Quantifying PFAS in Air Emissions: Method Developments & current status

Jelle Hofman

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Turning fundamental research into solutions

Creating value and increased competitiveness for companies and governments

Fundamental research

Research and education

Universities

Joint research projects,
Phds and postdocs

Applied research

Research in the economic reality

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Research & Technology Organisations

Contract research
Techtransfer
Research projects, labs, pilots

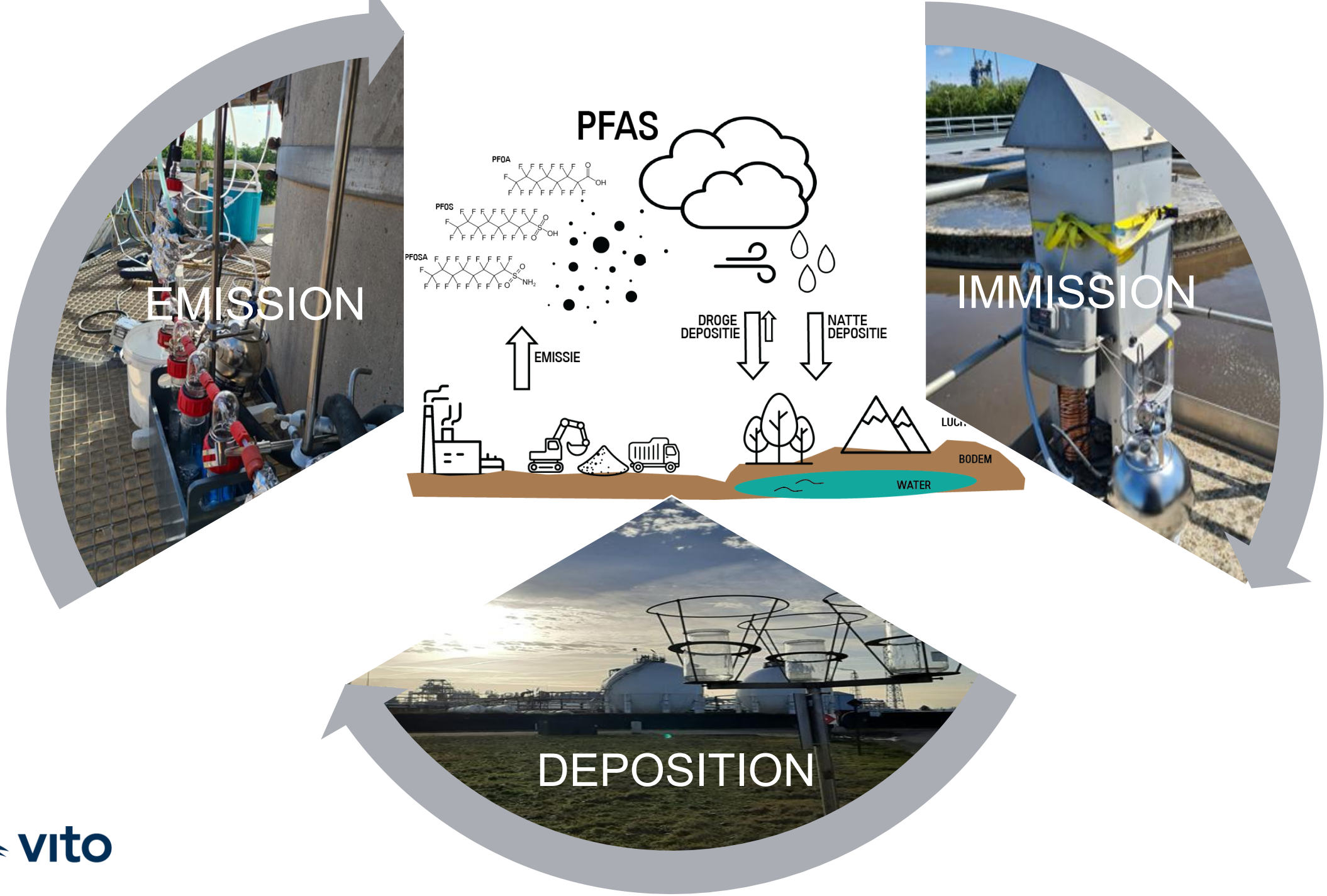
Industry

Governments

Citizens

Technology Readiness Level

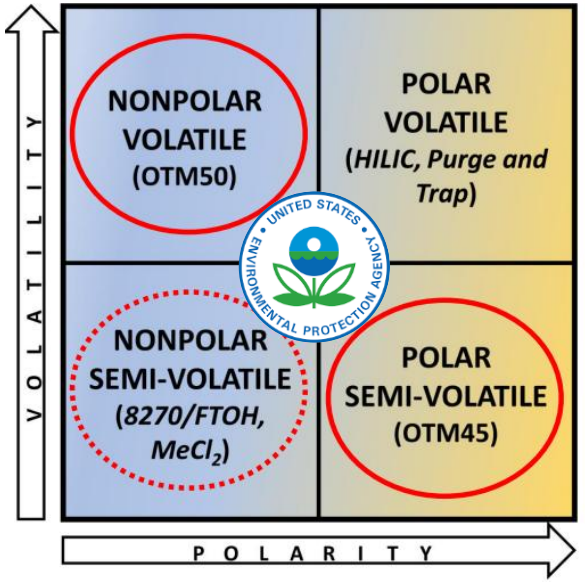
