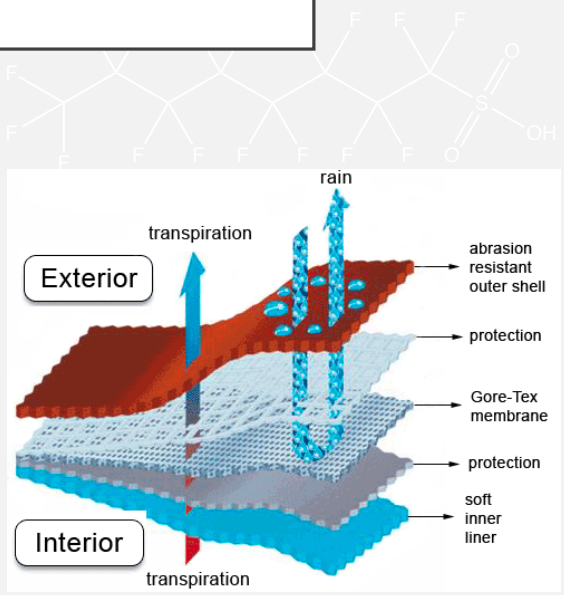
PFAS refers to the class. The different acronyms within the class (PFOS, PFOA, PFHxS, and PFNA) refer to different structures and chain lengths, which can influence their distribution in the environment, their potential toxic impacts, and how long they stay in the human body.

WHERE ARE THEY COMING FROM?



Teflon manufacturing, use and end-of-life.

AFFF testing, use, and end-of-life[1]

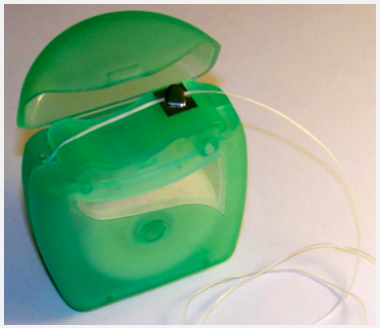


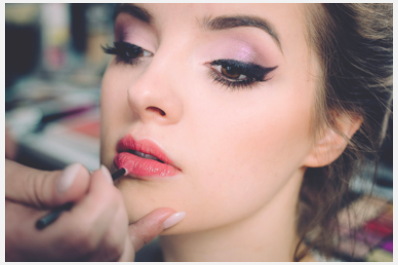
Gore-Tex, Scotchguard, other fabric and surface treatments (incl. impregnation sprays)

"nonstick chemicals" – legacy substances

[1]See References on last slide for image sources.

WHERE (ELSE) ARE THEY COMING FROM?





Food contact materials, furnishings (carpets, treated fabrics), cleaning products, pharmaceuticals and personal care products (including makeup).

HOW PEOPLE ARE EXPOSED

If you live near a contaminated site, drinking water is usually the major exposure route.

Without drinking water contamination*, food is usually the major source.

Research is ongoing to better understand other sources (e.g. indoor exposures via cleaning/ personal care products, carpets, outdoor air).

*most water has low levels of PFAS; contaminated sites have high levels

HOW DID WE GET HERE?

- Standard approach for chemical hazard assessment:
  - P : persistence ✓
  - B : bioaccumulation
  - T: toxicity

?

Understanding PFAS bioaccumulation potential and toxicity required new approaches, because standard paradigms failed.

UNIQUE PROPERTIES REQUIRE NEW METHODS

- Prior to PFAS attention, regulatory methods relied largely on partitioning.

- PFAS don't partition, they *distribute*.
- Driven by protein binding.
- Leads to their unique behavior in the environment and in organisms.

WHAT ARE THE HEALTH CONCERNS?

EPIDEMIOLOGICAL STUDIES

PFAS disrupt lipid metabolism and have a variety of health effects likely linked to this mechanism.

- Certain PFAS can cause liver damage, and are associated with increases in total cholesterol and LDL (sometimes referred to as "bad cholesterol").
- Blood levels of PFOA and PFOS are associated with an increased risk of thyroid disease.
- Blood levels of PFOA and PFOS are associated with pregnancy-induced hypertension and pre-eclampsia (high blood pressure).

