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Fluoropolymers in Focus: Diverging Global Approaches and the Road Ahead

Caroline Andersson
Director
Fluoropolymers Product Group

Dr. Michael Schlipf
CEO & Head of Pro-k Fluoropolymer Group
FPS GmbH

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Fluorocarbon Polymer Solutions

Industrieverband Halbzeuge und Konsumprodukte aus Kunststoff e.V.

Fluoropolymers in Focus: Diverging Global Approaches and the Road Ahead

Management of PFAS emissions across fluoropolymer lifecycle

Fluorocarbon Polymer Solutions (FPS) GmbH

In cooperation with Fluoropolymergroup of pro-K

Dr. Michael Schlipf

Burgkirchen, Germany

C5 PFAS Summit Europe 2026
19th - 20th May 2026
Brussels, Belgium

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Safety of fluoropolymers and associated PFAS concern

- Fluoropolymers are considered safe due to:
    - high molecular weight
    - inert and non-reactive nature
    - non-mobility & insolubility
    - non-bioavailability and non-bioaccumulation

- The concern associated to fluoropolymers is limited to potential release of non-polymeric PFAS during their life-cycle mainly during
    - manufacturing phase
    - end of life phase (incineration)

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Manufacturing phase (manageable) PFAS emissions

Time-unlimited derogation is proposed for the manufacture of PFAS (including fluoropolymers) under controlled conditions in the updated Background Document

Until end of 2030: 0.0090% to air, 0.0010% to water and 0% to soil for emissions of non-polymeric PFAS residues from polymerization aid technology in fluoropolymer manufacturing

From end of 2030 : 0.0030% to air, 0.0006% to water and 0% to soil for emissions of non-polymeric PFAS residues from polymerization aid technology in fluoropolymer manufacturing

6,5 years after EiF: 0.01% to all compartments for all PFAS emissions

These limits (except soil) are acceptable to fluoropolymer manufacturers

Requires additional control on unreacted monomers and polymerization by-products

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Established PFAS abatement technologies

Non-polymeric PFAS can be captured and destroyed at the FP manufacturing/processing sites using following commonly deployed technologies:

- **Ion exchange resins** - widely used technique to capture very low concentrations of PFAS
- **Filtration methods**, e.g., reverse osmosis and ultrafiltration - separates short-and long-chain PFAS
- **Scrubbing and adsorption by granular activated carbon**
- **Electrochemical oxidation and foam fractionation** - excellent recovery efficiency for long chain PFAS
- **Thermal oxidation** - combustion efficiency of more than 99.999%

The mentioned abatement techniques are good for all types of emissions to air and water including polymerization aids, monomers and by-products.

Assessment of exposure to fluoropolymer micropowders

- Undergoing study to provide data on:
  - Potential bioavailability and toxicity of fluoropolymers by performing an acute in vivo absorption, distribution, metabolism, and excretion (ADME) study using a rodent animal model
  - Potential occupational exposure of fluoropolymers in the inhalation tract by performing computational 3D Modelling of Deposition Pattern of Fluoropolymers (multi-path particle dosimetry (MPPD) model)

- Organized by FPS GmbH and funded by several FP manufacturers and processors

- Study project managed by a leading US based engineering consultancy, Exponent

- Testing program developed as advised by US EPA and experiments conducted in US EPA approved lab

- Timeline: Q4 2026

Cellular uptake – ADME study (OECD 417)