1 2 3 4 5 6 7 8 9

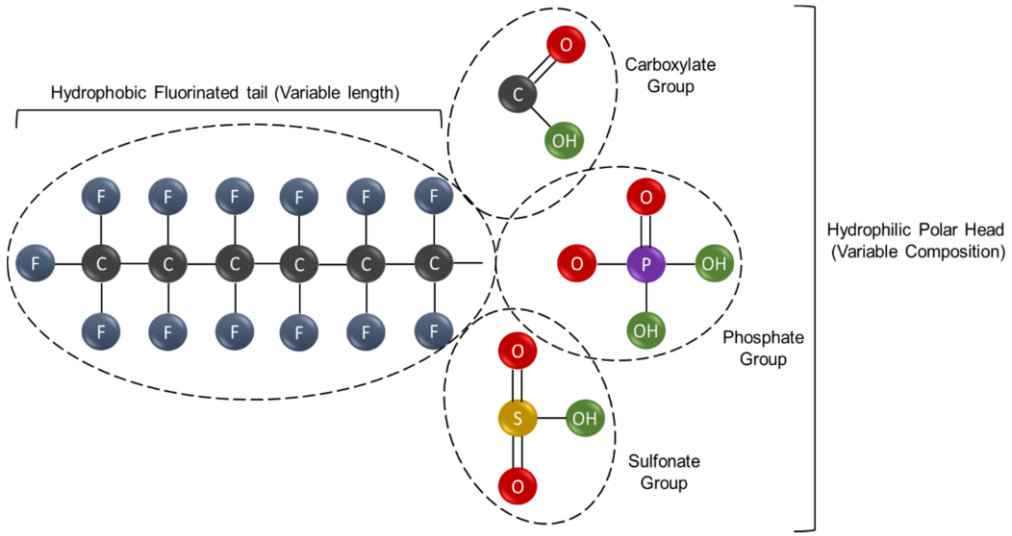

EMISSION
PFAS
PFOA
PFOS
PFOSA
EMISSIE
DROGE DEPOSITIE
NATTE DEPOSITIE
BODEM
WATER
IMMISSION
DEPOSITION

PFAS DIVERSITY

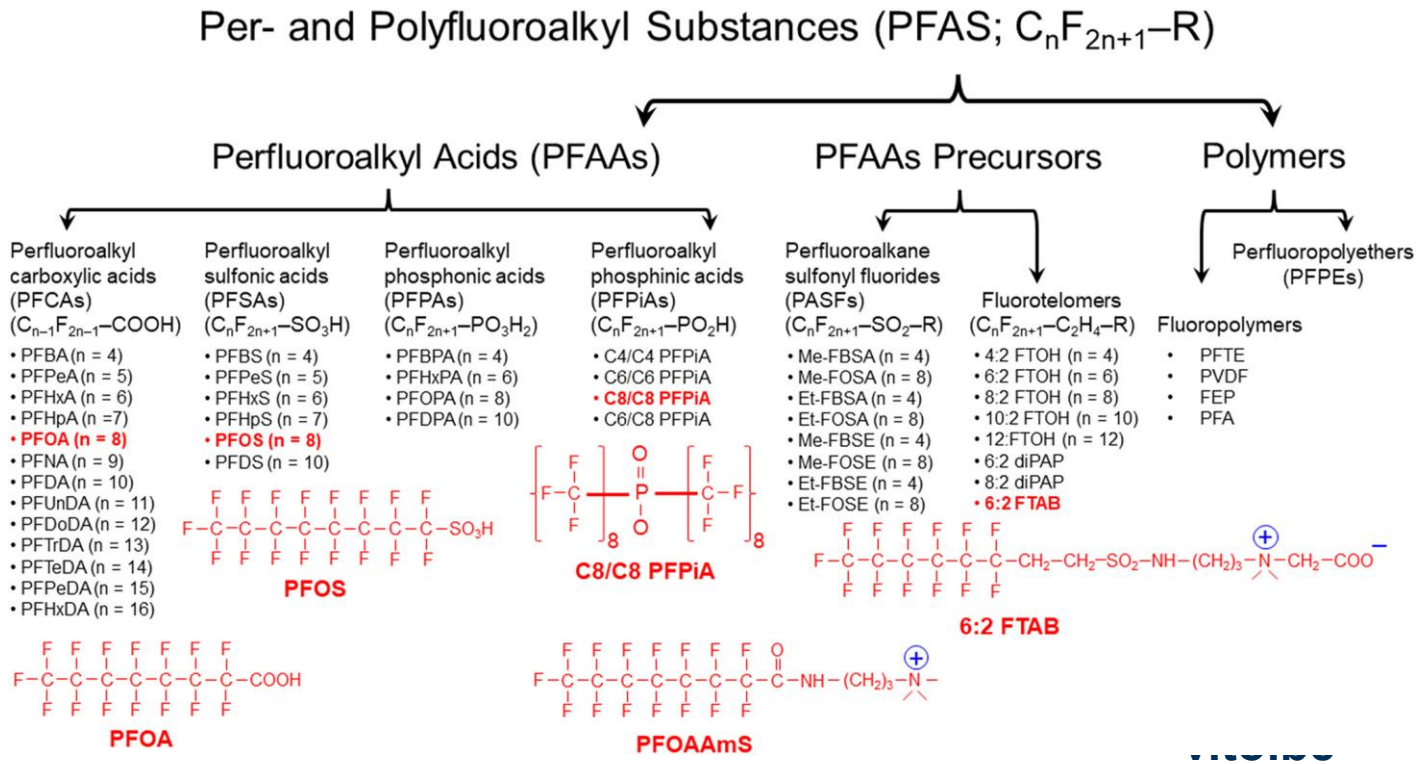
WHAT?

- Molecules with varying (i) carbon chain length, (ii) functional groups and (iii) number of fluor atoms
- PFAA + Polymers + Precursors
- Particle-bound, semi-volatile and volatile





https://doi.org/10.3390/toxics10020044

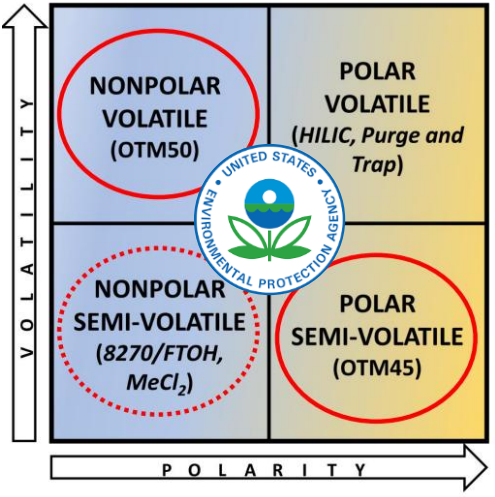


https://doi.org/10.1029/2021RG000765

2021–2023
Development & validation LUC/VI/003

Oct 2023
Publication LUC/VI/003

Jan 2024
Visit + NDA US EPA



Feb 2024
Interlaboratory comparison (ILC)

