Addressing the concerns related to fluoropolymers during their lifecycle

PFAS TSCA Workshop

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Fluoropolymers are a critical component of modern society

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- to ensure safety & well-being;
- unlock innovation & technological advancements;
- implement decarbonization technologies and achieve environmental sustainability

(non-polymeric) PFAS emissions' management during fluoropolymer lifecycle

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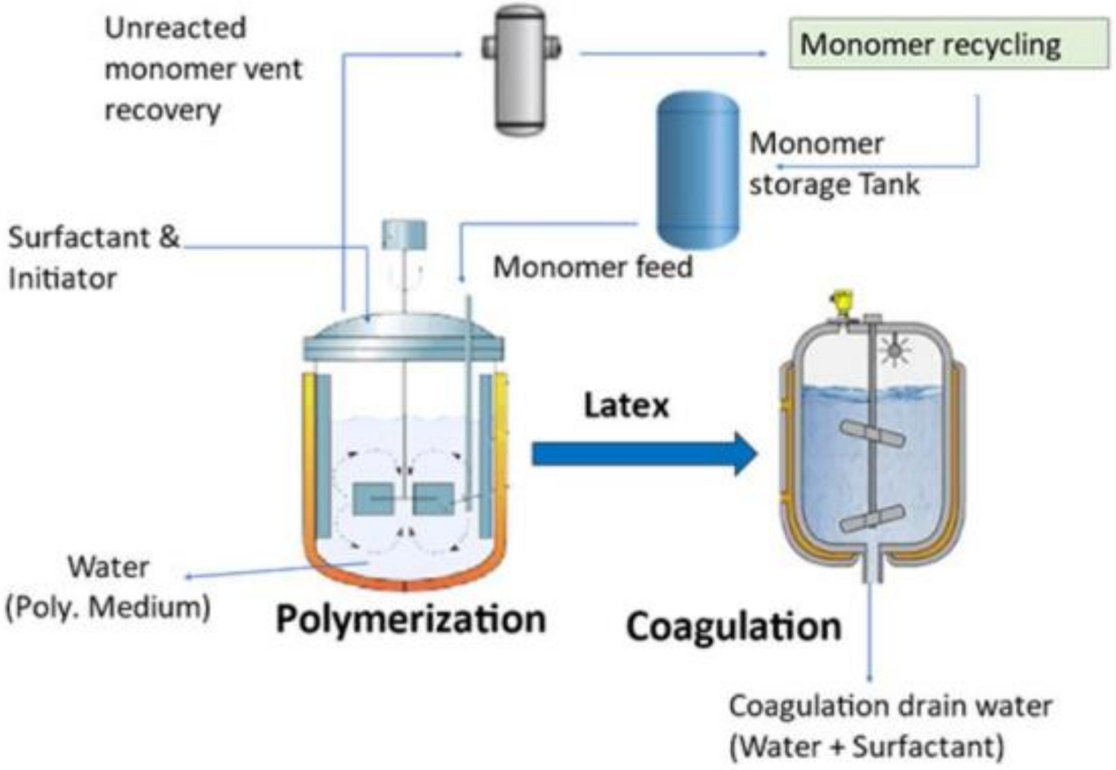
- Manufacturing phase
  - Recycling/reuse of unreacted PFAS intermediates
  - Responsible use/Phasing out of PFAS polymerization aids
  - Abatement of by-products
- Use phase
  - Fluoropolymers are highly stable and do not degrade to non-polymeric PFAS
  - Limited wide dispersive consumer uses – powders & mixtures
- End of life phase
  - Complete mineralization when incinerated – no generation of non-polymeric PFAS
  - Fluoropolymer waste is chemically inert - does not partition to air, water & soil

Unreacted monomer recovery/reuse (PTFE)



The unreacted monomer, TFE, is collected through a vent recovery process and sent to the monomer recycling unit where - after purification - the monomer is stored in storage tanks for reuse in the polymerization process.

This is a continuous closed loop system that ensures that the monomer does not get released to the environment.

Being insoluble in water, TFE is not present in the polymer latex and also not released into the coagulation drain water. Therefore, the chance of monomer emissions is considered negligible.

TFE is not a PFAS as per OECD definition.