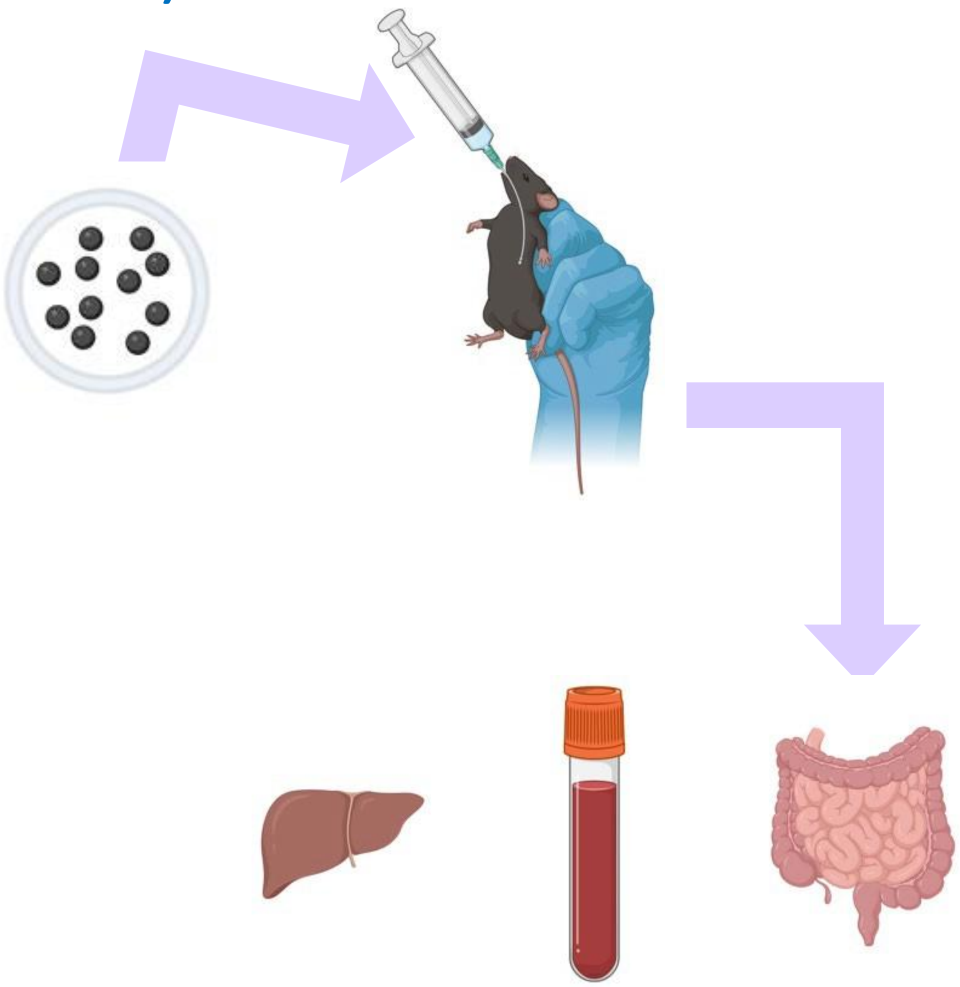
- **Objective**: Assess gastrointestinal uptake & systemic absorption of PTFE micropowders

- **Dosing:** single high level oral dose of blended PTFE micropowder, representing 4 commercially relevant PTFE micropowder products, covering a range of particle sizes

- **Sampling & analysis**
  - Serial blood & excreta collection overtime, followed by GI tract and liver harvest after 7 days

- **Status:** Protocol in finalization

- **Timeline:** Study completion expected by Q3



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MPPD Modelling results of micro powders of PTFE - Relative Distribution in the Lung

- MPPD model calculates the deposition and clearance of particles in the human respiratory tract, based on respiratory physiology, air flow and particle characteristics.

