PFAS: THE BASICS IN FIREFIGHTING

PFAS is a chemical acronym

PFAS are a group of man-made chemicals that have been manufactured and used by a variety of industries since 1940

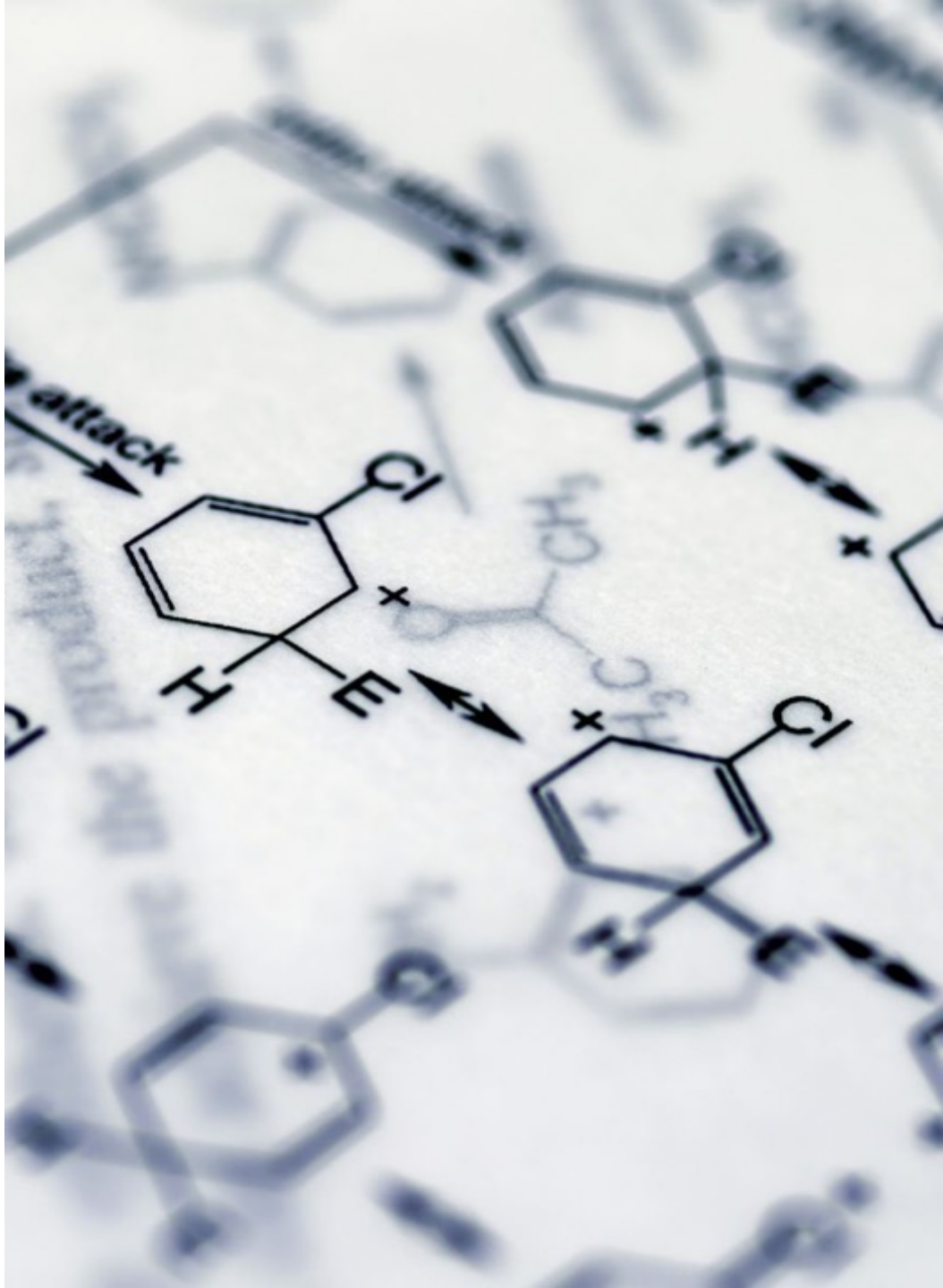
PFAS is a chemical acronym that stands for per- or polyfluoroalkyl substances:

Per means all
Poly means many
Fluoro means fluorine
Alkyl means carbon with all single bonds

