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Pilot-Scale Fluoropolymer Incineration Study: Thermal Treatment of a Mixture of Fluoropolymers under Representative European Municipal Waste Combustor Conditions

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Significance and Motivation

A recent study by Conversio, a consultancy based in Germany, has shown that at its end-of-life approximately 85% of all fluoropolymers end up in waste-to-energy recovery incinerators. A subsequent question of regulators was: Do fluoropolymers get fully incinerated without any formation of short chain or long chain PFAS? A recent project executed by the Karlsruhe Institute of Technology (KIT) in cooperation with Société Générale de Surveillance (SGS) was conducted to assess the same.

Experimental Parameters

Main applications of the four highest volume fluoropolymers (PTFE, PVDF, PFA and FKM) representing more than 80% of commercial fluoropolymer production based on data from Pro-K (German association of polymers processors) were considered. Post-use samples from these applications were incinerated as a mixture under standard operating conditions for municipal and industrial waste incineration. Figure 1 presents the experimental conditions. Experiments were conducted under two sets of conditions over a period of 9 days. The first experiments were conducted at a process setting of 860°C and 2.0 s residence time. These experiments were conducted in three stages. Initially, background tests were performed using natural gas and 100 kg/h wood chips. This was followed by the same fuel conditions with the addition of 320 g/h of fluoropolymer. The final test involved switching back to background conditions. The duration of each of these tests ranged from 9 – 13 hrs. A second set of experiments was conducted at a process setting of 1100°C and 2.0 s residence time. These tests were conducted in the same sequence as the first set of tests. The feed rates for the wood chips and the fluoropolymer mixture were identical to the tests at 860°C and 2.0 s residence time. The test duration for this second set of tests also ranged from 9 – 13 hrs.

test	parameters	number of HF and PFAS sampling	locations	duration [hrs]	RUN	date / remarks		day
start-up with natural gas and oil				24		25.2.23; 10 a.m.	day 1 and 2	
starting solid feeding (wood chips)				24		26.2.23; 10 a.m.		
background of rotary kiln / combustion chamber with oil, natural gas and 100 kg/h wood chips	T_{PCC}: 860 °C; 2.0 s	3	Top of post-combustion chamber (E1b), after boiler, stack	11	1	27.2.2023; 9 am	day 3	Monday
solid fuel: woodchip (100 kg/h) + 320 g/h FP together with oil and natural gas		no		9		feeding of fluoropolymers over night		
		3		11	2	28.2.2023; 9 am	day 4	Tuesday
background of rotary kiln / combustion chamber with oil, natural gas and 100 kg/h wood chips		no		13		stop feeding flouropolymers in the evening		
		3		11	3	01.03.2023; 9 am	day 5	Wednesday
Change of temperature post combustion chamber				12		over night		
background of rotary kiln / combustion chamber with oil, natural gas and wood chips	T_{PCC}: 1100 °C; 2.0 s	3	Top of post-combustion chamber (E1b), after boiler, stack	11	4	02.03.2023; 9 am	day 6	Thursday
solid fuel: woodchip (100 kg/h) + 320 g/h FP together with oil and natural gas		no		9		feeding of fluoropolymers over night		
		3		11	5	03.03.2023; 9 am	day 7	Friday
background of rotary kiln / combustion chamber with oil, natural gas and 100 kg/h wood chips		no		13		stop feeding flouropolymers in the evening		
		3		11	6	04.03.2023; 9 am	day 8	Saturday
shut down				24			day 9	

Material	Mass fraction [wt.-%]
PTFE tubes	63,00
PTFE tape	7,00
PVDF	18,00
PFA	6,00
FKM rubber	6,00

mass flow = 320 g/h

Figure 1: Experimental setup

The fluoropolymers were fed as a mixture at relative proportions that correspond to the mass fractions sold in the European marketplace. These data are also shown in Figure 1. Suspension and emulsion polymerized PTFE application samples represented about 70 mass percent of the fluoropolymer feed rate.

The main operational parameters for the two sets of tests are summarized in Figure 2. The temperature of the flue gas outlet exiting the rotary kiln was in the range of 800-900°C. The temperature of the flue gas post-combustion chamber outlet was very close to the targets for these tests (860°and 1100°C in the combustion chamber for setting 1 and 2, respectively). The O_2 and CO measurements for setting 1 and 2 varied somewhat. For setting 1, the values were 11.2 vol % dry and 0.2 mg/m^3, respectively, while for setting 2 the O_2 measurements were somewhat lower (7.0 % with an increase in the CO concentration (1.2 mg/m^3). The water vapor concentration as measured in the boiler exit ranged from 6.2% in setting 1 to 8.49% in setting 2.

		unit	setting S1 RUN 1, 2, 3	setting S2 RUN 4, 5, 6
Rotary kiln	mass flow wood chips	kg/h	98	98
	main air	m_N^3/h	418	423
	mass flow heating oil	kg/h	61	46
	volume flow natural gas	m_N^3/h	4	4
	volume flow combustion air	m_N^3/h	872	753
	inclination	°	2	
	rotation speed	rev p.m.	0.2	0.4
	temperature flue gas outlet	°C	800 - 900	
	thermal power	MW	1.1	0.9
combustion chamber	volume flow natural gas to burner D4.1	m_N^3/h	22	35
	sum of volume flow combustion air to burner D4.1	m_N^3/h	671	429
	volume flow natural gas to burner D4.2	m_N^3/h	22	35
	sum of volume flow combustion air to burner D4.2	m_N^3/h	671	428
	residence time	s	2	
	temperature flue gas post-combustion chamber outlet (with control)	°C	860	1095
	CO (level E2)	mg/m^3	0.2	1.2
	O_2 (level E2)	Vol.-% dry	11.2	7.0
	thermal power	MW	0.46	0.72
	total thermal power rotary kiln and post combustion chamber	MW	1.59	1.67
boiler / fluegas	volume flow	m_N^3/h	3958	3238
	O_2	Vol.-% dry	11.9	9.0
	CO	mg/m^3	1.35	1.64
	water vapour	Vol.-% wet	6.20	8.49

Figure 2: Main operational parameters at two experiments

There were multiple sampling locations for this study. Flue gas was sampled near the exit of the combustion chamber (location 1), at the exit of the boiler (location 2), and at the entrance to the stack (location 3), while liquids and residues were also sampled and analyzed after each RUN (see Figure 3, Test facility sampling locations).

The test facility BRENDA comprises a rotary kiln with a post-combustion chamber, a boiler for heat recovery and a flue gas cleaning system, which complies with German emission regulations (17 BImschV). The thermal power of the rotary kiln is of maximum 1.5 MW, while that of the post-combustion chamber is about 1 MW, which results in a total thermal output of BRENDA of maximum 2.5 MW.

The fluoropolymers mixture after blending with wood chips and consequent weighing was delivered to the rotary kiln. To secure optimal combustion conditions, natural gas and heating oil were supplied additionally to the rotary kiln, while the post combustion chamber was supplied with natural gas only.

The mass flow of the fluoropolymers mixture was set at 320 g/h, which corresponds to a pure Fluorine mass flow of 230 g/h. This level increases the fluoropolymer ratio to fuel, while at the same time keeps the Fluor-concentration below the total halogen limit of 1%, as set by the legislature.

The combustion gases of the rotary kiln enter the post combustion chamber (PCC). It contains two natural gas burners staggered in an antiparallel manner, with a slight shift to each other. The temperature and the residence time in PCC were adjusted mainly with the help of the above mentioned burners, supported by a slight shift of about 200 kW into the post combustion chamber.

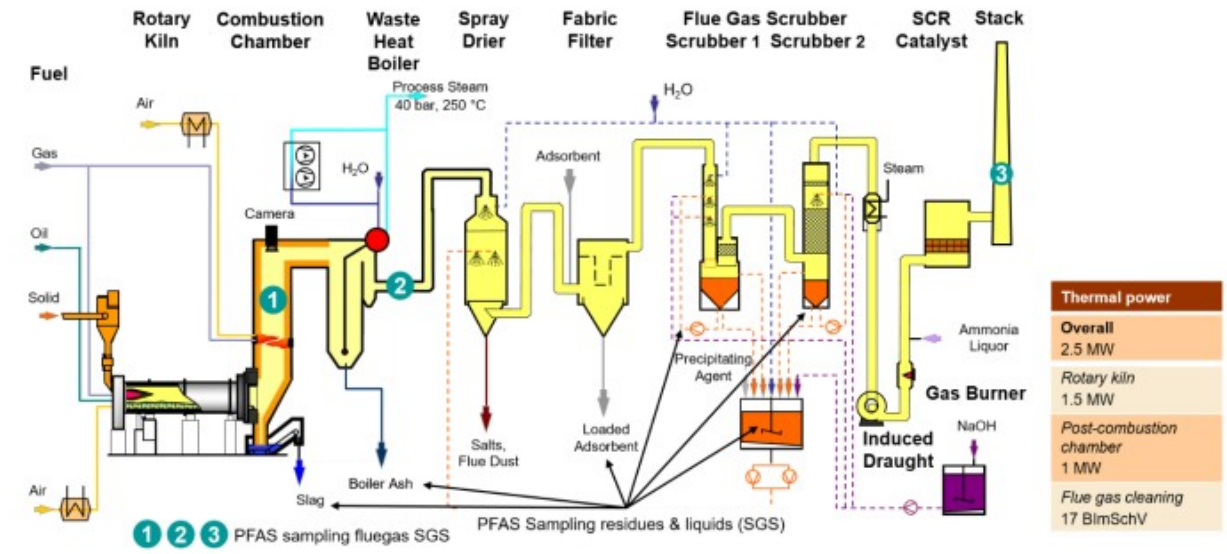

Figure 3: Test facility-BRENDA at KIT

The minimum residence time is calculated according the methodology of the German Technical Supervision Agency ("TÜV") from 2007. The data which were published in the report were re-calculated and then adapted to the operational conditions in this study (Setting 1 and Setting 2). Figure 4 presents the layout of the post combustion chamber with the geometry relevant for the determination of the residence time.