Jun 2024
Publication LUC/VI/003 revision

Jun–Dec 2024
Lab audits TAUW, SGS & Eurofins

Corrective actions

>March 2025
Accreditation ongoing

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460

MUTUAL CONFIDENTIALITY AGREEMENT

Between the U.S. Environmental Protection Agency and Vlaamse Instelling voor Technologisch Onderzoek

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Full length article

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HIGHLIGHTS

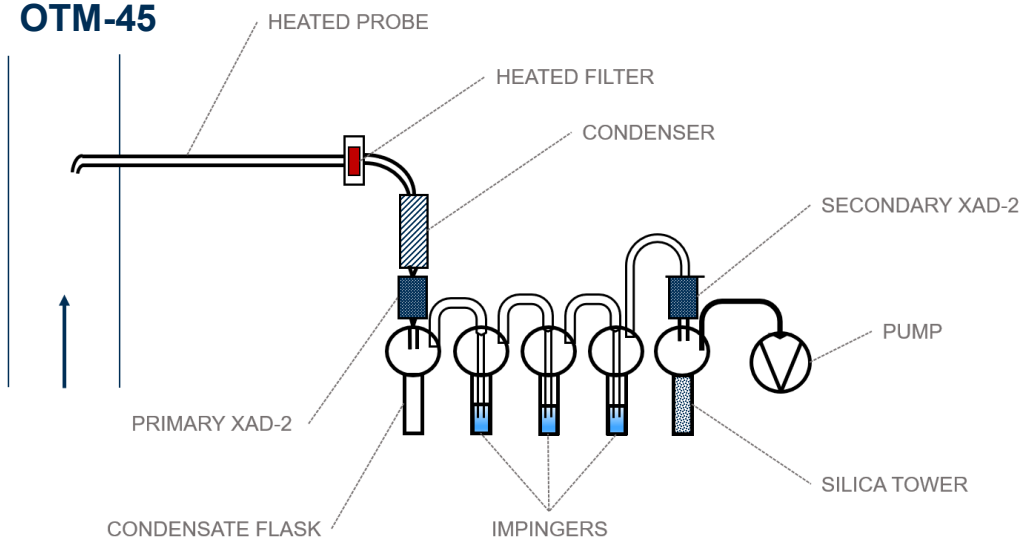
GRAPHICAL ABSTRACT

LUC/VI/003

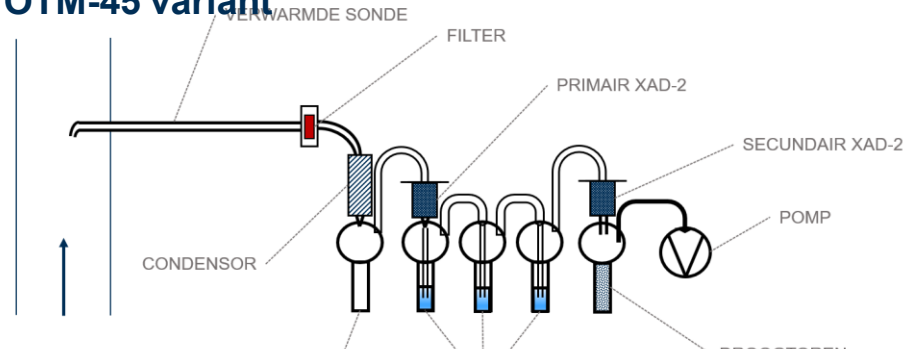
SAMPLING TRAIN

- Principal sampling train (OTM-45)
  - 2 additional variants (OTM-45 variant + cooled probe)
- Procedure (~5-6 hours):
  - 5 medium blanks
  - Leak test + Field blank collection (6)
  - Isokinetic sampling (min. 3 hours (~2 Nm³))
  - Leak test + Collection Field samples (7)
  - Post-rinse blank collection (2)
- Sample aggregation
- Sample extraction
- LC-MS/MS (WAC/IV/A/025)

