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Assessing ambient air PFAS exposure:
validated active sampling methods for risk evaluation

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PFAS
PER- AND POLY-FLUOROALKYL SUBSTANCES

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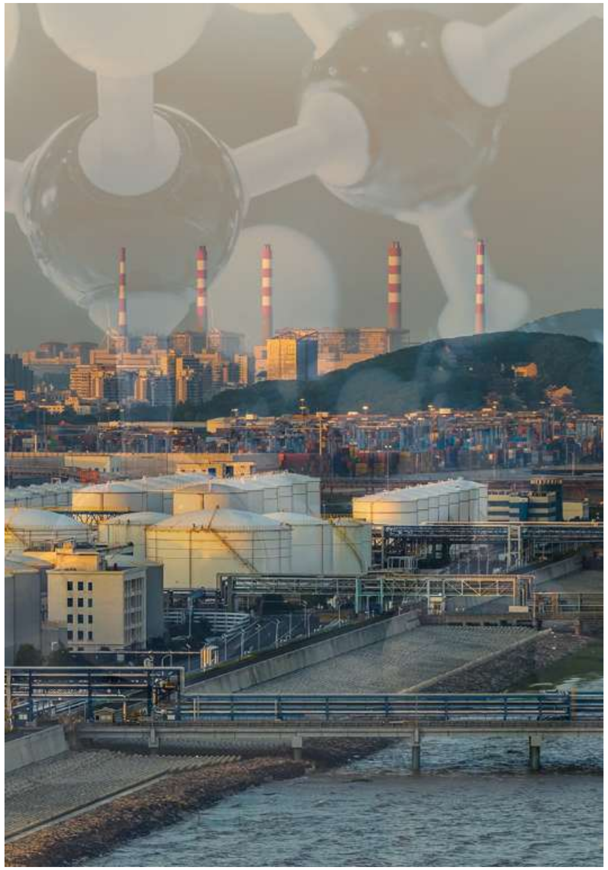
Better Food. Better Health. Better World.

PFAS hazards

Numerous studies link PFAS exposure
to a wide range of adverse effects, including **metabolic disorders**, **immunotoxicity**, and **cancer** (particularly for PFOA and PFOS).

Indeed, the International Agency for Research on Cancer
has classified **PFOA** as **carcinogenic to humans** (Group 1) and **PFOS** as **possibly carcinogenic** (Group 2B).

Despite the progressive development of regulations
limiting the use and emission of PFAS in products and the environment (REACH restrictions and environmental monitoring measures in the EU and other countries), **the inhalation pathway remains an exposure route that is still undercharacterized** compared to the more extensively studied ones (such as ingestion, for example).



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PFAS in air across environments

This review synthesizes findings from **25 studies** reporting airborne PFAS across four categories: outdoor general environments, indoor general environments, outdoor occupational environments, and indoor occupational environments.

Volatile precursors such as fluorotelomer alcohols dominated most environments, while particle-bound ionic PFAS were more common in occupational settings, suggesting **distinct exposure pathways**.

Despite the relatively low airborne PFAS concentrations, this review confirms that **inhalation remains a critical exposure pathway** due to the **persistence, bioaccumulation, and toxicity** of PFAS. Standardized measurement methods, geographically diverse monitoring and integration with exposure modeling are urgently needed. Strengthening **regulatory frameworks** and establishing **protective exposure limits** will be essential to mitigate long-term health impacts.

Distribution and Concentration of Airborne Per- and Polyfluoroalkyl Substances (PFAS): A Review
Published in: *Fundamental Research* (2025)
DOI: https://doi.org/10.1016/j.fmre.2025.01.002

KEY POINTS of air monitoring

The lack of harmonized procedures makes it challenging to assess the risk associated with this exposure pathway, which enables:

- **Addressing an emerging need:** meeting the demand for reliable data on a still **poorly characterized exposure route** such as ambient air.
- **Aligning with global regulatory trends:** increasing regulatory pressure on PFAS, particularly in Europe and the United States, suggests that requirements for monitoring, emission management, and **potentially air reference values may emerge in the future**.
- **Supporting business decision-making:** the generated data can be used for **risk assessments**, **occupational safety evaluations**, and environmental management plans.

