Environmental and health impacts related to PFAS and TFA

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Workshop on sustainable alternatives to PFAS

with a focus on F-gases and electronics

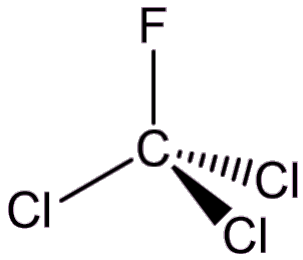
24 April 2026, 9:00-15:45

Centre de Conférence Albert Borschette *(Rue Froissart 36, 1040 Etterbeek – room 1.B)*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101036756.

A precautionary tale….

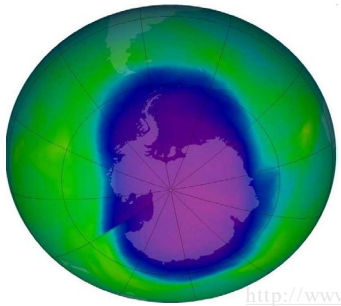
James Lovelock (1919 – 2022)



- **Invented the Electron Capture Detector (ECD)**
- **First to detect chlorofluorocarbons (CFCs) in the atmosphere**

- CFCs pose "no conceivable hazard"

Lovelock J (1988). The Ages of Gaia: A Biography of Our Living Earth



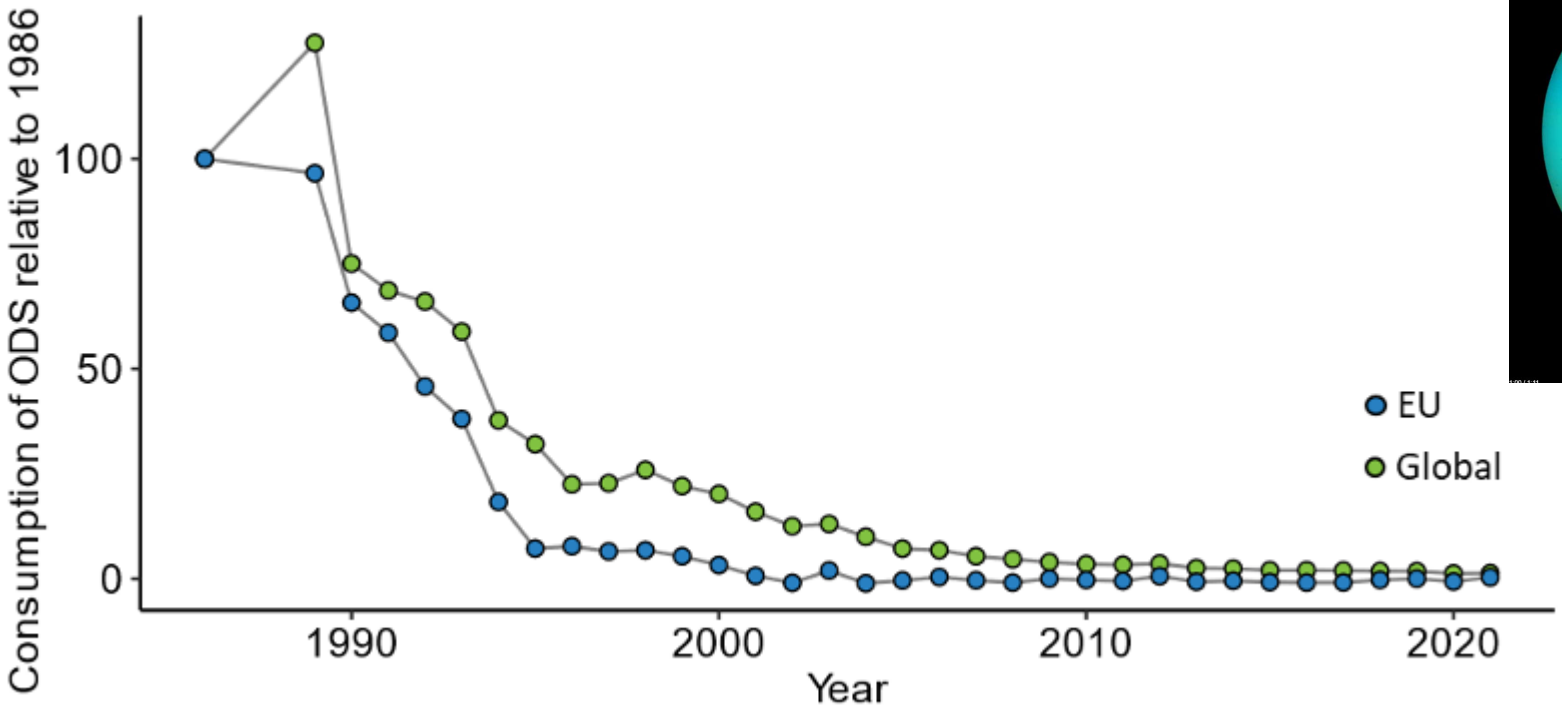
http://www.nasa.gov/vision/earth/environment/ozone_resource_page.html

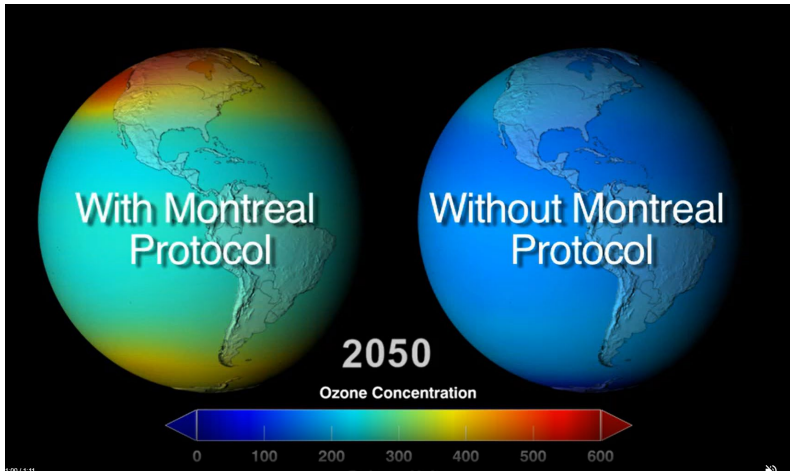
- CFCs pose "no conceivable toxic hazard"

Lovelock J (2000). Homage to Gaia: The Life of an Independent Scientist

https://en.wikipedia.org/wiki/James_Lovelock

The Montreal Protocol saved the planet. without it there would be no photosynthesis





EU and global relative consumption of ozone depleting substances (ODS, like chlorofluorocarbons) since 1986, showing the reduction the consumption of ODS due to the Montreal Protocol.

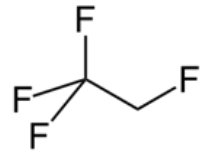
Chirsir, Palm *et al.* (2024 in press), ESEU, DOI: 10.26434/chemrxiv-2024-tn5t5

EEA (2023) EU and global consumption of controlled ozone-depleting substances — European Environment Agency. In: European Environmental Agency. 826

https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=10824

The history of the Montreal Protocol is a history of burden shifting via «drop in substitution»

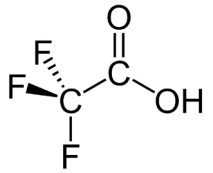
- 1st Gen: Chlorofluorocarbons (**CFCs**) – *Ozone depletion*
- 2nd Gen: Hydrochlorofluorocarbons (**HCFCs**)– less ozone depleting, but *green house gases*
- 3rd Gen: Saturated hydrofluorocarbons (**HFCs**) -> green house gases, *mild formation of TFA*



1,1,1,2-Tetrafluoroethane
(HFC-134a, Norflurane)

$h \cdot \upsilon$

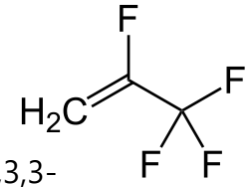
high global warming potential



Triflouroacetic acid (TFA) Yield between 7- 23%

Extremely persistent and mobile
Accumulates in the environment

- 4th Gen: F-gases after Kigali amendment (2019): Unsaturated hydrofluoroolefins (**HFOs**), less global warming potential, ***increased formation of TFA***



2,3,3,3-
Tetrafluoropropene
(µHFC-1234yf)