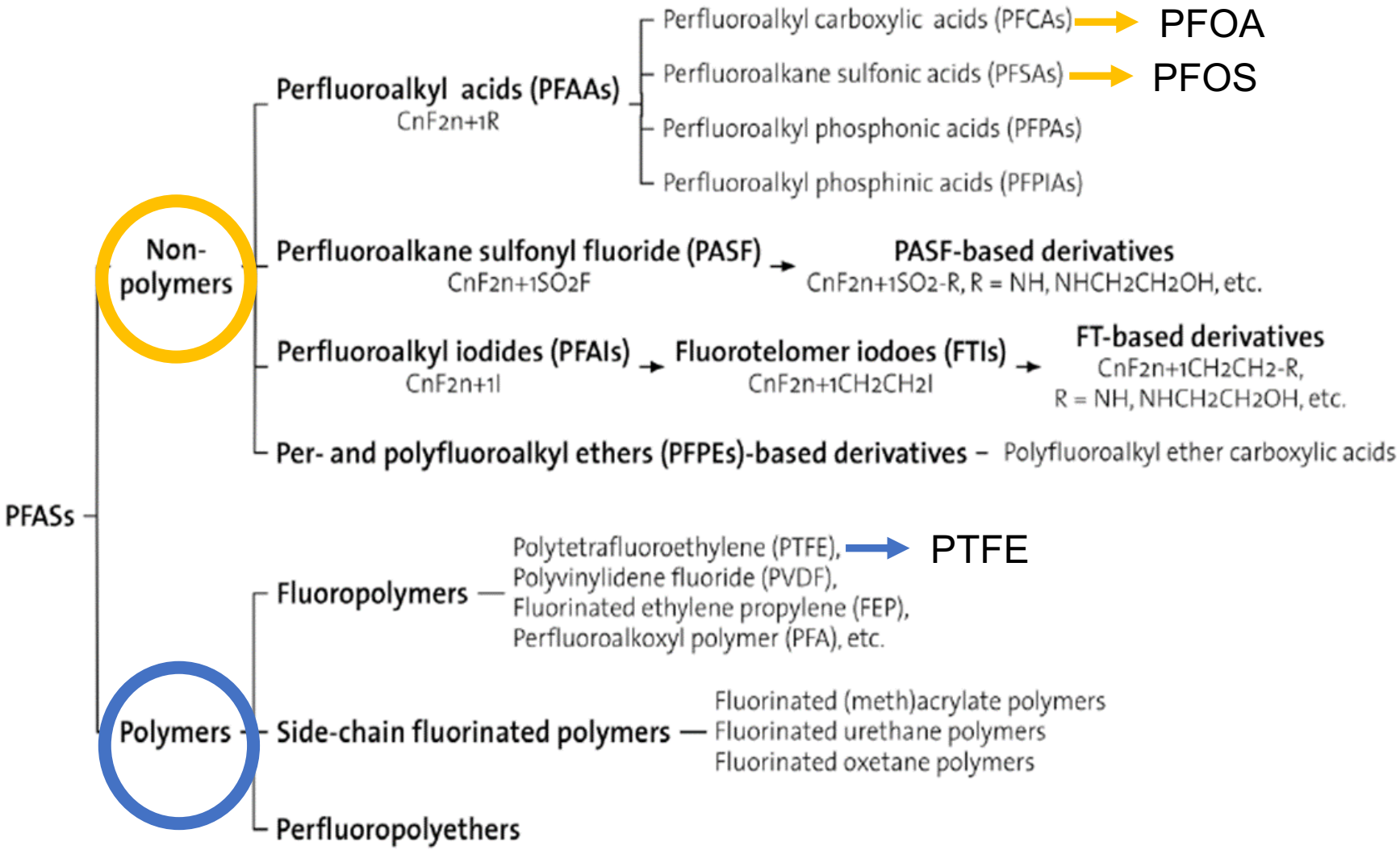
Substances means chemical

Together it means any chemical with a carbon atom bonded to two or more fluorine atoms.

"Forever Chemicals" persistence is due to the strength of the carbon-fluorine bond



PFAS acronyms are overwhelming



OECD(2013), OECD/UNEP Global PFC Group, Synthesis paper on per- and polyfluorinated chemicals (PFCs), Environment, Health and Safety, Environment Directorate,

Not all PFAS are the same

PFAS	Drinking Water Health-based values
PFNA	6ng/L (ppt)
PFOA	8ng/L (ppt)
PFHxA	400,000 ng/L (ppt)
PFOS	16 ng/L (ppt)
PFHxS	51 ng/L (ppt)
PFBS	420 ng/L (ppt)
Gen X	370 ng/L (ppt)

PFAS all have different properties, different toxicity levels and different applications

PFAS has many applications

More than 10,000 PFAS have been identified

PFAS use in textiles

PFAS has been used for a wide range of functional applications within textiles, upholstery, leather, apparel and carpets. Home textiles (>50%) and consumer apparel (34%) are the most dominant sectors for PFAS use.

Why are PFAS used?

Water, oil, chemical and dirt repellent

Durability under extreme conditions such as temperature, pressure, radiation and chemicals

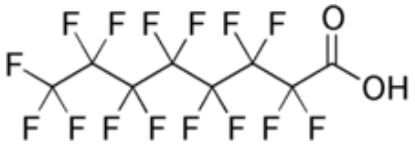
Electrical and thermal insulation

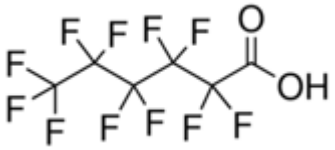
Resistant to natural processes of degradation

UV resistant

https://echa.europa.eu/-/echa-publishes-pfas-restriction-proposal.