KEY POINTS of air monitoring

There is not yet a single, universally validated method for all PFAS in the air.

In particular combinations of sampling substrates used are often different from each other

Air	Sampling	Main target
Outdoor / ambient air	high volume sampler with filter GFF/QFF + PUF, XAD-2 o PUF-XAD-PUF	Particulate matter + gas phase, semi-volatile and some ionic PFAS
Indoor air	Low volume with multi-bed adsorbent tube	FTOH, FOSA/FOSE, PFAS volatile or semi-volatile
Indoor air	Filter + sorbent in series	Particulate/gas phase separation
Passive air sampling	PUF/XAD/PDMS passive strippers	Screening, time trends
Emission	Specific sampling trains, impingers, filters, sorbents	PFAS from stack emission, plants, landfills

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MXNS methods

In our laboratory, we developed two internally validated approaches for active ambient air sampling:

- **Low-volume method (indoor):** ideal for personal monitoring and the characterization of individual exposure in occupational settings.
- **High-volume method (outdoor):** designed to sample large volumes of air, enabling low limits of quantification and the analysis of compounds at very low concentrations.

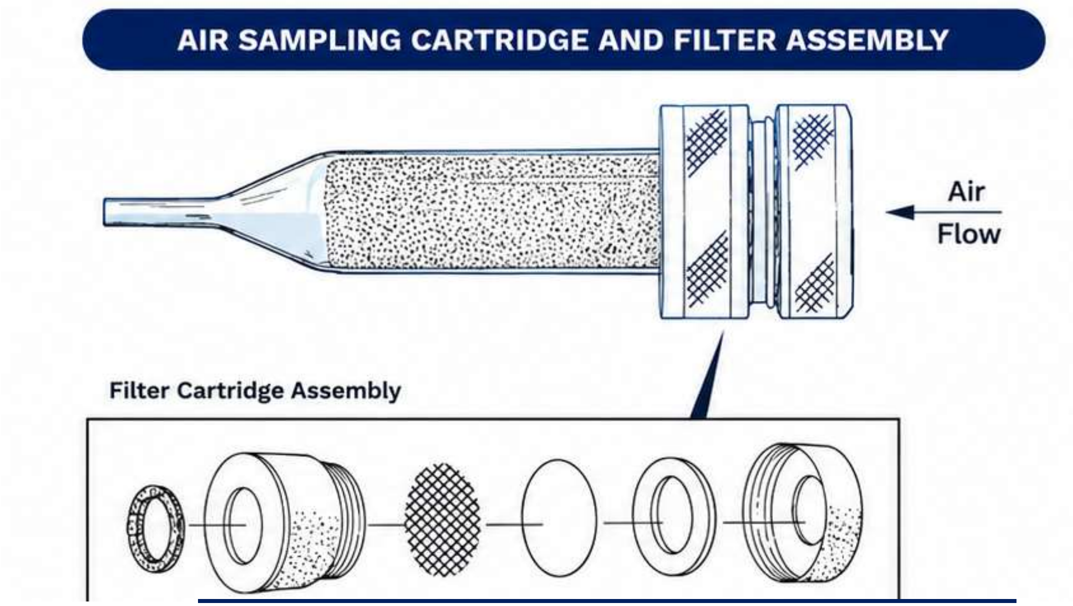
Both approaches allow the determination of:

- **PFOA, PFOS, PFHxS, HFPO-DA (Gen-X)** and other medium- and long-chain PFAS,

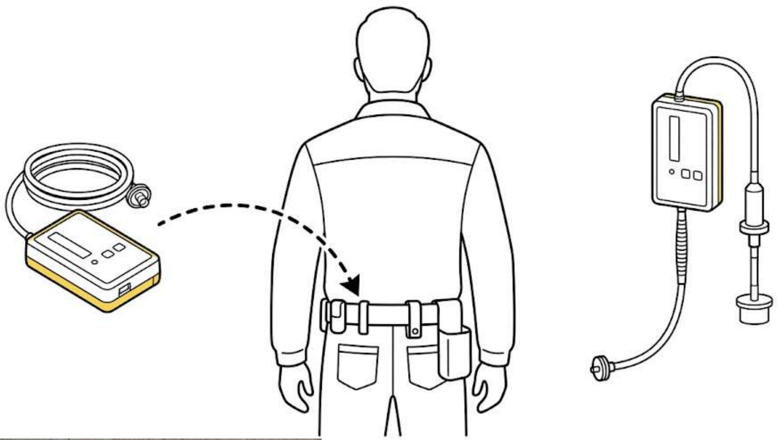
with recoveries above **70%**, ensuring analytical robustness and comparability of results