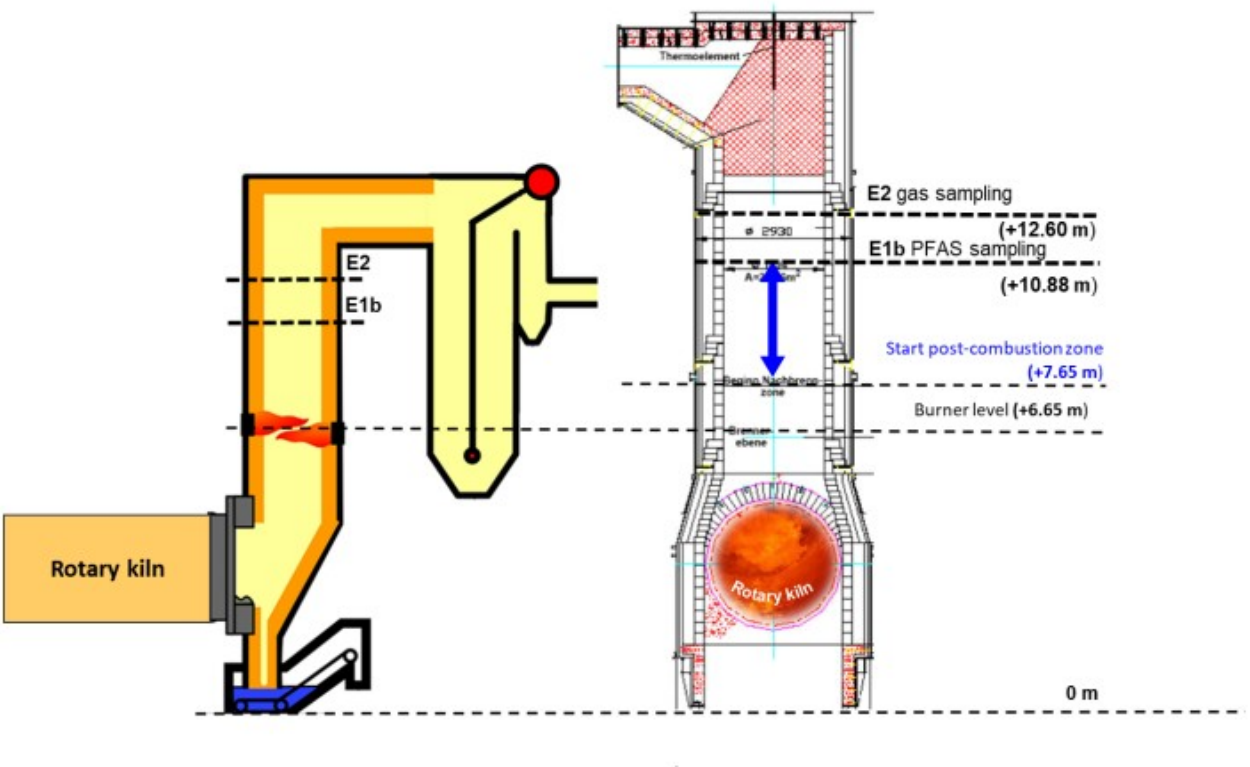

Fig. 4: BRENDA layout with details relevant for the residence time

Table 1 shows the detailed values for the design of the settings.

The volume flow of the required flue gas amount to reach the two seconds was calculated with a target value search.

Table 1. Parameters calculated for the residence time in the PCC

PFAS Project, Level E1b		
	setting 1	**setting 2**
Start post combustion zone [m] 1 meter above the burners	7.65	7.65
Temperature in the post combustion chamber (PCC) [°C]	860	1100
Volume flow V_{PCC} [m_N^3/h wet] after boiler	3947	3257
Cross section PCC [m^2]	2.82	2.82
Volume flow V_{PCC} [m^3/h]	16,382	16,382
Height h [m] level E1b	10.88	10.88
Residence time from start PCC zone to level E1b [s]	**2.00**	**2.00**

The two seconds are the residence time of flue gas from start of post-combustion zone until PFAS sampling point E1b, calculated with calibrated temperature measurements on the top of post combustion chamber (PCC).

The flue gas was sampled for both short-chain and long-chain PFAS in addition to organic and inorganic fluoride. Volatile organic C_1-C_4 fluorocarbons were also sampled using a tedlar bag at all three sampling locations. At location 2, gas-phase HF was measured in near real-time using a tunable diode laser (TDL). The purpose of the three gas-phase sampling locations was to assess the potential emissions of PFAS at different locations in the system and to use this data to assess potential sources of PFAS in this system. PFAS sampling of residues and liquids is also shown in Figure 3. In addition to these three sampling points, flue gas scrubber water upstream of the SCR catalyst was collected and analyzed for PFAS.

Table 2 provides a list of analytes measured in this study and the Limit of Quantification (LOQ). In addition to PFAS and fluoride ion, volatile C_1-C_4 fluorocarbons and trifluoroacetic acid (TFA) were also measured. The C_1-C_4 fluorocarbons were measured by gas chromatography coupled to mass spectrometry (GC-MS). Adsorbable organic fluoride (AOF) was measured using Combustion Ion Chromatography (CIC) and inorganic fluorine in impinger samples were measured by Ion Selective Electrode. TFA was measured using Ion chromatography (IC) and long chain PFAS from impinger samples were measured using Ultrahigh-Performance Liquid Chromatography coupled to tandem Mass Spectrometry (UPLC-MS/MS). HF was also measured at the post-combustion zone location using TDL spectroscopy.

Appendix 1 presents a list of long-chain PFAS measured in this study.

Table 2. Analytes and reporting limits

Analyte	LOQ
Volatile C1-C4 Compounds	5-30 ug/m^3
(CF4, CHF3, C2F6, C2HF5, CF2=CF-CF3, cy-C4F8)	
Adsorbable Organic Fluorine	2 ug/L
Inorganic Fluorine	0.1 ug/L
Trifluoroacetic Acid	0.02 ug/L
PFAS (see Appendix for list of compounds measured)	0.02 ug/L

Note: LOQ for AOF, Inorganic fluorine, TFA, and PFAS are for aqueous samples.

Experimental Results

Fluorine Recoveries

Fluorine recoveries ranged from 69 to 84% using the TDL (at sample location 2). The variability in these data from run to run was low. In contrast, the impinger data analyzed at the same sample location showed about 10 to 20% lower fluorine recoveries. The data are summarized in Table 3. The TDL data provide strong evidence for complete mineralization of fluoropolymer feed mixture.

Table 3: Fluorine Recovery (TDL Measurement)

Run	Settings	HF (TDL)	volume flow @standard wet conditions	volume flow @270 °C	Fluorine	Fluorine Recovery
		mg/m_B^3 wet Gas	[m_N^3/h]	[m_B^3/h]	g/h	%
2	860°C, > 2s, oil + nat. gas + wood chips + 230 g/h F	23.50	3,956	7,866	175.64	76%
		23.93	3,952	7,859	178.62	78%
		25.80	3,943	7,841	192.16	84%
5	1100°C, > 2s, oil + nat. gas + wood chips + 230 g/h F	25.44	3,299	6,560	158.53	69%
		26.58	3,231	6,424	162.23	71%
		26.93	3,217	6,397	163.64	71%

Long-chain PFAS

A large majority of the PFAS measured in impinger samples were near or below reporting limits (>98% of data collected at 860°C and >96% of data collected at 1100°C). Table 3 presents PFAS data for 4 compounds where measurements exceeded reporting limits in several cases. Of particular note is a HFPO-DA measurement which exceeded reporting limits by a factor of 47. Maximum PFBA, PFBS, and 6:2 FTS measurements exceeded reporting limits by much lower factors, ranging from 9 – 12.

These data was re-analyzed to assess the veracity of data. The results are also presented in Table 4. The results indicate that the high measurement values for HPFO-DA could not be reproduced. The results for PFBA and PFBS were also lower when re-analyzed. The lack of reproducibility of data and the lower

measurement values upon re-analysis suggests that cross-contamination is a possible reason for high measurement values for HPDO-DA, PFBA, and PFBS in the initial analysis.

PFAS analyses of wastewater and ash residue samples indicated a large majority of the samples were below reporting limits. One notable exception was a deslagger water bath sample where HFPO-DA was a factor of 16 above the report limit.

Table 4. PFAS Analysis of Impinger Samples

Initial Analysis

PFAS Compound	RL (ng/m^3)	# > RL	ng/m^3 (max)
PFBA	2.8	5	35.8
PFBS	1.4	22	19.5
6:2 FTS	1.4	17	12.5
HFPO-DA	1.4	31	66.3

Re-Analysis

PFAS Compound	RL (ng/m^3)	# > RL	ng/m^3 (max)
PFBA	2.8	0	2.8
PFBS	1.4	7	10.7
6:2 FTS	1.4	11	16.2
HFPO-DA	1.4	16	25.2

Note: For each data set, the total number of measurements equal 54: 27 for each combustion condition.

Short-chain PFAS

TFA was non-detect for all 76 impinger samples analyzed, at a reporting limit of 14 µg/m^3 (ppb).

Volatile Fluorocarbons (FC)

Tetrafluoromethane (CF_4) was the only volatile FC detected in the GC-MS analysis. Values of CF_4 at stack were near detection limits (20-27 µg/m^3) and detected in 2 of 14 samples. The results are considered questionable because CF_4 was only detected in one post-combustion sample. There is no plausible reason for larger CF_4 values downstream of the combustion unit unless a non-combustion source is considered.

Discussions

There is one prior published pilot-scale study of the combustion of PTFE (Aleksandrov et al. 2019). Combustion tests were performed at two conditions: 870°C and 4 s residence time and 1020°C and 2.7 s residence time and wood chips were used as the supplemental fuel. The prior study burned 0.3 wt % PTFE. Sampling was performed at a single location, downstream of the waste heat boiler. Thirty-one PFAS compounds were sampled and analyzed (see Table 1 of Aleksandrov et al. for a list of PFAS measured).

Fluorine recoveries were determined indirectly via IR water vapor measurements. The fluorine recoveries ranged from 56 to 78%, with three of the four tests yielding recoveries less than 70%. Eleven PFAS compounds were detected from the combustion and/or control samples and each at a level above 100 ng/m^3 in at least one sample. PFOA was detected in all but one sample and at values as high as 2.7 $\mu g/m^3$ (see Table 3 of Aleksandrov et al.).