The confusion continues….C8 and C6





	PFOA (“C8”)	PFHxA (“C6”)
½ life in humans	1000	<28
½ life in nature	∞	∞

C8 and C6 mean different things to different people.

To a generic chemist C8 means... nothing.

To a PFAS chemist or toxicologist C8 means... **PFOA PFOS**

To a textile chemist C8 means... a finish containing polymers with C8 groups hanging off the side.

PFOA and PFOS are commonly referred to as “C8” because they have eight carbon atoms

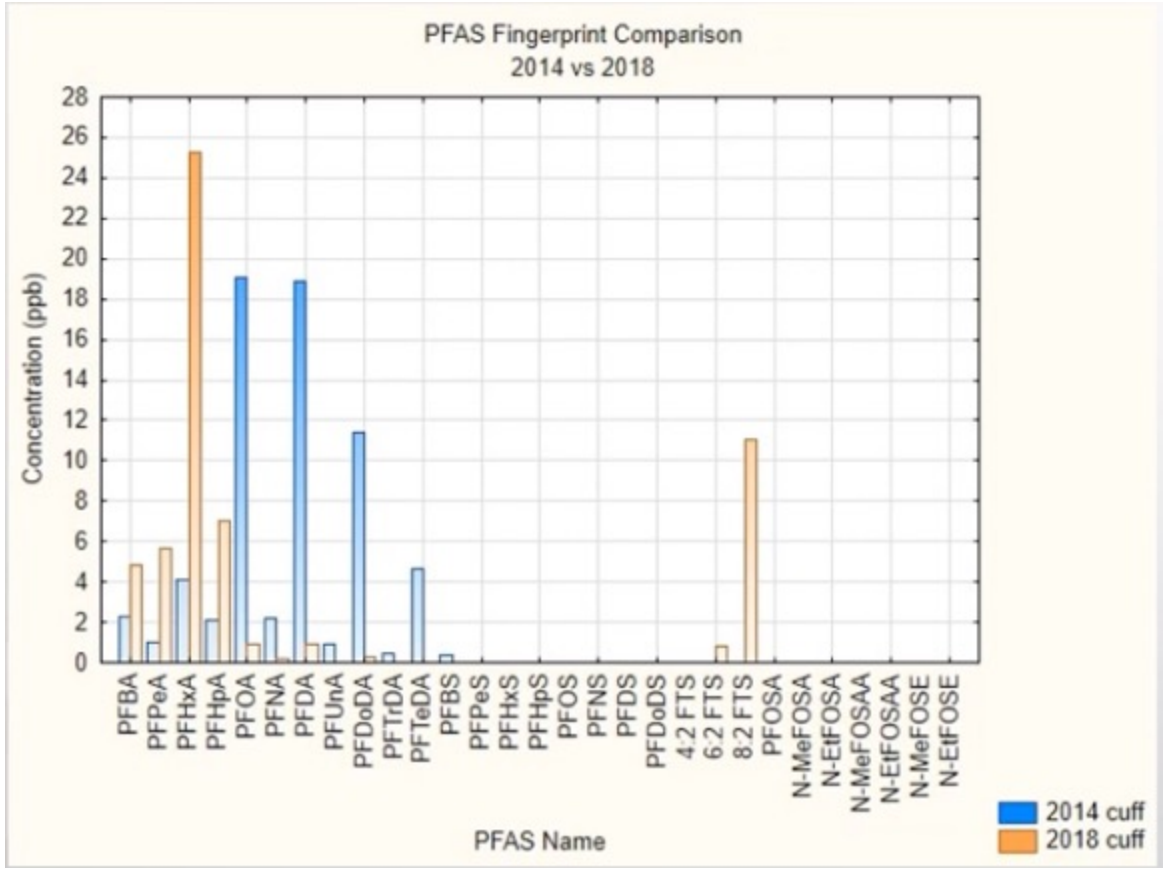
European transition from C8 to C6

The Stockholm Convention:

- **PFOS has been restricted in the EU for more than 10 years** already, under the EU's Persistent Organic Pollutants (POPs) Regulation.

- **PFOA and PFOA-related compounds have been banned under the POPs Regulation since 4 July 2020.**

- In June 2022, **PFHxS was included.** This global ban is expected to enter into force at the end of 2023.