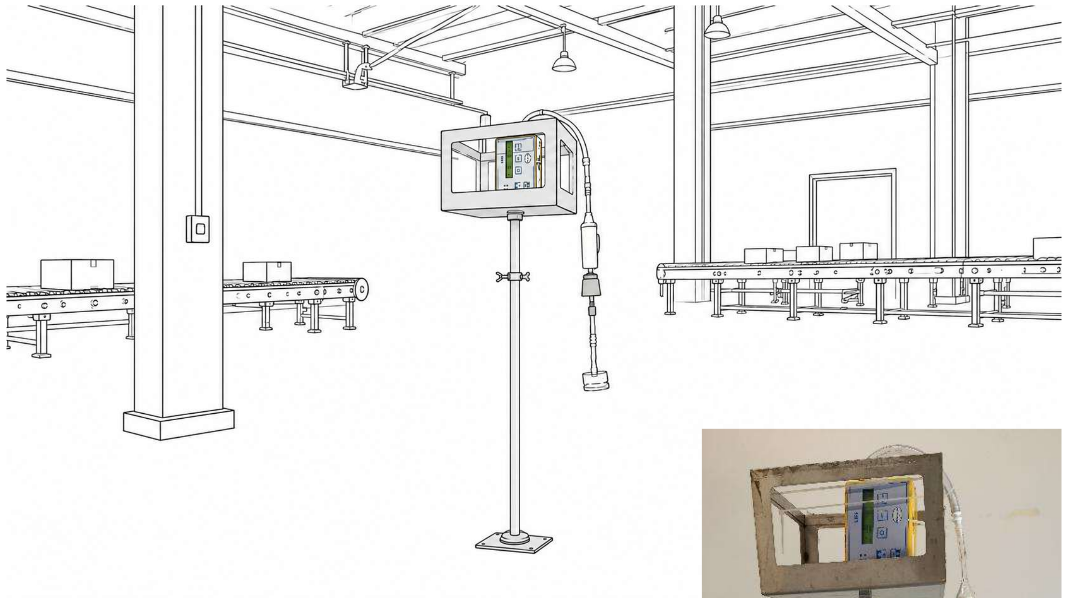
Low-volume sampling

The internal method was inspired by EPA Method TO-10A, which describes the determination of pesticides and PCBs in ambient air using polyurethane foam (PUF) sampling followed by chromatographic analysis.

