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Wasser

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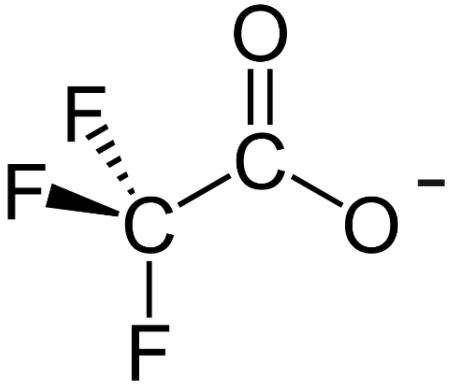
Sources, Fate and Exposure to Trifluoroacetic Acid (TFA)

Finnian Freeling
PFAS-Conference, 09. October 2025

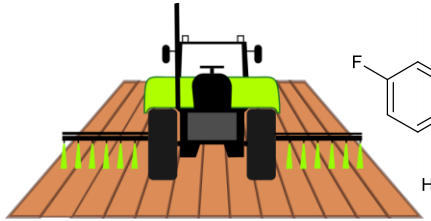
Fact Sheet Trifluroacetic acid

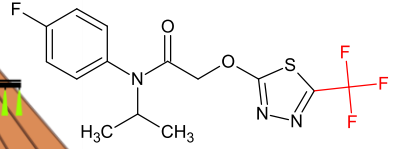


Trifluoroacetate (TFA)

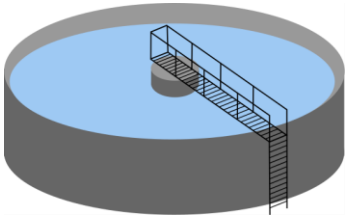
- **OECD** definition: member of the group of **PFAS**
- occurs in its **anionic form** in the aquatic environment
- exceptionally high **persistence** and **mobility**

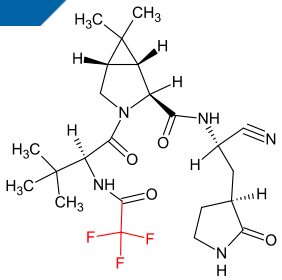
Anthropogenic sources | Overview



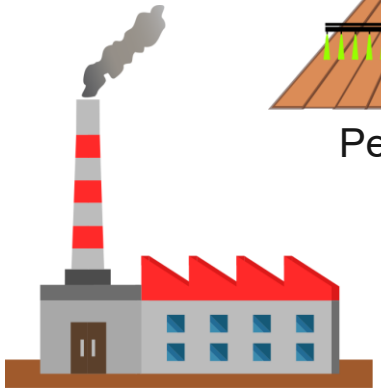


Pesticides with C-CF_3-moieties



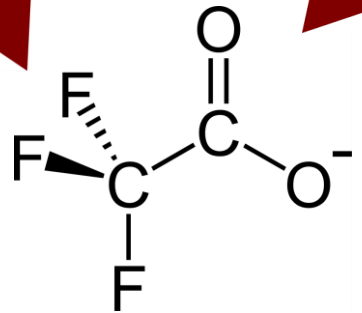


Pharmaceuticals with C-CF_3-moieties



Industrial discharges

Atmospheric deposition



Atmospheric deposition | Precursors

Precursor compound	molar TFA yield	Reference
Hydrofluorocarbons (HFC)		
HFC-245eb	up to 100%	Behringer et al. (2021)
HFC-245fa	up to 10%	WMO (2010)
HFC-134a	7-20%	Wallington et al. (1996)
HFC-143a	up to 10%	Behringer et al. (2021)
HFC-365mfc	up to 10%	WMO (2010)
HFC-227ea	100%	WMO (2010)
HFC-236fa	up to 10%	WMO (2010)
HFC-43-10mee	up to 100%	Behringer et al. (2021)
Hydrofluoroolefins (HFO)		
HFO-1234yf	100%	Hurley et al. (2008)
HFO-1234ze(E)	up to 10%	WMO (2010)
HFO-1336mzz(E und Z)	up to 20%	Henne et al. (2012)
Hydrochlorfluoroolefins (HCFO)		
HCFO-1233zd(E)	2%	Sulbaek Andersen et al. (2018)
HCFO-1224yd(E und Z)	100%	Behringer et al. (2021)

(tega.com)


(sprayfoam.com)


(publicdomain pictures.net)


(flickr.com)