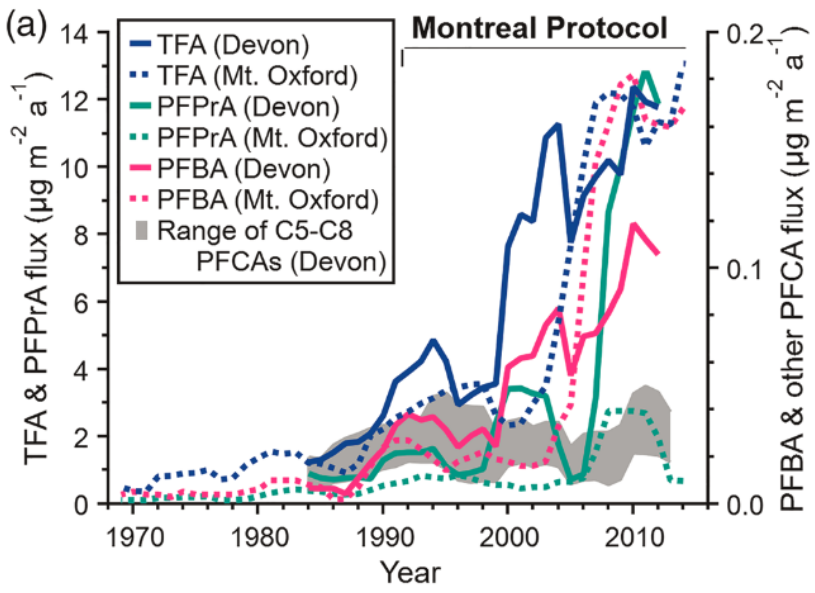
$h \cdot \upsilon$

low global warming potential

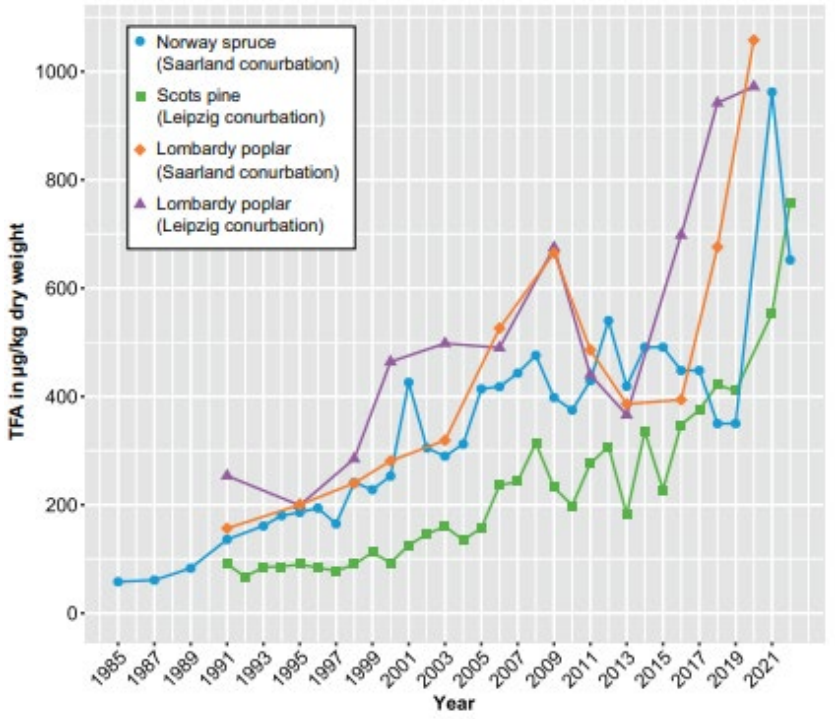
TFA Yield = 100% !

TFA is accumulating everywhere, largely coinciding with F-gas use following the Montreal Protocol

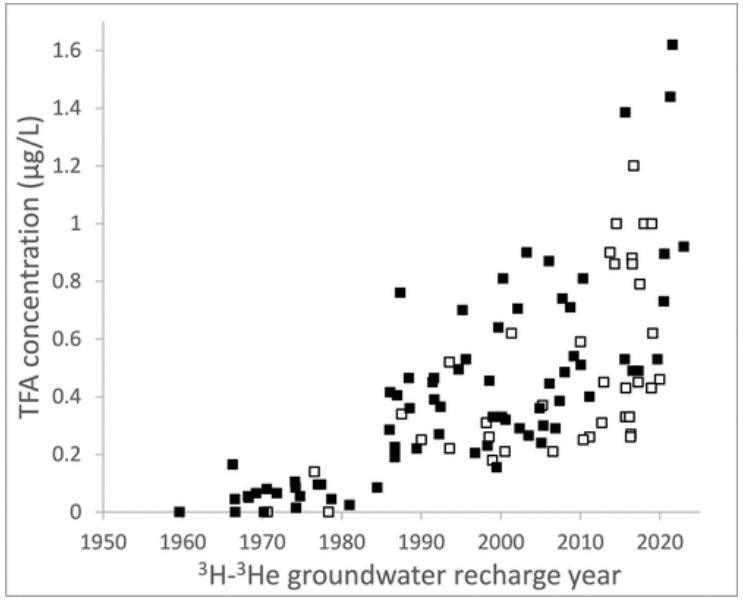
TFA accumulating in arctic ice cores



and in tree leafs



and in groundwater



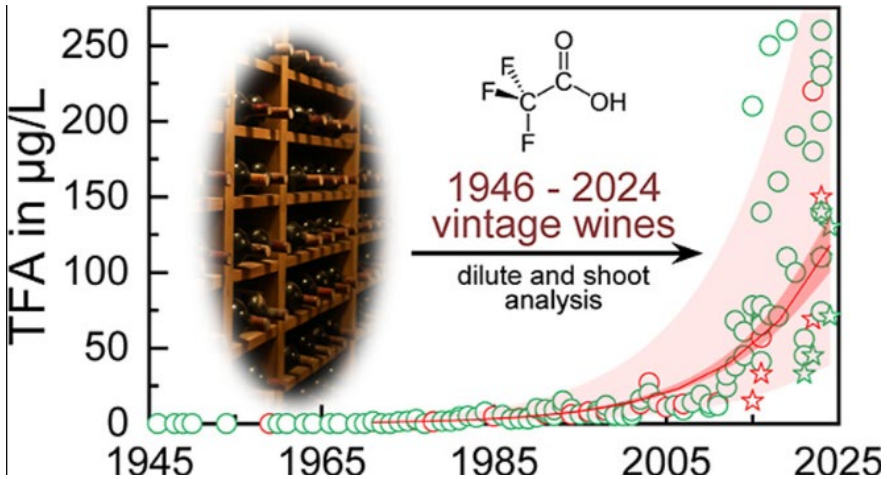
Pickard et al. Geophysical Research Letters (2020),47, e2020GL087535

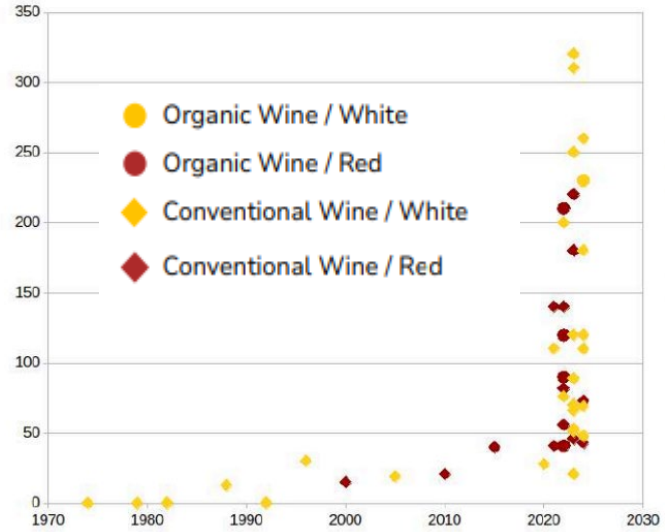
Freeling and Björnsdotter, Current Opinion in Green and Sustainable Chemistry 2023, 41:100807

Albers and Sültenfuss, Environmental Science & Technology Letters 2024 11 (10), 1090-1095

TFA is increasing in all that we drink

…Wine

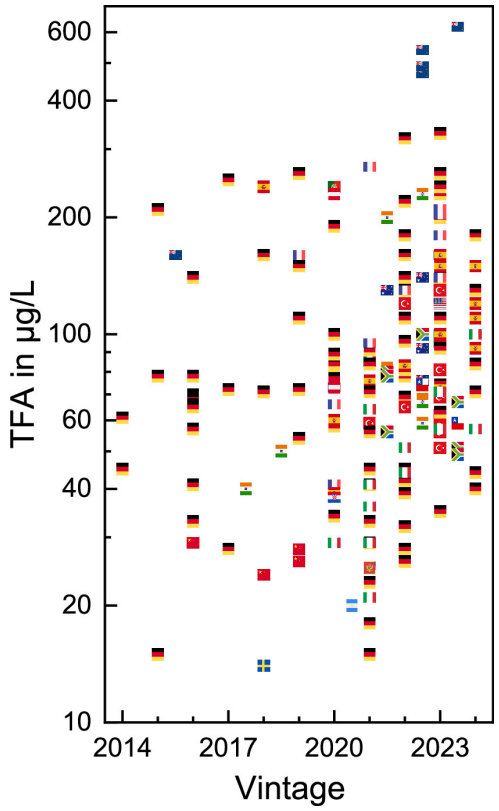




Freeling et al. *Environ. Sci. Technol.* 2025, 59, 49, 26762-26769)

Wine image: Sai Balaji Varma Gadhiraju

Up to 600 µg/L



Drinking water (median)[1,2]

- Germany: 1.5 µg/L
- 19 Countries: 0.23 µg/L

Tee (median): 2.4 µg/L[2]