Abatement / Phase-out of PFAS polymerization aids

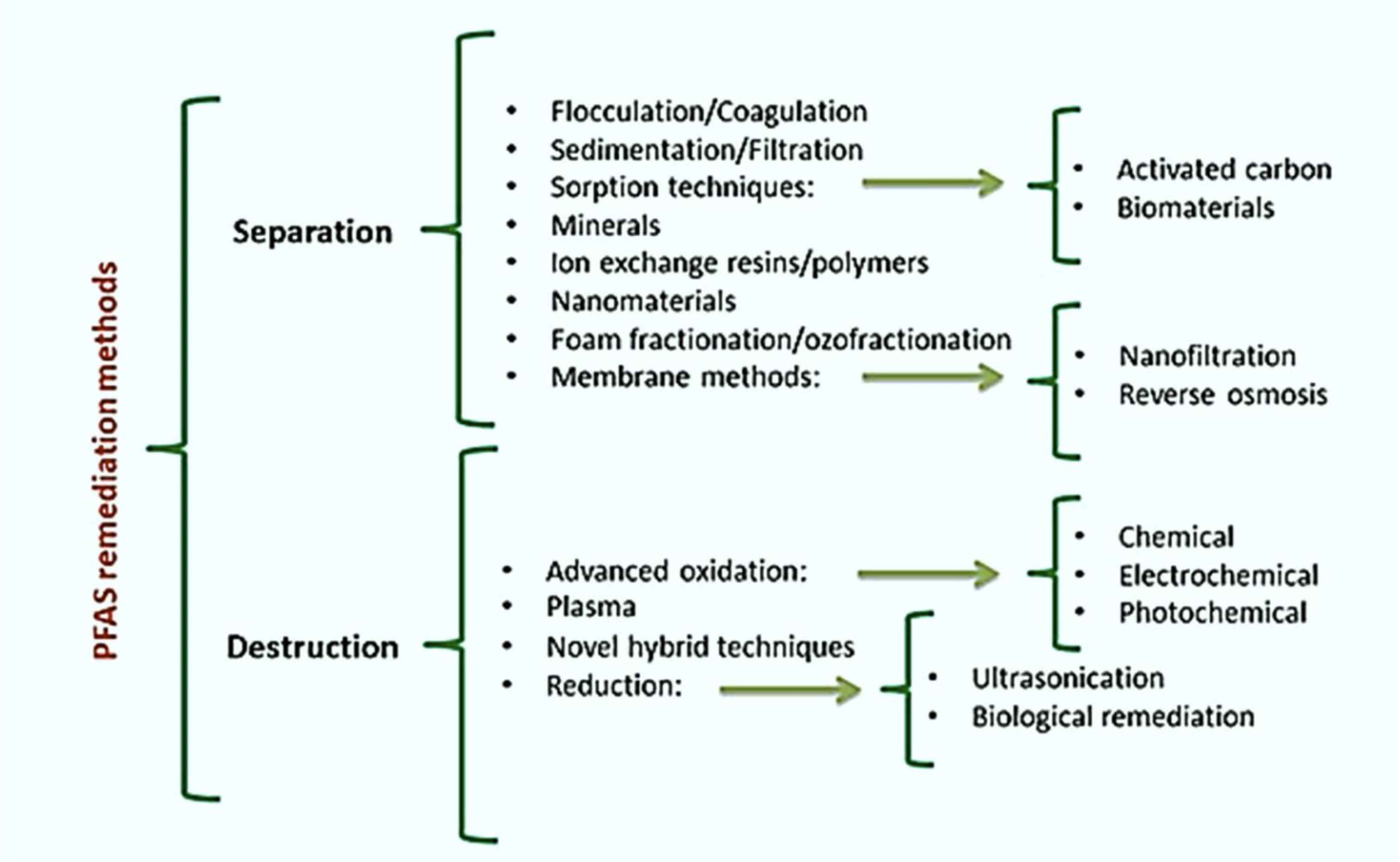
- PFAS polymerization aids do not get consumed during polymerization
- Raw materials, by-products and degradation products may also be PFAS
- PFAS polymerization aids are partially recovered/reused & abated:
  - Recycling: 80-85 %
  - Capture: ~99 %
  - Destruction: ~100 %

Fluoropolymer manufacturers are developing and shifting to non-PFAS polymerization aids

Abatement of PFAS by-products

- Unintentional generation vary depending upon product, process and polymerization aids used
- Concentrations are limited (PTFE produced with hydrocarbon polymerization aid)
  - Targeted PFAS measured using UPLC-MS/MS –
    - less than 5 ppb (sum of 70 PFAS)
    - EU REACH proposal limit – 250 ppb (sum)
  - Non-targeted PFAS measured using LC-HRMS –
    - single digit ppm (without abatement)
    - << 1ppm (with abatement)
    - 1ppm PFAS x 50,000 tons of fluoropolymers = 50 Kgs per annum

Abatement technologies



Shifting paradigms in PFAS resin removal with biomaterial alternatives
H. Karimi-Maleh et al.