Atmospheric deposition | Precursors

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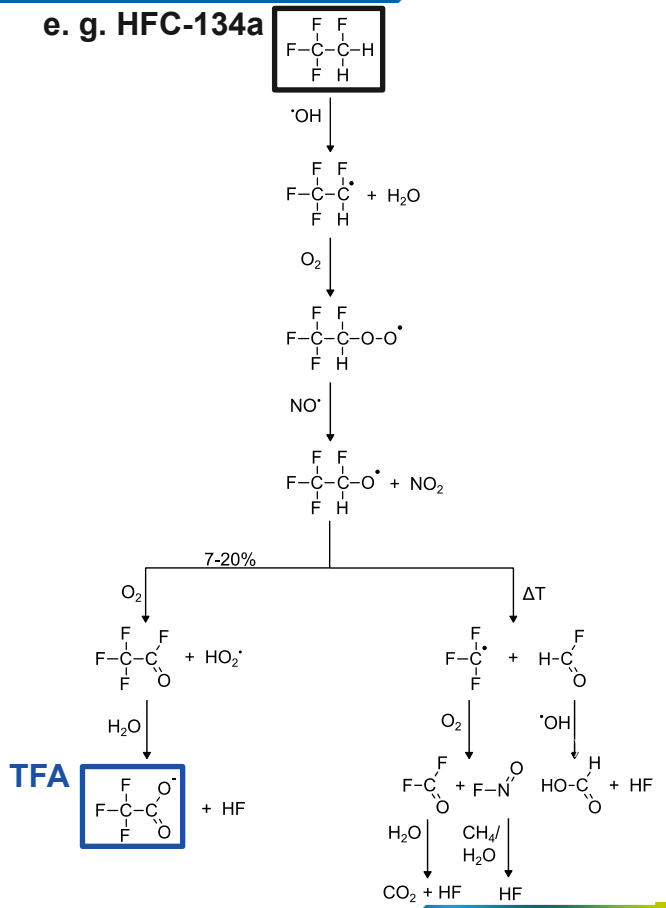
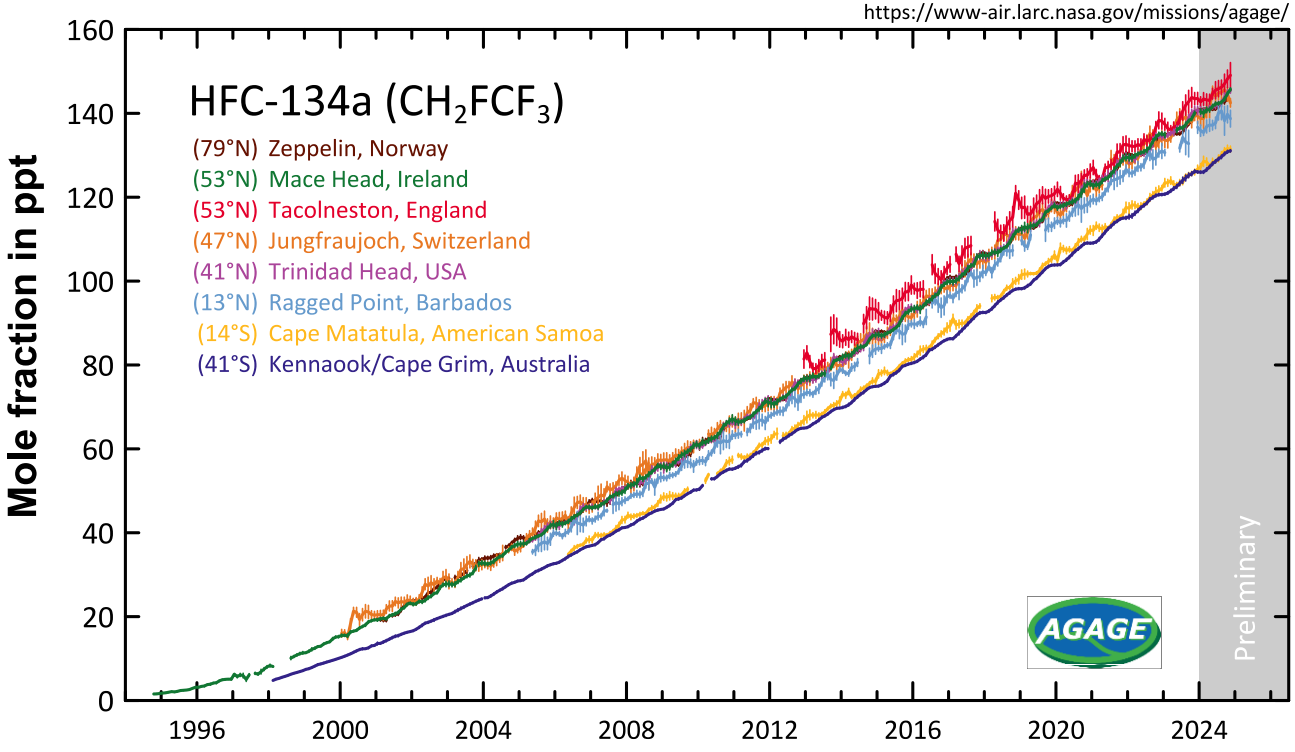


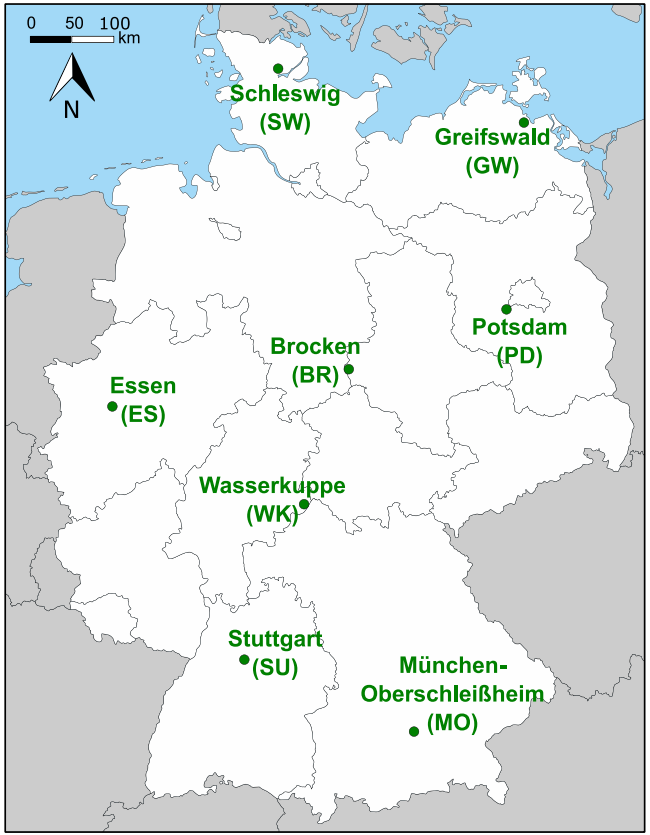
Atmospheric deposition | Precursors

https://www-air.larc.nasa.gov/missions/agage/



Atmospheric deposition | Monitoring

- **Goal:** Characterizing the current atmospheric TFA-deposition in Germany
- **8 sampling sites**
- **Continuous monitoring** over 25 months



Atmospheric deposition | Monitoring

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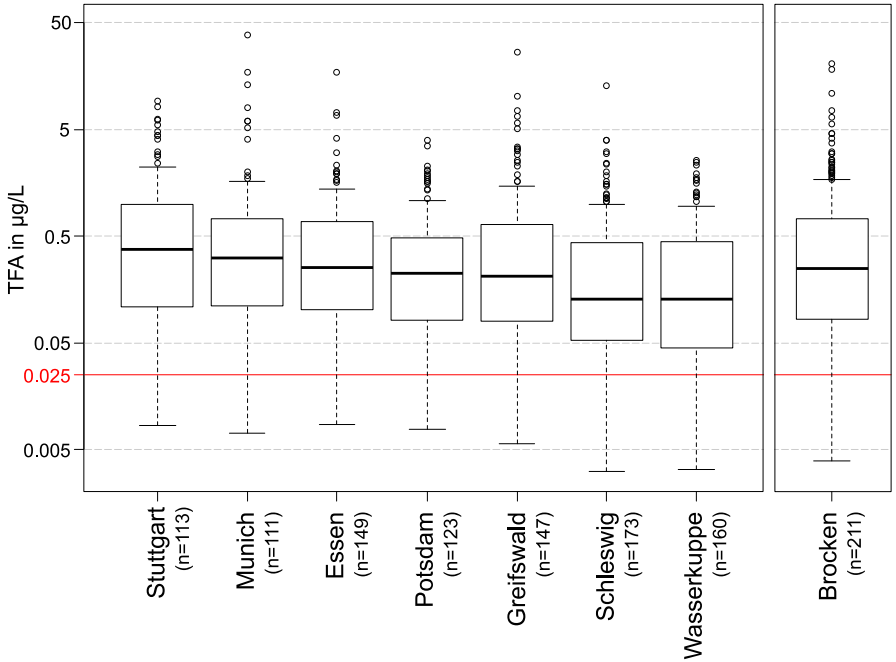
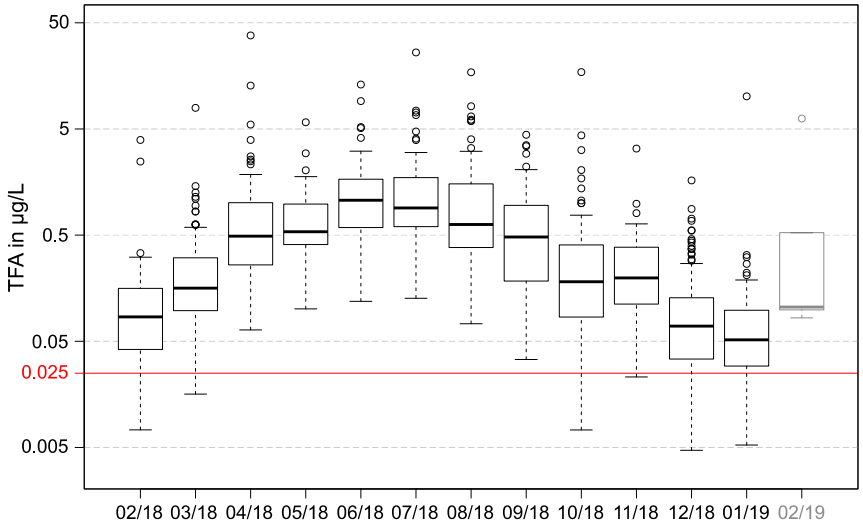
data grouped by **sampling site**