The European Commission pledged to "ban the most harmful chemicals in consumer products, allowing their use only where essential" as part of the European green deal in 2020.

https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program#what

Transition from C8 to C6 in Firefighting PPE

Tested 14 whole fabric samples from 2007 to 2018

2007	2018
PFOA < 23.5ppb	PFOA 0.96 ppb
PFHxA and PFHpa in **1.41ng**/100cm^2	No detectable PFAS (1 sample)
	PFHxA and PFHpa in trace amounts

A grain of sand is 58,000ng

Globally regulated PFAS

2010/2015 PFOA STEWARDSHIP PROGRAM :

- By 2010, **95 percent reduction** in both facility emissions to all media of perfluorooctanoic acid (PFOA), precursor chemicals that can break down to PFOA.
- Elimination of these chemicals from emissions and products by 2015.

CHINA REGULATIONS

- Published list of new chemical pollutants in January 2023
- PFOS and PFHxS – Production, Use, Import and Export banned
- PFOA – Production and Use limited

https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

New regulations - EU

Broadest Restriction proposal encompassing approximately 10,000 PFAS submitted 13th January 2023. Currently being evaluated by ECHA committees based on a full ban or a ban with use-specific derogations depending on viable alternative solutions. 5600 comments received. Expected 2026/2027. Transitional time frames may be different for example:

Application	Time Frame	Reasoning
Food packaging	18 months	Viable alternatives readily available
Industrial Food Production	5 years	Alternatives under development, not available yet
Implantable medical devices i.e. pacemakers or heart valves	12 years	Identification, development and certification of alternatives needed Adverse human health implications Certification schemes, Legal obligations Patenting

In firefighting, identification, development and certification of alternatives is needed in both firefighting foams and PPE to ensure the same standard of protection is maintained and the standards such as EN469:2020 and NFPA 1971 are met.

https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

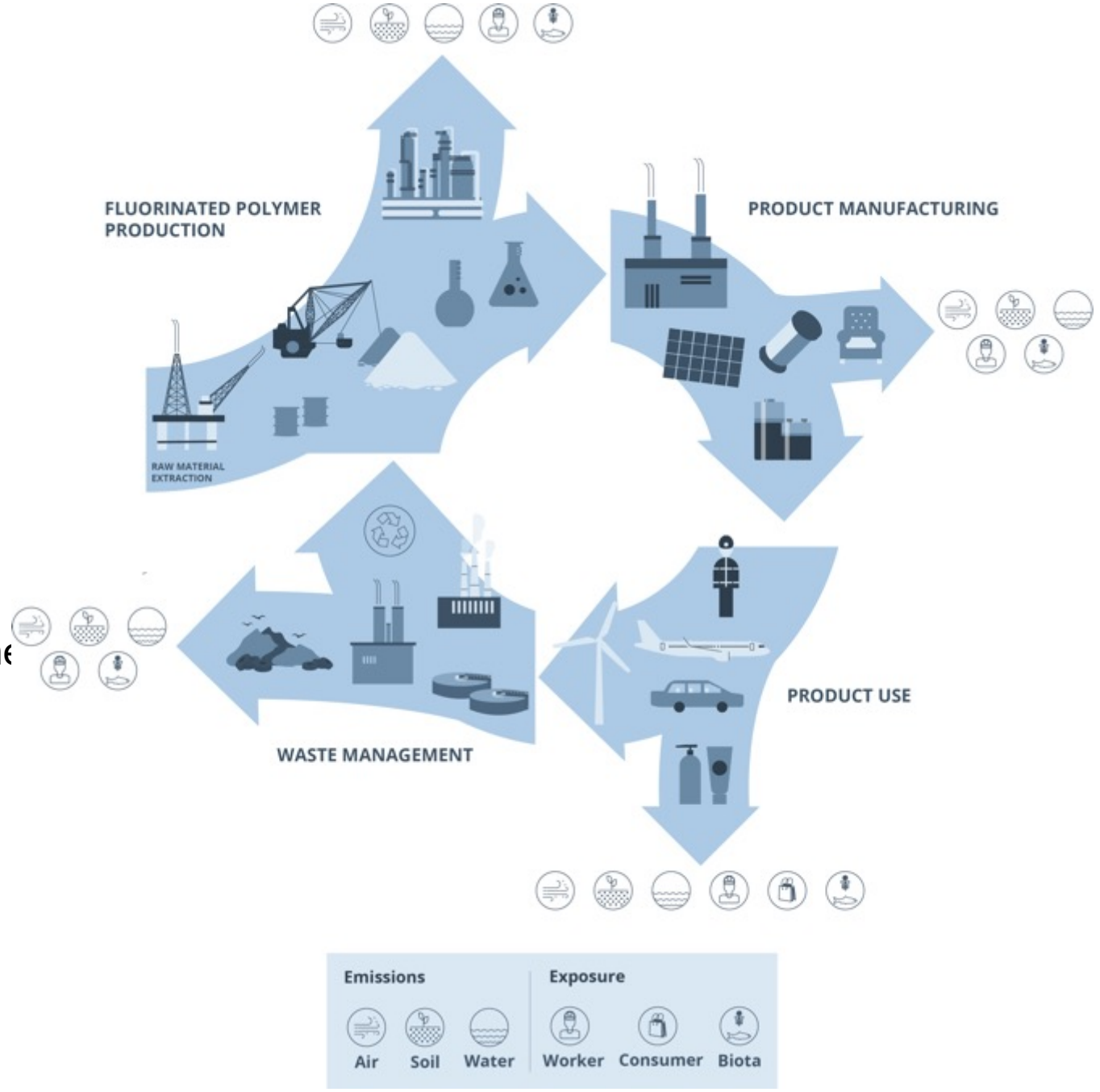
Human Exposure to PFAS

Occurs through:

- Consumer products
- The environment
- Uptake from food and drinking water

Supported by human biomonitoring studies with highest exposure levels in populations close to the emission sources

For the environment we do not only find PFAS close to the sources of emissions but also in remote areas far from the source



https://www.eea.europa.eu/publications/zero-pollution/cross-cutting-stories/pfas

Routes of exposure

Inhalation

Absorption

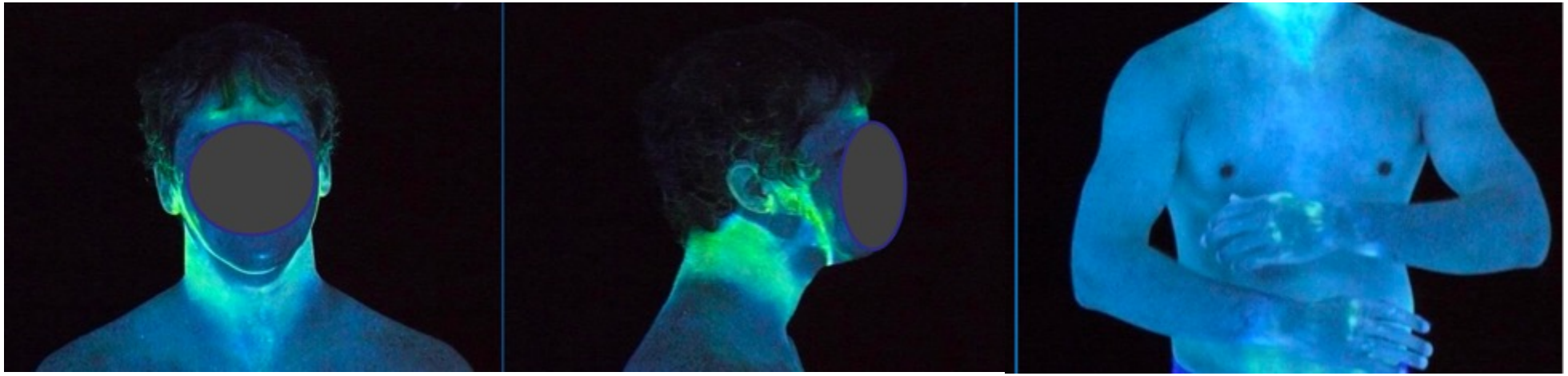
Ingestion

https://www.eea.europa.eu/publications/zero-pollution/cross-cutting-stories/pfas

Skin Absorption

The interfaces of clothing do not completely prevent particles from penetrating.
The highest values of leakage to the interior of the PPE were observed at the lower legs.

Based on **literature**, **information from firefighters** and **interface study**, the skin area that can be contaminated during firefighters ‘activities is: neck (420 cm2), head (680 cm2), hands (600 cm2) and lower legs (1300 cm2). Together these represent a skin area of **3000 cm2**