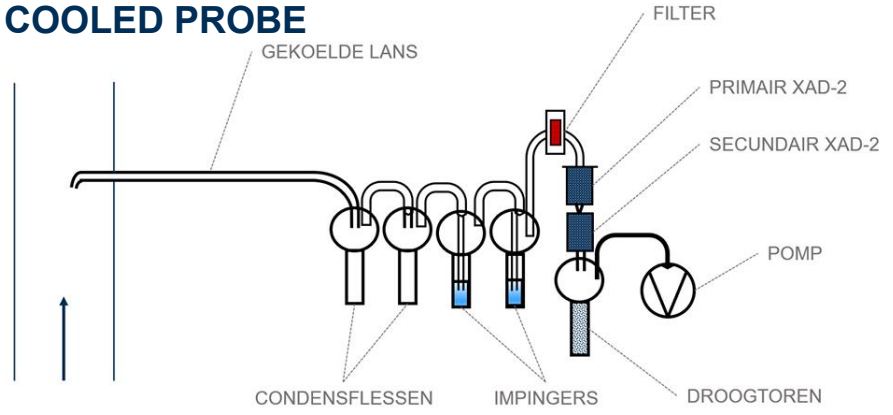
OTM-45

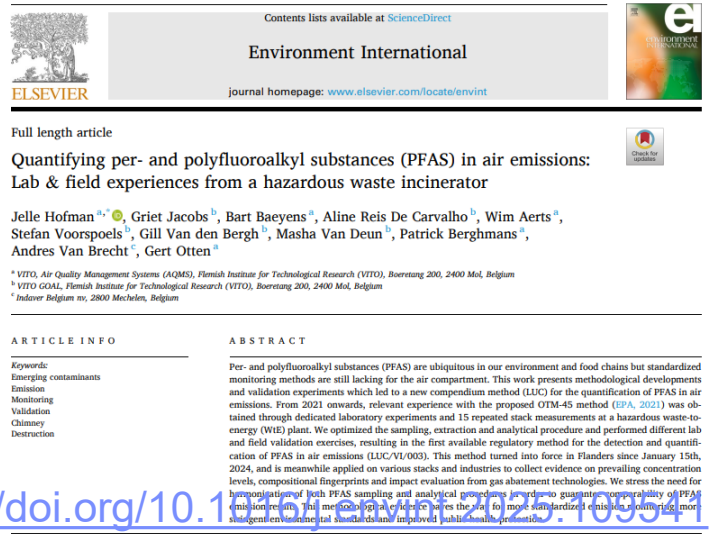


OTM-45 variant



COOLED PROBE





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ARTICLE INFO

Keywords:
Emerging contaminants
Emission
Monitoring
Validation
Chimney
Destruction

ABSTRACT

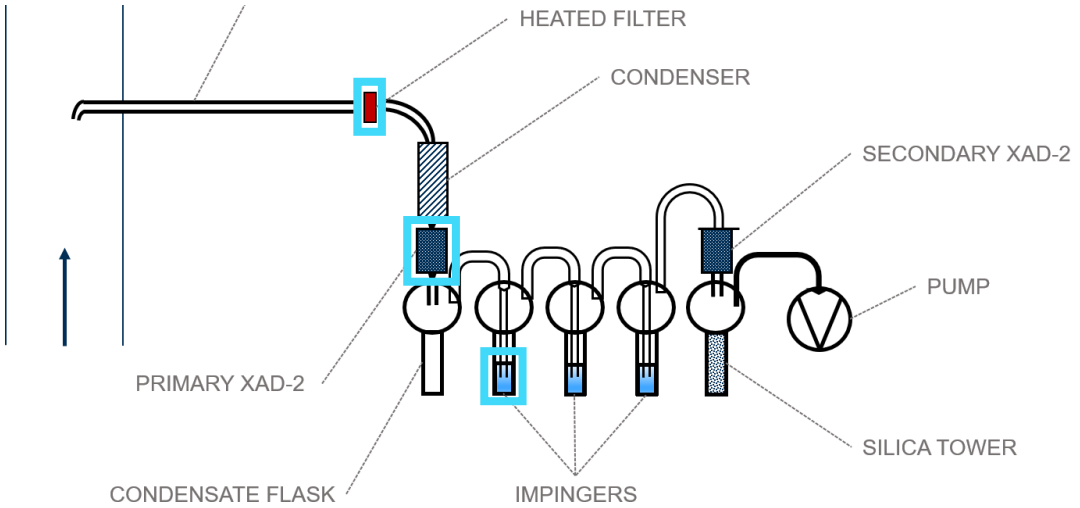
Per- and polyfluoroalkyl substances (PFAS) are ubiquitous in our environment and food chains but standardized monitoring methods are still lacking for the air compartment. This work presents methodological developments and validation experiments which led to a new compendium method (LUC) for the quantification of PFAS in air emissions. From 2021 onwards, relevant experience with the proposed OTM-45 method (EPA, 2021) was obtained through dedicated laboratory experiments and 15 repeated stack measurements at a hazardous waste-to-energy (WtE) plant. We optimized the sampling, extraction and analytical procedure and performed different lab and field validation exercises, resulting in the first available regulatory method for the detection and quantification of PFAS in air emissions (LUC/VI/003). This method turned into force in Flanders since January 15th, 2024, and is meanwhile applied on various stacks and industries to collect evidence on prevailing concentration levels, compositional fingerprints and impact evaluation from gas abatement technologies. We stress the need for harmonization of both PFAS sampling and analytical procedures in order to guarantee comparability of PFAS emission results. This methodological evidence paves the way for more standardized emission monitoring, more stringent environmental standards and improved public health protection.

https://doi.org/10.1016/j.envint.2024.109041

VALIDATION

ILC, Feb 2024

- AIM: test equivalence sampling train variants + determine reliability method
  - Validation sampling + analytical procedure
  - Preconditioned air (temp/RH) + spiked media (filter, water , XAD2)
  - Evaluation:
    - Sampling Standard (SS) Recoveries (%): 50-130%
    - Internal Standard (IS) Recoveries (%): >20% *(13C-8:2diPAP and 13C-PFHxDA >= 10% (WAC VI/A/003))*
    - Breakthrough (%): <30%
    - **Native PFAS Recoveries (%): 70-120%**
    - **Observed uncertainty (U, k=2): <50%**