The current study differs from the prior test in two important ways. The fluorine recoveries in this study were determined from direct spectroscopic measurements and were above 70% in five of the six tests. Secondly, PFAS reporting limits were on the order of 1 ng/m^3 or less and a large majority of samples (>98%) were at or below reporting limits. The current study provides strong evidence that incinerating a mixture of fluoropolymers under representative municipal waste combustion conditions leads to complete mineralization of the C-F bonds, no significant emissions of long-chain PFAS, and no significant emissions of TFA or light fluorocarbons such as CF_4 or C_2F_6. The prior study did not provide evidence that the PFAS detected were from sources other than the combustion of PTFE.

Conclusions

The study clearly demonstrated that fluoropolymers are converted to inorganic fluorides and carbon dioxide. The inorganic fluorides detected were hydrogen fluoride. A large majority of samples indicated that long-chain PFAS were below levels of 1 ng/m^3 (> 99% of samples associated with 860°C condition and > 98% of samples associated with 1100°C condition). There were no short chain PFAS detected post incineration. TFA was non-detectable in all samples with a reporting limit of 14 $\mu g/m^3$. **The results confirm that fluoropolymers at their end of life when incinerated under representative European municipal incinerators conditions do not generate any measurable levels of PFAS emissions and therefore pose no risk to human health and the environment.**

The main reason to include fluoropolymers in the EU PFAS restriction proposal was persistence (resistance to degradation in the environment) in the environment. The absence of organic fluorides and more specifically PFAS in tests representative of municipal waste incineration confirms complete mineralization of fluoropolymers and provides critical data in support for exempting Fluoropolymers from the EU REACH PFAS restriction proposal.

References

TÜV report from 19th of January 2007: Expert opinion on compliance with and monitoring of the combustion conditions (residence time, temperature) in the afterburning zone of the THERESA test facility at the Forschungszentrum Karlsruhe GmbH

Aleksandrow, K, Gehrmann, H-J, Hauser, M., Matzing, H., Pigeon, D., Stapf, D., and Wexler, M., Waste incineration of Polytetrafluoroethylene (PTFE) to evaluate potential formation of per- and Poly-Fluorinated Alkyl Substances (PFAS) in flue gas, Chemosphere, 2019, 226, 898-906.

Appendices

1. List of long-chain PFAS analytes analyzed in this study

Common Name[a]	Abbreviated Name	CAS[b] Registry Number	Isotopic Pre-Extraction Pair
Perfluoroalkylcarboxylic acids (PFCAs)			
Perfluorobutanoic acid[1,3,4]	PFBA	375-22-4	$^{13}C_4$-PFBA
Perfluoropentanoic acid[1,3,4]	PFPeA	2706-90-3	$^{13}C_5$-PFPeA
Perfluorohexanoic acid[1,2,3,4]	PFHxA	307-24-4	$^{13}C_2$-PFHxA
Perfluoroheptanoic acid[1,2,3,4]	PFHpA	375-85-9	$^{13}C_4$-PFHpA
Perfluorooctanoic acid[1,2,3,4]	PFOA	335-67-1	$^{13}C_4$-PFOA
Perfluorononanoic acid[1,2,3,4]	PFNA	375-95-1	$^{13}C_5$-PFNA
Perfluorodecanoic acid[1,2,3,4]	PFDA	335-76-2	$^{13}C_2$-PFDA
Perfluoroundecanoic acid[1,2,3,4]	PFUnDA	2058-94-8	$^{13}C_2$-PFUndA
Perfluorododecanoic acid[1,2,3,4]	PFDoA	307-55-1	$^{13}C_2$-PFDoA
Perfluorotridecanoic acid[2,3,4]	PFTrDA	72629-94-8	$^{13}C_2$-PFDoA
Perfluorotetradecanoic acid[2,3,4]	PFTeDA	376-06-7	$^{13}C_2$-PFTeDA
Perfluoro-n-hexadecanoic acid	PFHxDA	67905-19-5	$^{13}C_2$-PFHxDA
Perfluoro-n-octadecanoic acid	PFODA	16517-11-6	$^{13}C_2$-PFDoA
Perfluorinated sulfonic acids (PFSAs)			
Perfluoro-1-butanesulfonic acid[1,2,3,4]	PFBS	375-73-5	$^{13}C_3$- PFBS
Perfluoro-1-pentanesulfonic acid[1,3]	PFPeS	2706-91-4	$^{13}C_3$-PFHxS Or $^{13}C_3$-PFBS
Perfluoro-1 -hexanesulfonic acid[1,2,3,4]	PFHxS	355-46-4	$^{18}O_2$-PFHxS or $^{13}C_3$-PFHxS
Perfluoro-1-heptanesulfonic acid[1,3]	PFHpS	375-92-8	$^{13}C_4$-PFHpA
Perfluoro-1-octanesulfonic acid[1,2,3,4]	PFOS	1763-23-1	$^{13}C_4$-PFOS
Perfluoro-1-nonanesulfonic acid[3]	PFNS	68259-12-1	$^{13}C_4$-PFOS
Perfluoro-1-decanesulfonic acid[3]	PFDS	335-77-3	$^{13}C_4$-PFOS
Perfluorododecane sulfonate	PFDoS	79780-39-5	$^{13}C_4$-PFOS
Perfluorinated sulfonamides (FOSAs)			
Perfluoro-1-octanesulfonamide[3,5]	FOSA	754-91-6	$^{13}C_8$-FOSA
N-Methylperfluorooctanesulfonamide [5]	MeFOSA	31506-32-8	d3-MeFOSA
N-ethylperfluorooctanesulfonamide [5]	EtFOSA	4151-50-2	d5-EtFOSA
Perfluorinated sulfonamidoacetic acids (FOSAAs)			
N-methyl perfluorooctanesulfonamidoacetic acid[2,3]	MeFOSAA	2355-31-9	d3-MeFOSAA
N-ethyl perfluorooctanesulfonamidoacetic acid[2,3]	EtFOSAA	2991-50-6	d5-EtFOSAA
Fluorotelomer sulfonates (FTS)			
1H,1H,2H,2H-Perfluorohexane sulfonic acid[1,3]	4:2 FTS	757124-72-4	M2-4:2 FTS
1H,1H,2H,2H -Perfluorooctane sulfonic acid[1,3]	6:2 FTS	27619-97-2	M2-6:2 FTS
1H,1H,2H,2H -Perfluorodecane sulfonic acid[1,3]	8:2 FTS	39108-34-4	M2-8:2 FTS
1H,1H,2H,2H-perfluorododecane sulfonate (10:2)	10:2 FTS	120226-60-0	M2-10:2 FTS
Fluorinated Replacement Chemicals			
4,8-Dioxa-3H-perfluorononanoic acid	ADONA[1]	919005-14-4	$^{13}C_4$-PFOS
Hexafluoropropylene Oxide Dimer Acid	HFPO-DA (GenX)[1]	13252-13-6	$^{13}C_3$-HFPO-DA
Additional Targets			
Decafluoro-4-(pentafluoroethyl)cyclohexanesulfonate)[4]	PFecHS	67584-42-3	$^{18}O_2$-PFHxS

Fluorinated Replacement Chemicals			
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9Cl-PF3ONS (F-53B Major)[1]	756426-58-1	$^{13}C_4$-PFOS
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid OR 11-Chloroeicosafluoro-3-oxaundecane-1-sulfonate[a]	11Cl-PF3OUdS (F-53B Minor)[1]	763051-92-9 83329-89-9	$^{13}C_4$-PFOS

Perfluorinated sulfonamide ethanols (FOSEs)			
2-(N-methylperfluoro-1-octanesulfonamido)-ethanol[5]	N-MeFOSE	24448-09-7	d7-N-MeFOSE
2-(N-ethylperfluoro-1-octanesulfonamido)-ethanol[5]	N-EtFOSE	1691-99-2	d9-N-EtFOSE
Additional Targets			
Nonafluoro-3,6-dioxaheptanoic acid[1,5]	NFDHA	151772-58-6	$^{13}C_5$-PFHxA
Perfluoro(2-ethoxyethane)sulfonic acid[1,5]	PFEESA	113507-82-7	$^{13}C_3$-PFBS
Sodium perfluoro-1-dodecanesulfonate[5]	PFDoS	1260224-54-1	$^{13}C_4$-PFOS
Perfluoro-4-methoxybutanoic acid[1,5]	PFMBA	863090-89-5	$^{13}C_5$-PFPeA
Perfluoro-3-methoxypropanoic acid[1,5]	PFMPA	377-73-1	$^{13}C_4$-PFBA
3:3 Fluorotelomer carboxylic acid[5]	3:3 FTCA	356-02-5	$^{13}C_2$-FHEA
5:3 Fluorotelomer carboxylic acid[5]	5:3 FTCA	914637-49-3	$^{13}C_2$-FHEA
7:3 Fluorotelomer carboxylic acid or 3-perfluoropheptyl propanoic acid[4, 5]	7:3 FTCA or FHpPA	812-70-4	$^{13}C_2$-FOEA
2H-perfluoro-2-decenoic acid[4]	8:2 FTUCA or FOUEA	70887-84-2	$^{13}C_2$-FOUEA
2-perfluorodecyl ethanoic acid[4]	10:2 FDEA	53826-13-4	$^{13}C_2$-FDEA
2-perfluorooctyl ethanoic acid[4]	8:2 FTA or FOEA	27854-31-5	$^{13}C_2$-FOEA
2H-perfluoro-2-octenoic acid[4]	6:2 FHUEA	70887-88-6	$^{13}C_2$-FHUEA
2-perfluorohexyl ethanoic acid[4]	6:2FTCA or 6:2 FHEA	53826-12-3	$^{13}C_2$-FHEA

Chemours

03 May 2023

"Integrated Water Management - revised lists of surface and groundwater pollutants"- Considerations from Chemours

In October 2022 the Commission adopted a proposal to revise the list of priority substances in surface water and groundwater. The proposal includes a quality standard for a new group entry for 24 per and polyfluoroalkyl substances (PFASs) - a large group of chemicals with widely different physical, chemical and toxicological properties[1].

If the proposal is agreed by the Council and the European Parliament, Member States will be required to monitor these substances in surface and groundwater and will be legally obliged to take measures to achieve the proposed quality standards, where they are exceeded[2]. The appropriateness and reliability of the proposed quality standard for PFASs is, however, heavily debated based on scientific uncertainties, procedural irregularities, implementation difficulties and proportionality considerations, all of which are elaborated below.