data grouped by **sampling time**



- precipitation-weighted average : **0.34 µg/L**
- annual wet deposition in Germany: **68 t/a**

- evidence for **OH radical** initiated oxidation

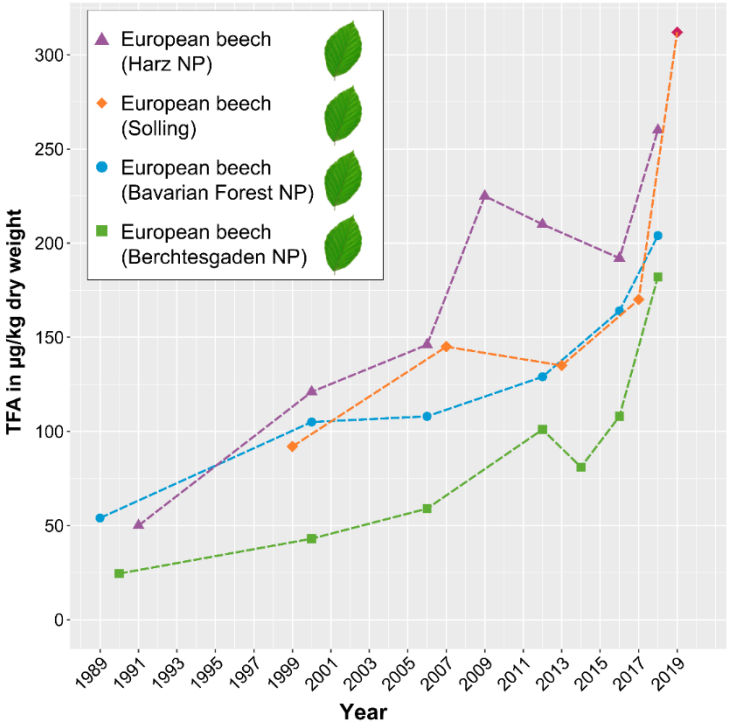
Freeling et al. (2020); https://doi.org/10.1021/acs.est.0c02910

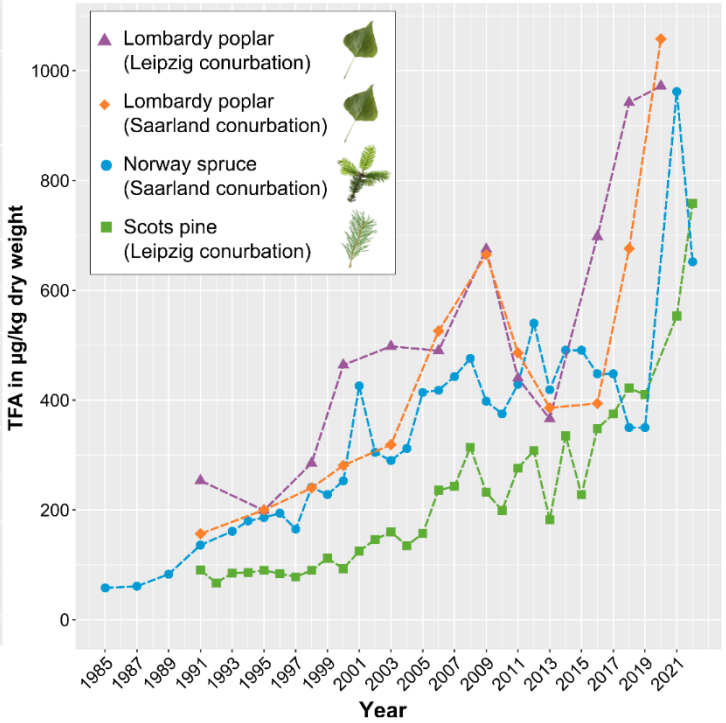
Atmospheric deposition | Temporal trends

- TFA is efficiently **taken up** and **accumulated** by vascular plants
- Plant leaves could serve as a **biomonitoring tool** for TFA

  ➡ Analysis of archived samples of the **German Environmental Specimen Bank** for TFA