The Use phase

- Fluoropolymers are mainly used in industrial set-ups as articles and components
- The use of fluoropolymers as powders and mixtures in wide dispersive consumer applications e.g. cosmetics, ski-waxes, inks, TULAC applications is insignificant (<1%).
- The high molecular weight of fluoropolymers makes it difficult to penetrate human proteins and therefore bio-accumulation is highly unlikely.
- Fluoropolymers are not bioavailable. Bioavailability is necessary for bioaccumulation. To establish this, GFL is working on a project with US EPA to generate toxico-kinetics data on key fluoropolymers.

Fluoropolymers satisfy OECD's Polymers of low concern criteria

	PTFE	PVDF	PFA	FKM
Molecular Weight (Mn)	520,000 – 45,000,000	70,000 – 300,000	200,000 – 450,000	30,000 – 340,000
Particle Size Distribution (MMAD)	Powders: 3 – 500 µm	Powders: 5 – 300 µm Pellets: 2 – 4 mm	Powders: 50 – 250 µm Pellets: 2 – 4 mm	NA (sheets or blocks)
Water Solubility (Octanol/water partition coefficient; K_{ow})	Insoluble/ practically insoluble; (NA)	Insoluble/ practically insoluble; (NA)	Insoluble/ practically insoluble; (NA)	Insoluble/ practically insoluble; (NA)
Ionic character	Neutral	Neutral	Neutral	Neutral
Reactive Functional Groups	< 1 (none)	None	< 1 (none)	None
Stability (thermal max continuous temp)	Stable (260°C)	Stable (150°C)	Stable (260°C)	Stable (180°C)
Low molecular weight leachables	< 1 ppm	None (USP class VI (121°C)	< 50 ppb	< 0.4 - < 1 ppm

The End-of-Life phase

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Incineration	Landfill	Recycling
84%	13%	3%