- **Initial model run assumption:** likely unreasonable exposure conditions (Worst-case exposure)
  - PTFE concentration of 10 mg/m^3, 6 hrs/day, 5 days/week, no PPE

- **Deposition**: >93% deposits in upper head (extra thoracic) respiratory tract

- **Lower Lung Exposure**: 1.5–2.4% reaches tracheobronchial region; 1.1–1.6% reaches alveolar regions

- **Clearance***: >99% cleared from tracheobronchial region by end of work week

- **Conclusion**: negligible inhalation exposure to the deeper and most sensitive lung regions for a healthy adult worker handling micro powders of PTFE

* *The clearance model for head region is not available in MPPD (v3.04)*

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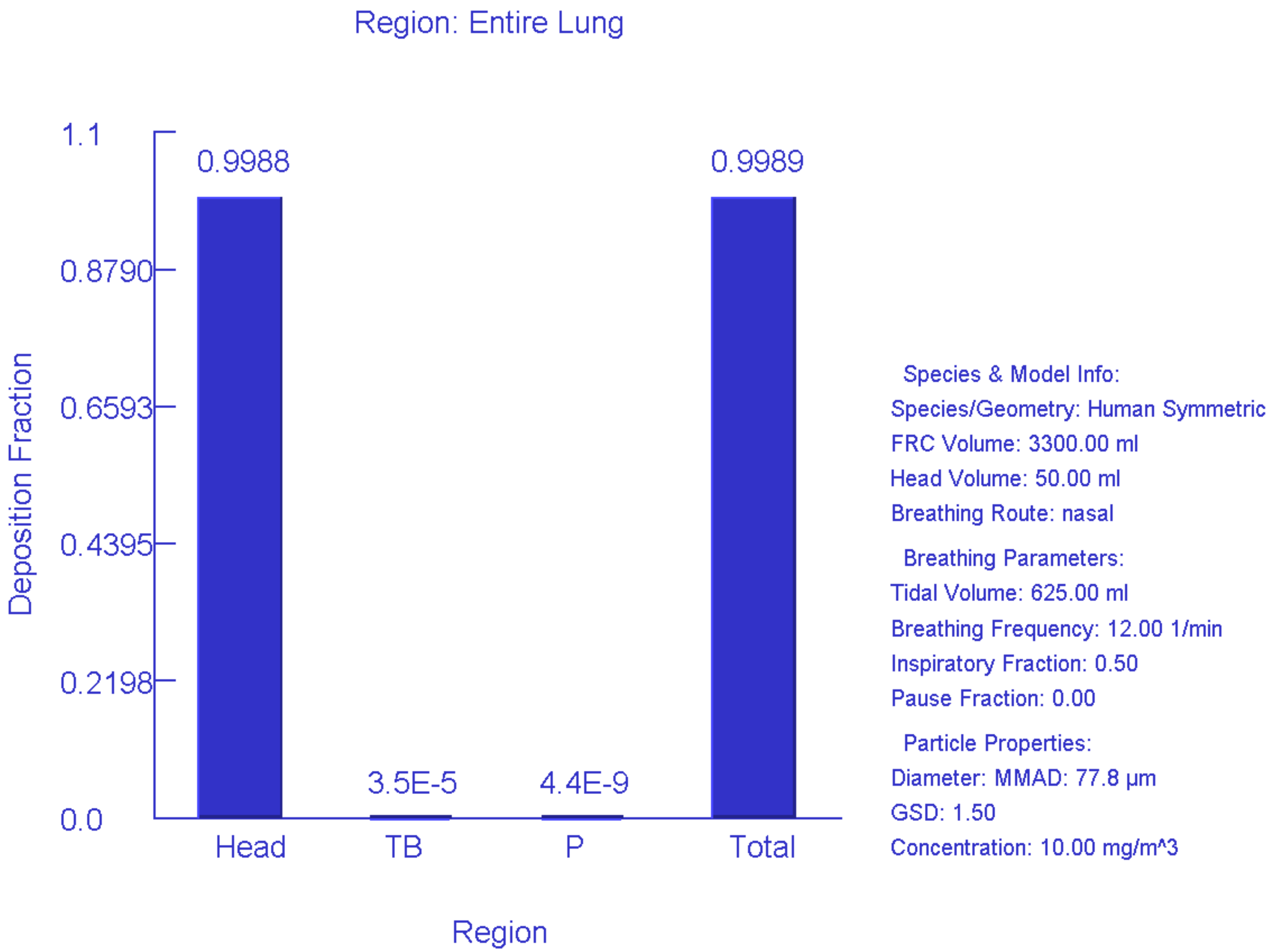
MPPD Modelling result of Blended PTFE Aerosol – Relative Distribution in the Lung