For example, in March 2023, the Senate of the Czech Republic concluded that the implementation of the PFAS quality standard will depend on analytical methods that have yet to be developed and sufficient laboratory capacity, making the proposal "very ambitious and difficult to achieve".[3] Implementation is further complicated by the fact that the list of PFAS substances diverges from the recently revised Drinking Water Directive, and the proposed thresholds are far more stringent, making it inconsistent and a significant financial burden, as recently highlighted by some Member States' authorities.

In addition, the European Commission's own Regulatory Scrutiny Board highlighted various deficiencies in the impact assessment accompanying the proposal, including a failure to assess the impact on individual Member States or to estimate the order of magnitude of the expected impacts. A simple, 'best-case' assessment of likely compliance with the proposed surface water quality standard, based on available monitoring data, revels that widespread failure of the quality standard is likely throughout the EU, with resulting the legal consequences of upgrading WWTWs (waste water treatment works) with quaternary treatment to remove PFASs from effluents estimated to cost **at least €300 billion** over the next 20 years, with no guarantee that quality standards will be met. At the same time, in terms of comparison, the COM IA quantified the benefits from the measures on PFAS ranging from €12.7 million to €41.4 million annually in the European Economic Area countries.

[1] https://environment.ec.europa.eu/publications/proposal-amending-water-directives_en
[2] Articles 16(1) and (8) of Directive 2000/60/EC ("WFD")
[3] CZ_SENATE_CONT1-COM(2022)0540_EN.pdf (europa.eu) accessed on 2023-04-27

In the meantime, a proposal for a REACH restriction of PFAS is being considered by the European Chemicals Agency (ECHA), which would prohibit the use of PFASs in non-essential uses 'at source[4]'. As highlighted in recent EU parliament discussions on the revised water directives, controls at source should be prioritized prior to the implementation of end-of-pipe measures, such as quality standards[5].

We strongly believe that water quality targets must be based on sound science as well as predictable and proportionate requirements to enable authorities and industry to practically measure and achieve outcomes protective of the environment.

- **The following paper provides Chemours considerations on the proposed quality standard for PFASs and explores the link between the proposal and other relevant regulatory processes, such as the ongoing 'universal' restriction of PFAS under REACH. Chemours is suggesting either of the two alternative regulatory options presented as a more proportionate and legally coherent approach to regulate the presence of PFASs in surface water and groundwater.**

In summary, we call for either:

- **Proposal a) remove the group of PFAS from the revised EQS and groundwater directives and, instead, add them to the water framework directive 'watch list' (the appropriate destination for substances where scientific uncertainties remain)**
- **OR Proposal b) align the list of substances in the proposal with the existing list of PFAS in the Drinking Water Directive and implement a quality standard for the sum of listed PFAS of 0.2 µg/l based on the principles established in the EQS guidance.**

Chemours indeed considers that any of the two alternative regulatory options presented above are more proportionate and legally coherent approach to regulate the presence of PFASs in surface water and groundwater.

[4] ANNEX XV RESTRICTION REPORT PROPOSAL FOR A RESTRICTION for PFAS

[5] Draft report amending Directive 2000/60/EC establishing a framework for Community action in the field of water policy, Directive 2006/118/EC on the protection of groundwater against pollution and deterioration and Directive 2008/105/EC on environmental quality standards in the field of water policy

About us

Chemours' chemistry makes an essential contribution to improving the lives of people everywhere, but our duty to the world we all share drives us to meet essential needs in the most responsible way possible.

Sustainable production is in Chemours' DNA. As part of our 2030 Corporate Responsibility Commitment Goals, Chemours has committed to reduce emissions of fluorinated organic substances by 99% by 2030 from our production. This commitment is not just words: based on actions taken to date we already expect to reduce the emissions from our site in The Netherlands by 80% by January 2024 and plans further reduction as defined in our CRC goals.

Sound science-based, predictable, and proportionate environmental legislation is critical to enable companies like ours to plan and implement such endeavours. We stand ready to support EU legislation which sets ambitious, realistic, and proportionate requirements that are protective of the environment and human health and sufficiently robust to be legally certain and enforceable by the authorities. Standards should avoid unintended impacts such as regrettable substitution and result in overall benefits for society.

General Framework

We welcome the Commission's Proposal for amending Directive 2000/60/EC establishing a framework for Community action in the field of water policy ("WFD"), Directive 2006/118/EC on the protection of groundwater against pollution and deterioration ("GWD") and Directive 2008/105/EC on environmental quality standards in the field of water policy ("EQSD), referred hereinafter as "the Proposal". We fully support the improvement of the prioritization process, including a more transparent and efficient setting of environmental quality standards, reflecting the best available scientific data.

Coherence with other ongoing regulatory processes

It is clear that measures to control emissions under the Water Directives[6], which constitute environmental release legislation, should have strong coherence with upstream source focused legislation, most notably REACH[7] and the Industrial Emissions Directive[8], especially since Article 16(6) of the Water Framework Directive obliges the European Commission to set proportionate levels for quality standards considering appropriate combination of product and process controls. The European Parliament has

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[6] Directive 2000/60/EC establishing a framework for Community action in the field of water policy ("WFD"), Directive 2006/118/EC on the protection of groundwater against pollution and deterioration ("GWD") and Directive 2008/105/EC on environmental quality standards in the field of water policy ("EQSD)

[7] Regulation (EC) N° 1907/2006 of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), OJ L 396, 30.12.2006

[8] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)

proposed to reinforce this coherence though various amendments to the revised directive prioritising **source control** over end-of-pipe measures[9].

In this regard, it should be noted that a proposal to restrict PFAS under REACH has recently been submitted by four Member States and Norway to ECHA, where it is undergoing scientific scrutiny in ECHA's committees for risk assessment (RAC) and socioeconomic analysis (SEAC). It is expected – for the time being - that the restriction will become effective in 2026.

The REACH restriction may allow the continued use of PFASs where a ban is concluded to be disproportionate or may require continued use for applications where risks are considered to be adequately controlled (e.g., under responsible manufacturing conditions). Indeed, the proposal includes numerous permanent and time-limited derogations (up to 13.5 years after entry into force)[10], which are associated with some releases. Additional derogations may be adopted prior to the restriction entering into force. In this context, it is inappropriate to anticipate the results of the REACH process, which should be allowed to proceed to its conclusion. To cover the concerns raised by PFAS in the meantime, whilst avoiding disproportionate impacts, we believe these substances should be placed on the WFD watch list until then. As a matter of fact, the proposed EQS would effectively set unachievable conditions in contradiction to potential derogations, identified by SEAC and the Member States to be critical for society

To the contrary, it appears that the values set in this Proposal will oblige Member States to achieve the set EQS by means of additional measures of their choice, which they deem appropriate. These potential measures will likely affect the manufacture, placing on the market and use of the fluoropolymers that are allowed to continue under the conditions of the REACH restriction.

Implementation of the proposed EQS for PFASs would amount to a *de facto* restriction, on the manufacture, placing on the market and use of the 24 PFASs included in the Proposal.[11] Also, such a ban would apply ahead of the entry into force of the PFAS restriction and it would therefore be premature as it would not consider the measures the REACH restriction might determine to minimize risks deriving from PFAS.

In addition, the Proposal fails to consider whether existing Best Available Technique ("BATs") would allow the 24 PFAS threshold to be achieved. As of today, with the current technologies, it is not possible to achieve such limits. Our recommendation is to develop Best Available Techniques to minimize emissions from industrial plants, in line with the Industrial Emissions Directive, before integrating such substances and limits into the PHS list. Article 16(6) of the WFD in fact determines that "Where appropriate, action at Community level for process controls may be established on a sector-by-sector basis". It

[9] Draft report amending Directive 2000/60/EC establishing a framework for Community action in the field of water policy, Directive 2006/118/EC on the protection of groundwater against pollution and deterioration and Directive 2008/105/EC on environmental quality standards in the field of water policy
[10] ANNEX XV RESTRICTION REPORT PROPOSAL FOR A RESTRICTION for PFAS, p.4, Column 2, paragraphs 4, 5 and 6
[11] REACH Regulation, article 68

seems evident that this issue would be better approached on a sector level, through emissions control.

From our perspective, this failure to address and review the BATs runs counter the general objectives of the amended Water Directives.[12] In that regard, we believe that BATs should be reviewed under the Industrial Emissions Directive and related Best Available Technique Reference documents ("BREFS") to be agreed within the Joint Research Centre (JRC) and a reasonable value agreed, in line with the conclusions of the Scientific Committee on Health, Environmental and Emerging Risks ("SCHEER").

Our two proposals are presented below.

[12] Dir 2006/60/EC article 10(2)(a); [12] Dir 2008/105/EC articles 3(3b) and 4(3)(b)

Our proposals on the current revision

Proposal A: Address the significant scientific and regulatory uncertainty by moving PFASs to the Watchlist.

This option has been developed in response to the following limitations of the Commission's Proposal, as elaborated below:

1. The derivation of the quality standard for the group of 24 PFASs is not scientifically robust and inconsistent with applicable Technical Guidance;
2. The proposed quality standard cannot be reliably implemented;
3. The criteria for PHS have not been demonstrated for the group of 24 PFASs;
4. Source control measures should be prioritised over end-of-pipe measures;
5. The costs of implementing the proposed quality standard would be disproportionate and would not guarantee compliance.

To address these shortcomings a quality standard for PFASs should not be proposed until the scientific and procedural uncertainties associated with it are resolved and the REACH PFAS restriction has been implemented. Until then, PFASs should be added to the WFD 'watch list'. PFASs have not previously been listed on the watch list and the knowledge gained from such an approach would help Member States and the Commission to develop a more fit-for-purpose and proportionate approach to regulating PFASs.