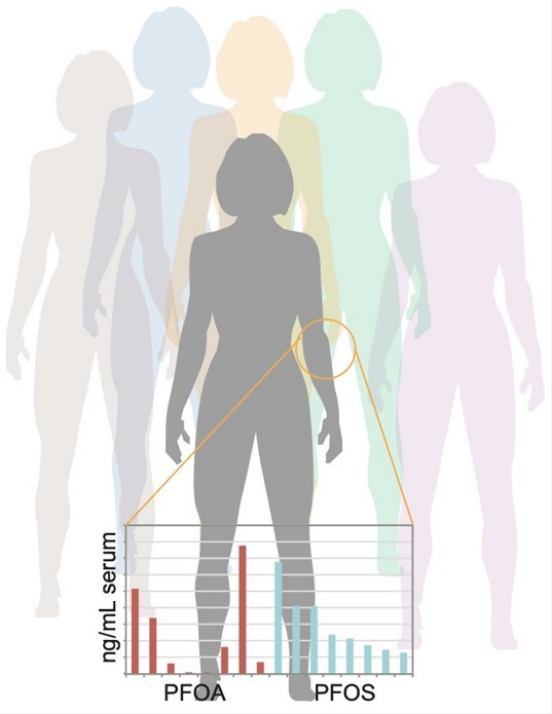
EPIDEMIOLOGICAL STUDIES

PFAS can have developmental effects, and are known to be transferred through breast milk, cord blood, and the placenta.

- Observations suggest increased risk of reduced fertility.
- Small decreases in birth weight with increasing blood levels of PFOA and PFOS.
- Levels of certain PFAS in the blood are linked to reduced antibody responses to vaccine. This is a type of immune suppression. Possible links with increased risk of asthma have also been found.

CHALLENGES IN EPIDEMIOLOGY

- Not a "controlled experiment."
- Populations have a lot of natural variability.
- May be co-exposed to other chemicals.
- May have other reasons for being vulnerable to a particular condition.
- Could come from "background" population, contaminated site, or occupationally exposed people.



ANIMAL STUDIES*

Based on laboratory experiments:

- Increased liver weight, decreases in serum lipids (may be rodent-specific) degenerative and necrotic effects on liver (may have relevance to humans).
- Reduced response to antigens (immune suppression) – agrees with human population observations.
- Decreases in mammary gland development at very low doses.
- Decreases in body weight of offspring, decreased offspring survival, impacts on locomotor activity (these are all developmental effects).

Consistent observations across human and animal studies:
Effects on lipid metabolism, immune suppression, developmental effects.
Data limited to a small number of compounds, mostly carboxylic and sulfonic acids.

*mostly on rodents

PFAS AND CANCER

Based on human populations:

- Correlations found between PFDA, a long-chain PFAS, and prostate cancer in more than one population (including occupationally exposed).
- Residents near chemical plant in Ohio had higher rates of kidney, testicular, prostate and ovarian cancers.
- In Greenland (Inuit Population) PFAS related to breast cancer risk (with other POPs).

Based on studies in animals:

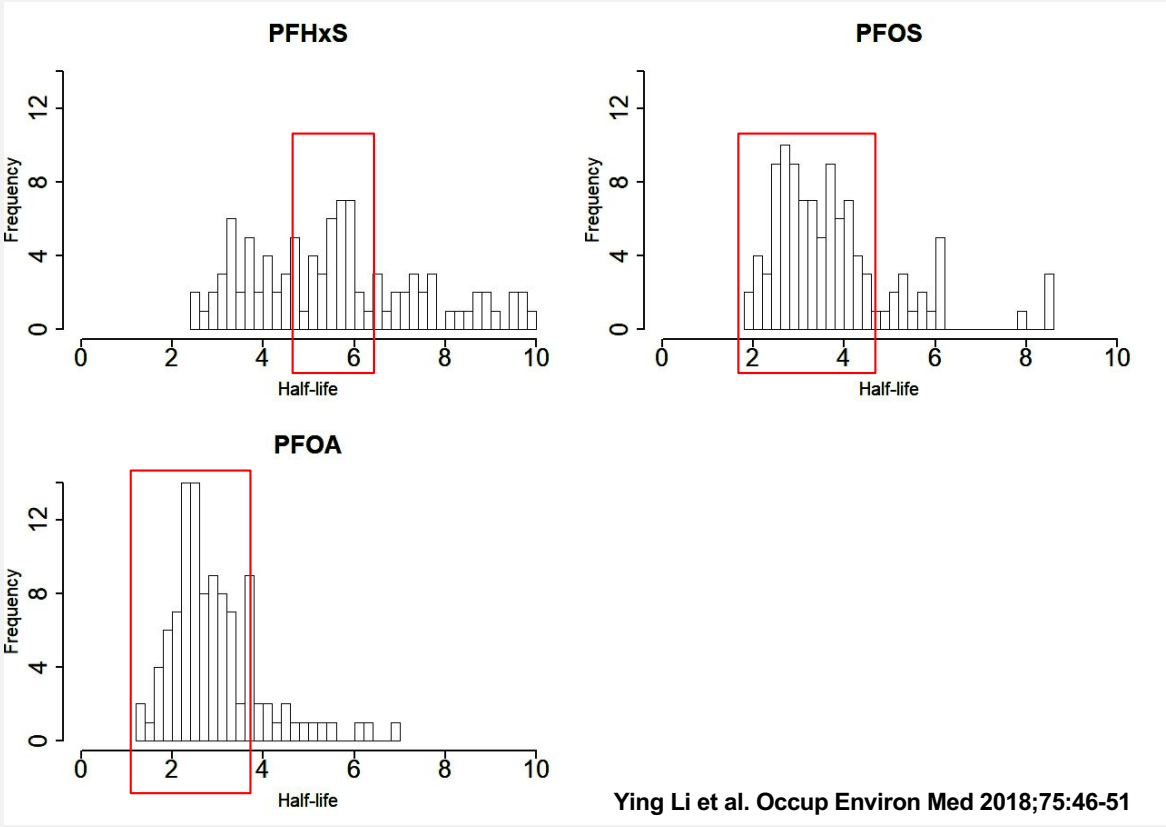
- PFOA associated with testicular, liver and pancreatic cancer in male rats.
- PFOS associated with both liver and thyroid cancers.
- No studies are available for most PFAS.

