Refrigerant Column, January 2025

PFAS, TFA and the Hidden Risks of Synthetic Refrigerants

By Björn Palm

Across Europe, the debate over **PFAS chemicals** is intensifying. Several countries, including Sweden, have called for a **complete EU ban** on these substances. The PFAS group includes more than **10,000 synthetic chemicals**, all sharing at least one carbon atom bonded exclusively to fluorine or carbon. By this definition—adopted by the OECD—**almost all synthetic refrigerants qualify as PFAS**.

PFAS have many uses, from waterproof coatings for clothes and shoes to flame retardants, gaskets, ski wax, and pesticides. But refrigerants are by far the largest source, accounting for **over 60% of total PFAS emissions**.

A related concern is **trifluoroacetic acid (TFA)**, formed when HFCs and HFOs degrade in the atmosphere. TFA is itself a PFAS with a long lifetime, meaning even short-lived refrigerants can leave behind persistent residues that accumulate in nature.

Rising Evidence of Harm

PFAS have already been linked to contaminated drinking water in Sweden, particularly near air force training sites where firefighting foams were used. Health impacts in exposed populations have raised alarms.

At the **ATMO Summit in Prague**, my colleague **Michael Kauffeld** from Karlsruhe University presented new data on PFAS and refrigerant breakdown products:

- **TFA in German tree leaves** increased more than fivefold between 1985 and 2022 (see Fig. 1) [1].
- **Glacier ice cores** reveal similar long-term rises.
- **Drinking water in many European cities** is already near or above the EU's 2026 threshold of **500 ng/L total PFAS** (see Fig. 2) [2].

The report *TFA – The Forever Chemical in the Water We Drink* [2] concludes that the risks of TFA have been underestimated due to lack of data, calling for an **immediate phase-out of F-gases**. In Germany, F-gases are cited as the **second-largest source of TFA in drinking water**, after pesticides. One study found that **98% of PFAS detected in European drinking water was TFA** [4].

Because TFA is water-soluble, it not only contaminates drinking water but also enters the food chain, steadily increasing human exposure.

The Refrigerant Dilemma

Different refrigerants produce different amounts of TFA when they break down. According to Kauffeld [3]:

- **R1234yf** (widely used in car AC systems) converts **entirely into TFA**.
- **R32**, not classified as PFAS, produces none.

This highlights a **difficult trade-off**: refrigerants with low **GWP** may still generate large amounts of TFA, raising new health and environmental concerns.

For years, scientists debated whether TFA could be harmful at foreseeable concentrations. But new research suggests **toxic effects on mammalian reproduction and liver health** [4]. More than **170 PFAS researchers** have signed a declaration stressing that **no exceptions should be made** to the OECD definition of PFAS, since all of them are potentially hazardous [5].

PFAS, Children and Synthetic Chemicals

PFAS are part of a broader picture: the impact of synthetic chemicals on **children's health**. A recent review [6] shows worrying trends:

- Childhood cancer rates have risen by **35%** in the past 50 years.
- Disorders of reproduction, developmental delays, autism, and asthma are all on the rise.
- Average IQ in the U.S. has dropped by **2–5 points since the 1950s**. The number of children with IQs above 130 has halved, while those below 70 have increased by 50%.

For PFAS specifically, evidence links exposure to **testicular cancer, weakened immune responses, lower birth weights, early puberty, and metabolic disorders**. Children, the review concludes, are more vulnerable to synthetic chemicals than adults—and the full risks are still unknown.

A Call for Change

Taken together, the evidence is sobering. PFAS—and especially TFA from synthetic refrigerants—represent not only a **climate problem** but also a **public health threat**.

This strengthens my conviction that we must **phase out synthetic refrigerants** and adopt **natural alternatives** as quickly as possible. Doing so will not only reduce greenhouse gas emissions but also protect the health of today's children and generations to come.