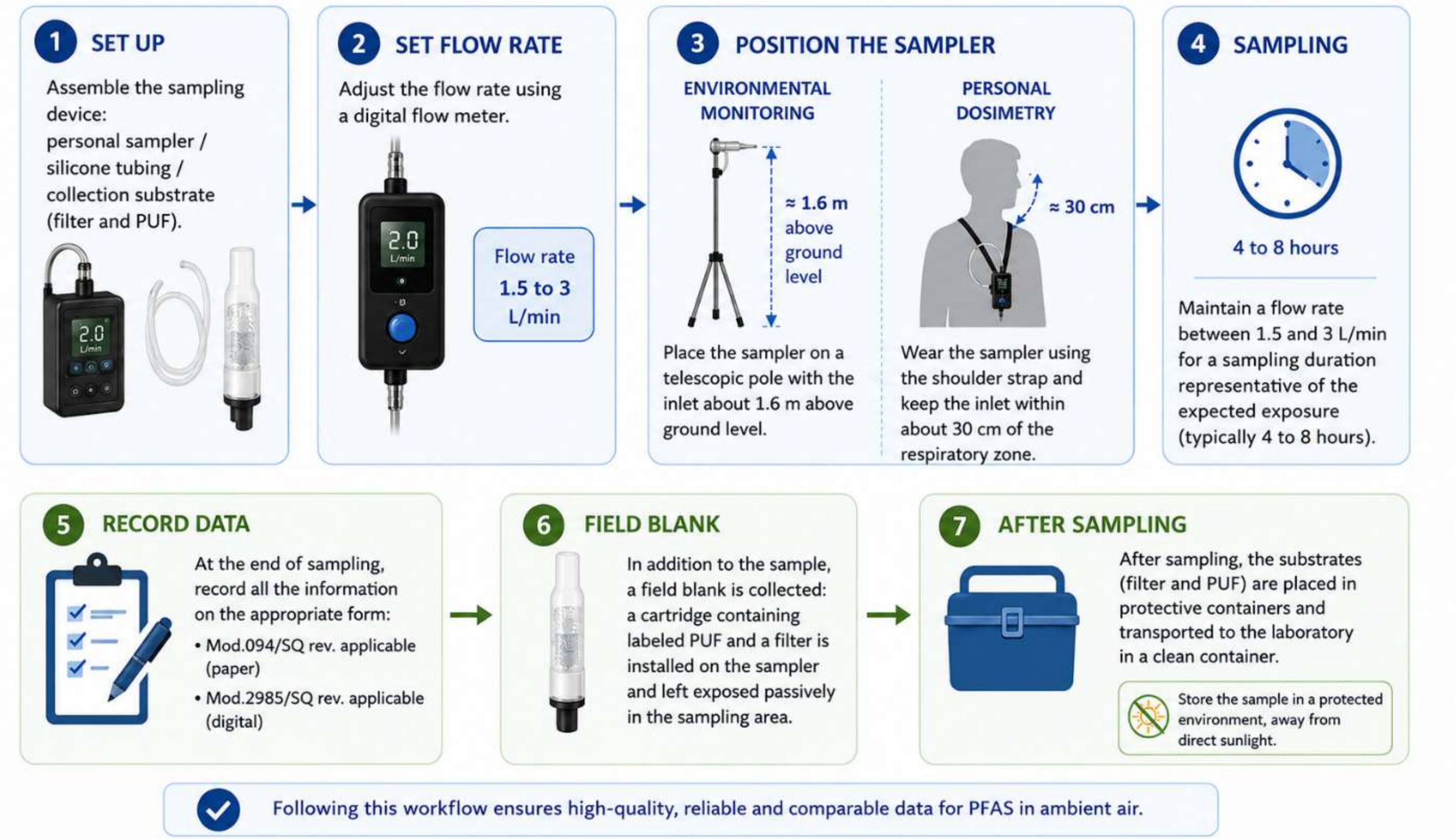


Low-volume sampling



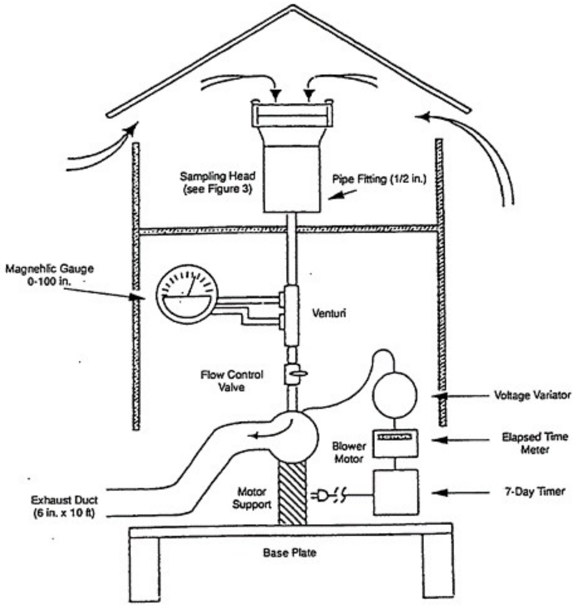


Low-volume sampling



High-volume sampling

The internal method was inspired by EPA Method TO-9A, which is the reference method for high-volume air sampling of semi-volatile organic compounds using filter + PUF systems, enabling collection of both particulate and gaseous phases.