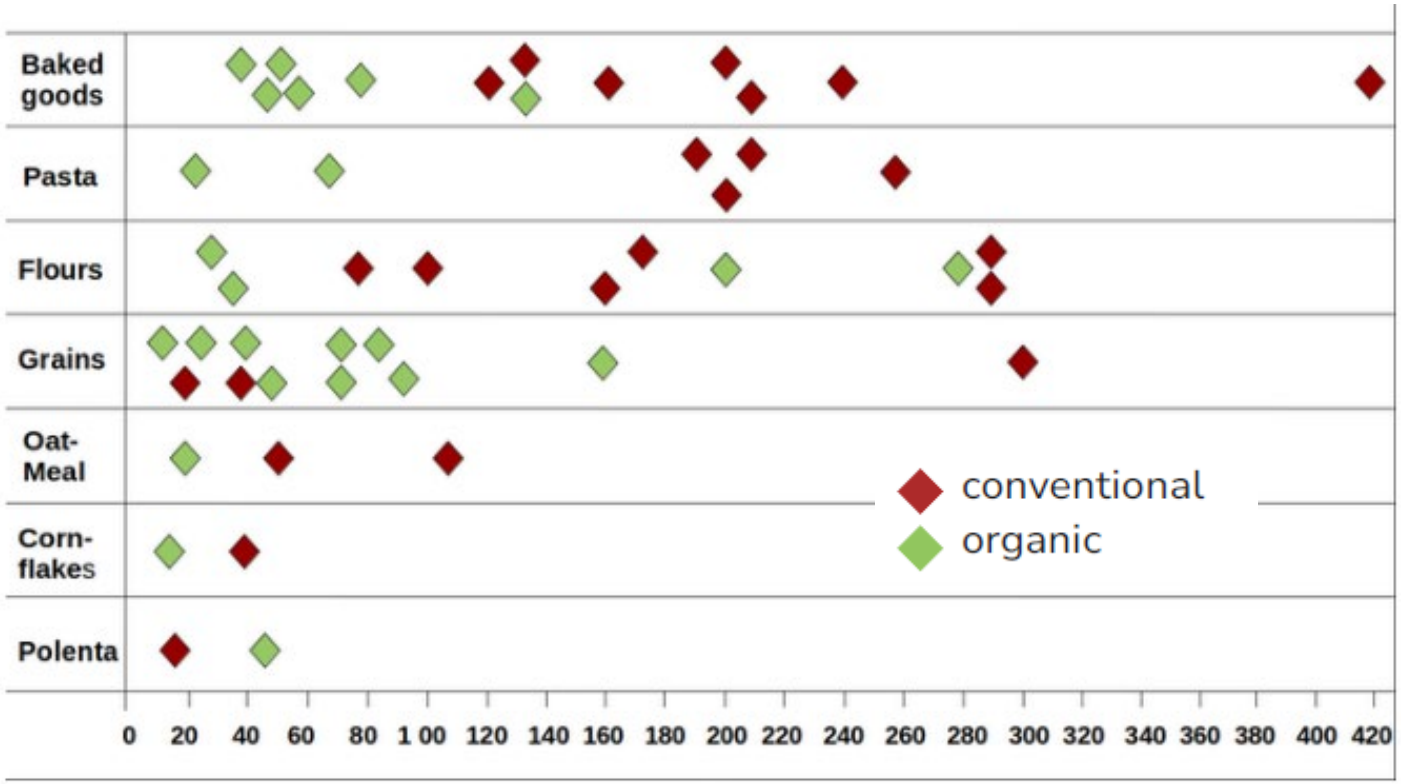
Beer (median) 6.1 µg/L[2]

Orange juice (mean 34 µg/L)[3]

Apple juice (mean 6.2 µg/L)[3]

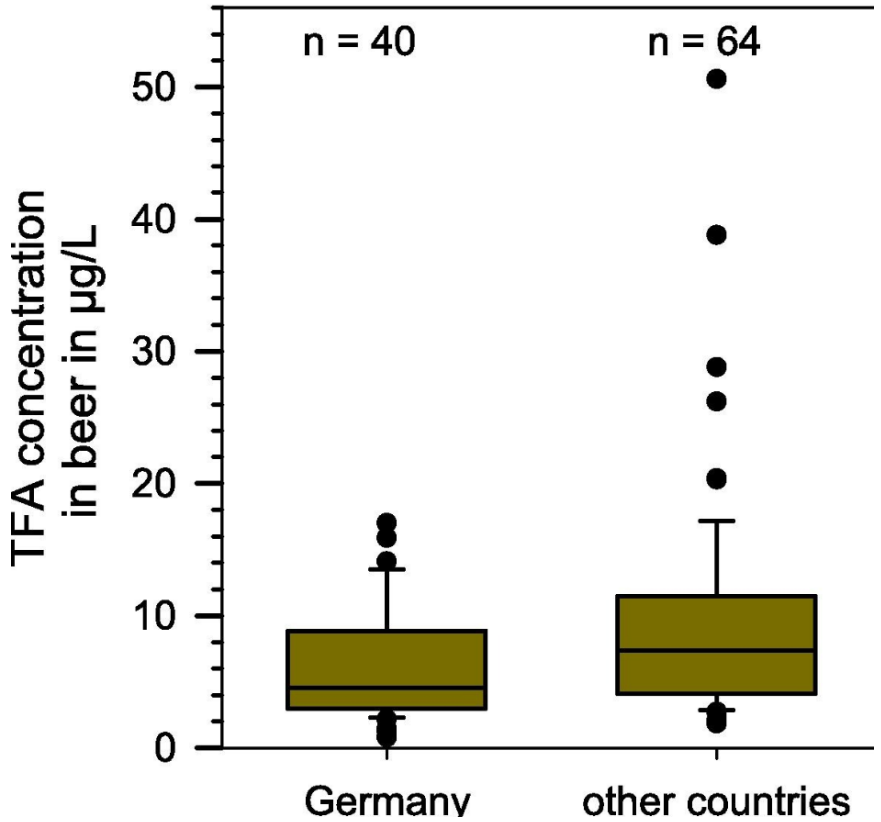
1. Neuwald et al. *Environmental Science & Technology* **2022** *56* (10), 6380-6390
2. Scheurer & Nödler. *Food Chemistry*, *351*, 129304.
3. Van Hees et al. https://cdnmedia.eurofins.com/european-east/media/uxcnaa2c/eurofins_tfa_tfms_juice_24_final.pdf

PAN Europe: Message from the Bottle – The Rapid Rise of TFA Contamination Across the EU



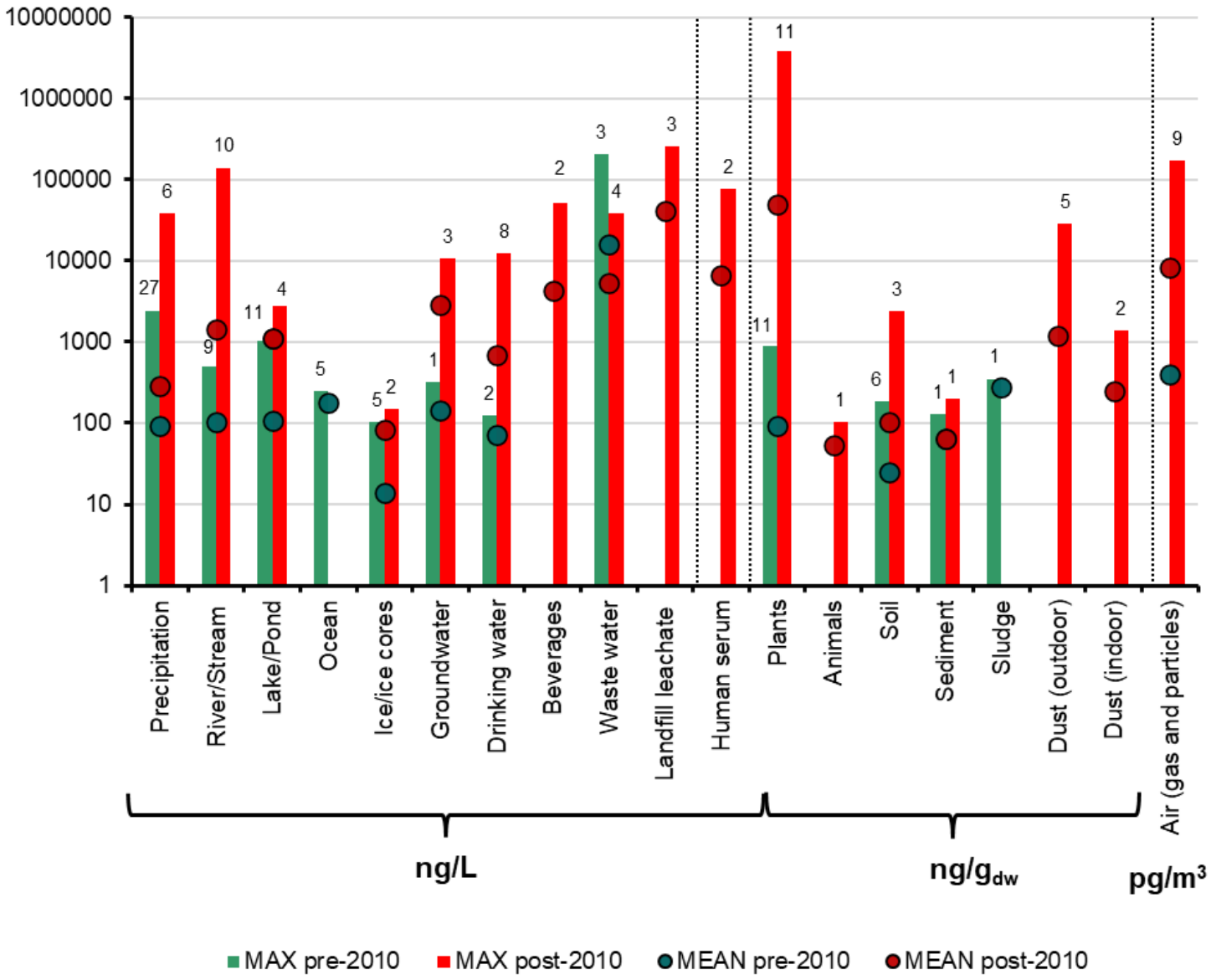
µg/kg dw

https://www.pan-europe.info/resources/reports/2025/06/forever-chemical-TFA-our-daily-bread