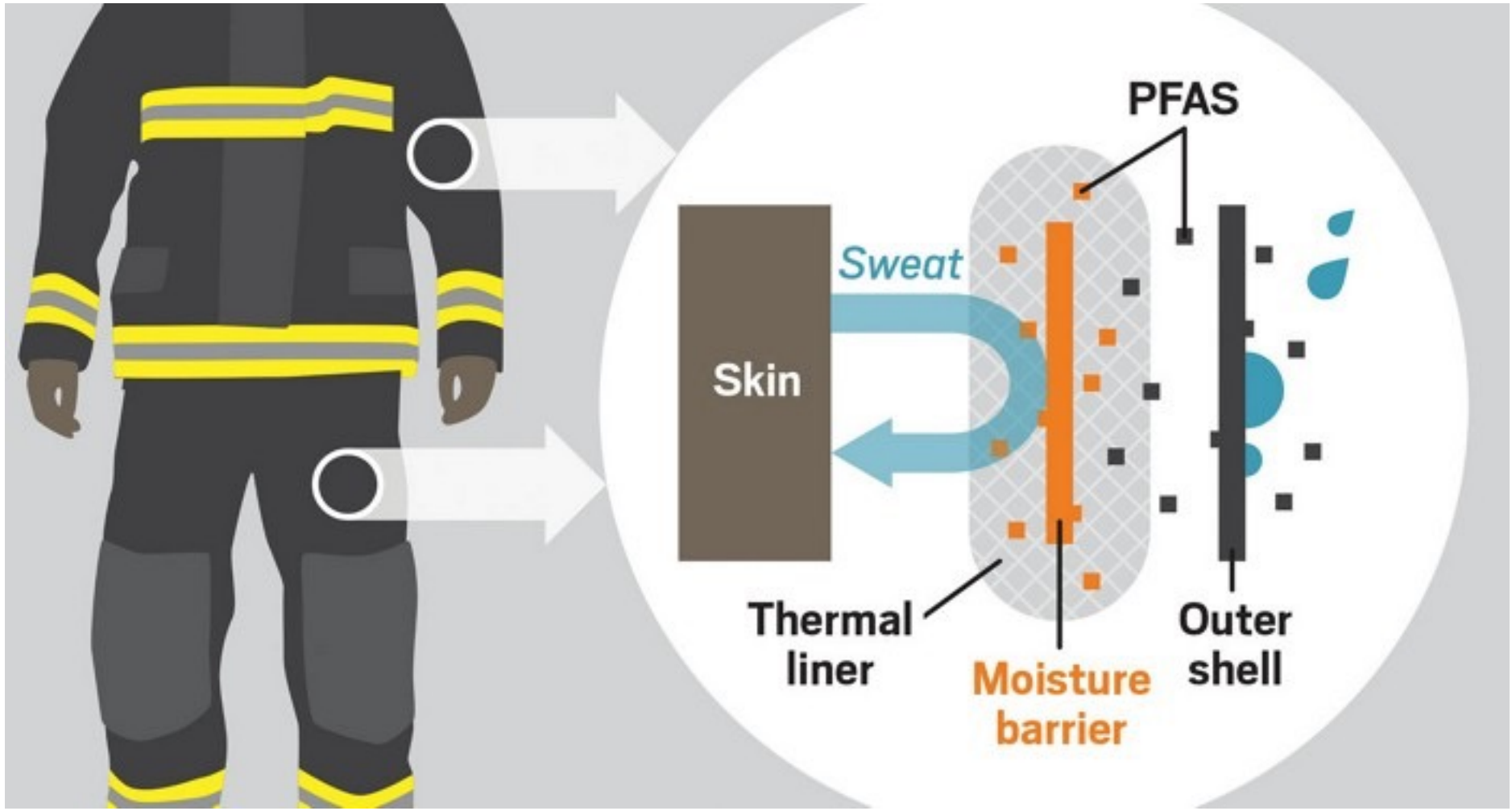
[Lund and Browder 1944], [EPA 2011].

Skin Absorption

Conclusion of the Risk Assessment

- No permeation through the skin was measured after 24 hours of continuous contact between the contaminated textiles and the skin.
- There is no acute hazard or risk, and on a long-term basis, the risk for systemic toxicity and carcinogenicity is considered very limited.
- It is advised to wear all PPE - the EN 469 Level 2 personal protective clothing together with all other PPE; and all PPE needs to be compatible.
- Wear full ensemble during all stages of fire, also overhaul activities.

PFAS in firefighting garments



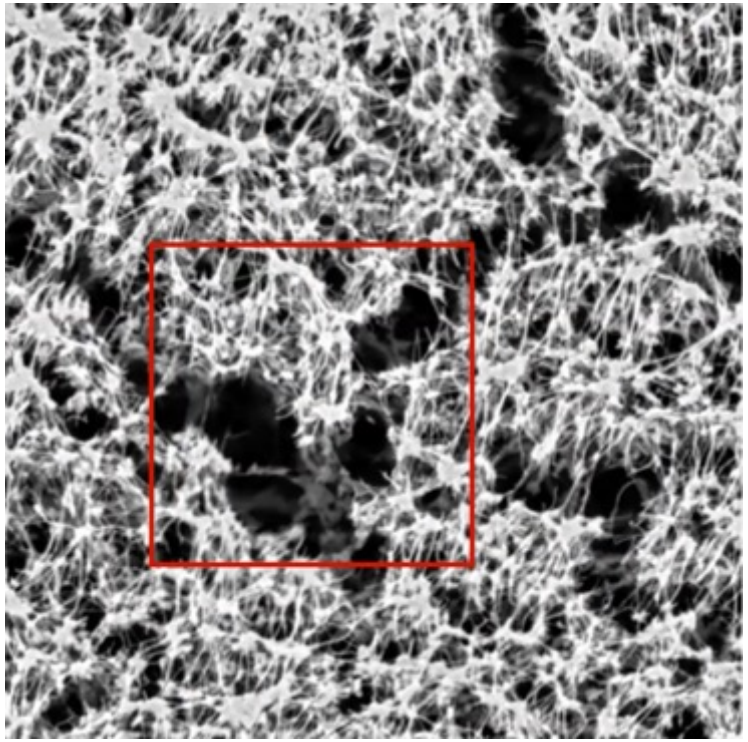
PFAS can be found in the moisture barrier and the durable water repellent on the outer shell

PFAS in a moisture barrier

Polytetrafluoroethylene (PTFE) is a member of the fluoropolymer class of per-and polyfluorinated alkyl substances (PFAS).