Atmospheric deposition | Temporal trends

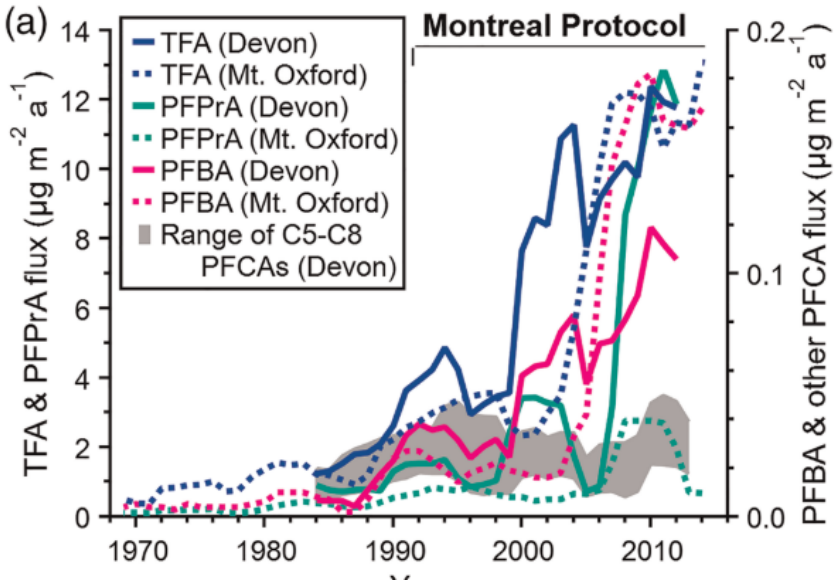




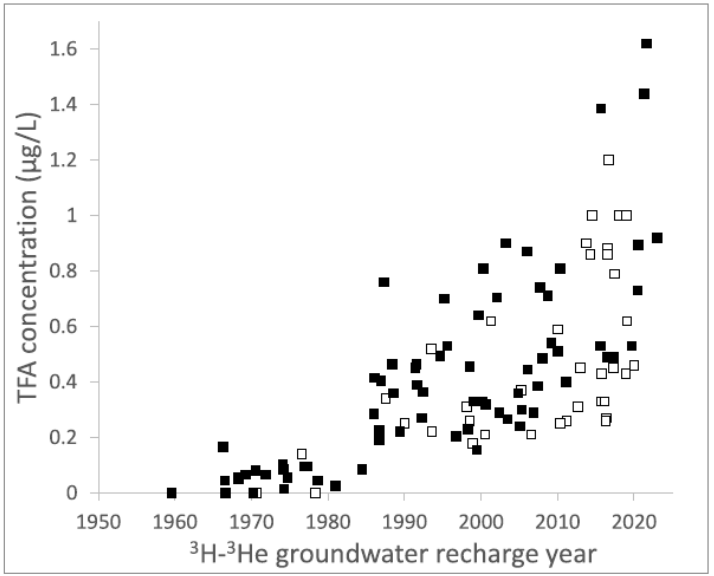
Freeling et al. (2022); https://doi.org/10.1021/acs.estlett.2c00164

Atmospheric deposition | Temporal trends

- Ice cores (Canada):



- Groundwater (Denmark):



Pickard et al. (2020); https://doi.org/10.1029/2020GL087535

Albers & Sültenfuss (2025); https://doi.org/10.1021/acs.estlett.4c00525

Atmospheric deposition | Prediction

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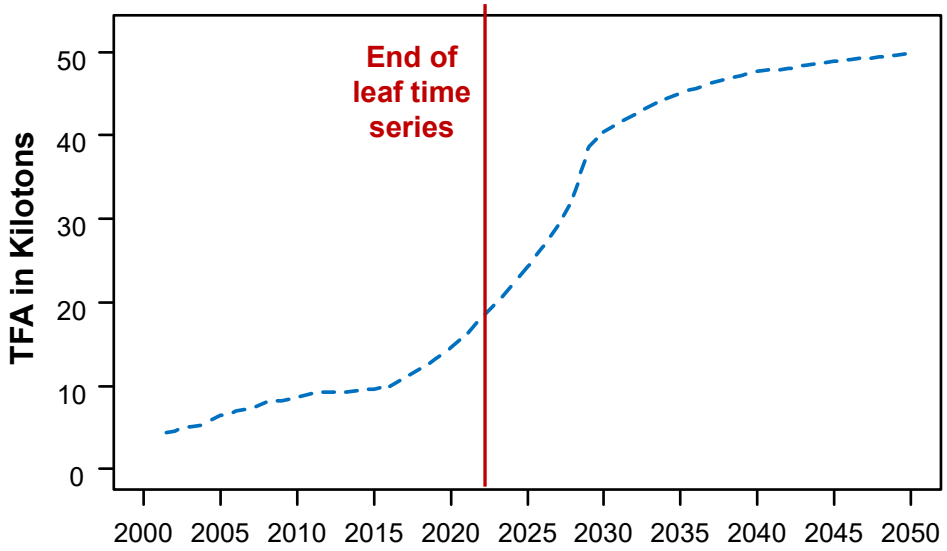
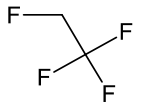
Modeled TFA deposition from the degradation of propellants and refrigerants emitted in the EU:



3rd Gen. of refrigerants

e. g. HFC-134a

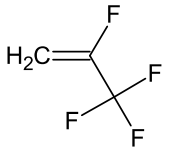


$GWP_{100\ years}$: **~1300**

Molar TFA yield: **7-20%**

4th Gen. of refrigerants

e. g. HFO-1234yf

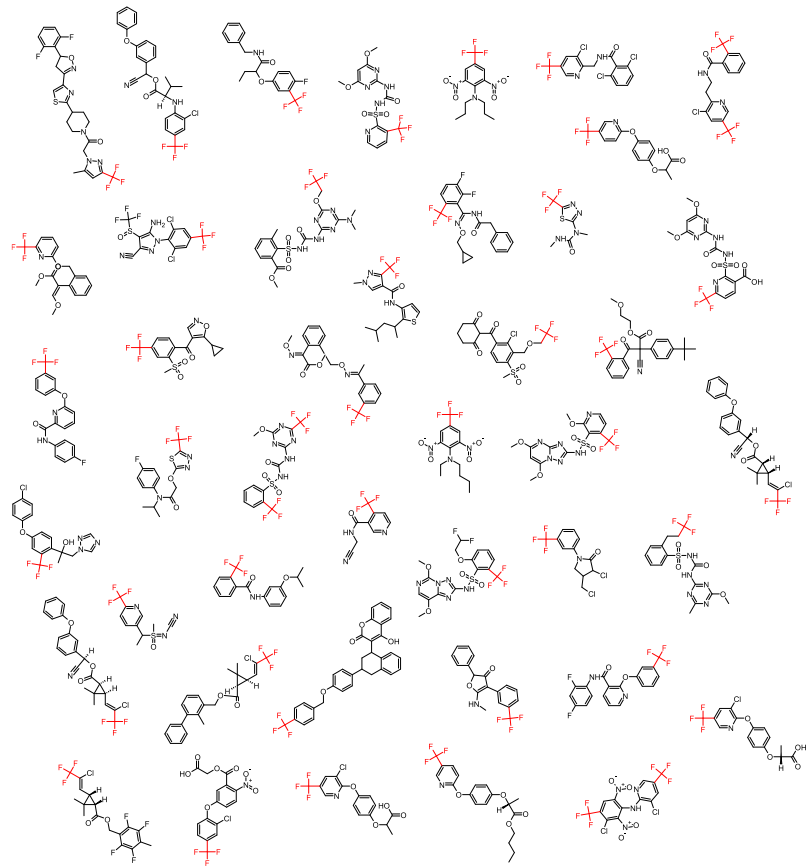


$GWP_{100\ years}$: **~4**

Molar TFA yield: **100%**

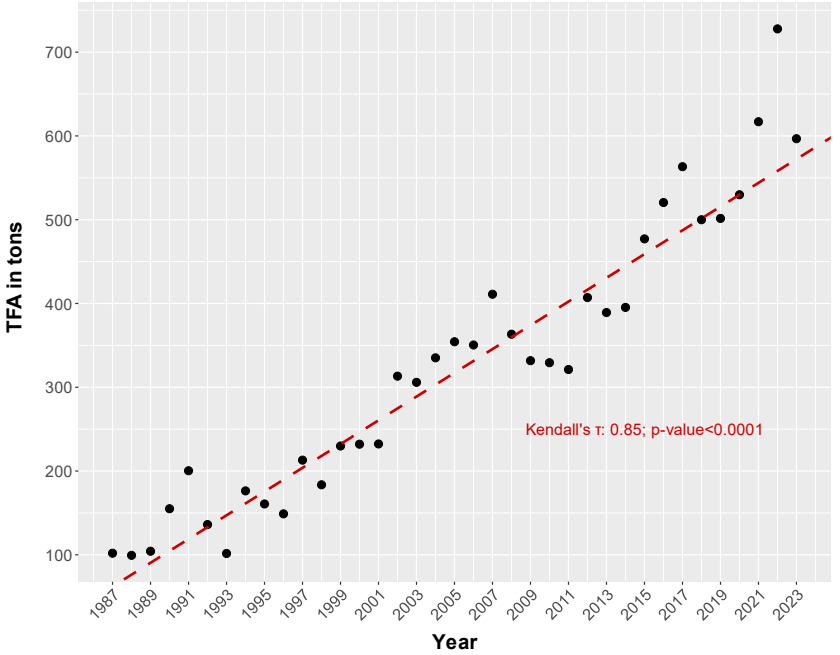
Behringer et al. (2021); https://www.umweltbundesamt.de/en/publikationen/persistent-degradation-products-of-halogenated

Pesticides | Formation potential



assuming stoichiometric TFA formation

TFA formation potential based on the **sales volume of** C-CF_3-pesticides in Germany:



Data source:
https://www.bvl.bund.de/SharedDocs/Downloads/04_Pflanzenschutzmittel/01_meldungen_par_64/meld_par_64_Wirkstoffabsatz_seit_1987.xlsx

Pesticides | Groundwater monitoring

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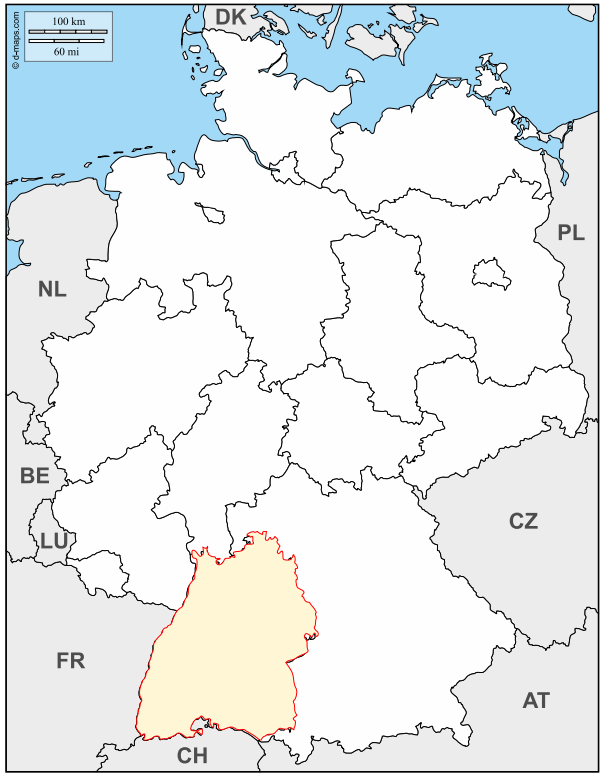
Are **elevated TFA** concentrations in the aquatic system associated with **agricultural land use**?

➡ Monitoring data

Groundwater monitoring data of the German state of Baden-Württemberg:



Joerss et al. (2024); https://doi.org/10.1016/j.envint.2024.109061

Pesticides | Groundwater monitoring

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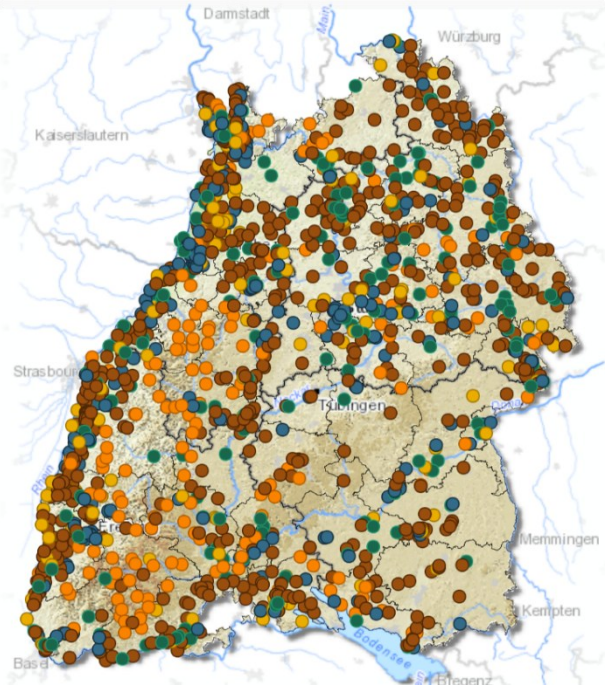
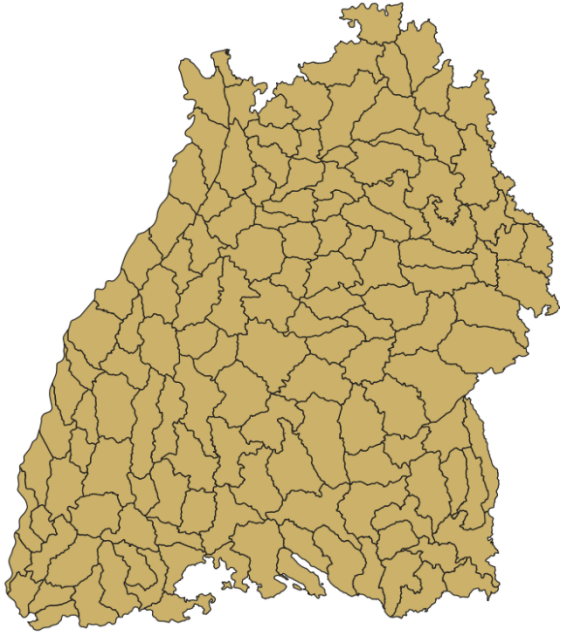
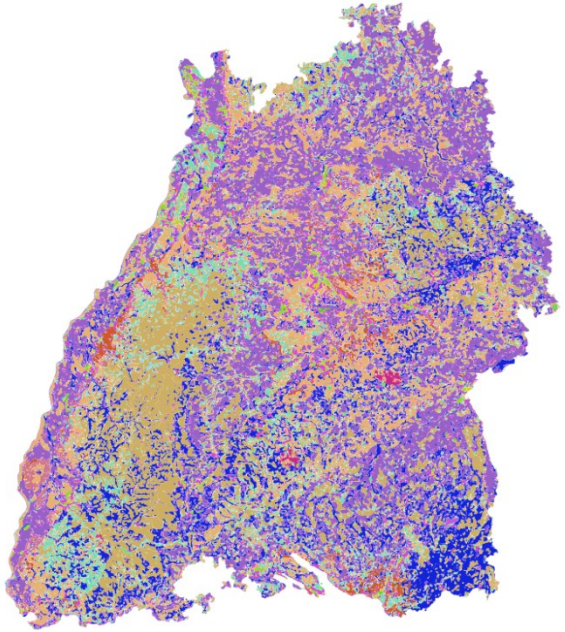