Scheurer und Nödler Food Chemistry 351 (2021) 129304

TFA is accummulating everywhere it can be measured

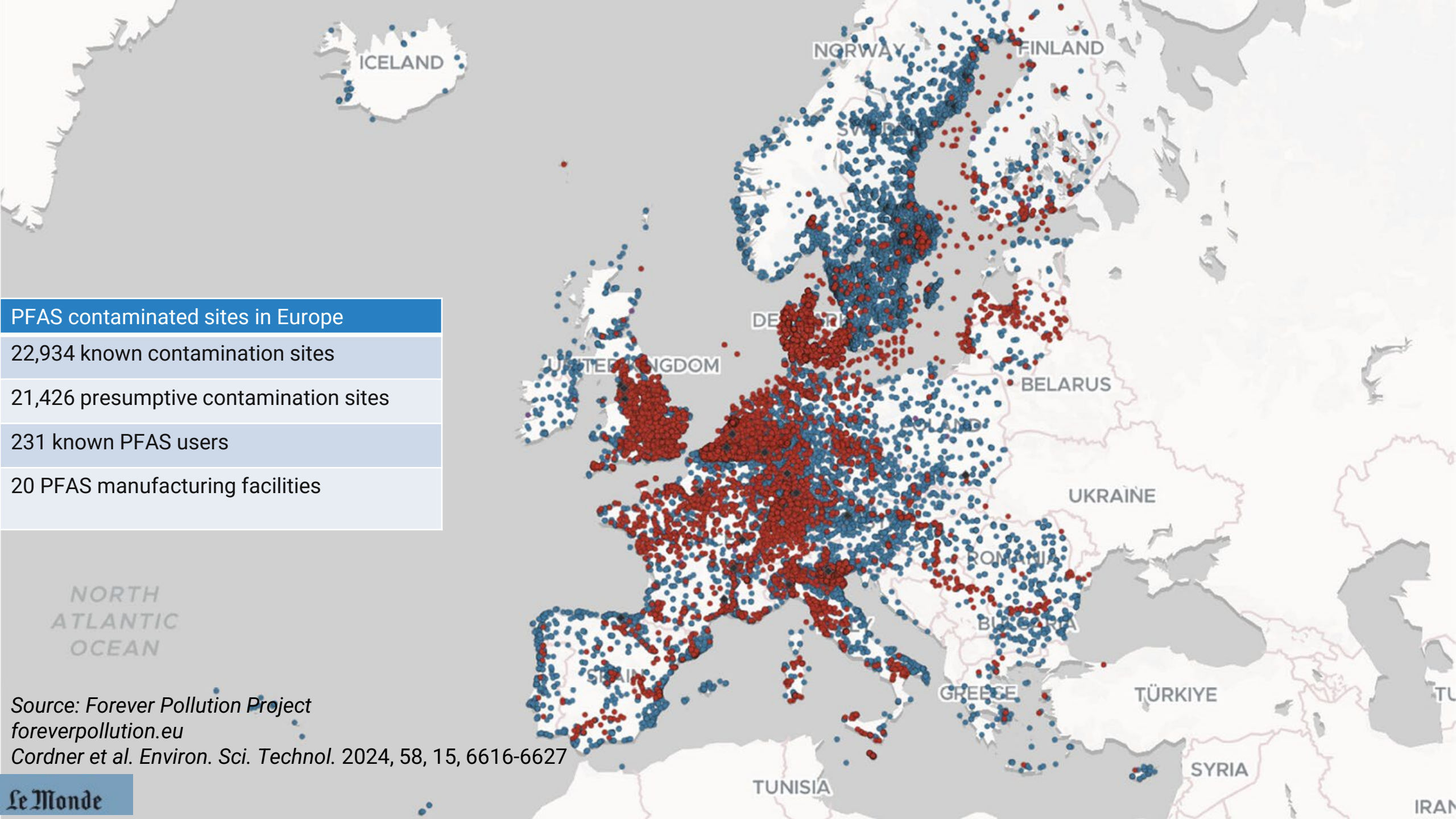


Chinese blood 97% detection
Median 8.5 µg/L
Similar to levels of the sum of all long-chain, bioaccumulative PFAS

USA blood serum 74% detection
Median 6.0 µg/L
Twice the levels of the sum of all long-chain, bioaccumulative PFAS

What levels of TFA will be in the blood of future generations?

Duan et al. (2020) Environ Int 134:105295.
Zheng et al. (2023) ES&T 2023, 57, 15782-15793
Arp et al. ES&T 2024, 58, 45, 19925-19935



PFAS contaminated sites in Europe
22,934 known contamination sites
21,426 presumptive contamination sites
231 known PFAS users
20 PFAS manufacturing facilities

Source: Forever Pollution Project
foreverpollution.eu
Cordner et al. Environ. Sci. Technol. 2024, 58, 15, 6616-6627

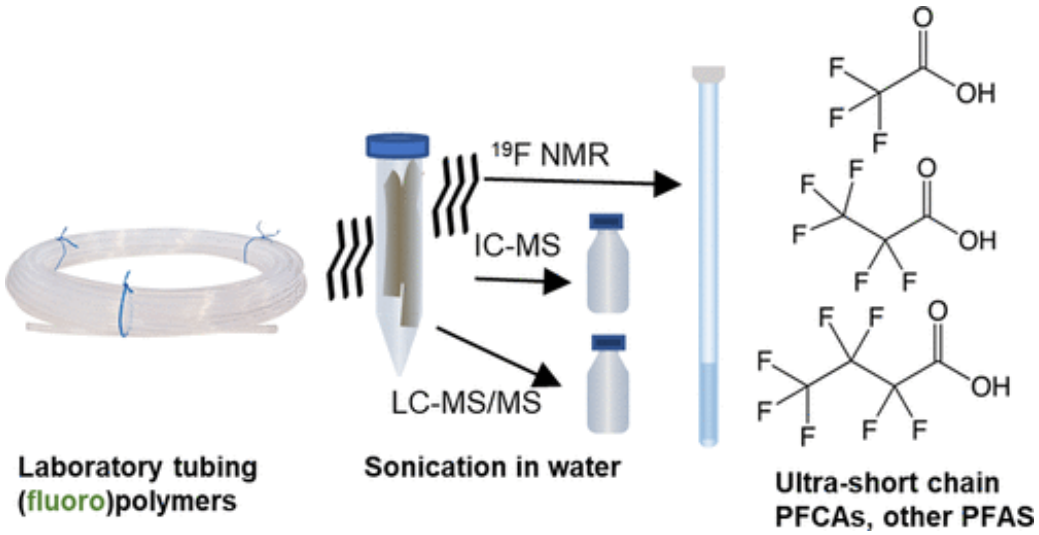
Le Monde

Release from PFAS and fluoropolymer production and products

PFAS production and products

Richard Hurd

- EU production of TFA 100 – 1000 tonnes/year
- TFA releases during F-gas, Fluoropolymer and PFAS production (e.g. 7500 µg/L in river Arias near a PFAS production facility)[1]

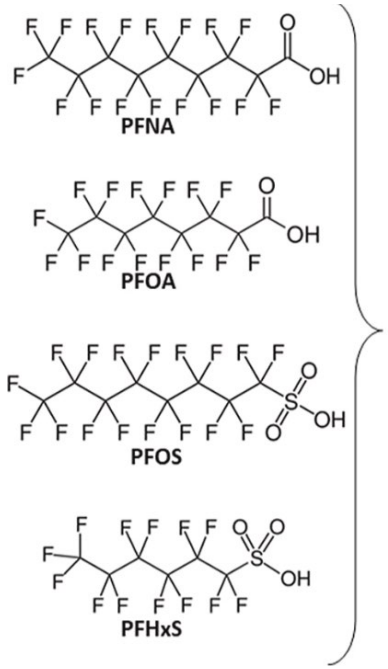


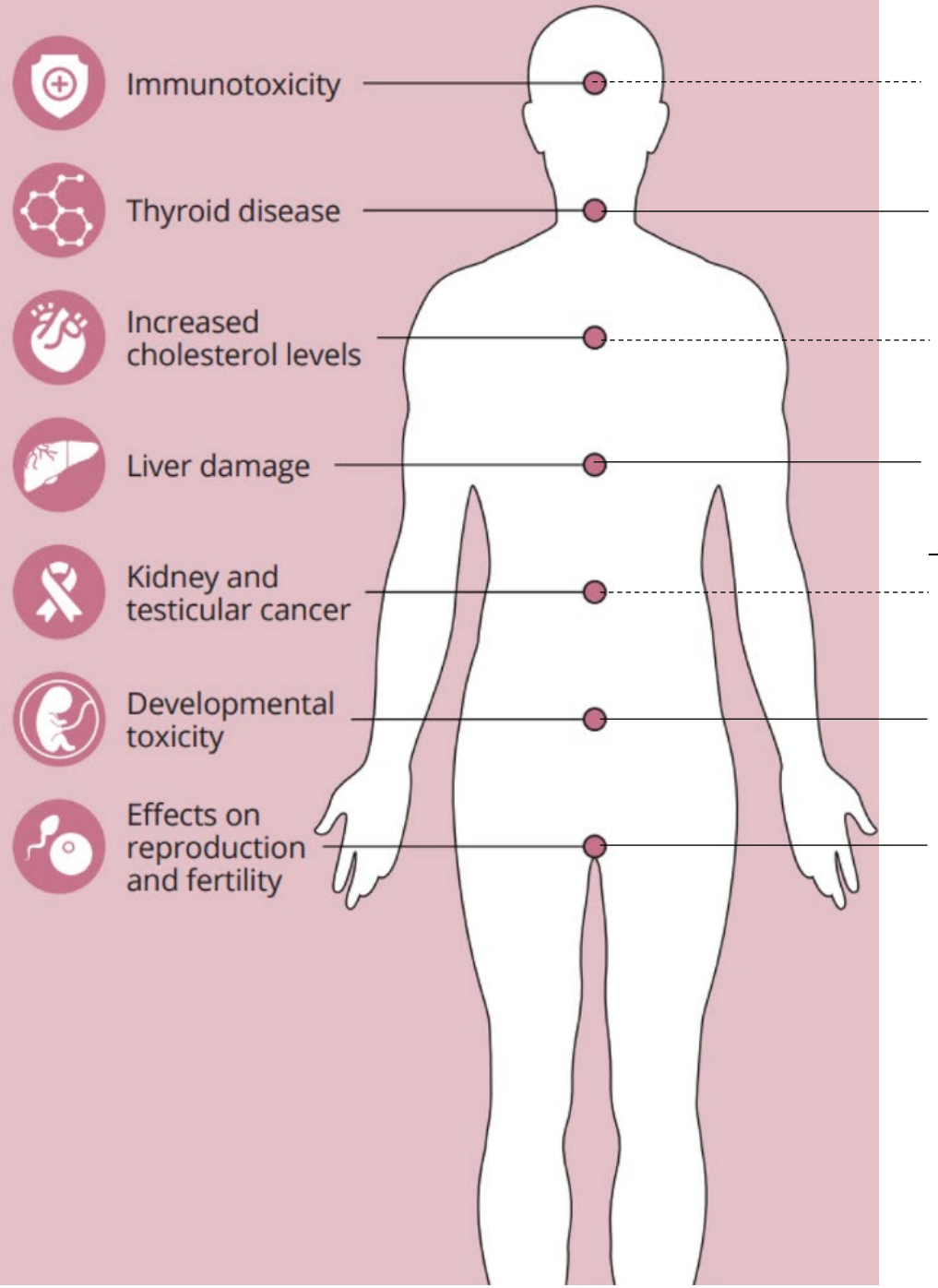
- Fluoropolymers *and plastics* leach TFA and other PFAS
- 126 +/- 96 µg/kg TFA leach from FEP tubing