KEY POINTS FOR SETUP

- Place the high-volume pump at the monitoring location and connect it to power until it is fully conditioned.
- Position the sampler in an open area, free from obstacles.
- Extend the exhaust tube downwind to prevent air recirculation into the sampling head.

High-volume sampling

High-volume sampling

1 PREPARE THE SAMPLER

Install the PUF in the glass cartridge and the membrane filter in the filter holder inside the pump (Fig. 1).

2 SET THE FLOW RATE

Adjust the flow rate according to the predetermined sampling time and the objective of the monitoring (e.g., construction site: 4–8 hours or longer; lane; learn monitoring etc). The appropriate flow rate, depending on the dust level, should be between

150 and 300 L/min.

3 SAMPLING

4–8 hours or longer

Run the sampler for the predetermined duration while maintaining the selected flow rate.

4 RECORD DATA

At the end of sampling, record all the information on the appropriate form:

- Mod.094/SQ rev. applicable (paper)
- Mod.2985/SQ rev. applicable (digital)

5 FIELD BLANK

In addition to the sample, a field blank is collected: a cartridge containing labeled PUF and a filter is installed on the sampler and left exposed passively in the sampling area.

6 AFTER SAMPLING

After sampling, the substrates (filter and PUF) are placed in protective containers and transported to the laboratory in a clean container.

Store the sample in a protected environment, away from direct sunlight.

✔ Following this workflow ensures high-quality, reliable and comparable data for PFAS in ambient air.

PFAS analysis – before sampling

1) sampling substrate preparation: washed with MeOH and dried

2) added C13-labelled **sampling standards**

(**P**er**F**luoro**O**ctanoic **A**cid & **P**er**F**luoro**O**ctane **S**ulfonic acid)

3) proceed with sampling

(# for validation tests, native compounds from the analyte list were spiked)