IARC found PFOA "possibly carcinogenic to humans" based on kidney and testicular cancers.

LONG BIOLOGICAL HALF-LIVES

Some PFAS have very long lifetimes in the human body, meaning it could take years for levels in blood to go down even after levels in the environment decline.

This makes them a particularly challenging remediation problem due to the time lag associated with action.

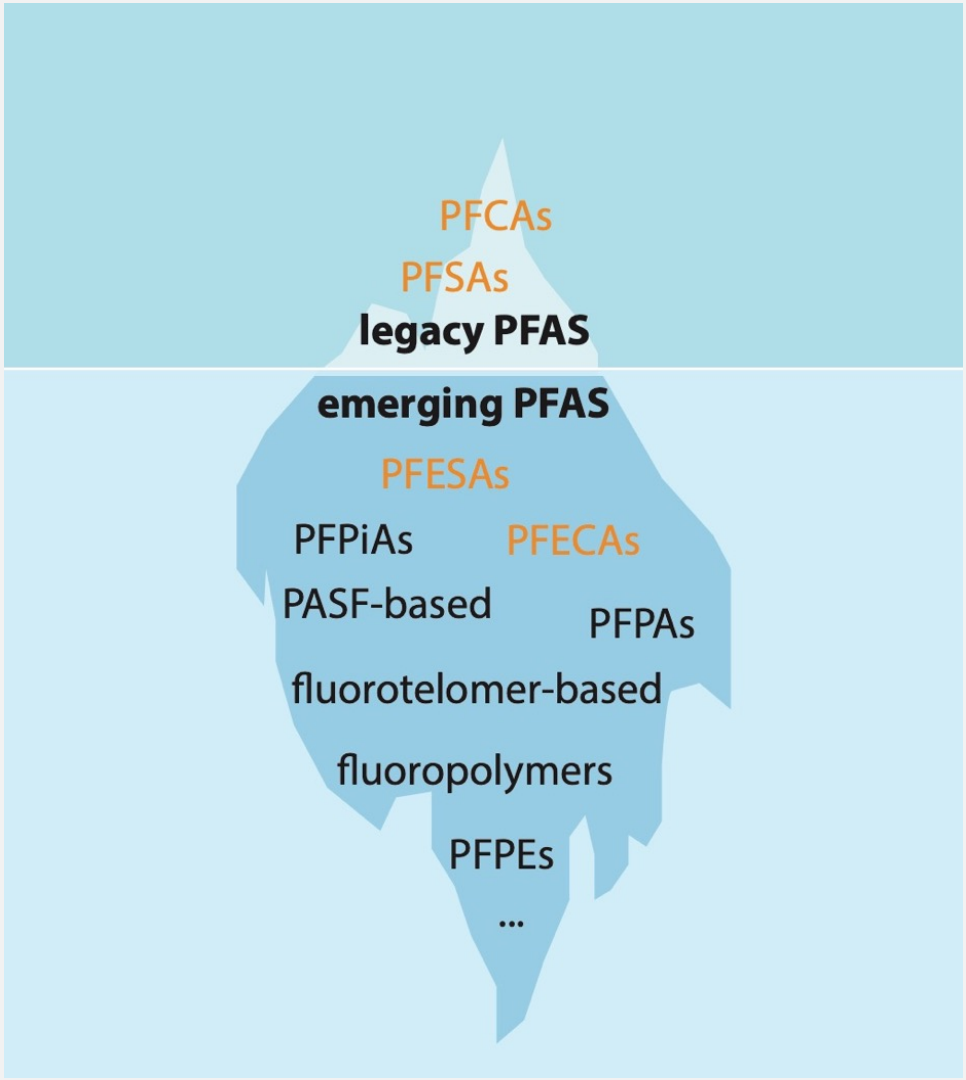


Ying Li et al. Occup Environ Med 2018;75:46-51

THE "ICEBERG" PROBLEM

Recent estimates indicate on the order of 5000 PFAS registered or in commerce (e.g. OECD 2018 report).

For the vast majority structurally diverse PFAS there are few available data.



A POTENTIAL PATH FORWARD: IDENTIFYING NON-ESSENTIAL USES

Table 1 Three essentiality categories to aid the phase out of non-essential uses of chemicals of concern, exemplified with PFAS uses

Category	Definition	PFAS examples
(1) "Non-essential"	Uses that are not essential for health and safety, and the functioning of society. The use of substances is driven primarily by market opportunity	Dental floss, water-repellent surfer shorts, ski waxes
(2) "Substitutable"	Uses that have come to be regarded as essential because they perform important functions, but where alternatives to the substances have now been developed that have equivalent functionality and adequate performance, which makes those uses of the substances no longer essential	Most uses of AFFFs, certain water-resistant textiles
(3) "Essential"	Uses considered essential because they are necessary for health or safety or other highly important purposes and for which alternatives are not yet established[a]	Certain medical devices, occupational protective clothing

[a] This essentiality should not be considered permanent; rather, a constant pressure is needed to search for alternatives in order to move these uses into category 2 above.

Reference: Cousins et al. 2019, Environmental Science: Processes and Impacts. (Critical Review)

WHERE DO WE GO FROM HERE?

Use	Category[a]
Personal care products including cosmetics	1
Ski waxes	1
Fire-fighting foams (commercial airports)	2