Why is PTFE used:

- PTFE is a very large molecule that is unable to enter the human cell passively due to its size.
- **Best repellence to water and oil -** pores 20,000 times smaller than water droplet
- **Not bioavailable -** it cannot get into the cell or bind to the cell, therefore it is classified as non-toxic.
- **Extremely stable molecule -** PTFE does not break down to be a source of non-polymer PFAS unless exposed to extremely harsh temperatures or chemicals that would themselves have a negative impact on human life.
- **PTFE is insoluble to water and durable**
- **Resistant to degradation to weather, UV and corrosion**
- **Resistant to the majority of chemicals**
- **Breathable -** allows water vapour to leave – 700 times larger than a water vapour molecule



PTFE is a very large molecule (400,000-10,000,000 molecular weight) compared to PFOA and PFOS (400-500 molecular weight units)

PFAS in Durable Water Repellents

Durable water and oil repellent treatments (DWR) are applied to Fire fighting garments.

These treatments provide important liquid and oil repellence for the fabrics to help keep water and other contaminates from soaking into the materials

DWR also reduces the burden associated with wet fabrics, by reducing the uptake of water which can also potentially impact performance

All oil repellents repel water but not all water repellents repel oil

Current DWR treatments use C6 technology

PFAS and Standards

EN469:2020 currently **requires a >80% repellency of chemicals**. This is based on a European-wide risk assessment on how much repellency a firefighter garment needs. No current PFAS free alternative can meet this requirement.

6.2.2 Resistance to penetration test by liquid chemicals

Three specimens in the machine direction and three in the cross direction of the component assembly or garment assembly shall be tested in accordance with EN ISO 6530:2005 after pre-treatment as in accordance with 5.3 using a chemical application time of 10 s using the following liquid chemicals.

Table 4 — Chemical penetration testing

Chemical	Mass (%)	Temperature of chemical ± 2 °C
H_2SO_4	30	20
C_8H_{10} (o-xylene)	100	20

For each specimen, there shall be no penetration to the innermost surface and the index of repellency shall be ≥ 80 % classified according to the average result. This test shall be carried out, even if the garment has a moisture barrier.

Current Alternatives

Repellency and Flammability Questions

- How much liquid repellency do firefighters need?
- What types of liquid chemicals are of concern?
  - Water, gasoline/diesel fuel, hydraulic fluid, solvents
- What additional risks may be present without repellency?
  - Flammability concerns?
- What may impact flammability
  - Level of exposure - liquid splash versus soiling of fabric
  - Type of thermal threat - direct flame versus radiant heat
  - Post exposure time – immediate or extended time, cleaned versus not

The Trade-off

Chemical repellency

Oil repellency

Water repellency

Breathability

Durability

Washability

Uptake of hydrocarbons and other heavy metals by the raw textile

Number of reimpregnations

Run-off of water repellent

Degradation

Risk Assessment

RISK = HAZARD X EXPOSURE

1. Hazard Identification
2. Dose-response Relationship
3. Exposure Assessment
4. Risk Characterization

“The Dose Makes the Poison”

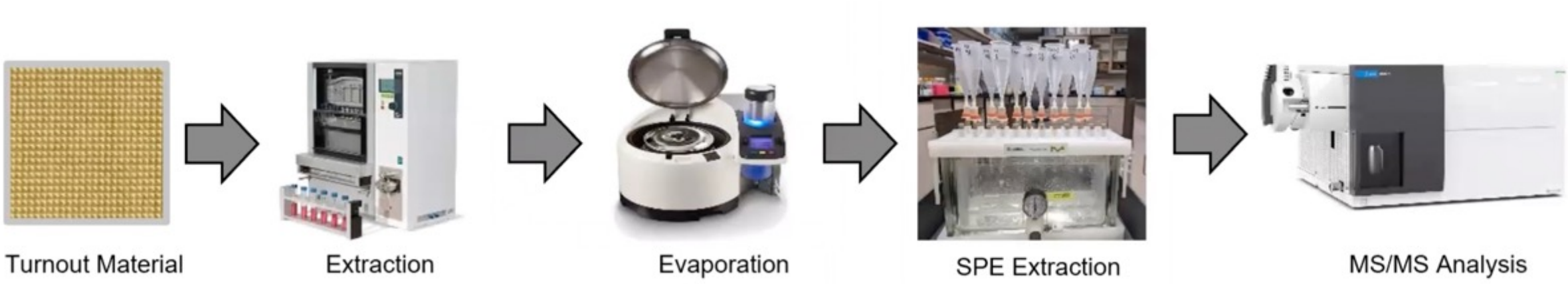
Testing for PFAS

Human testing:

- Blood test
- Urinalysis
- Food, drinking water, consumer product testing
- Mathematical modelling
- Environment and workplace monitoring