[1]https://www.generations-futures.fr/wp-content/uploads/2024/02/rapport-salindres-pfas.pdf

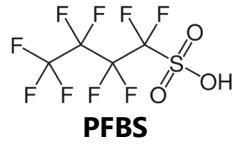
Joudan et al. Environ. Sci. Technol. Lett. 2024, 11, 3, 237-242

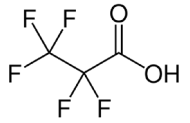
Legacy scenario

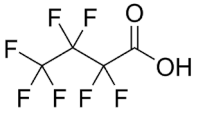


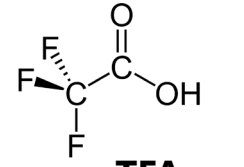


Emerging scenario









Brunn, H., Arnold, G., Körner, W. *et al.* . *Environ Sci Eur* **35**, 20 (2023). https://doi.org/10.1186/s12302-023-00721-8

Toxicity to Mammals

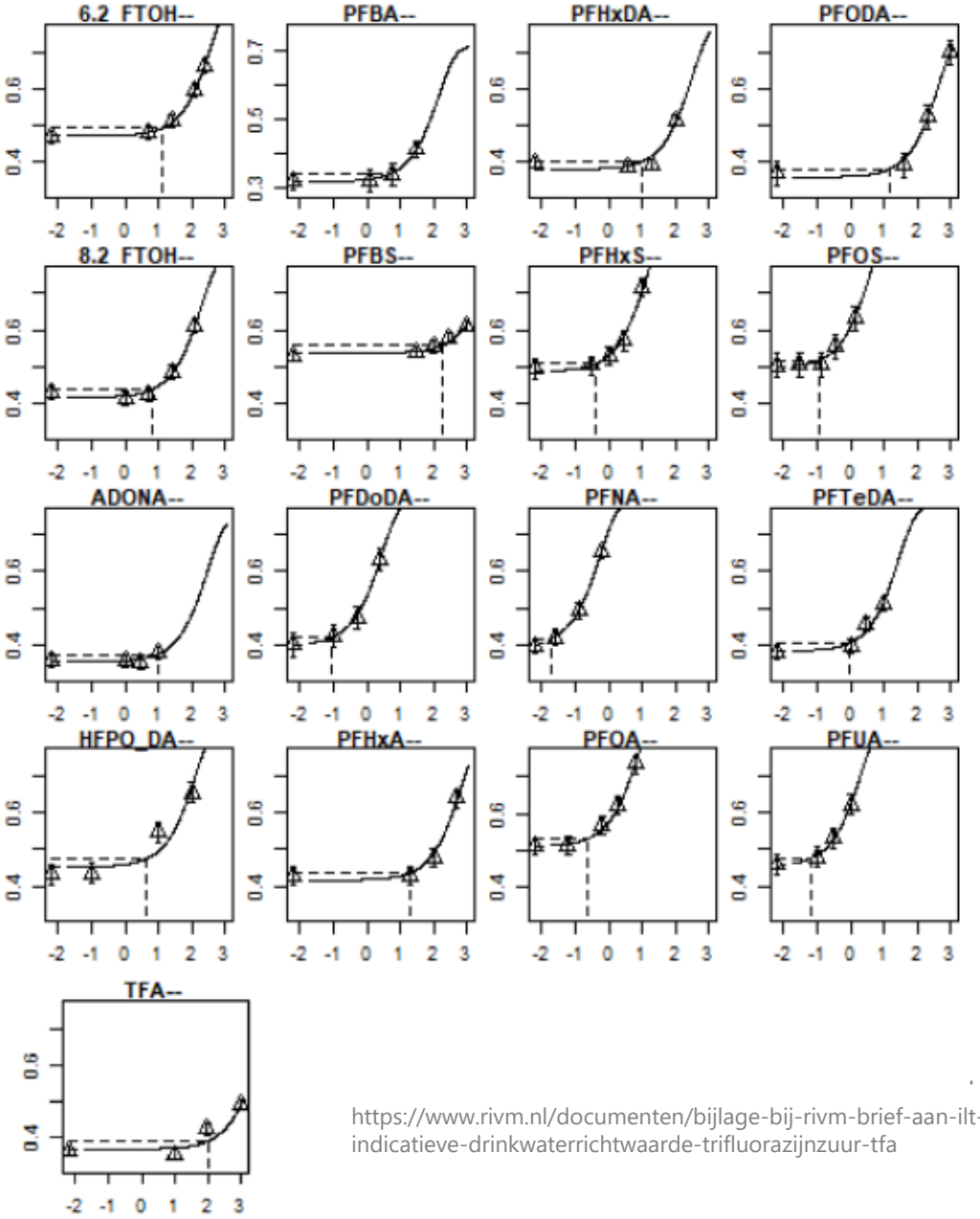
RIVM (2022)
Chronic rat toxicity (feeding)
Dose response: Male liver weight vs dose
Relevant potency factor: TFA is 0.002 x toxic as PFOA

*Corresponds to a **water threshold value of 2.2 µg/L***
Exceeded in an increasing number of areas

ECHA REACH Dossier (2024)
Han Wistar Rabbits
embryo-fetal developmental toxicity <180 mg/kg/day

multiple folded retina and absent aqueous/vitreous humor were above the … historical control data range

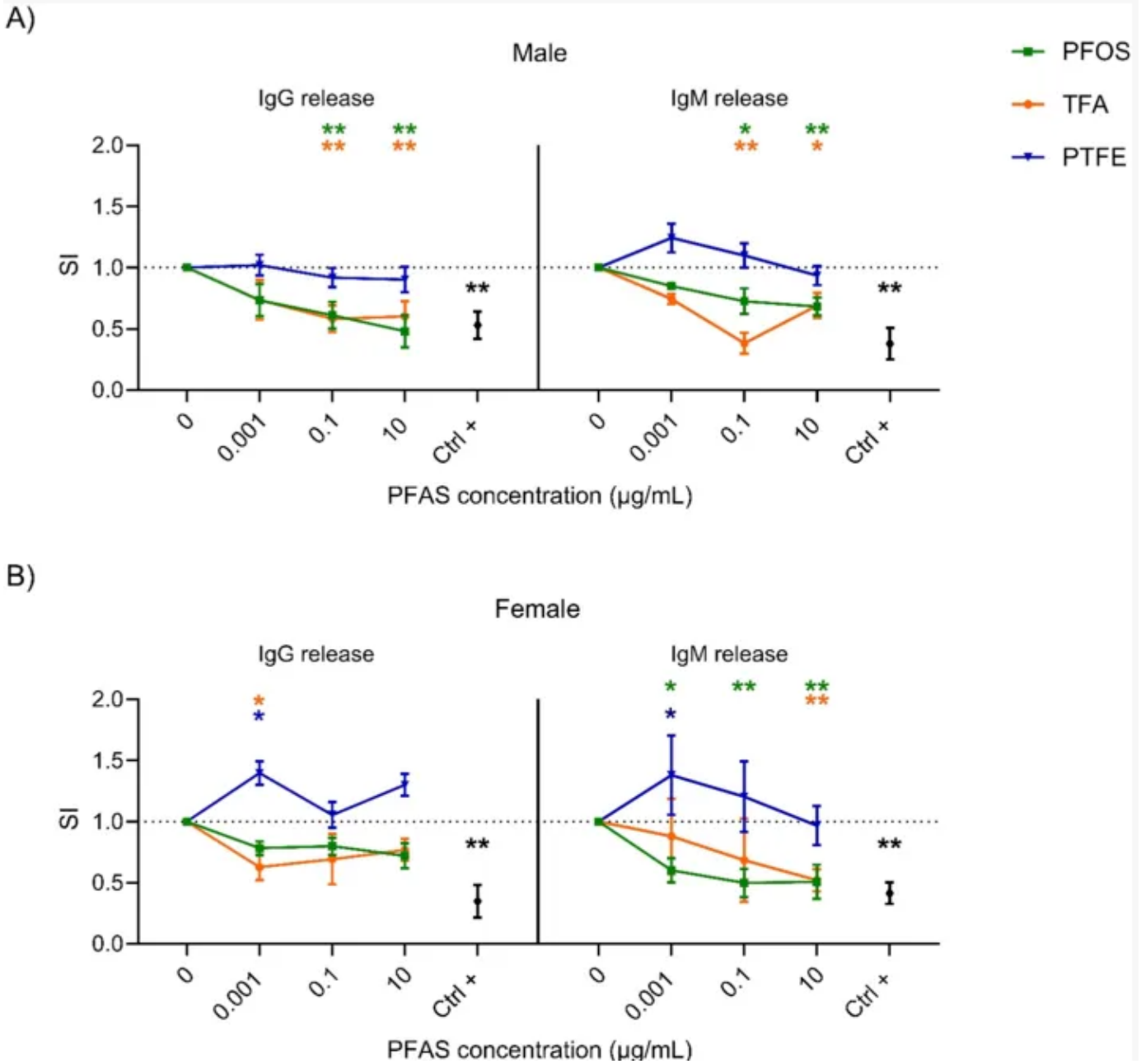
Category 1B: Presumed human reproductive toxicant



https://www.rivm.nl/documenten/bijlage-bij-rivm-brief-aan-ilt-indicatieve-drinkwaterrichtwaarde-trifluorazijnzuur-tfa