- Almost all the inhaled particles (by mass) are deposited in the head (extra thoracic) region (99.9%)
- Negligible deposition in the tracheobronchial and alveolar regions
- Relative distribution of particles is largely determined by the particle size distribution (or, MMAD)



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PFAS emissions during incineration – a hoax!

Facility	Temperature [°C]	Residence Time [s]	PFAS - analytics	R2PIC / Concentrations/ Removal Efficiency	Reference
BRENDA/ GORE	870 1020	4,0 2,7	LC/MS/MS	31 PFAS $_{total}$: > 99,99 ± 8x10^{-5} %* 31 PFAS $_{total}$: > 99,99 ± 2,83x10^{-4} %*	Aleksandrov et. al
BRENDA/ GFL	860 1095	2,0	UPLC-MS /MS GC / MS	40 PFAS $_{total}$: > 99,99 %* 40 PFAS $_{total}$: > 99,99 %*	Gehrmann et al.
Waste-to-energy/ Sweden	850 - 1125	-	LC/MS	Conc.$_{8\ PFAS,\ total}$ = 4,6 ng/m$^3_{tr}$. (Flue gas)	Björklund et al.
Clean Harbors / Aragonite Utah	1122 - 1149	-	LC/MS/MS	49 PFAS $_{total}$: > 99,9999	Clean Harbors
Cement Australia Gladstone Kiln	>1450	12-15	GC (acc. USEPA SW-846 0010 method)	27 PFAS$_{total}$: > 99,33499**	Cement Australia

*** Calculated with 0 % LOQ for the Case$_{Ci}$ < LOQ; **calculated with 50% LOQ for c < LOQ**

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Full-scale, real-time incineration study at GKS municipal waste incineration plant (MSWI)

Partially funded by the **German Environment Agency (Umweltbundesamt, UBA)**

Involves **40 WtE (Waste to Energy) incineration units** as well as several respected institutions and stakeholders such as:

- ITC/KIT: Institute for Technical Chemistry
- TEER: Department of Thermal Processes and Emission Reduction in Waste Management and Recycling Industry
- ATAB: Working Group of Waste-Fired Power Plants in Bavaria
- ITAD: Association of German Municipal Waste Incineration Plants
- ESWET: European Suppliers of Waste-to-Energy Technology
- VDI: Air Quality Control Standardization Committee
- Multiple German testing institutes & PFAS testing laboratories

Key findings:

Demonstrate that toxic PFAS emissions from MSWIP to air are insignificant confirming a similarly high degradation efficiency of fluoropolymers during incineration

<u>**Degradation efficiency, Total Delta Destruction Rate (TD2R) estimated to be ≥ 99,9999 %**</u>