groundwater monitoring sites with **TFA data** (n=1598)

+

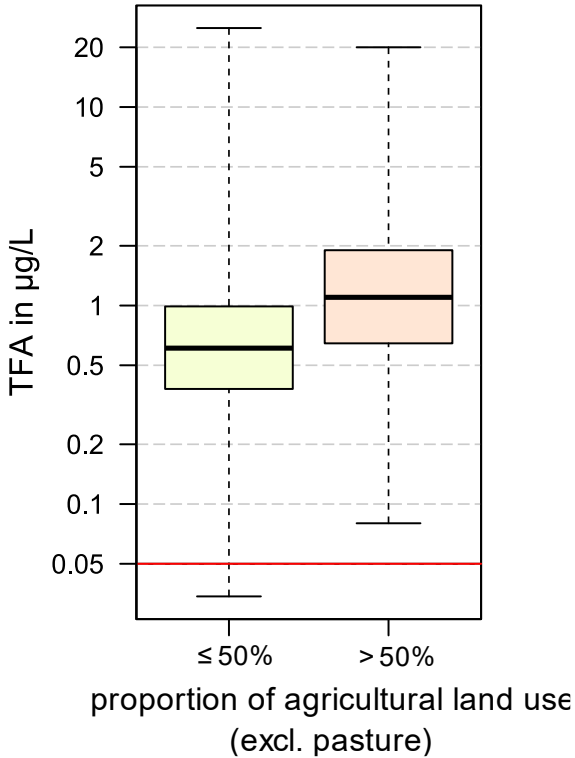
spatial extents of groundwater bodies according to WFD

+

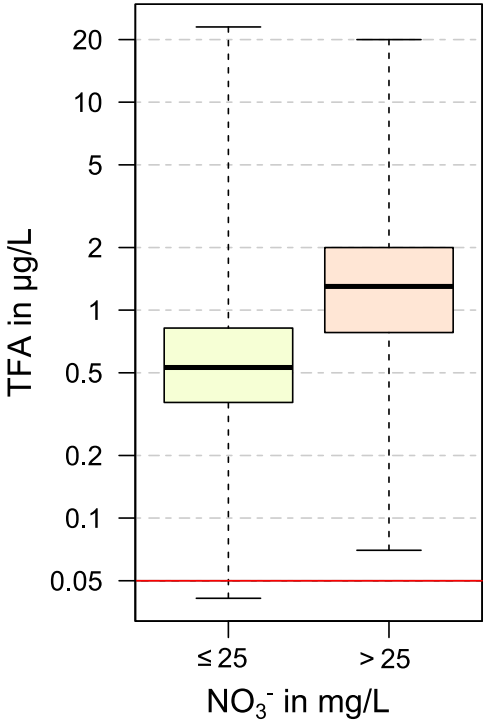
land use according to CORINE land cover program

Joerss et al. (2024); https://doi.org/10.1016/j.envint.2024.109061

Pesticides | Groundwater monitoring



Mean	1.14 µg/L	**1.59 µg/L***



Mean	0.92 µg/L	**1.84 µg/L****

Two-Sample Permutation Test of Difference in Means: *p<0.001 **p<0.0001

Joerss et al. (2024); https://doi.org/10.1016/j.envint.2024.109061

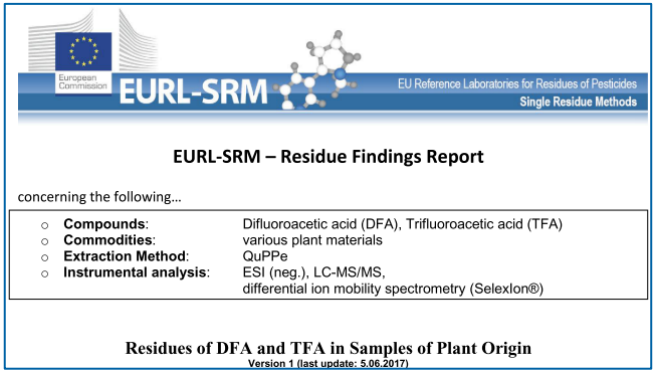
Manure?

- The analysis of a small number of samples suggests **high concentrations** of TFA in **manure**
- The **application of manure** could provide an additional entry path for TFA

Many research needs:
how are processes such as **biomass loss** (e.g., through harvesting), **plant physiological traits** (e.g., growth rates), and the **breakdown of plant litter** contributing to **long-term TFA accumulation in plants** as well as **TFA circulation** within the biosphere, lithosphere, and hydrosphere?

Occurence | Food

- Reports increasingly highlight the widespread occurrence of TFA across various plant-based food:


EURL-SRM

EU Reference Laboratories for Residues of Pesticides

Single Residue Methods

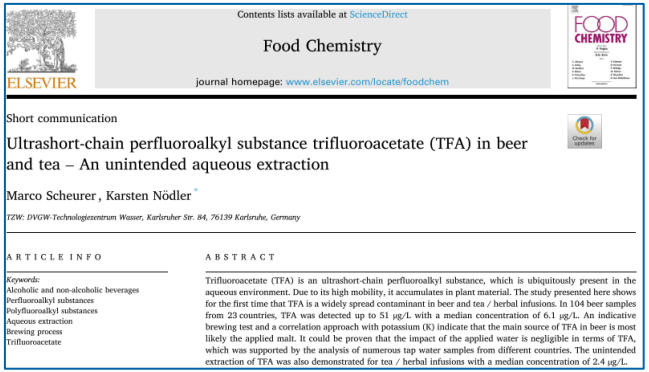
EURL-SRM – Residue Findings Report

concerning the following…

Compounds:	Difluoroacetic acid (DFA), Trifluoroacetic acid (TFA)
Commodities:	various plant materials
Extraction Method:	QuPPe
Instrumental analysis:	ESI (neg.), LC-MS/MS, differential ion mobility spectrometry (Selexlon®)