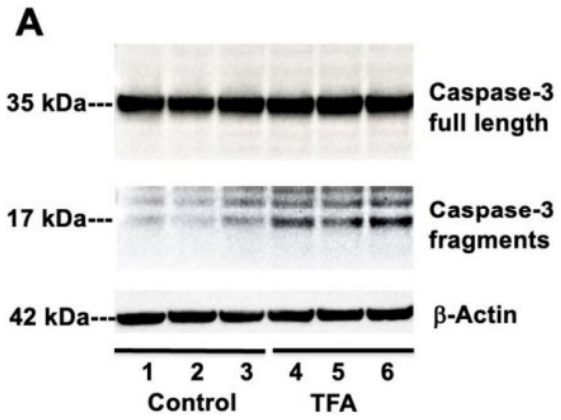
Emerging data on immunotoxicity

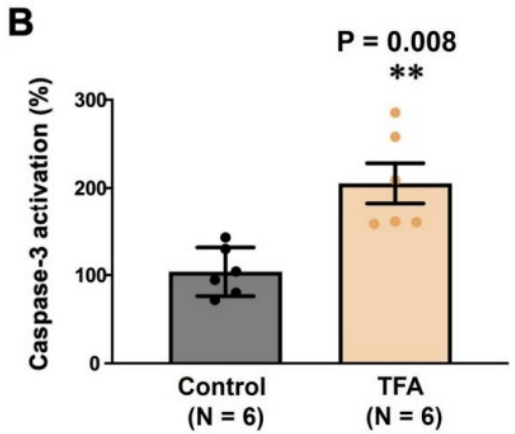
“ TFA reduced antibody production at levels comparable to PFOS, indicating that chain length alone is not a reliable predictor of immunotoxic potential”



Iulini, M., Galbiati, V., Marinovich, M., & Corsini, E. (2025). Decoding PFAS immunotoxicity: a NAMs-based comparison of short vs. long chains. *Frontiers in Toxicology*, *7*, 1665163.

Link to neurotoxicity with TFA-binding to proteins



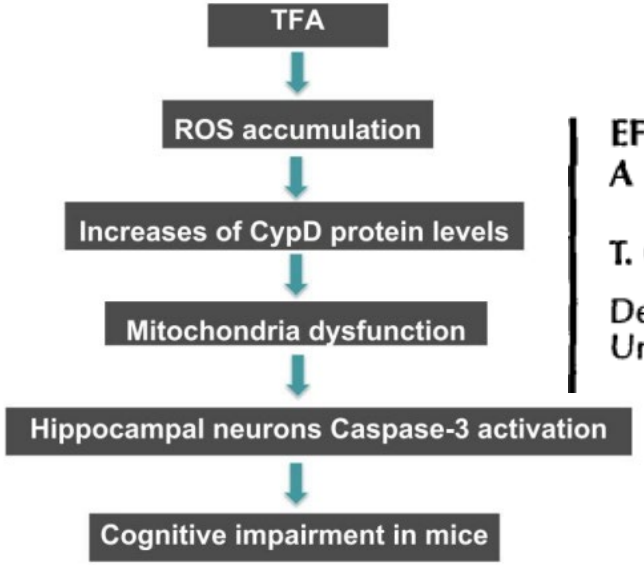


Aging and Disease
www.aginganddisease.org
Early access date: February 26, 2025
http://dx.doi.org/10.14336/AD.2024.1430

Original Article

Trifluoroacetic Acid Induced a Cyclophilin D-Dependent Cognitive Impairment in Mice

Yun Li[1,2#], Yichi Xu[1,3], Yuanlin Dong[1], Christa J. Nehs[4], Zhongcong Xie[1], Yiying Zhang[1*]

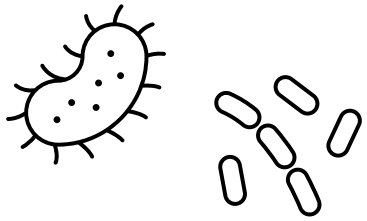


EFFECTS OF TRIFLUOROACETIC ACID, A HALOTHANE METABOLITE, ON C6 GLIOMA CELLS

T. G. Ma, Y. H. Ling, G. D. McClure, M. T. Tseng

Department of Anatomical Sciences and Neurobiology, University of Louisville, Louisville, Kentucky

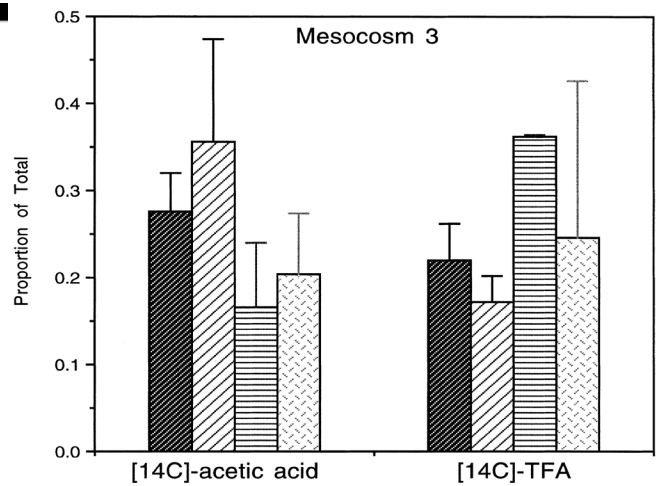
TFA able to become part of the lipids and biomolecules inside microbes …. no follow-up since 1999

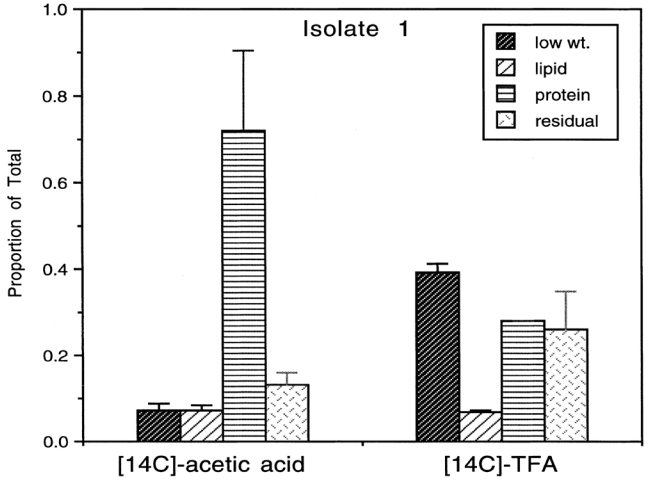


Trifluoroacetate, an Atmospheric Breakdown Product of Hydrofluorocarbon Refrigerants: Biomolecular Fate in Aquatic Organisms

LAUREL J. STANDLEY* AND
THOMAS L. BOTT

Stroud Water Research Center, Academy of Natural Sciences of Philadelphia, 970 Spencer Road, Avondale, Pennsylvania 19311





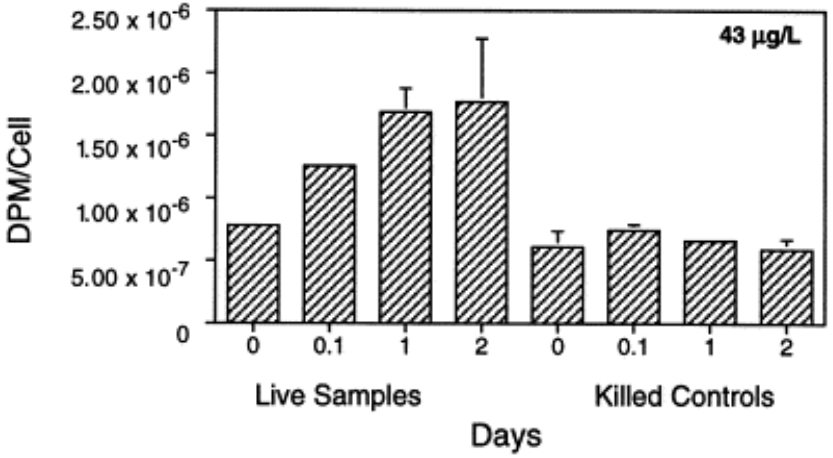
ELSEVIER

Water Research
Volume 33, Issue 6, April 1999, Pages 1538-1544

Research Note

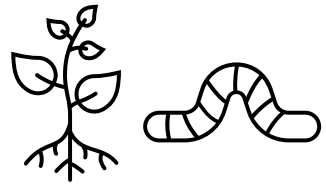
Incorporation of trifluoroacetate, a hydrofluorocarbon decomposition byproduct, by freshwater benthic microbial communities

Thomas L. Bott, Laurel J. Standley



If TFA covalently bonded with lipids, membranes, biomolecules, etc. they would ultimately be degraded to TFA… again

Toxicity to soil and terrestrial systems



Soils / terrestrial ecosystems

- Effects on the soil pH, microbial respiration, bacterial abundance and litter decomposition were reported at TFA concentrations in soil in hotspots **(0.0013–2.4 mg/kg$_{dw}$)**,

- **Soil concentrations at TFA hotspots already exceed concentrations which decrease soil respiration, potentially impacting the bioeconomy**