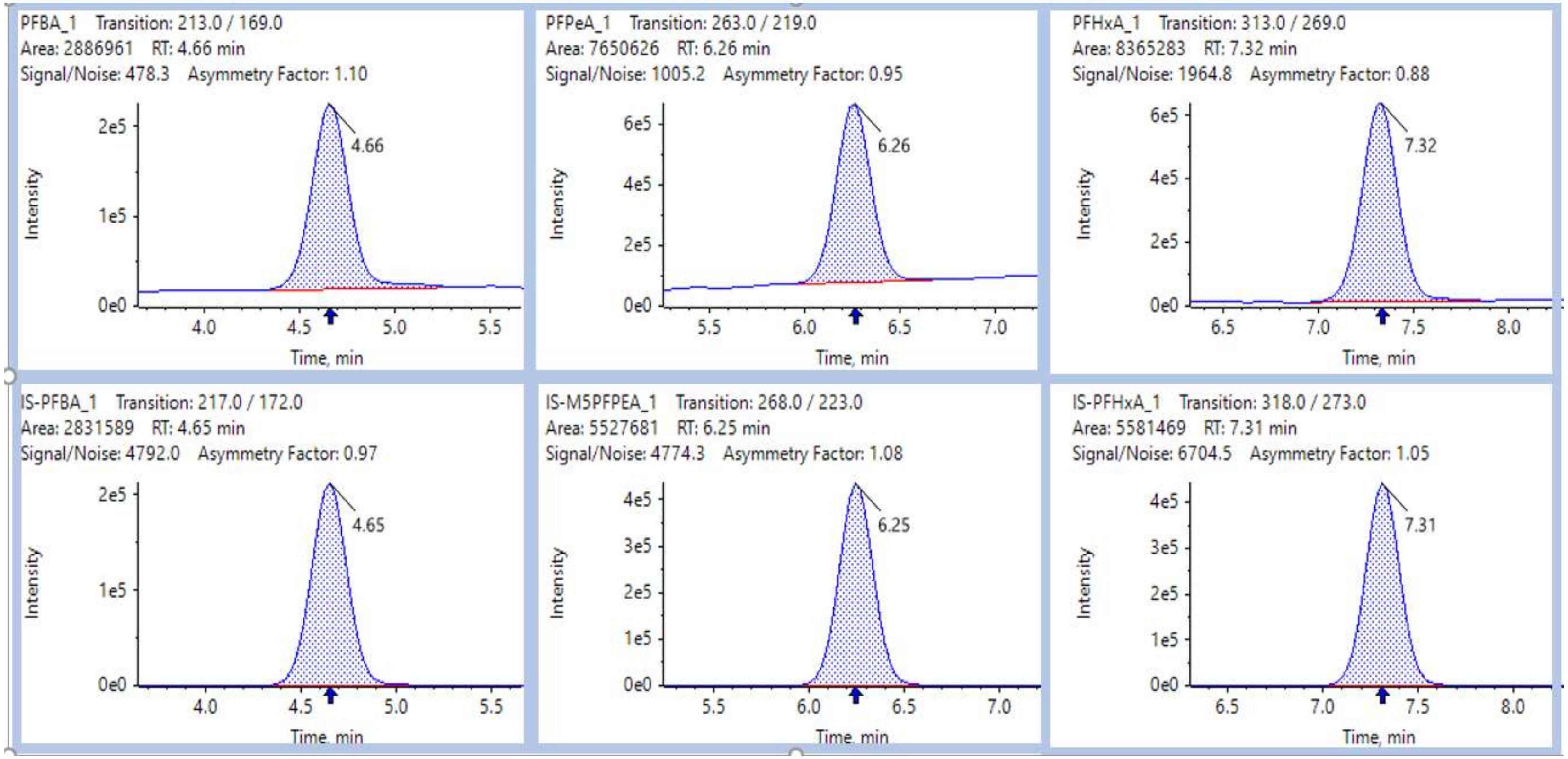
PFAS analysis – back in the lab

4) surrogate standards addition
5) 3 cicle methanol extractions
6) syringe standards addition
7) volume reductions, injection, analysis

PFAS analysis – our methods and list of compouds

Category	Compounds
Short-chain PFAS	PFMPA, PFMBA, PFBA, PFPeA, PFHxA, PFBS, PFPeS
Long-chain PFAS	PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTrDA, PFTeDA, PFHxDA, PFODA, PFHxS, PFHpS, PFOS, PFNS, PFDS, PFUnDS, PFDoDS, PFTrDS
Fluorotelomer Precursors	4:2 FTS, 6:2 FTS, 8:2 FTS, 10:2 FTS, 6:2 FTCA, 8:2 FTCA, 10:2 FTCA, 6:2 FTUCA, 8:2 FTUCA, 6:2 FTAB
Ether PFAS and Alternatives	C6O4, HFPO-DA, ADONA, NFDHA, PFEESA, PFOSA, N-MeFOSAA, N-EtFOSAA, N-MeFOSE, N-EtFOSE, 9Cl-PF3ONS, 11Cl-PF3OUDS

PFAS analysis – back in the lab



PFAS analysis: some experiences

PFAS analysis in external environment

Monitoring covers around 130 samples

Period July 2025 to January 2026

Dataset allows to try to:

- Identify dominant components
- Emission patterns? Tempora differences , seasonal signals?