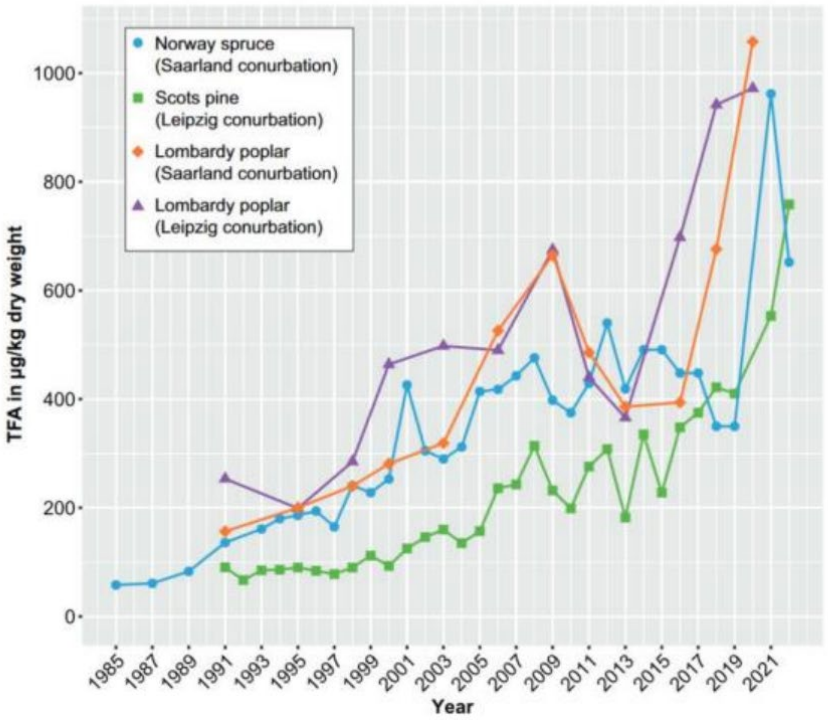

Figure 1. Rising TFA concentration in tree leaves, Germany [1]

Refrigerant	Additional Information (Blend composed of)	Safety class	Normal boiling point[1]	GWP_{100}[1]	GWP_{20}[1]	TFA formation potential[2]	HFC-23 formation potential[3]
R-32	Used pure and in blends	A2L	-52 °C	749	2 620	-	-
R-125	*Only in blends below GWP = 750*	*A1*	*-49 °C*	*3 820*	*6 790*	-	-
R-134a	*Only in blends below GWP = 750*	*A1*	*-26 °C*	*1 470*	*4 060*	*7-20 %*	-
R-227ea	*Only in blends below GWP = 750*	*A1*	*-15.6 °C*	*3 580*	*5 830*	*100 %*	-
R-450A	R-134a and R-1234ze(E)	A1	-23.4/-22.8 °C	618	1 708	up to 14 %	0.8 - 2.6 %
R-452B	R-125, R-32 and R-1234yf	A2L	-51.0/-50.3 °C	769	2 231	26 %	-
R-454B	R-32 and R-1234yf	A2L	-50.9/-50.0 °C	516	1 806	31 %	-
R-454C	R-32 and R-1234yf	A2L	-46.0/-37.8 °C	162	565	79 %	-
R-455A	R-32, R-1234yf and R-744	A2L	-51.6/-39.1 °C	162	565	76 %	-
R-513A	R-134a and R-1234yf	A1	-29.2 °C	647	1 788	up to 65 %	-
R-1233zd(E)	Used pure and in blends	A1	18.1 °C	0.0651	4	up to 10 %	1.3 - 4.4 %
R-1234yf	Used pure and in blends	A2L	-29.4 °C	0.0268	< 1	100 %	-
R-1234ze(E)	Used pure and in blends	A2L	-19 °C	0.0459	1	up to 10 %	1.3 - 4.4 %
R-1233zd(E)	Used pure and in blends	A1	18.1 °C	0.0651	4	up to 10 %	1.3 - 4.4 %

[1] Normal boiling point and GWP values from UNEP RTOC 2022

[2] TFA formation rate from Behringer et al.: Umwelt- und Klimaauswirkungen natürlicher und halogenierter Kältemittel in Flüssigkeitskühlsätzen und Verflüssigungssätzen. German UBA (2024)