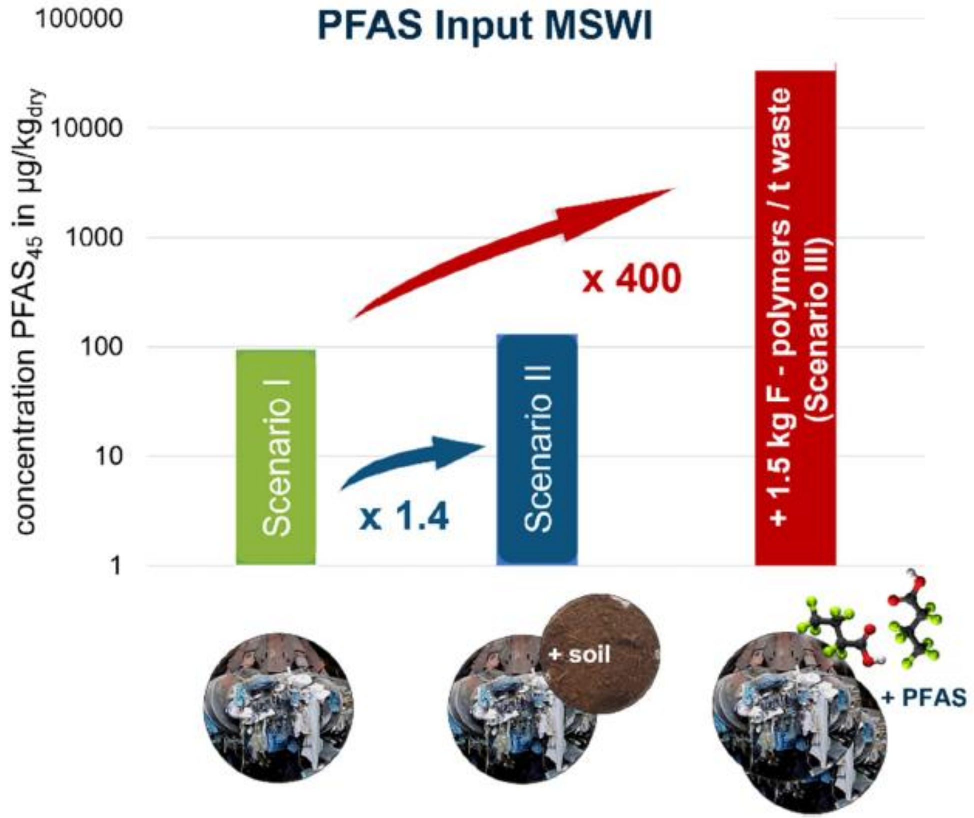
Full-scale, real-time incineration study at GKS municipal waste incineration plant (MSWI)

Three scenarios:

1.) Combustion of municipal solid waste (household waste and household-type commercial waste) as the reference Scenario I.

2.) Co-incineration of PFAS-contaminated soil with compost and sewage sludge, added to the waste stream of Scenario I.

3.) Substantial over-dosing of PFAS, introduced into the waste from Scenario I.



Result:

Thermal waste treatment plants act as sinks for PFAS, achieving fluorine-related Total Delta Destruction Rates (TD^2R) of > 99.9999 wt.-%.

Conclusions

- Fluoropolymers are safe products –> non-bioaccumulative and non-toxic
- Emissions during manufacturing can be effectively controlled using established abatement technologies
- Mineralization of fluoropolymers during end-of-life incineration:
  - Evidence shows destruction efficiencies reaching 99.9999%, indicating that fluoropolymers can be safely managed within existing waste treatment infrastructures without significant environmental release of PFAS.

Overall, fluoropolymers present an insignificant risk to the environment by implementing effective emission control technologies in manufacturing. Also, data proves near complete mineralization of fluoropolymers under standard incineration conditions in municipal and hazardous waste incinerators.

Hence, fluoropolymers should be exempted for manufacturing and use in all kind of applications while shifting the focus towards implementation of abatement technologies during manufacturing & processing phase.

Fluoropolymers are the fundament of modern society and modern technology. Restriction is not an option – exemption is a must!

THANK YOU

Responsible Fluoropolymer Manufacturing

Caroline Andersson

PFAS Summit Europe
19-20 May 2026, Brussels

Fluoropolymers
Product Group of Plastics Europe

What is the Fluoropolymers Product Group (FPG)?

The Fluoropolymers Product Group (FPG) represents Europe's leading fluoropolymer producers and experts

We are the voice of the industry calling for responsible manufacturing, sustainable life cycle management and regulatory clarity.

We ensures that fluoropolymers can continue to play their vital role in enabling innovation and sustainability across key industries, including healthcare, renewable energy, semiconductors, transportation and more.