Fabric Testing:

- Currently most methods of extracting PFAS are from liquids i.e. water or blood
- Limited test methods available to extract PFAS from fabric



Testing textiles for PFAS

Annex 4: Limit values and fastness, part 4
Anhang 4: Grenzwerte und Echtheiten, Teil 4

OEKO-TEX®
INSPIRING CONFIDENCE

Annex 4 / Anhang 4

Limit values and fastness, part 4 / Grenzwerte und Echtheiten, Teil 4

(The testing procedures are described in a separate document / Die Prüfverfahren sind in einem separaten Dokument beschrieben)

Product Class / Produktklasse	I Baby	II in direct contact with skin / mit Hautkontakt	III with no direct contact with skin / ohne Hautkontakt	IV Decoration material / Ausstattungsmaterialien
PFCs, Per- and polyfluorinated compounds / Per- und polyfluorierte Verbindungen[9,21]				
PFOS, PFOSA, PFOSF, N-Me-FOSA, N-Et-FOSA, N-Me-FOSE, N-Et-FOSE; / Sum / Summe [µg/m2]	1.0	1.0	1.0	1.0
PFOA [µg/m2]	1.0	1.0	1.0	1.0
PFHpA [mg/kg]	0.05	0.1	0.1	0.5
PFNA [mg/kg]	0.05	0.1	0.1	0.5
PFDA [mg(kg]	0.05	0.1	0.1	0.5
PFUdA [mg/kg]	0.05	0.1	0.1	0.5
PFDoA [mg/kg]	0.05	0.1	0.1	0.5
PFTrDA [mg/kg]	0.05	0.1	0.1	0.5
PFTeDA [mg/kg]	0.05	0.1	0.1	0.5
Further Perfluorinated carboxylic acids, each; according to Annex 5 / je; gemäß Anhang 5 [mg/kg]	0.05			
Perfluorinated sulfonic acids, each; according to Annex 5 / je; gemäß Anhang 5 [mg/kg]	0.05			
Partially fluorinated carboxylic / sulfonic acids, each; according to Annex 5 / je; gemäß Anhang 5 [mg/kg]	0.05			
Partially fluorinated carboxylic / sulfonic acids, under observation / unter Beobachtung	u.o. / u.B.[10]			
Partially fluorinated linear alcohols, each; according to Annex 5 / je; gemäß Anhang 5 [mg/kg]	0.50			
Esters of fluorinated alcohols with acrylic acid, each; according to Annex 5 / je; gemäß Anhang 5 [mg/kg]	0.50			
Other PFOA related Substances / andere PFOA-bezogene Stoffe[22]	u.o. / u.B.[10]			

PFAS is an active area of research

Number of PFAS articles

PUBLICATION DATE	
Last Year	131
Last 6 Months	68
Last 3 Months	32
Last Month	12
Last Week	2

PFAS search results by topic

Contaminants in Aquatic and Terrestrial Environments	134
Ecotoxicology and Public Health	75
Treatment and Resource Recovery	27
Critical Review	14
Correspondence/Rebuttal	11
Viewpoint	11
Perspective	7
Anthropogenic Impacts on the Atmosphere	6
Addition/Correction	5
Feature	5
Comment	4
Editorial	4
Policy Analysis	3

https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program#what

Research is ongoing

Studies showing the relationship between PFAS and firefighting are conflicting

"C8 Study Group" – PFOS evelated in firefighters compared to the unemployed but not compared to other occupations

U.C Berkeley Tubbs Fire – PFOS, PFHxS higher in deployed firefighters compared to not deployed

Fox Study – Firefighters PFAS same as general population

San Francisco women's firefighters – no detectable PFHxA or PFHpA. Other PFAS consistent with office workers.

Some studies have shown evidence of PFOA with cancer in laboratory animals
No clinical case of cancer has been shown to have been caused by exposure to PFAS by meeting causation criteria

Sources of PFAS health data should come from peer-reviewed science or government documents NOT social media

What is the Criteria for Causation?

"I wish they didn't turn on that seatbelt sign so much! Every time they do, it gets bumpy."

What research is needed?

- Formal exposure assessment – is firefighting PPE a significant source of occupational exposure?
- Testing methods for PFAS in textiles
- Dermal absorption of PFAS – volatile vs non-volatile?
- What is the impact of UV light, heat and laundering on PFAS and PFAS free alternatives?
- Performance and exposure trade-offs
- Evaluation of cleaning efficiency
- Analyze for PFAS transferring to skin

Summary

- PFAS is a chemical acronym representing over 10,000 chemicals
- PFAS are found in many applications
- Their properties differ widely from each other
- PFAS are used because they have the greatest performance for the requirements of firefighting PPE
- Alternatives are available, but have a trade-off
- Research is ongoing to assess causation between cancer and PFAS
- Regulations are currently focused on specific PFAS