1) Derivation of the quality standard for the group of 24 PFAS is not scientifically robust and the resulting standard is not 'fit for purpose'

The threshold values for PFAS are derived from an EFSA tolerable weekly intake (TWI) for four PFAS (PFOA, PFNA, PFOS and PFHxS – based on reported effects on the immune system).[13] The Commission applied a Relative Potency Factor (RPF) methodology (based on liver effects in rats) to extend the applicability 'read-across' the TWI from the four substances it was derived for (PFOA, PFNA, PFOS and PFHxS) to a further 20 PFAS in order to derive the EQS for the sum of 24 PFASs, expressed as PFOA equivalents.[14]

The methodology used to make this read-across is non-standard and does not meet minimum standards of scientific best practice. Therefore, it is not sufficiently reliable for regulatory use; especially in the context of the WFD where there are legal consequences of failing to meet the standard. In addition, the methodology is also not consistent with

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[13] EFSA CONTAM Panel (EFSA Panel on Contaminants in the Food Chain), Schrenk D,Bignami M, Bodin L, Chipman JK, del Mazo J, Grasl-Kraupp B, Hogstrand C, Hoogenboom LR,Leblanc J-C, Nebbia CS, Nielsen E, Ntzani E, Petersen A, Sand S, Vleminckx C, Wallace H, Barregard L, Ceccatelli S, Cravedi J-P, Halldorsson TI, Haug LS, Johansson N, Knutsen HK, Rose M, Roudot A-C, Van Loveren H, Vollmer G, Mackay K, Riolo F and Schwerdtle T, 2020. Scientific Opinion on the risk to human health related to the presence of perfluoroalkyl substances in food. EFSA Journal 2020;18(9):6223, 391, doi: 10.2903/j.efsa.2020.6223

[14] SCHEER (Scientific Committee on Health, Environmental and Emerging Risks), Final Opinion on Draft Environmental Quality Standards for Priority Substances under the Water Framework Directive - PFAS, 18 August 2022 p. 10

the Commission's own EQS guidance[15], which requires a common mode of action (in this case immunotoxicity) to be apparent, before a mixture based EQS is proposed, which has not been confirmed for the additional 20 PFASs. [16]

This uncertainty was explicitly acknowledged by the European Commission Scientific Committee on Health & Emerging Environmental Risks ("SCHEER") in their opinion on the proposed quality standard. Notably, the Committee indicated that it was *not in the position to assess whether the most critical EQSs (in terms of impact on environment/health) have been correctly identified*. [17]

In addition, the Commission's impact assessment for the proposal noted (on page 76) that the uncertainties associated with the RFP approach were considered too large to allow its use in legislation and that an approach analogous to the drinking water directive should be used instead; this assessment was ignored by the Commission in the Proposal. Specifically, on page 76 it says : *For PFAS, the use of a relative potency factor (RPF) approach was considered for setting a group EQS but the scientific justification for that is still too uncertain to be introduced in the legislation. Consequently, a sum of all PFAS approach analogous to the DWD (see Annex 7 for more information) seems a more appropriate way forward.*

From a procedural perspective, it should also be highlighted that the Commission failed to follow applicable technical guidance[18] when using the non-standard methodology described above to derive the proposal quality standard. The Commission's EQS guidance unequivocally states that **when there is an existing standard for a substance under the EU Drinking Water Directive, as is the case for PFASs, this should be used as the basis to derive the applicable QS for the water directives (also taking into account the efficiency of drinking water treatment)[19].** The methodology described in the Commission's guidance ensures regulatory consistency and coherence between the Drinking water and the Water Framework Directive. The implications of this failure to follow the technical guidance are elaborated in the description and supporting justification for the proposed Option B (please see below).

Finally, but of no less importance, we note that the proposed quality standard for PFASs, based on the sum of 24 individual PFAS, is not an appropriate approach to control risk. Specifically, whilst common 'arrowhead' PFAS substances are included in the list of 24 PFAS, such as PFOS, PFOA and PFHxS, the Commission's proposal ignores other substances (e.g., 'related' substances that can degrade in the environment or during wastewater treatment to form the arrowhead). As such, the proposed quality standards

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[15] European Commission (2018). Technical Guidance for Deriving Environmental Quality Standards. Guidance Document 27.

[16] SCHEER (Scientific Committee on Health, Environmental and Emerging Risks), Final Opinion on Draft Environmental Quality Standards for Priority Substances under the Water Framework Directive - PFAS, 18 August 2022 . p. 11 as expressly confirmed by SCHEER

[17] *Ibid.* p. 20, Sheer in its opinion noted that " *due to the different approaches used in deriving QSeco and QShh, as well as the identified gap in recent data on ecotoxicity and the incongruity between the existing AA-EQS and proposed AA-QS values for PFOS*" it was not possible to assess whether the most critical EQSs were correctly identified.

[18] European Commission (2018). Technical Guidance for Deriving Environmental Quality Standards. Guidance Document 27. Section 3.7.

[19] *Ibid*

for surface water and groundwater, whist initially appearing protective of the environment and human health because of their stringency, could fail to address risks, where these are from precursors. Therefore, the proposed standard, irrespective of the scientific uncertainties surrounding their derivation, cannot be considered to be fit-for-purpose. Of note is that the EU Drinking Water Directive, acknowledging this issue, explicitly **includes a provision for a quality standard for drinking water based on 'Total PFAS'[20].** Failure of the Commission to harmonise their Proposal with existing regulatory approaches for PFASs, as required by the applicable technical guidance, highlights a fundamental misunderstanding of the PFAS issue and understanding of appropriate approaches to regulate them.

In summary, we raise a series of serious concerns in relation to the approach and methodology used to group the 24 PFAS and derive their quality standard. The standard should be reviewed before it is implemented.

2) The quality standards cannot currently be implemented

The analytical limit of Quantification (LOQ) for some of the 24 PFASs included in the group are not currently sensitive enough to establish with certainty if the EQS in biota and water has been passed or failed (see attached table). This prevents the reliable implementation of the proposed standards as, given the consequences for member states of failing a standard, there must be legal certainty as to whether a limit is passed or failed.

It is important to note that the European Commission is aware of these limitations and is already obliged to develop technical guidance on analytical methods for PFASs within the context of the drinking water directive by January 2024, thus acknowledging the difficulties associated with the reliable measurement of PFASs in drinking water. This technical guidance must be available, and extended to surface water and biota, **before any EQS is implemented**.

Of interest, is that the proposed EQS in surface water is a factor **of ten lower than the existing drinking water quality standard** emphasising that the analytical challenges for EQS will be ever greater than those acknowledged for drinking water. In any case, clear rules in data handling will be required to ensure that 'false positives' are avoided during compliance monitoring against any quality standard, particularly as it will be necessary to sum the concentration of the 24 PFASs; each of which are potentially below limits of quantification. We note that Environment Canada (2022[21]) propose to treat measurements reported as below limit of detection or below the limit of quantification as zero (rather than as ½ LOQ or LOQ) to avoid a scenario where a quality standard is failed simply as a consequence of summing the achievable quantification limits.

3) The criteria for PHS have not been demonstrated for the group of 24 PFASs

[20] DIRECTIVE (EU) 2020/2184 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2020 on the quality of water intended for human consumption, Annex I, part B

[21] https://www.canada.ca/en/health-canada/programs/consultation-draft-objective-per-polyfluoroalkyl-substances-canadian-drinking-water/overview.html

First the 24 PFAS selected in the list are inherently different in terms of mode of action, hazard profiles and exposure. It is unclear what criteria were applied for grouping those specific PFAS.
Second, we also question whether PFAS meet the criteria for priority hazardous substance ("PHS") and whether this process followed proper standards of transparency and due process.

According to the existing article 2(30) of the WFD, hazardous substances are defined as "*substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern*".[22] However, in the proposed amendment in article 2(30)(a) of the Proposal, these are defined as "*priority substances which are marked as 'hazardous' on the basis that they are recognised in scientific reports, in relevant Union legislation, or in relevant international agreements, as being toxic, persistent and liable to bio-accumulate or as giving rise to an equivalent level of concern, where this concern is relevant to the aquatic environment*".[23]

In that regard, the impact assessment accompanying the proposal notes that for the identification of PHS, "*the following processes and legislations are relevant: substances of Very High Concern (SVHC) under REACH, Persistent Organic Pollutants (POPs) under the Stockholm Convention and substances identified as Persistent, Bio-accumulative and Toxic (PBTs) under Regulation (EEC) No.793/93*".[24]

However, neither the old nor the new definitions of PHS (nor elsewhere in the text of the Water Directives) refers to assessments undertaken under REACH or the Stockholm Convention. Therefore, the basis upon which each of the substances are identified as PHS is unclear. Specifically, it is not clear which PFAS were considered PBT and which were included because of their SVHC properties or an assessment of equivalent concern to PBT substances. This corresponds to an incorrect interpretation of the law, lacking a legal basis and wrongly broadening the scope of the legal definitions.

In addition to all the above, we believe that the Commission failed to demonstrate why each of the 24 PFAS were identified as PHS.
In summary, the hazardousness of these individual substances to be qualified as PHS has not been demonstrated and data are not sufficient to justify their inclusion: more data need to be collected to substantiate such inclusion and sound analytical methods need to be developed to ensure that the legislation can be enforced

4) Source control measures should be prioritised over end-of-pipe measures
As specified in article 16 of the Water Framework Directive, for the priority substances, the Commission shall submit proposals of controls for:
- the progressive reduction of discharges, emissions and losses of the substances concerned, and, in particular
- the cessation or phasing-out of discharges, emissions and losses of the substances as identified in accordance with paragraph 3, including an appropriate timetable for doing

[22] Dir 2006/60/EC article 2(30)
[23] Proposal, proposed amendment article 2(3)(a)
[24] Commission Staff Working document accompanying the Proposal, p. 159

so. The timetable shall not exceed 20 years after the adoption of these proposals by the European Parliament and the Council in accordance with the provisions of this Article. In doing so it shall identify the appropriate cost-effective and proportionate level and combination of product and process controls for both point and diffuse sources and take account of Community-wide uniform emission limit values for process controls.
It is therefore evident that the accent should be placed on emissions limits at source (manufacturing sites, waste management plants etc, such as in the Industrial Emissions Directive implementing measures (BREFs, BATs)), instead of determining end-of-pipe obligations.

5) The costs of implementing the proposed quality standard would be disproportionate and would not guarantee compliance

As already noted by the Commission's regulatory scrutiny board, Czech Senate and the European Parliament[25], the Commission's impact assessment for the proposal fails to appropriately assess the costs that individual Member States would bear for implementing the proposed quality standards. Without such an assessment it is not possible for the Commission to conclude that the proposal is proportionate.