Chemosphere 380 (2025) 144449

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HIGHLIGHTS

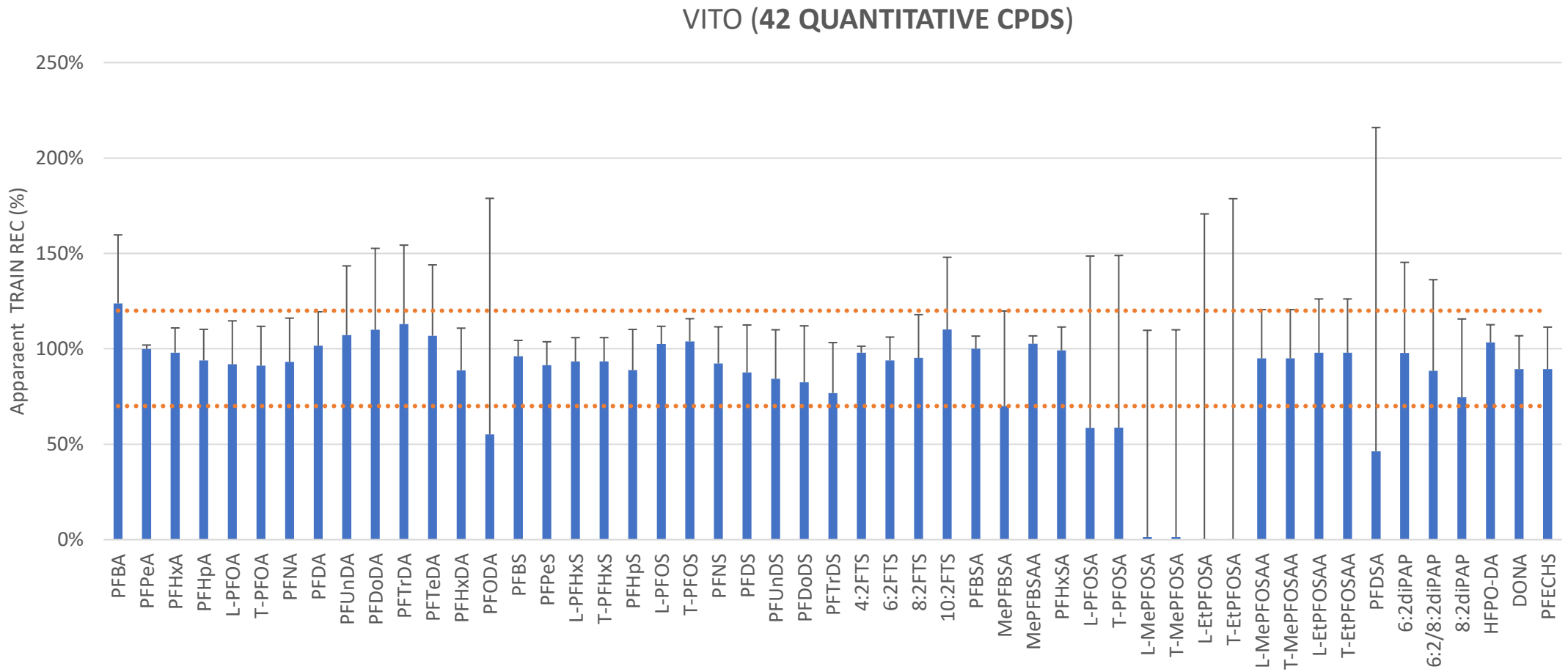
- This work presents the first empirical evidence comparing different monitoring methods for C4-18 PFAS in air emissions.
- A French, German and 3 Belgian labs participated in this Interlaboratory comparison (ILC).
- Equivalence of three sampling train variants was evaluated for 50 individual PFAS compounds (C4-18).
- Our findings contribute to cross-boundary standardisation of PFAS emission monitoring.

GRAPHICAL ABSTRACT

https://doi.org/10.1016/j.chemosphere.2025.144449

VALIDATION

ILC2024

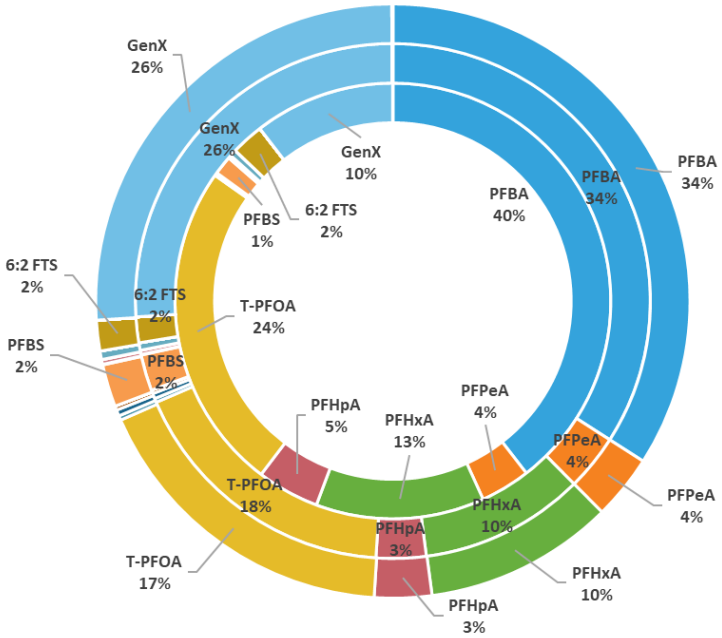


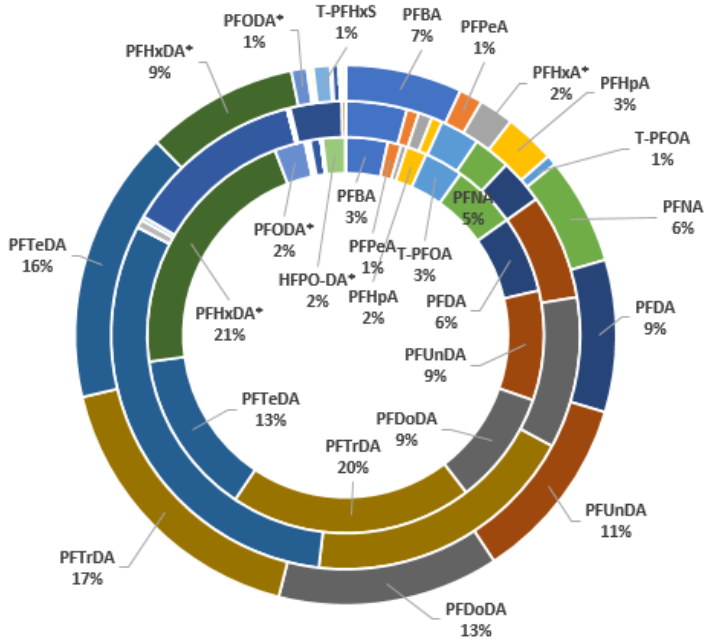
https://doi.org/10.1016/j.chemosphere.2025.144449