FPG Members

AGC
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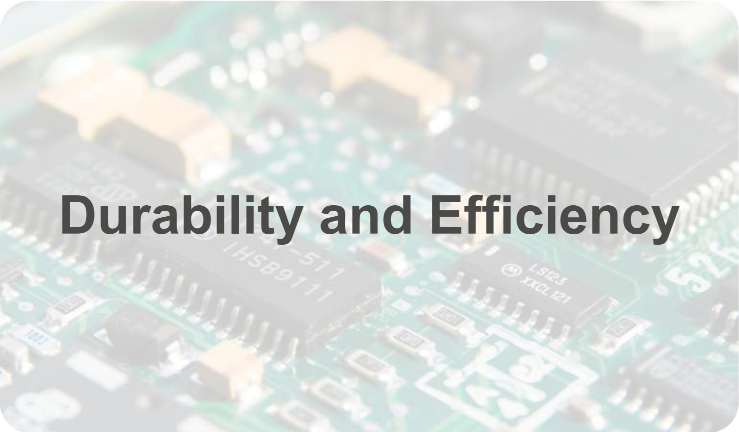
Fluoropolymers: Examples of Societal and Environmental Value

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Medical equipment


Architecture


Renewable energy


Water

FPG Focus Areas

1. Advancing Responsible Manufacturing

FPG established the Manufacturing Programme to ensure that fluoropolymers are produced responsibly with the lowest possible emissions, actively addressing legitimate regulatory questions and concerns regarding manufacturing emissions.

2. Ensuring Sustainable End-of-Life (EoL) Management

As part of industry's action on EoL, FPG initiated an independent report to build understanding of fluoropolymers and EoL. The report pays particular attention to waste reduction, incineration and recyclability of fluoropolymers.

3. Assessment of Alternatives (AoA)

End of April, FPG published an independent focused evaluation of alternatives, analysing their safety, sustainability, life cycle, feasibility, and performance with the aim to contribute to the understanding on the complexities of substitution.

FPG Manufacturing Programme

FPG Manufacturing Programme

- A voluntary initiative adopted by six major European fluoropolymer manufacturers in September 2023.
- Built on three core pillars: emission reduction, technology exchange, and safe downstream handling.
- Sets ambitious, formula-based targets to drastically reduce non-polymeric PFAS emissions to both air and water by 2024 and 2030.

AGC ARKEMA Chemours DAIKIN GORE SYENSQO

Emissions Reduction

The programme sets strict average emission factors based on the total annual amount of fluoropolymers produced.

The established targets for non-polymeric PFAS residues from polymerisation aid technologies are:

By the end of 2024

Maximum 0.009% to air and 0.001% to water

By the end of 2030

Maximum 0.003% to air and 0.0006% to water

Equation 1. Calculation of emission factors

$$EF_{comp} = E_{comp} / m \times 100,$$

Where:

EF	emission factor of the produced/ processed PFASs	[%]
comp	receiving environmental compartment i.e.: water or air	[-]
E	Tonnes of PFASs emitted per year	[t/y]
m	Tonnes of PFASs produced/ processed per year	[t/y]

Reference: Annex B to the Restriction Proposal (page 227)

Progress and Achievements

- ✓ All participating members successfully met and maintained the 2024 emission reduction targets established for non-polymeric PFAS residues from polymerisation aid technology.
- ✓ The industry sustained these rigorous limits throughout 2025, demonstrating long-term feasibility.
- ✓ Achieving these targets required significant capital investments and complex engineering breakthroughs.

Technology Exchange Platform

ⓘ The Technology Exchange Platform (TEP) supports innovation by enabling European fluoropolymer manufacturers to share, assess, and improve emission control technologies. The TEP assess PFAS emissions to water, air and in waste.