This is a significant deficiency as, based on the estimated costs for similar initiatives in the past, it can readily be concluded that these costs will be extremely high.

It is possible to estimate the likely costs for Member States and for the UK of implementing the proposed PFAS standard. In that regard, whilst the UK has now left the EU, it remains a representative example of likely impacts in the EU.
Especially, a 2019 Environment Agency (England and Wales) study on PFOS[26] in the aquatic environment can be used to estimate 'best case' compliance with the new PFAS EQS. These data indicate that ~50% of waterbodies below wastewater treatment works would fail the proposal PFAS EQS, solely on the basis of the reported PFOS concentration. Similarly, from the same study, **all** freshwater, estuarine and coastal sites where concentrations of PFOS were monitored in fish (73 waterbodies monitored in total) would fail the new PFAS EQS, again, solely on the basis of the reported PFOS concentration alone. This is a 'best case' estimate as the concentration of other PFASs were not taken into account.

Hence, this would imply that a minimum of 50% of wastewater treatment works in England and Wales would need to implement advanced treatment if they were required to comply with the proposed EQS for PFASs. Based on estimates for the costs of upgrading wastewater treatment works in the UK to remove steroid oestrogens (specifically EE2) from wastewater effluents, this upgrade would now cost in the order of **at least £80 billion (€90 billion) 20 years**[27] and would only likely ensure that the

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25 https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/740239/EPRS_BRI(2023)740239_EN.pdf

26 PFOS is included in the group of 24 PFASs proposed PFAS EQS (with an RPF 2) but was previously listed as a PHS. Hence monitoring data is available.

27 The UK impact assessment for the previous priority substances proposal (2012) estimates that the costs of upgrading ~1,360 WWTW in England and Wales (~20% of the total number) would cost £27 to

EQS for PFAS in surface water was achieved. This level of treatment would not ensure that the PFAS EQS would be achieved in biota. It is important to note that the proposed EQS for EE2 was not implemented, presumably because of proportionality concerns and that no upgrade of WWTWs occurred.

Nevertheless, similar data are available for EU member states. Recent WFD monitoring data available for the Netherlands (from EIONET) reveals that 26% of surface water samples would exceed the new PFASs EQS based on PFOS alone.

Similarly, data from Wallonie and Flanders (from EIONET) reveals that 100% of mussel samples from Flanders would exceed the new PFAS EQS based on PFOS alone, whilst 66% of surface water samples in Wallonie would exceed the PFAS EQS based on PFOS alone.

As a further example, Rijkswaterstaat, the Dutch agency tasked with the protection of national water bodies, has been monitoring PFAS concentrations since 2008. Last year, a study by Dr Chiel Jonker[28] was published, in which the 2008-2020 monitoring data are analyzed. While the report signals a trend of **decreasing concentrations** of PFAS in Dutch waters, it can be concluded from the data that the proposed EQS would be exceeded in most, if not all, locations. Furthermore, the data for the entry points into the Netherlands of the three major rivers (Rhine, Meuse and Scheldt rivers), suggest that the proposed EQS would be substantially exceeded, at least as far as these river basins are concerned, in Germany, Belgium and possibly France.

Other studies seem to indicate the same. For instance, a 2016 study Lindim et al[29] reports that both the predicted concentrations for PFOS and PFOA exceed the EQS in several major European river basins. Similar findings were reported in Sweden[30] and elsewhere[31,32,33]. While several of these studies indicate a trend of decreasing concentrations of monitored PFASs, the proposed EQS will continue to be exceeded.

The failure to achieve EQS will result in legal consequences for Member States who will be obliged to take actions in order to attempt to meet the EQS. The Czech Senate already

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£31 billion over 20 years. (£20 to £23 million per WWTW). Simple extrapolation of this estimate to upgrade 50% (3,400) of WWTW in England and Wales (would correspond to costs of ~£70 billion over 20 years (67.5 to 77.5 billion). Accounting for UK inflation from 2012 to 2022 (average annual inflation of 2.4% reported by the Bank of England) results in an estimate in 2022 prices of ~£90 billion over 20 years (~€110 billion over 20 years based on average 2022 £:€ exchange rate of 1.17 reported by the European Central Bank). This corresponds to ~€32 million per WWTW upgrade over 20 years. Approximate (rounded) values only are presented above because of the gross uncertainties inherent in the estimations. There are additional uncertainties associated with these estimates, including whether the treatment proposed to remove EE2 from wastewater effluents (and associated costs) would be appropriate to be installed for PFASs - although it not considered that treatment of PFAS would be technically easier than EE2.

[28] Poly- en perfluoralkylstoffen (PFAS) in de Rijkswateren, 2021

[29] https://pubmed.ncbi.nlm.nih.gov/27448037/

[30] https://pubs.acs.org/doi/full/10.1021/acs.est.7b05718

[31] https://www.sciencedirect.com/science/article/pii/S030438942101325X

[32] https://pubs.acs.org/doi/10.1021/acs.est.2c02765

[33] https://www.sciencedirect.com/science/article/pii/S0048969721066134

flagged that the costs to achieve the targets will be significantly higher than assumed in the submitted impact assessment.

In this framework, we also question whether the Commission has considered the impact such measures would have on water treatment companies and taken on board their inputs on what is technically measurable, what limits are concretely achievable, and at what cost.

There are approximately 18,000 WWTW in the EU[34]. If the best-case assumption from the UK that a minimum of 50% (9,000) of WWTW will need to be upgraded is applied to the EU this would correspond to costs of at least €300 billion over the next 20 years in the EU[35], with no certainty that the EQS will be achieved.

Conclusion

The proposed quality standards for PFASs in surface water (EQS) and groundwater (GWQS) are not scientifically robust, implementable, or proportionate. Their implementation would result in extensive societal impacts (i.e. costs) without reliable environmental or human health benefits. ECHA is currently evaluating a proposal for a restriction on the use and placing on the market of PFASs in the EU/EEA under REACH. Until the REACH restriction process is concluded it would be premature to implement the proposed quality standards. Concretely, until appropriate 'product control' measures, such as the REACH restriction, are implemented it cannot be concluded that end-of-pipe (process) measures (such as GWQS) would be proportionate; particularly recognizing the legal consequences for Member States of non-compliance.

As a consequence, we recommend ***that the EQS and GWQS for PFASs in the respective Annexes to the Directive 2006/118/EC and Directive 2008/105/EC*, are removed and, instead, *PFAS are added to the WFD Watch List until the uncertainties associated with the derivation of an appropriate EQS/GWQS and its implementation are resolved, and the REACH restriction (source control) process is concluded***

[34] https://www.waterworld.com/wastewater/article/16201111/analysis-europes-waterwastewater-in-numbers
[35] ~€32 million over 20 years multiplied by 9,000 WWTW = ~€300 billion over 20 years

Proposal B: Align substances with the Drinking Water Directive and determine limit values following the principles in the EQS guidance

Any proposed EQS should be aligned with the existing provisions of the Drinking Water Directive both in terms of scope and limit values, in accordance with existing Commission guidance documents, in order to ensure effective and consistent implementation and enforcement. There is currently a lack of alignment of the proposed EQS with the Drinking Water Directive.

In fact, the proposed European standards for the indicators added, for instance, to Annex I of the Groundwater Directive are much stricter than the values proposed by the expert hydrogeologists of the Common Implementation Strategy (" CIS") Working Group on Groundwater and the list of substances is not the same as the list for the Drinking Water Directive, same applies to the limits for surface water. This weakness has been also flagged by some competent authorities, with the suggestion to bring consistency to the list of PFAS in the GWD and the DWD.

It is also important to note that the European Commission is already obliged to develop technical guidance on analytical methods for PFASs within the context of the drinking water directive by January 2024, acknowledging the potential difficulties associated with the reliable measurement of PFASs in water. This technical guidance must be available, and extended to surface water and biota, **before any other EQS is implemented**. Some Member States are worried that the lack of thereof, and in addition the lack of appropriate laboratories in the member states will render the proposal as very ambitious and difficult to achieve.

Of interest, is that the proposed EQS in surface water is a factor **of ten lower than the existing drinking water quality standard** emphasising that the analytical challenges for EQS will be ever greater than those acknowledged for drinking water. In any case, clear rules in data handling will be required to ensure that false positives are avoided during monitoring against any EQS, particularly as it will be necessary to sum the concentration of the 24 PFASs, potentially below limits of quantification.

According to the Commission guidance for deriving EQS, where an existing drinking water quality standard is available, as is the case for PFASs, it shall be used as the basis for the EQS. This guidance was not followed for PFASs. In addition, the EQS guidance also states that the effectiveness of water treatment should be accounted for when deriving the EQS[36], which was also not applied by the Commission[37]. A conservative assumption of treatment efficacy can be considered to be 50% effectiveness, which would result in a **EQS of 0.2 µg/l for the sum of 22 PFASs**. Such an EQS would align the WFD, EQS and GWQS with the drinking water legislation and create a harmonised and consistent basis for a legislation.