Residues of DFA and TFA in Samples of Plant Origin

Version 1 (last update: 5.06.2017)


Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Short communication

Ultrashort-chain perfluoroalkyl substance trifluoroacetate (TFA) in beer and tea – An unintended aqueous extraction

Marco Scheurer, Karsten Nödler *

TZW: DVGW-Technologiezentrum Wasser, Karlsruher Str. 84, 76139 Karlsruhe, Germany

ARTICLE INFO

Keywords:
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Perfluoroalkyl substances
Polyfluoroalkyl substances
Aqueous extraction
Brewing process
Trifluoroacetate

ABSTRACT

Trifluoroacetate (TFA) is an ultrashort-chain perfluoroalkyl substance, which is ubiquitously present in the aqueous environment. Due to its high mobility, it accumulates in plant material. The study presented here shows for the first time that TFA is a widely spread contaminant in beer and tea / herbal infusions. In 104 beer samples from 23 countries, TFA was detected up to 51 µg/L with a median concentration of 6.1 µg/L. An indicative brewing test and a correlation approach with potassium (K) indicate that the main source of TFA in beer is most likely the applied malt. It could be proven that the impact of the applied water is negligible in terms of TFA, which was supported by the analysis of numerous tap water samples from different countries. The unintended extraction of TFA was also demonstrated for tea / herbal infusions with a median concentration of 2.4 µg/L.


eurofins

WHITE PAPER

Trifluoroacetic acid (TFA) and trifluoromethane sulphonic acid (TFMS) in juice and fruit/vegetable purees

Patrick van Hees[1,2], Patrik Karlsson[1], Ludmila Bucuricova[1], Helena Olsman[1], Leo Yeung[2]

[1]PFAS Competence Centre, Eurofins Food & Feed Testing Sweden AB, [2]Man-Technology-Environment (MTM) Research Centre, Örebro University, Sweden


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Chemisches und Veterinäruntersuchungsamt Stuttgart

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Trifluoressigsäure – Bedenkliche Gehalte in unserem Obst und Gemüse?

Lucia Buchstab und Ellen Schenbaum

Seit einigen Jahren wird vermehrt über erhöhte Konzentrationen an Trifluoressigsäure – die kleinste der Per- und Polyfluoralkylsubstanzen (PFAS) – in Oberflächen-, Grund- und Trinkwässern berichtet. Aufgrund ihrer guten Wasserlöslichkeit und Langlebigkeit verbreitet sich die Substanz rasch in der Umwelt und verbleibt dort. Doch was ist Trifluoressigsäure überhaupt? Wie gelangt sie in die Umwelt und gibt es auch eine bedenkliche Kontamination in unserem Obst und Gemüse?

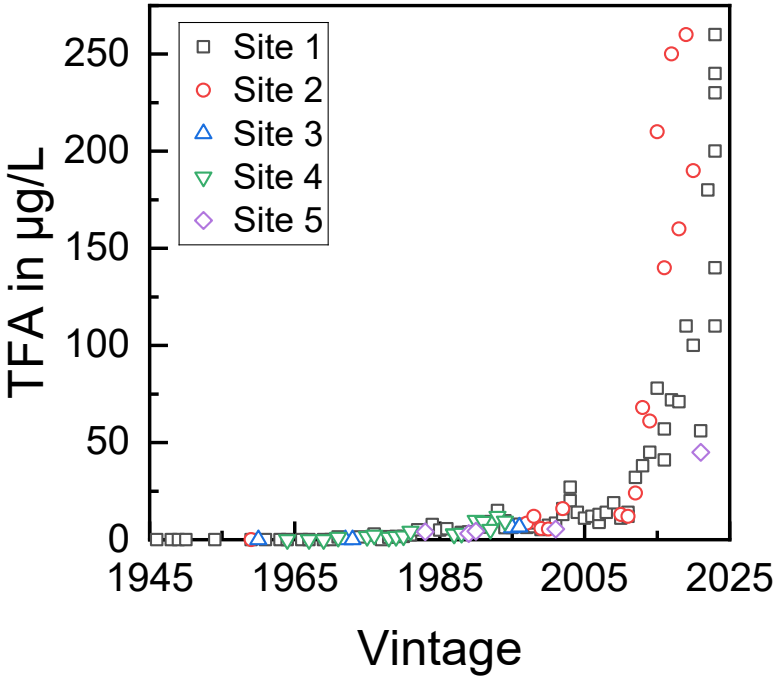
Rund um die Trifluoressigsäure

- http://www.eurl-pesticides.eu/userfiles/file/EurlSRM/EurlSrm_residue-Observation_TFA-DFA.pdf
- https://cdnmedia.eurofins.com/european-east/media/uxcnaa2c/eurofins_tfa_tfms_juice_24_final.pdf

- Scheurer & Nödler (2021); https://doi.org/10.1016/j.foodchem.2021.129304
- https://www.ua-bw.de/pubmobil/beitrag.asp?Thema_ID=5&ID=4167&subid=1

Occurence | Wine

Analysis of 1646–2024 vintage wines of a single winery in Southern Germany



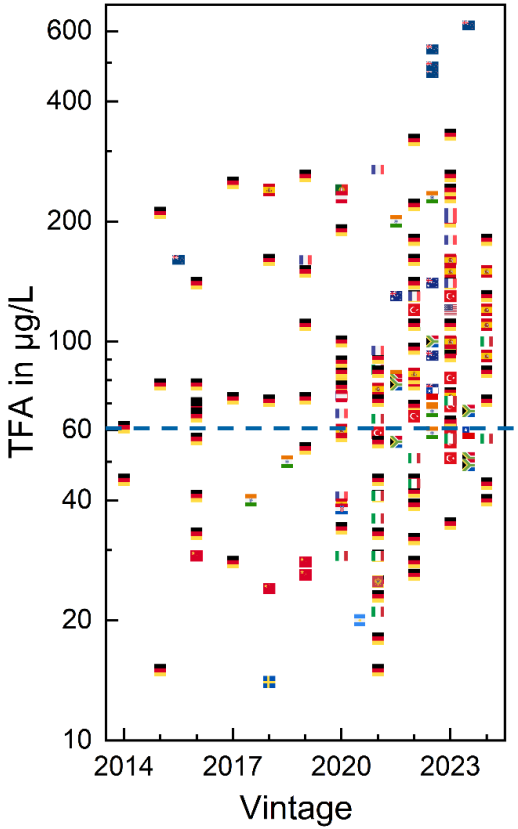
no detectable levels of TFA prior to 1970; pronounced increase from 2010 onward