[3] HFC-23 formation rate from Pérez-Peña et al. (2023) Pérez-Peña, M.P.; Fisher, J.A.; Hansen, C.; Kable, S.H. (2023): Assessing the atmospheric fate of trifluoroacetaldehyde (CF_3CHO) and its potential as a new source of fluoroform (HFC-23) using the AtChem2 box model. Environ. Sci.: Atmos., 3, 1767–1777

Table 1. Synthetic refrigerants with GWP below 750, showing share of molecules degrading into TFA or R23 [3]

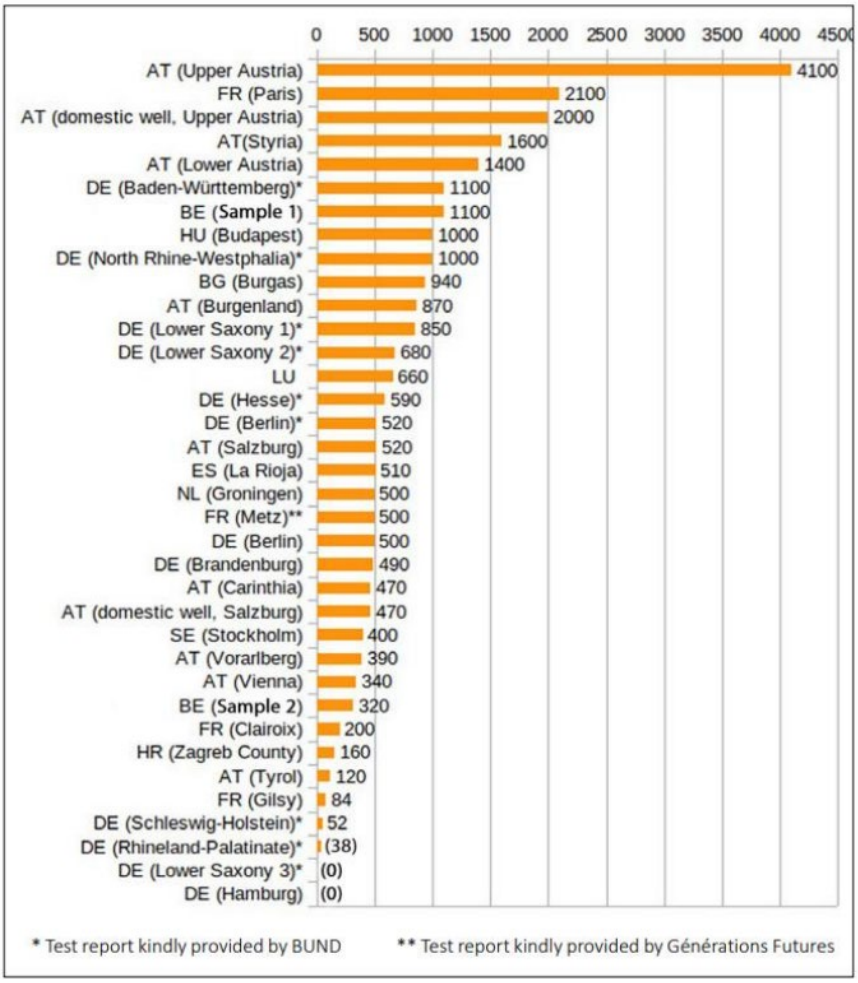

Figure 2. TFA in European drinking water, ng/L (EU PFAS limit from 2026: 500 ng/L) [2]

References

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[3] Kauffeld, M., 2024. *PFAS – A growing concern in the HVACR industry*. ATMO Summit, Prague, Nov 2024.
[4] Arp, H.P. et al., 2024. *The Global Threat from the Irreversible Accumulation of TFA*. *Environ. Sci. Technol.*, 58, 19925–19935.
[5] *Scientists' Statement on Defining PFAS*. June 2024.
[6] *Manufactured Chemicals and Children's Health — The Need for New Law*. *New England Journal of Medicine*, Jan 2025. DOI: 10.1056/NEJMms240909