Jan Kopřiva

TFA affecting soil health

Chen et al. *Environ. Sci. Technol.* **2018**, *52* (15), 8263− 8271

Planetary Boundary Threat of TFA and CFCs

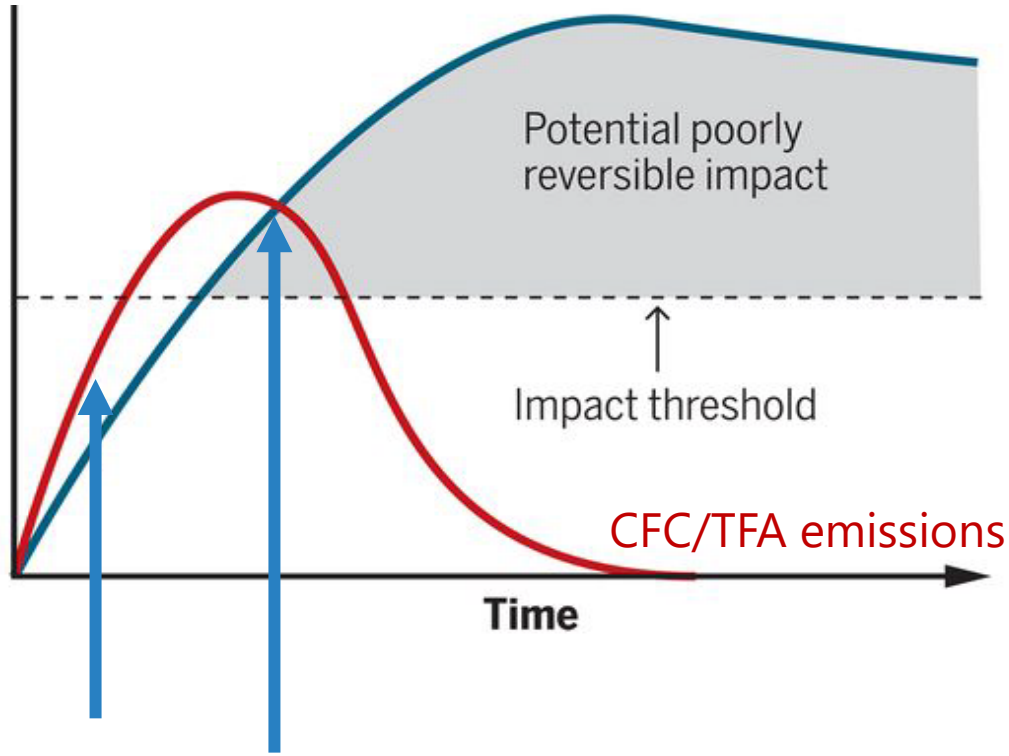
Disturbances to the «homeostasis» or of earth processes.
Conditions for novel entities:[1,2]

Planetary boundaries

Condition 1: pollution disrupts a vital earth system process of which we are ignorant.
TRUE: disruption at hotspots occur now, ignorant on life-long intergenerational impacts

Condition 2: disruptive effect is not discovered until …manifested at a global scale
TRUE: TFA increases globally

Condition 3: impacts are poorly reversible because level of global pollution cannot be readily reduced
TRUE: TFA is already locked in to our markets and global ecosystem. TFA made today will exist in the plants and blood of animals for the future of the Earth

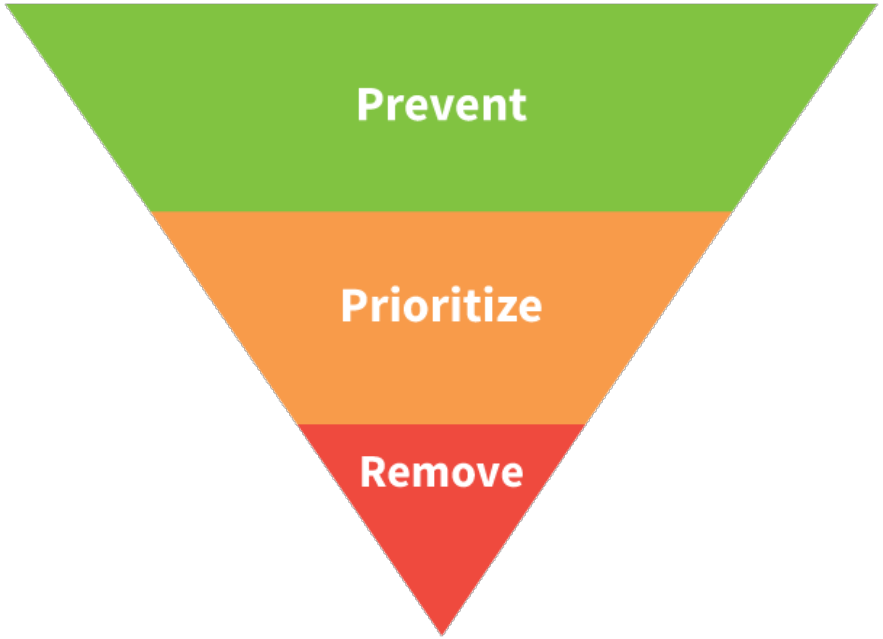


Not a threat
CFCs - Lovelock (1988)
TFAs – Boutonnet (1999)

Planetary boundary threat realized and exceed
CFC – ozone depletion -> Montreal Protocol
TFA – ?????

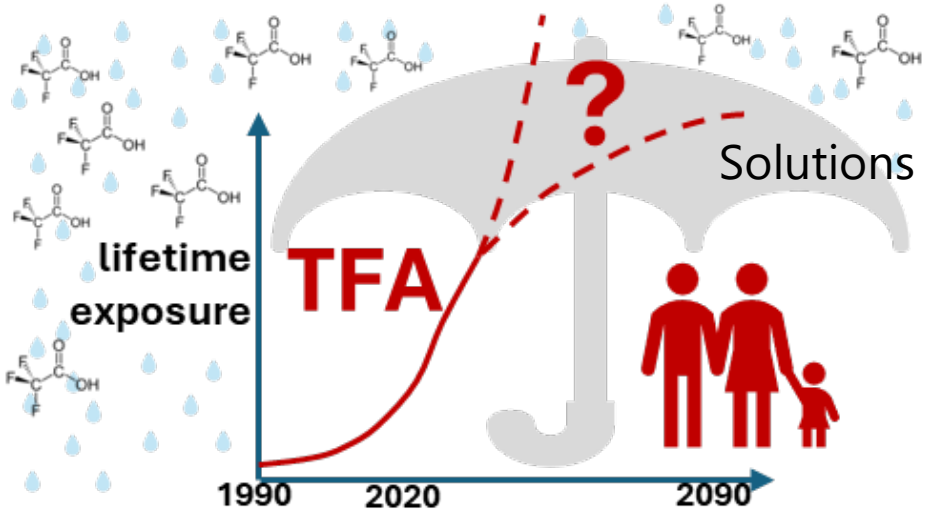
1. Persson et al. *Environ. Sci. Technol.* **2013**, *47* (22), 12619− 12622
2. MacLeod et al. *Science* 373,61-65(2021)

We have the tools to flatten the accumulation curve of PFAS and TFA in the blood of future generations



All you need is love and:

- Transition to PFAS and TFA free alternatives,
- Integrate financial incentives to transition from the biggest sources of exposure
- Remove TFA and PFAS from active emission sources and hotspots, ideally via the polluter pays principle