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[36] European Commission (2018). Technical Guidance for Deriving Environmental Quality Standards. Guidance Document 27

[37] ibid

Conclusion

In conclusion, we propose to revise the **list of PFAS substances included in the EQS and make it consistent with the list of PFAS for drinking water and define a concentration list for the sum of listed PFASs of 0.2 µg/l based on the principles in EQS technical guidance that states that the treatability of raw water is considered when setting quality standards. Alignment of the EQS with the drinking water quality standard would provide clear direction to member states regarding the management of water resources. Specifically, measures associated with achieving EQS levels that are coherent with Drinking Water Directive standards would result in an integrated regulatory approach with resulting efficiency gains.**

Chemours

03 May 2023

Table of analytical detection limits for PFASs according to US-EPA methods – Shaded rows denote that current state of the art analytical limits of quantification for drinking water are higher than necessary for reliable implementation (LOQ < EQS/3)

Name	abbreviation	Carbon chain length	CAS	EC	DWD	ENV CANADA	WFD EQS	EQS RPF	US-EPA 533 MRL	US-EPA 533 DL	US-EPA 537.1 DL	Normalised min LOQ EQSaqua (ng/L)	Normalised min LOQ EQSbiota (ng/kg)
Perfluorobutanoic acid (PFBA)	PFBA	4	375-22-4	206-786-3	Y	Y	Y	0.05	5	13	n/a	29.3	513.3
Perfluoropentanoic acid (PFPA)	PFP(e)A	5	2706-90-3	220-300-7	Y	Y	Y	0.03	3	3.9	n/a	48.9	855.6
Perfluorohexanoic acid (PFHxA)	PFHxA	6	307-24-4	206-196-6	Y	Y	Y	0.01	3	1.7	1	146.7	2566.7
Perfluoroheptanoic acid (PFHpA)	PFHpA	7	375-85-9	206-798-9	Y	Y	**Y**	0.505	3	0.7	n/a	2.9	50.8
Perfluorooctanoic acid (PFOA)	PFOA	8	335-67-1	206-397-9	Y	Y	**Y**	1	4	0.53	0.53	1.5	25.7
Perfluorononanoic acid (PFNA)	PFNA	9	375-95-1	206-801- 3	Y	Y	**Y**	10	4	0.7	0.7	**0.1**	2.6
Perfluorodecanoic acid (PFDA)	PFDA	10	335-76-2	206-400-3	Y	Y	**Y**	7	3	1.6	1.6	**0.2**	3.7
Perfluoroundecanoic acid (PFUnDA)	PFUnDA	11	2058-94-8	218-165-4)	Y	Y	**Y**	4	2	1.6	1.6	**0.4**	6.4
Perfluorododecanoic acid (PFDoDA)	PFDoDA	12	307-55-1	206-203-2	Y	Y	**Y**	3	3	1.2	1.2	**0.5**	8.6
Perfluorotridecanoicacid(PFTrDA)	PFTrDA	13	72629-94-8	276-745-2	Y	Y	**Y**	1.65	7	0.72	0.72	0.9	15.6
Perfluorobutane sulfonic acid (PFBS)	PFBS	4	375-73-5	206-793-1	Y	Y	Y	0.001	3		1.8	1466.7	25666.7
Perfluoropentane sulfonic acid (PFPS)	PFP(e)S	5	2706-91-4	220-301-2	Y	Y	**Y**	0.300 5	4	6.3	n/a	4.9	85.4
Perfluorohexane sulfonic acid (PFHxS)	PFHxS	6	355-46-4	206-587-1	Y	Y	**Y**	0.6	3	1.4	1.4	2.4	42.8
Perfluoroheptane sulfonic acid (PFHpS)	PFHpS	7	375-92-8	206-800-8	Y	Y	**Y**	1.3	3	5.1	n/a	**1.1**	19.7
Perfluorooctane sulfonic acid (PFOS)	PFOS	8	1763-23-1	217-179-8	Y	Y	**Y**	2	4	1.1	1.1	**0.7**	12.8
Perfluorononane sulfonic acid (PFNS)	PFNS	9	6859-12-1		Y	N	N						
Perfluorodecane sulfonic acid (PFDS)	PFDS	10	335-77-3	206-401-9	Y	N	**Y**	2				0.7	12.8
Perfluoroundecane sulfonic acid		11	749786-16-1		Y	N	N						
Perfluorododecane sulfonic acid		12	797803-9-5		Y	N	N						
Perfluorotridecane sulfonic acid		13	791563-89-8		Y	N	N						
Perfluorotetradecanoic acid	PTFeDA	14	376-06-7	206-803-4	N	Y	**Y**	0.3	8	1.1	1.1	4.9	85.6

Chemours™

03 May 2023

Name	abbreviation	Carbon chain length	CAS	EC	DWD	ENV CANADA	WFD EQS	EQS RPF	US-EPA 533 MRL	US-EPA 533 DL	US-EPA 537.1 DL	Normalised min LOQ EQSaqua (ng/L)	Normalised min LOQ EQSbiota (ng/kg)
Perfluorohexadecanoic acid	PFHxDA	16	67905-19-5,	267-638-1	N	N	Y	0.02				73.3	1283.3
Perfluorooctadecanoic acid	PFODA	18	16517-11-6	240-582-5	N	N	Y	0.02				73.3	1283.3
Ammonium perfluoro (2-methyl-3-oxahexanoate)	HFPD-DA or Gen X	6	62037-80-3		N	Y	Y	0.06	5	1.9	1.9	24.4	427.8
Propanoic Acid / Ammonium 2,2,3-trifluoro-3-(1,1,2,2,3,3-hexafluoro-3-(trifluoromethoxy)propoxy)propanoate	ADONA	7	958445-44-8		N	Y	Y	0.03	3	0.88	0.55	48.9	855.6
2- (Perfluorohexyl)ethyl alcohol	6:2 FTOH		647-42-7	211-477-1	N	N	Y	0.02				73.3	1283.3
2-(Perfluorooctyl)ethanol	8:2 FTOH		678-39-7	211-648-0	N	N	Y	0.04				36.7	641.7
Acetic acid / 2,2-difluoro-2-((2,2,4,5-tetrafluoro-5- (trifluoromethoxy)-1,3-dioxolan-4-yl)oxy)-	C604		1190931-41-9		N	N	Y	0.06				24.4	427.8
11-Chloroeicosafluoro-3- oxaundecane-1-sulfonic acid	11Cl-PF3OUdS	9	763051-92-9		N	Y	N		5	1.5	1.5		
9-Chlorohexadecafluoro-3- oxanonane-1-sulfonic acid	9Cl-PF3ONS	8	756426-58-1		N	Y	N		2	1.4	1.8		
Nonafluoro-3,6- dioxaheptanoic acid	NFDHA	7	151772-58-6		N	Y	N		20	16	n/a		
1H,1H, 2H, 2H- Perfluorodecane sulfonic acid	8:2 FTS	8	39108-34-4		N	Y	N		5	9.1	n/a		
Perfluoro(2- ethoxyethane)sulfonic acid	PFEESA	4	113507-82-7		N	Y	N		3	2.6	n/a		
1H,1H, 2H, 2H- Perfluorohexane sulfonic acid	4:2FTS	4	757124-72-4		N	Y	N		3	4.7	n/a		
Perfluoro-3- methoxypropanoic acid	PFMPA	4	377-73-1		N	Y	N		4	3.8			
Perfluoro-4-methoxybutanoic acid	PFMBA	5	863090-89-5		N	Y	N		3	3.7			
1H,1H, 2H, 2H- Perfluorooctane sulfonic acid	6:2FTS	6	27619-97-2		N	Y	N		5	14			

Name	abbreviation	Carbon chain length	CAS	EC	DWD	ENV CANADA	WFD EQS	EQS RPF	US-EPA 533 MRL	US-EPA 533 DL	US-EPA 537.1 DL	Normalised min LOQ EQSaqua (ng/L)	Normalised min LOQ EQSbiota (ng/kg)
N-ethyl perfluorooctanesulfonamidoacetic acid	NEtFOSAA	8	2991-50-6		N	Y	N		5	2.8	2.8		
N-methyl perfluorooctanesulfonamidoacetic acid	NMeFOSAA	8	2355-31-9		N	Y	N		6	2.4	2.4		

PLASTICS EUROPE
Enabling a sustainable future
Fluoropolymers Product Group

Fluoropolymer manufacturers in Europe commit to the highest industry standards for manufacturing worldwide

Press release

Brussels, 21 September 2023 – The Fluoropolymers Product Group (FPG), a product group part of Plastics Europe, representing the world's leading fluoropolymer manufacturers, today announces the launch of a new Manufacturing Programme for European manufacturing sites. The industry-led initiative goes further than current European Union requirements, effectively setting the highest standards for fluoropolymer manufacturing worldwide. With this programme, FPG members provide concrete solutions to address legitimate questions and concerns about emissions generated during the manufacturing of fluoropolymers, which are essential for the EU's green and digital transitions.

This programme includes a concrete commitment to minimize emissions of non-polymeric PFAS residues from polymerization aids to the environment from fluoropolymer manufacturing by the following FPG member companies: AGC, Arkema, Chemours, Daikin Chemical Europe, W. L. Gore & Associates and Solvay.

The commitment reflects the concrete actions of the individual FPG members in the past years aimed at ensuring that fluoropolymers, which underpin many critical parts of our economy, from semiconductors to fuel cells and EV battery components are produced responsibly, with the lowest possible emissions using the best available technologies. The companies' efforts in implementing these best available technologies have led today to the launch of a joint commitment with the implementation of the programme at the industry level to begin no later than 31 December 2023.

The programme comprises three pillars, specifically (further details can be found here):

1. An industry-led commitment to achieve Average Emissions Factors for non-polymeric PFAS residues from polymerisation aid technology that is used in the fluoropolymer manufacturing process;
    - By end 2024: 0.009% to air; 0.001% to water
    - By end 2030: 0.003% to air; 0.0006% to water
2. A platform to promote the adoption of commercially available state-of-the-art technologies to minimize non-polymeric PFAS emissions in manufacturing; and,
3. A commitment to inform downstream users of fluoropolymers on their safe handling and use in the Guide for the Safe Handling of Fluoropolymer Resins.

"This Manufacturing Programme demonstrates that our industry delivers when it comes to the best possible emissions control. We are going well beyond legal requirements and in doing so will ensure that fluoropolymer production in the EU sets a new benchmark for the industry globally. We have listened to concerns and feedback from stakeholders and are working hard to find solutions. We are committed to working closely with regulators and our value chain to ensure any emissions from fluoropolymers are adequately controlled across their lifecycle. Fluoropolymers underpin many strategic technologies, and this programme has been developed to support their ongoing use as critical and responsible enablers of our economies", stated Nicolas Robin, Director of the Fluoropolymers Product Group.

By the end of 2024, the first emissions reduction targets will come into effect and members will work individually with their national authorities in relation to local sites. To ensure additional transparency, accountability and supervision of the implementation of the FPG Manufacturing Programme an exchange forum with key stakeholders including regulators and civil society will be established. The exchange forum will meet formally twice per year, with the first meeting planned for September 2024.

For further information please contact Nicolas Robin, Director of the Fluoropolymers Product Group.

Nicolas Robin, *Director of the Fluoropolymers Product Group*
+32 (0) 2 792 30 41 | [redacted]@plasticseurope.org

About Fluoropolymers

Fluoropolymers are a distinct subset of fluorinated polymers, with unique properties that cannot be guaranteed by other polymers. They are used in critical applications that help deliver strategic EU and UN climate objectives, are an enabler of the European Green Deal, the Net Zero Industry Act, the Critical Raw Materials Act, the EU Chips Act, the Hydrogen Strategy and the Sustainable and Smart Mobility Strategy and are central to the EU's strategic autonomy agenda.