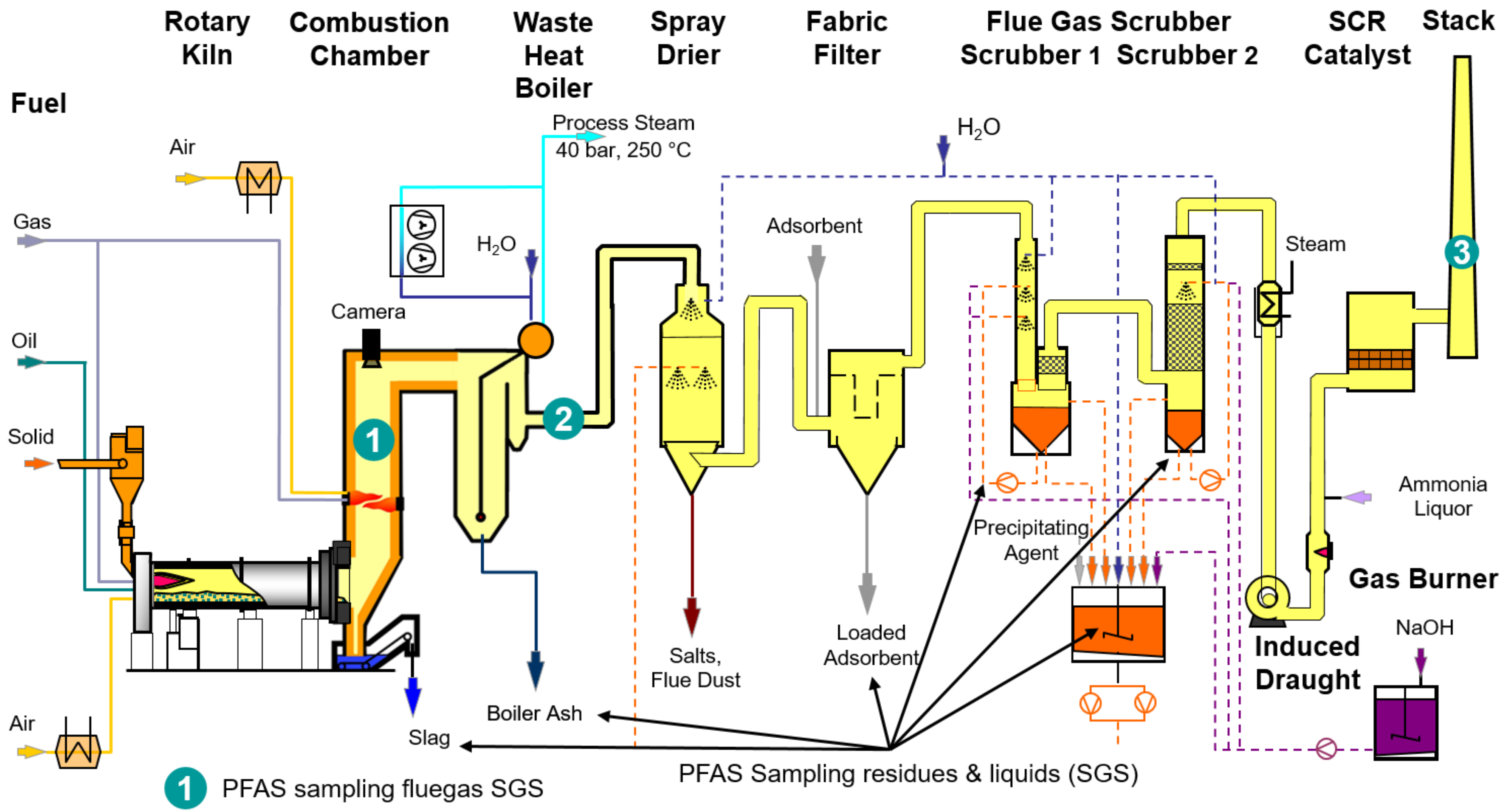
Conversio GmbH study 2022 in EEA

Fluoropolymer incineration project

A pilot scale trial at conditions similar to household and industrial waste-to-energy incineration plants that typically burn products containing fluoropolymers was conducted to assess the potential generation of any statistically significant uncontrolled emissions of Per- and Polyfluorinated Alkyl Substances (PFAS) at levels that might present a risk

Research partner	Karlsruhe Institute of Technology (KIT), Germany
Sampling partner	SGS Institut Fresenius GmbH, Industries & Environment, Germany
Laboratory partner	SGS Belgium NV, Institute for Applied Chromatography, Belgium
Feed sampling	Pro-K, Fluoropolymer processing and DU association, Germany
Incineration Advisor	Dr. Philip Taylor, P Taylor & Associates, LLC, USA
Academic Consultant	Dr. Bruno Ameduri, University of Montpellier, France
Data quality review	Environmental Standards Inc., USA
Observer	Umweltbundesamt (German Federal Environment Agency)

KIT test facility - BRENDA



Process conditions:

- 860ºC for 2 sec
- 1100ºC for 2 sec

Fluoropolymer feed:

- PTFE
- PVDF
- PFA
- FKM

Modified OTM-45 sampling method

The BRENDA plant is a large facility that is a good representation of commercial waste-to-energy plants

Incineration results

Fluorine recovery: Ranged from 69 to 84% using Tunable Diode Laser - provides strong evidence for the complete mineralization of fluoropolymer feed mixture

Trifluoroacetic acid: Not detected for all samples at a reporting limit of 14 µg/m3

PFAS analysis: A large majority of samples (> 98% of samples) indicated that targeted short & long-chain PFAS were non-detectable at levels of < 1 ng/m3

PFAS analyses of wastewater and ash residue: Non-detectable with reporting limits of 0.02 µg/l

GC-MS analysis for ultra short chain fluorocarbons: Non-detectable at a reporting limit of 5-30 µg/m3

*Peer-reviewed full report will be published in Chemosphere - Q2 2024

Landfilling

- Fluoropolymer waste is chemically inert, extremely stable and do not partition to air/water/soil*
- Studies conducted on PTFE to investigate potential degradation support stability of PTFE and lack of transformation to other PFAS**
- Fluoropolymers disposed in landfills do not pose any threat to environment

  e.g. PTFE is used as an inert geomembrane solution in the US***

* Danish EPA report, **Charles River Laboratory and ALS studies, *** Tippet et. al., 2023

Key messages

- Fluoropolymers are safe & critical for the functioning of modern society
- Release of non-polymeric PFAS during fluoropolymer lifecycle is effectively managed by:
  - Implementing recovery & reuse of unreacted raw materials
  - Responsible use / Phasing out use of PFAS polymerisation aids
  - Implementing abatement technologies to arrest unintentional by-products
  - Labelling/regulating wide dispersive consumer applications to ensure proper disposal at EOL
- Fluoropolymers can be manufactured & processed responsibly
- Fluoropolymers can be safely and sustainably managed at end-of-life

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Thank you!