Fire-fighting foams (military)	2 or 3
Apparel (medical: long operations)	3
Apparel (protective clothing oil and gas industry)	3
Apparel (medical: short operations, everyday)	2
Apparel (military: occupational protection)	2 or 3
Waterproof jacket (general use)	2
Easy care clothing	1
Food contact materials	1, 2 or 3
Non-stick kitchenware (fluoropolymers)	1 or 2
Medical devices (fluoropolymers)	1, 2 or 3
Pharmaceuticals	2 or 3
Laboratory supplies, equipment and instrumentation	1, 2 or 3
Perfluorosulfonic membranes in fuel cells	2
Perfluorosulfonic membranes in chlor-alkali process	3

[a] Note that the categories in the above table represent the current evaluation and may change in the future.

- Ongoing research is needed to document where PFAS are used (structure, quantity) and identify non-essential uses.
- Non-essential uses are "low hanging fruit" to turn off the tap and avoid human exposure.
- For PFAS already present in the environment, an "all hands on deck" approach is needed: identify the most critical (by volume, hazard) and develop more effective treatment strategies.
- Given known effects at low concentrations for some PFAS + extreme persistence, important to avoid further environmental releases as quickly as possible.

Reference: Cousins et al. 2019, Environmental Science: Processes and Impacts. (Critical Review)

REFERENCES

For information on PFAS in personal care products:

- https://www.ewg.org/skindeep/2018/03/07/is-teflon-in-your-cosmetics/#.WqvZHROPJBz
- https://www.nature.com/articles/s41370-018-0109-y

For summarized information on PFAS toxic effects:

- https://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=1117&tid=237
- https://ntp.niehs.nih.gov/results/areas/pfas/index.html

The Essential Use concept:

- https://pubs.rsc.org/en/content/articlelanding/2019/em/c9em00163h#!divAbstract

REFERENCES

- Photographic image sources:
- "Sliding a fried egg onto white plate" by yourbestdigs is licensed under CC BY 2.0
- AFFF testing on Navy ship. This Image was released by the United States Navy with the ID 060420-N-9928E-037
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