As a core pillar of the FPG Manufacturing Programme, it drives progress through:

- **Technology sharing:** Share information on commercially available state-of-the-art technologies to minimise non-polymeric PFAS emissions in manufacturing.
- **Analytical standardisation:** Exchange on methods to detect non-polymeric PFAS.
- **Operational improvement:** Ongoing exchange of best practices on emissions management, industrial hygiene, and material recovery.
- **Stakeholder engagement:** Outcomes are shared with stakeholders and legislators.

Safe Handling Guide

The Safe Handling Guide equips industry and downstream users with robust safety information and best practices for the handling, processing, and waste management of fluoropolymer resins. It is the third core pillar of the FPG Manufacturing Programme.

- **Materials Covered:** Guidance for key fluoropolymer resins including PTFE, ETFE, FEP, PFA, PVDF, and ECTFE, widely used across aerospace, transport, chemical processing, energy, and medical devices.
- This is the first of two guides. Work on the second update begins in the second half of 2026.
- The guide is available on the FPG Website

Assessment of Alternatives Study

Assess whether **viable alternatives to fluoropolymers exist** across selected applications in strategic EU industries, **applying the ECHA Analysis of Alternatives framework to concrete use cases** (Automotive fuel systems and semiconductor manufacturing)

The study fills a critical evidence gap in the EU PFAS policy debate, **providing a structured, application-level evaluation of the technical performance, economic feasibility, and industrial availability of potential substitutes**

Key Takeaways from the study

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- **No viable alternatives identified**:
  - In the automotive applications assessed, no substitute meets the required technical performance;
  - In semiconductor applications, alternatives either fail key criteria or lack sufficient validation for industrial use

- **System complexity is the rule, not the exception**:
  - Fluoropolymers are embedded across multiple interdependent components; substitution must be assessed at system level, not substance level

- **Costs and timelines are significant**:
  - Replacing fluoropolymer piping in a single semiconductor fab could cost ≥€50M; transition timelines are estimated at ~10 years in semiconductors and up to 20 years in automotive

End-of-Life Study

Provide an assessment of fluoropolymer EoL management, framing it within the full EU waste hierarchy, which includes waste prevention, recycling, thermal destruction, and landfilling.

Address gaps in information, as existing literature regarding fluoropolymer waste streams, incineration, and recyclability is currently fragmented and not fully up to date.

Key Takeaways from the study

- **A negligible waste stream:**
  - ~23,500 tonnes of fluoropolymer-containing waste collected annually in the EU, representing less than 0.01% of total EU waste by mass

- **Thermal treatment is highly effective:**
  - Hazardous waste incineration (~50% of EoL routes) achieves destruction efficiencies of 99.9999%;
  - Municipal waste-to-energy (~22%) delivers comparable performance

- **Recycling faces structural barriers:**
  - Only ~3.4% of EoL fluoropolymers are recycled;
  - Constraints include complex product integration, absence of dedicated sorting infrastructure, and no established secondary market in Europe

- **Upstream lifecycle benefits must be counted:**
  - Fluoropolymers extend component and system lifetimes by a factor of 3–10;
  - Small components such as seals and gaskets protect much larger systems, generating waste prevention benefits far beyond their own mass

Conclusion

1 **Commitment to Responsible Production** The Programme ensures that fluoropolymers are manufactured with the lowest possible emissions using state-of-the-art technology, directly answering regulatory concerns.

2 **Effective Risk Management** By setting and successfully meeting strict emission reduction targets, the industry demonstrates that effective risk management is already in place.

3 **Contributing to Evidence Based Regulation** Through the Assessment of Alternatives and End-of-Life studies, FPG provides regulators with the technical and scientific evidence needed to make informed, proportionate decisions.

4 **Alignment with EU Policy Goals** FPG's work, from voluntary manufacturing commitments to independent scientific studies, actively supports the development of the future IED Fluoropolymer/Elastomer BREF and reinforces the case for a risk-based, evidence-driven regulatory approach.

Thank you

FPG

fluoropolymers.org

caroline.andersson@plasticseurope.org

HAVE A QUESTION?

Q&A

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