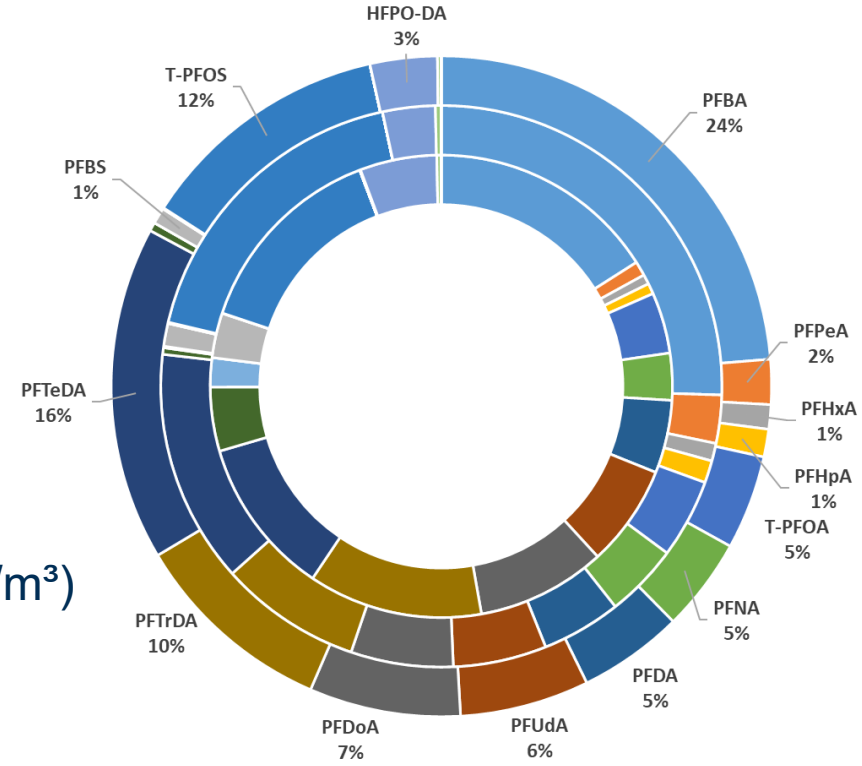
FIELD EXPERIENCES

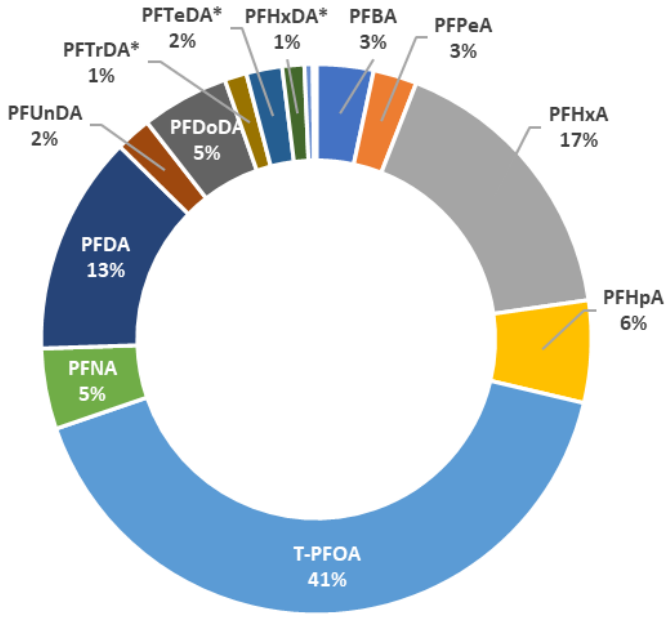
STACK FINGERPRINT

- Various chimneys/processes in Flanders
  - 11 ng/Nm³ – 43 mg/Nm³ (∑PFAS)
  - 2.5 ng/Nm³ - 6.7 mg/Nm³ (∑EFSA)
- <ELV (Netherlands), EFSA4 ambient air framework Belgium (0.3 ng/m³)
- Thermal transformation PFSA → PFCA
- Impact flue gas cleaning: AC, wet scrubbers



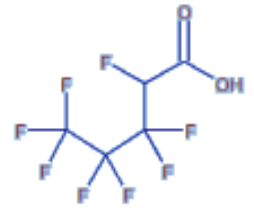


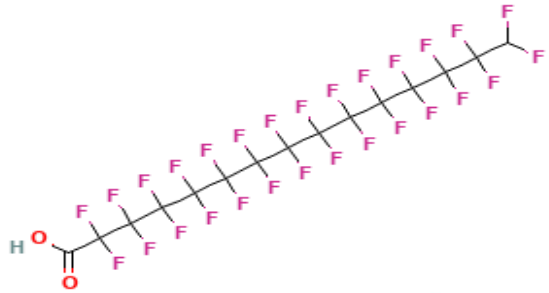


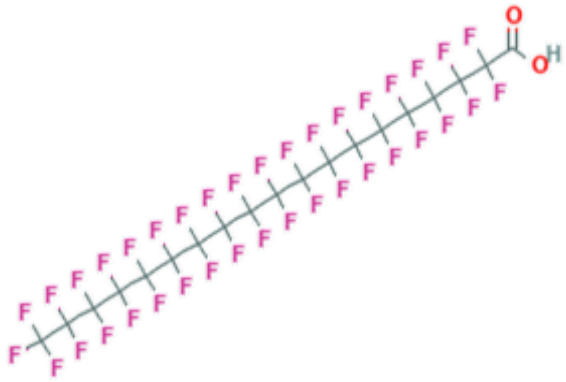


FIELD EXPERIENCES

OUT OF ANALYTICAL/LEGAL SCOPE (BUT PRESENT!)