PFAS most consistently

PFBA very common and often high

PFHxA frequent and stable

PFOA almost always detected

PFOS costant presence but at lower levels

MeFOSAA regular presence

6:2 FTS widespread presence

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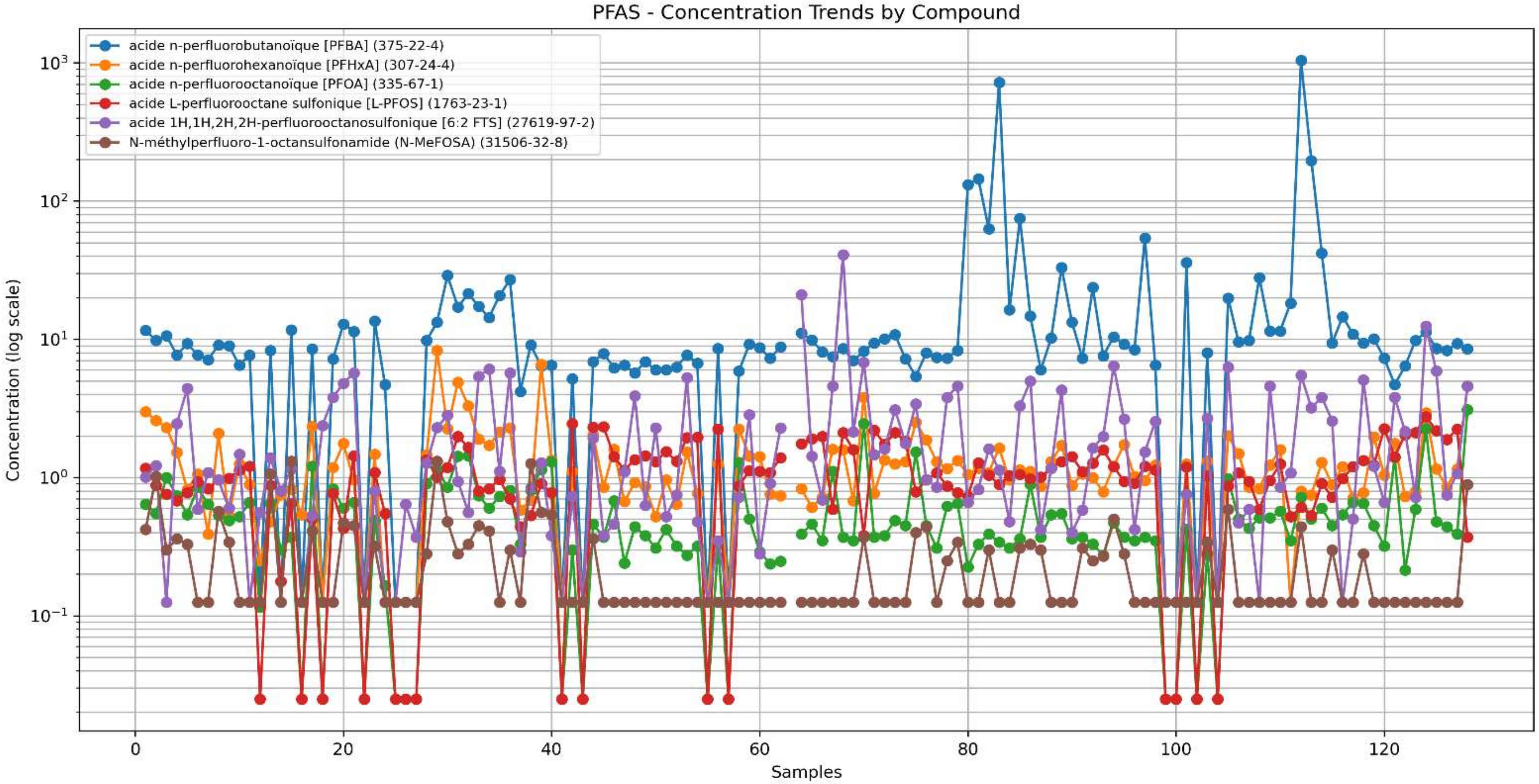
PFAS analysis: results



Take home message

Considering that.......

There are still no occupational exposure limits (OELs or TLVs) for total PFAS, but only for individual molecules

- PFOA (Perfluorooctanoic acid) TLV TWA-DFG MAKs: 0.005 mg/m3 (inhalable fraction)
- PFOS (Perfluorooctanesulfonic Free acid;TLV TWA-DFG MAKs: 0.01 mg/m3 (inhalable fraction)
- PFBA (Perfluorobutanoic acid) none occupational toxicology guidelines (Minnesota Department of Health for example, recommends a subchronic/chronic reference value for indoor air of 10 μg/m³ to protect against developmental, liver, and thyroid effects........)

There are still no harmonized and definitive methods and substrates for investigation of PFAS in air

Monitoring experiences in ambient and external **air show presence of these substances in air and the ability to detect them** with good recoveries

It's important to go on monitoring and carrying out experimental tests in real sites, comparing methods and substrates in order to find the most correct and suitable one to achieve representative analysis

Thanks so much

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