Freeling & Mira de Orduña Heidinger (2025); https://doi.org/10.26434/chemrxiv-2025-rd6ps-v2

Occurence | Wine

- TFA concentrations in 201 international wines from 2014−2024 vintages:
- current **drinking water** in Germany typically contains **0.5 to 1 µg/L** of TFA
- Even if TFA does not bioaccumulate in animals and humans, its accumulation in edible plant tissues can lead to **high dietary intake**

➡ **dietary exposure** to TFA is likely **underestimated** and may constitute a more significant intake pathway than drinking water

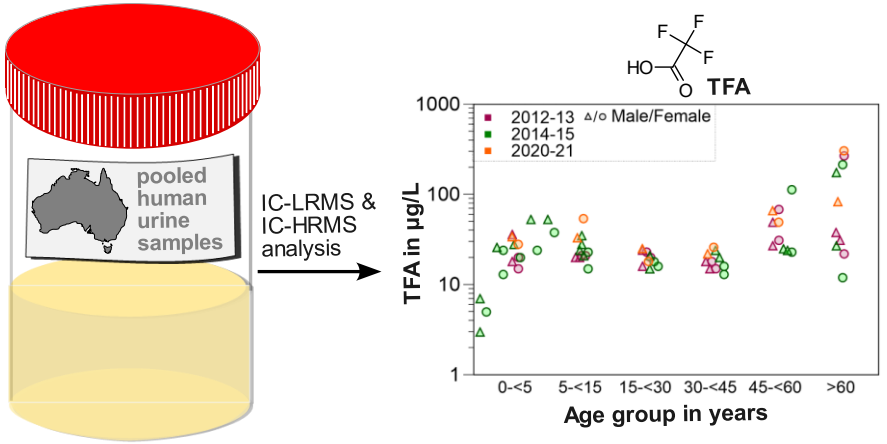


Freeling & Mira de Orduña Heidinger (2025); https://doi.org/10.26434/chemrxiv-2025-rd6ps-v2

Exposure

- TFA is mainly eliminated through renal excretion

- TFA in **urine** samples from Australia, pooled by collection year, age, and sex (*n* = 70 pools, 6040 individuals):



- TFA was detected in all urine samples ranging from 3.4 to 300 µg/L, with a **median of 24 µg/L**

➡ This suggests high **chronic exposure of Australians** to TFA, consistent with ubiquitous occurrence of TFA in food, drinking water and air reported in other countries

Muir et al. (2025); https://doi.org/10.1021/acs.estlett.5c00678

(Eco)toxicological relevance

- the currently known **toxicity** of TFA is **comparably low**:
  - e.g., aquatic organisms: freshwater PNEC of 560 µg/L
    based on the algal study reporting a 72 h EC10 (endpoint: growth rate) of 5600 µg/L (ECHA)
  - Low mammalian toxicity, the main effect from repeated exposure being mild liver hypertrophy
    according to a review by Dekant & Dekant (2023); https://doi.org/10.1007/s00204-023-03454-y

- 2020: Germany established a health guideline value for TFA in drinking water at 60 µg/L
  based on a chronic rat toxicity (feeding) study

- 2023: The Netherlands derived an indicative drinking water value for TFA at 2.2 µg/L
  based on the potency factor relative to PFOA and its threshold for drinking water

(Eco)toxicological relevance

- In May 2025, German authorities submitted a dossier to the European Chemicals Agency (ECHA) in accordance with the CLP* Regulation, proposing a harmonized hazard classification for TFA. The substance was classified as follows:
  - **Reproductive toxicant (Category 1B):**
    "*May damage the unborn child. Suspected of impairing fertility*"(hazard label: H360Df)
  - **Very persistent and very mobile (vPvM):**
    "*May cause very long-lasting and diffuse pollution of water resources*" (hazard label: EUH451)

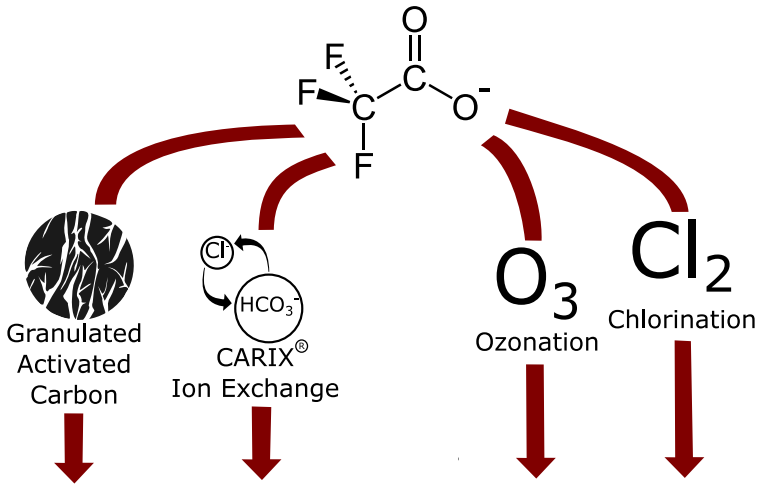
- With ongoing and increasing emissions of TFA from multiple anthropogenic sources, in concentrations of TFA in various environmental compartments **will increase**

*CLP: Classification, labelling and packaging of chemicals

https://www.bfr.bund.de/en/press-release/trifluoroacetic-acid-tfa-assessment-for-classification-in-new-hazard-classes-submitted/

What can be done?

- Current lack of cost- and energy-efficient **remediation techniques** for TFA
  (TFA in raw water = TFA in drinking water)



- Reverse osmosis (RO) requires a substantial amount of energy and water
- What happens with the concentrate?
- RO contradicts article 7(3) of the European Water Framework Directive:

  *"Member States shall ensure the necessary protection for the bodies of water identified with the aim of avoiding deterioration in their quality in order to **reduce the level of purification treatment required** in the production of drinking water"*

Scheurer et al. (2017); https://doi.org/10.1016/j.watres.2017.09.045

What can be done?

- Improving our understanding of the contributions of individual TFA sources and of the long-term health effects of TFA
  - ➡ essential to **assess the risk** associated with the use of TFA and its precursors and to implement **effective countermeasures**

- Implementing mitigation measures throughout the entire life cycle of TFA and its precursors
  - ➡ necessitates a tiered approach that **goes beyond end-of-pipe technologies** and encompasses strategies such as **substance avoidance** and **production-integrated environmental protection**

- Reducing the emissions of precursors compounds of TFA
  - ➡ But: **regrettable substitution** of TFA precursors with potentially more hazardous or otherwise problematic compounds **needs to be avoided**

The **formation** of highly persistent and mobile **transformation products** such as TFA needs to be **considered** during the development and authorization of chemicals

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