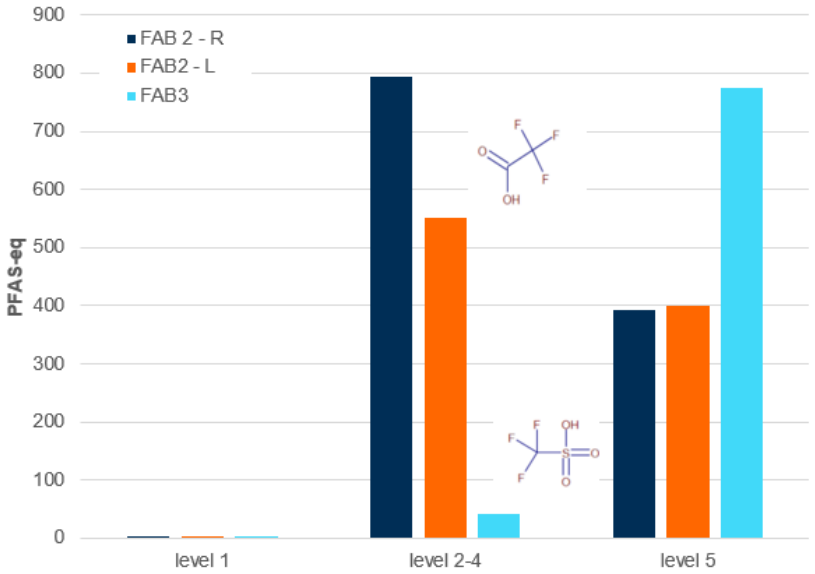


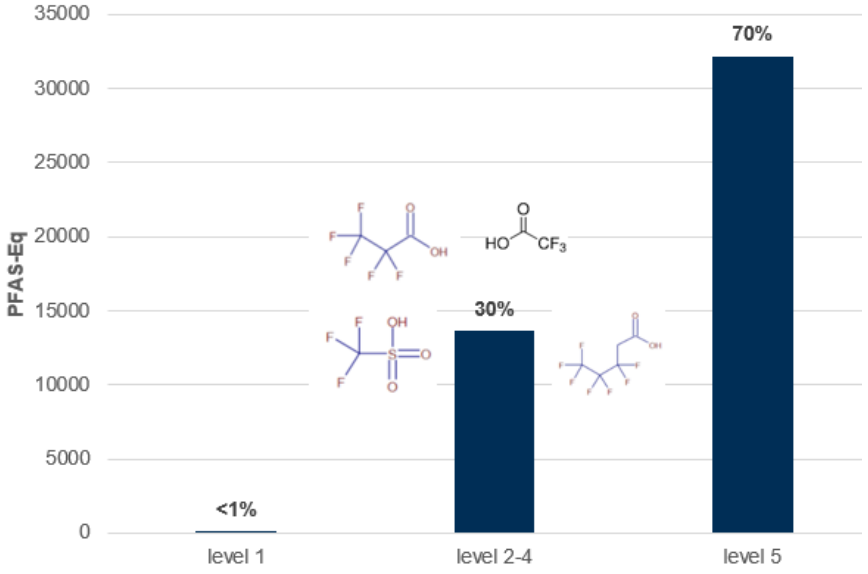


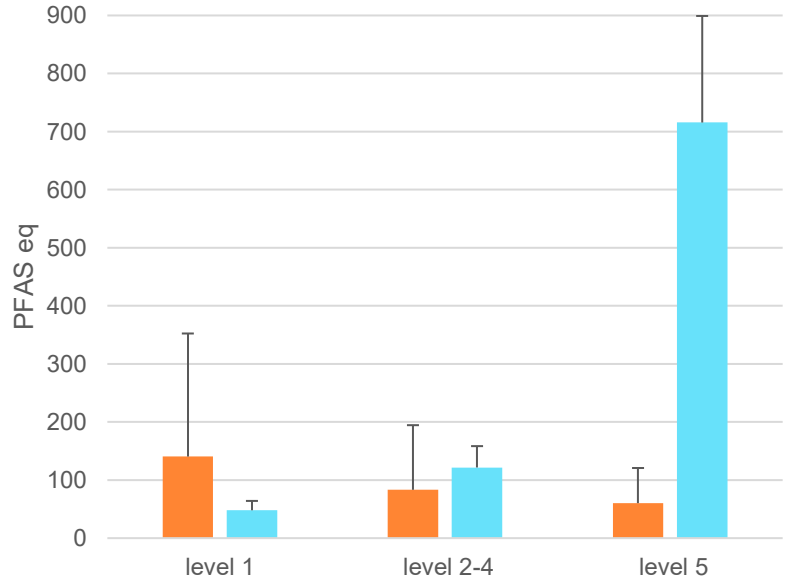


- Identified via NTA (HR-MS, DART-MS):
  - Ultra-short chain (<C4), e.g. PFPrA, TFA, TFMS,…
  - Poly-/H-substituted
  - Long-chain PFCA's up to 20C
- Ratio target vs unknown cpds varies strongly
- When relevant and analytical standards available