Acknowledgements

Registration opening soon!
Get notified about the event by visiting

zeropm.eu/final-event/

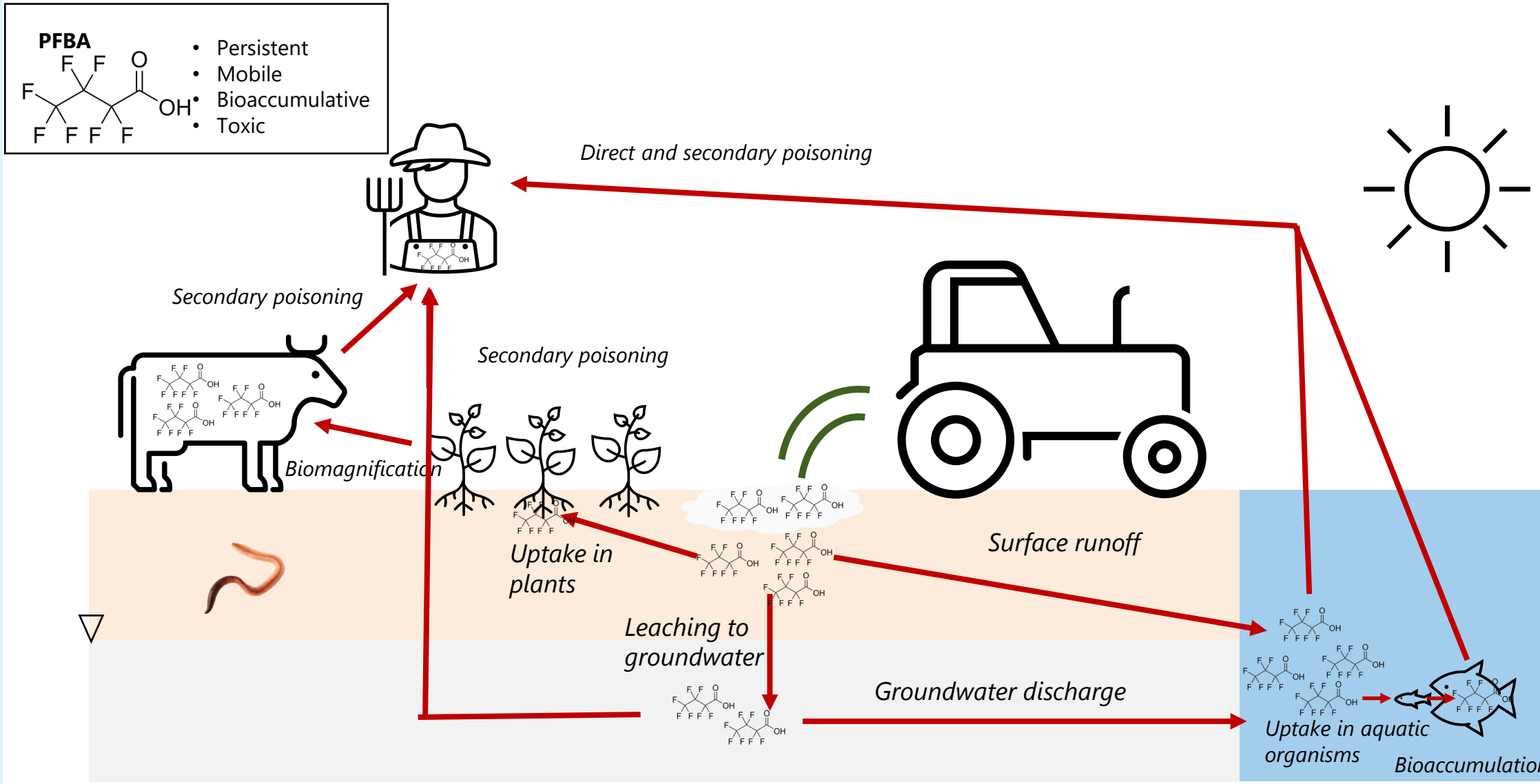
2021-2026

Thanks to funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101036756

https://zeropm.eu/

Extra slides

No dilution to this persistent and mobile pollution



Zhang et al (2021) Eng Int. https://doi.org/10.1016/j.envint.2021.106856

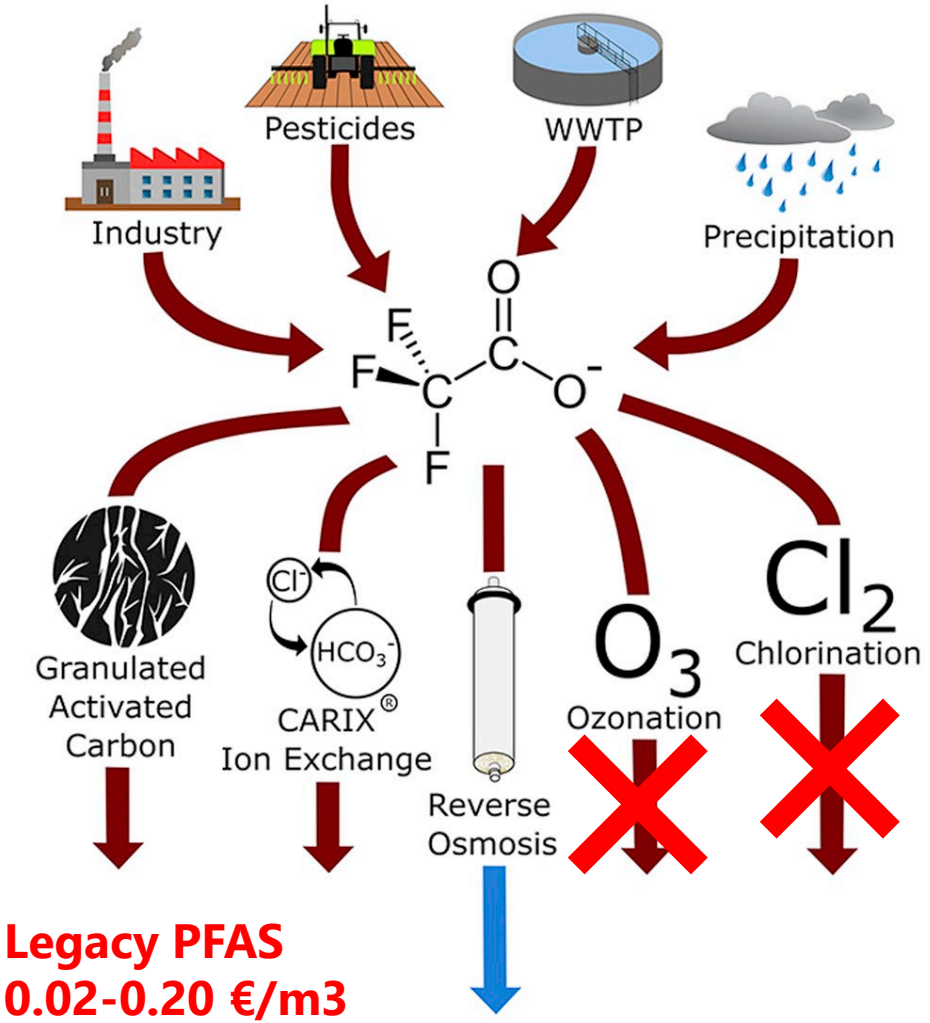
Technological and cost limitations

- TFA removal from water is Reverse Osmosis followed by Supercriticial water oxidation (ca 8 €/m^3)

Upscale to all water from PFAS contaminated sites

ca. 100 billion € /year

+ *all water synthetic*
+ *huge impact from green house gas emissions*
+ *Infrastructure upgrade not realistically plausible*

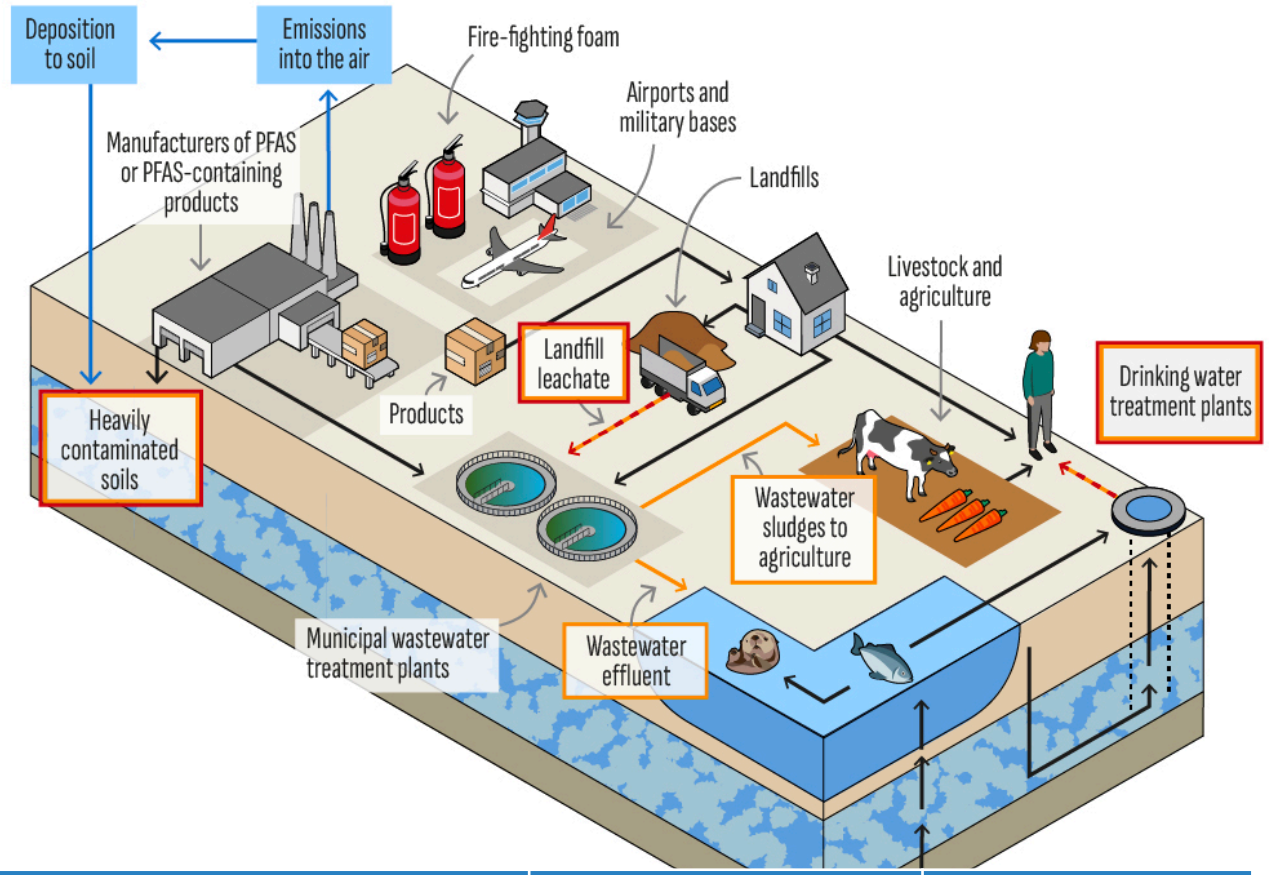


Legacy PFAS
0.02-0.20 €/m3

Emerging Scenario (with brine destruction)
5-10 €/m3

Scheurer et al. (2017). *Water research*, *126*, 460-471.

The cost of inaction increases as PFAS spreads



	Legacy Scenario	Emerging Scenario
	Targeting long-chain PFAS	Targeting all PFAS, including TFA
Heavily contaminated soils	1-5 B €/year	5-30 B €/year
Drinking water	0.2-0.7 B €/year	16-65 B €/year
Landfill leachate	0.0004-0.01 B €/year	0.02-0.7 B €/year
Wastewater effluent	Not included	20-70 B €/year
Wastewater sludges to agriculture	Not included	8-20 B €/year

- **Legacy Scenario**
  €38 - 100 billion over 20 years
- **Emerging Scenario**
  €2 trillion over 20 years
- Would address less than 1% of current PFAS uses in the EU
- Prevention/Reduction only feasible option
- Who will pay?

Remediation technology won't help if emissions still occur

Back of envelope calculation

Status quo (ECHA)
150 000 tonnes PFAS/ year emitted

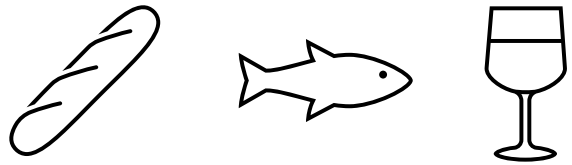
Vs

Theoretical extreme removal of PFAS in soil, industrial wastewater and drinking water
3 000 tonnes

Reality:
Economicaly and logistically
<<1% of PFAS emitted per year removed by next generation removal technology

Focussing on water and soil remediation won't remove:

➔ PFAS in the food supply
➔ PFAS locked in trees/ecosystems



Only prevention of emissions will work