  → **inclusion in LUC/VI/003 target scope?**

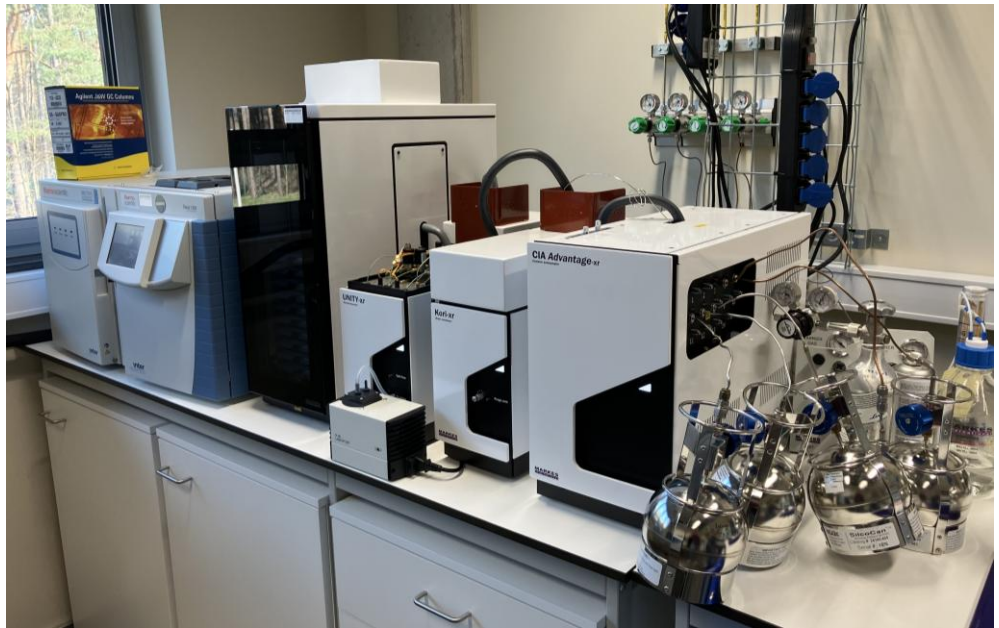






>2025

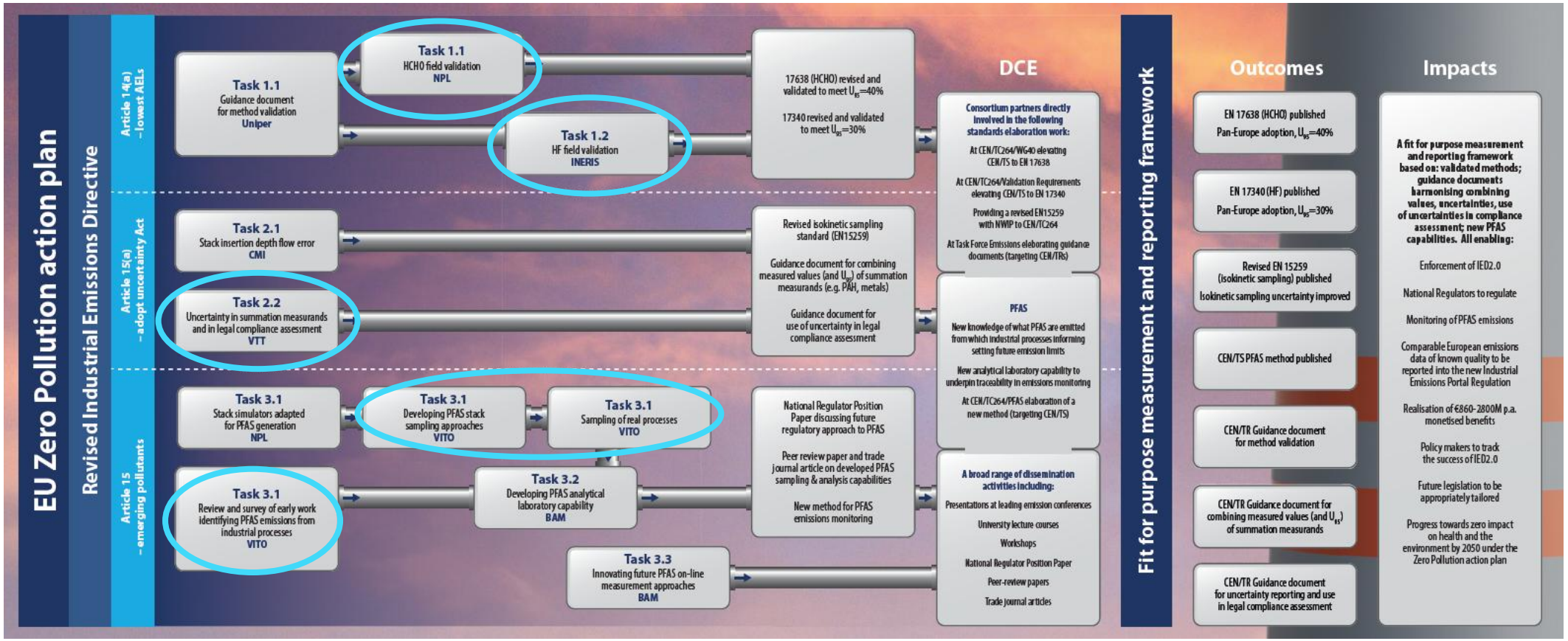
- Screening industries for relevant PFAS by combining target/non-target LC/GC methods
- Belgian method developments
  - Comparative ILC with accredited labs on stack
  - Optimization LUC/VI/003 → extension scope USC polar compounds, aligning LOQ levels, simplification sampling train/cost price
  - Method for non-polar USC/PICs compounds (canister + GC) ~OTM-50
- EU level:
  - **CEN/TC 264 WG48**
    - Convenor: Marc Coleman (NPL)
    - Secretary Ljuba Woppowa (VDI)
  - **EURAMET MetZeroPol**
    - Start EU standardisation

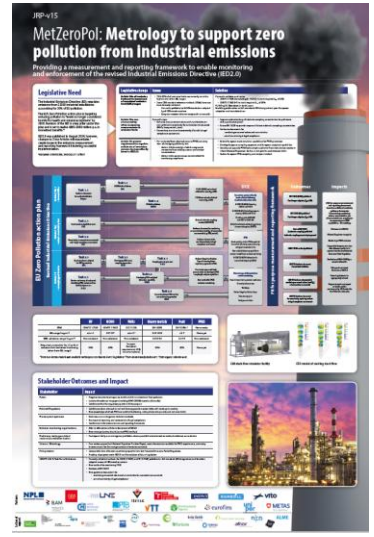


MetZeroPol

"An ILC at an industrial installation involving emissions teams from across Europe is key to showing the true pan-European variance associated with a measurement method under real conditions"

- Metrology to support zero pollution from industrial emissions (2025-2028)





Partners

vito.be

RESOURCES

- LUC/VI/003 method C4-18 polar compounds: https://reflabos.vito.be/2026/LUC_VI_003.pdf
- LUC/VI/003 development: https://doi.org/10.1016/j.envint.2025.109541
- 2024 ILC: https://doi.org/10.1016/j.chemosphere.2025.144449
- BAT study/inventory on reducing PFAS emissions to air: https://emis.vito.be/nl/bbt/publicaties/bbtbref-en-andere-publicaties/pfas-emissies-lucht
- Review of per- and poly-fluoroalkyl treatment in combustion-based thermal waste systems in the United States (2024) https://doi.org/10.1016/j.scitotenv.2024.172658
- A systematic review for non-targeted analysis of per- and polyfluoroalkyl substances (2025): https://doi.org/10.1016/j.scitotenv.2024.178240

"An increased NTA in the atmosphere and marine environment would help improve our understanding of the global fate and transport of PFAS."

“*you can only find what you search for*”

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