Fluoropolymers have been proven safe during their intended use phase. Although they fit the PFAS structural definition, as described by the OECD, they have very different physical, chemical, environmental, and toxicological properties. Fluoropolymers have documented safety profiles and are thermally, biologically, and chemically stable, negligibly soluble in water, nonmobile, nonbioavailable, nonbioaccumulative, and non-toxic.

An in depth-assessment of eighteen different fluoropolymers accounting for approximately 96% of the global commercial fluoropolymer market against thirteen widely accepted polymer hazard assessment criteria, showed that these polymers are of low concern (PLC) and pose no significant risk to human health and the environment.

About Fluoropolymers Product Group

The Fluoropolymers Product Group represents Europe's leading fluoropolymer producers and experts. With a unique set of properties unobtainable by other polymers, fluoropolymers are non-replaceable across many key sectors and applications. Fluoropolymers ensure safety, reliability, durability and performance in numerous technologies, industrial processes and everyday products that are critical for human health, safety and the environment.

We are committed to promoting innovation, safe use of their products, sustainable manufacturing and stewardship across the industry for all our products. As the voice of the industry across Europe, the Fluoropolymers Product Group advocates for a balanced regulatory environment based on scientific facts to ensure that European industries remain competitive and sustainable.

A product group of PlasticsEurope, FPG members are 3M, AGC, Arkema, Chemours, Daikin Chemical Europe, W. L. Gore & Associates and Solvay. Associate members are DuPont, Gujarat Fluorochemicals, Honeywell and HE Plastics.

Supporting European Sustainability and Competitiveness: An Alternative Approach to the Proposed Universal PFAS Restriction

September 2023

PROPOSING AN ALTERNATIVE APPROACH TO REGULATION

In February 2023, authorities in Denmark, Germany, the Netherlands, Norway, and Sweden submitted a proposal to the European Chemicals Agency (ECHA) that calls for a complete phase-out of the manufacture, import, sale, and use of per- and polyfluorinated substances (commonly known as PFAS). PFAS are a class of thousands of chemicals, each with different safety profiles and uses.

Unfortunately, the proposal of the five member states of the European Economic Area (EEA) is flawed. It uses a grouping approach based on chemical structure that also includes fluoropolymers, and in doing so, makes assumptions and false equivalencies about hazards and risks. In fact, the proposal aims to ban fluoropolymers, a subgroup of PFAS, even though they provide significant socio-economic benefits to European society while meeting the OECD criteria for “polymers of low concern”. In other words, fluoropolymers enable technology and innovation in almost all major European industries, from clean energy to semiconductors and batteries to transport and healthcare, and they have been demonstrated to not pose a risk to human life or the environment.

Hence, in its current form, the restriction proposal threatens to jeopardize a range of critical technologies and industries crucial for the EU Green Deal and other ambitious policy programs promoting the sustainable transformation of the European economy. It would slow down innovation, increase Europe’s geo-political dependencies, and have devastating consequences for European companies and business.

There is a better way: A more targeted approach to regulation could ensure the safe manufacturing and use of fluoropolymers while harnessing their socio-economic benefit.

- First, given their significant socio-economic value and provenly positive safety profile, the European Chemicals Agency (ECHA) should provide a time-unlimited derogation for, or exempt, fluoropolymers from a potential PFAS restriction.

- Second, the EU can use this opportunity to create a benchmark for global chemical regulation by setting science-based and most robust and rigorous standards for chemical manufacturing.

This would lead to a future where the use of safer, better-performing chemicals will fortify the European economy, safeguard important policy priorities, and ensure global competitiveness.

TIME-UNLIMITED DEROGATION FOR FLUOROPOLYMERS

A time-unlimited derogation, or exemption, from the proposed regulation is necessary when it comes to fluoropolymers, given their socio-economic benefits, distinct health and safety profiles, and, as we will demonstrate below, safe use and responsible manufacturing.

Fluoropolymers are high-performance materials with a unique combination of properties that make them the building blocks for an extraordinary range of product and industry applications. They are durable, have a high mechanical strength, inertness, and thermal stability, and they are resistant to chemical, biological, and physical degradation. This makes them indispensable across many sectors where applications must withstand the most challenging and high-stress conditions, and where failure is not an option.[1] **In fact, fluoropolymers are used in components that touch 50% of the EU's $16 trillion economy.[2]**

If fluoropolymers were eliminated through regulation, the EU would face exponentially reduced chances of meeting its ambitious policy goals within their intended timeframe — including goals of the EU Green Deal, the EU Chips Act, and its strategic autonomy. In addition, a phase-out of fluoropolymers would cause economic instability, likely job loss, and increased uncertainty around manufacturing safety and environmental impact of unproven substitutes.

Enabling the Clean Energy Transition

As just one example of fluoropolymers' criticality to countless product applications is their use in the production of green hydrogen. One way to produce renewable hydrogen is through the electrolysis of water, powered by renewable energy sources. In this context, fluoropolymer-based ion membranes (widely known through the leading brand name Nafion™) are key. Used in so called polymer electrolyte membrane water electrolysis (PEMWE) and polymer electrolyte membrane fuel cells (PEMFCs), these membranes are highly durable, ensure reliable operations, and provide high ionic conductivity, high electrical resistivity, as well as low gas permeability. There are no equivalent alternatives with the same combination of properties offered by these membranes.

As the advancement of PEMWE and PEMFC technology highly depends on the use of Nafion™ membranes, they are essential not only to today's green hydrogen initiatives but also to tomorrow's clean energy ambitions. Their use across industry has enabled the development of lighter weight, low maintenance, and more robust fuel cells used in the transportation industry and in sufficiently small-scale water electrolyzer technologies.

Hence, fluoropolymers are essential to green hydrogen's increased production, infrastructure, usage, and deployment. A ban of fluoropolymer-based Nafion™—for which there are currently no alternatives—is projected to result in minimum economic losses to the European economy of between €976 million and €1.4 billion.[3]

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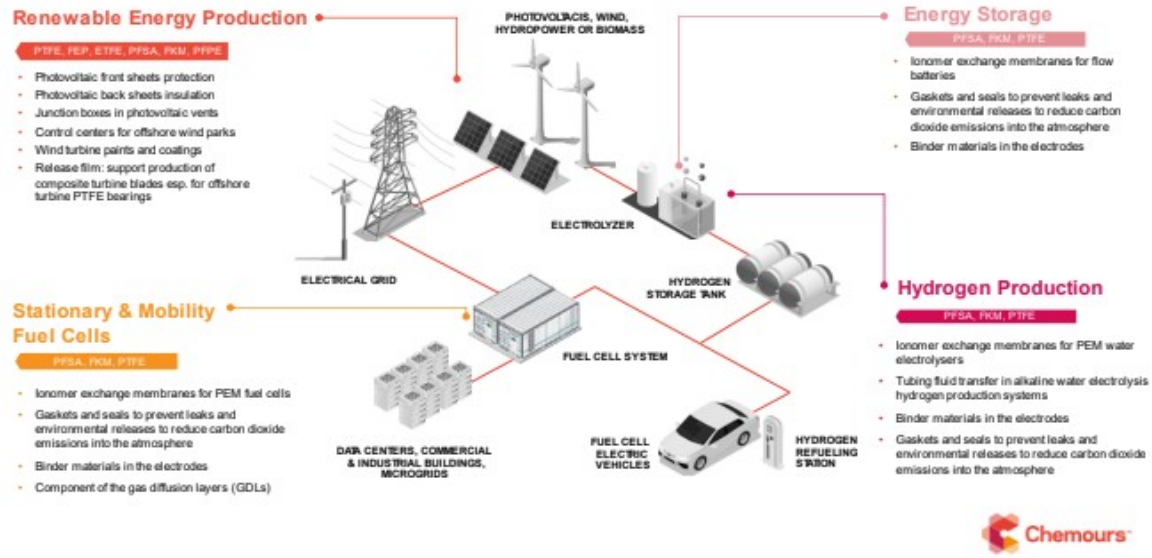
1 A critical review of the application of polymer of low concern and regulatory criteria to fluoropolymers
2 Socio-economic Analysis of a potential REACH restriction on Fluoropolymers Teflon™ Perfluoro Alkoxy, attached as Reference E in Chemours submission 9 Aug 2023, receipt reference 4e266294-5779-4bd1-bd6c-9465a3079202
3 Socio-Economic Analysis of a potential REACH restriction on Fluoropolymers, Nafion™ Ion Exchange Membanes attached

Energy production components containing fluoropolymers



An overly broad ban on PFAS promises to hinder EU policy ambitions, including the EU Green Deal and REPowerEU initiative, both of which directly rely on the use and expansion of green hydrogen in order to reduce dependence on fossil fuel imports and achieve climate targets. Moreover, a ban would severely disrupt or reroute a significant amount of industry investment into green hydrogen projects, further stifling the European economy. Without fluoropolymers, it would be impossible to harness hydrogen at the scale and scope required to meet these clean energy goals.

If the energy transition is indeed among the EU's highest priorities, fluoropolymer-based ion exchange membranes are essential and require exceptional consideration—among other fluoropolymers—to exist outside of REACH regulations. This is critical to advance and scale clean hydrogen energy and reach the EU's policy goals.

Bolstering Resilience & Competitiveness in Advanced Electronics

According to the European Chemicals Agency (ECHA), the semiconductor sector consumes 45% of the fluoropolymers used in the electronics industry.[4] This is not least because fluoropolymers offer a whole range of specific physical and chemical characteristics that are vital for semiconductor manufacturing. They exhibit low surface tension, stability and chemical compatibility, inertness, purity, chemical and permeation resistance, a wide range of temperature stability, a low coefficient of friction, electrical properties, bacterial growth resistance, non-flammability and a long lifetime (more than 25 years).[5]

In particular, fluoropolymers' high resistance to various external influences, especially their chemical inertness, which ensures an extremely high degree of purity for the aggressive

as Reference G in Chemours submission 9 Aug 2023, receipt reference 4e266294-5779-4bd1-bd6c-9465a3079202

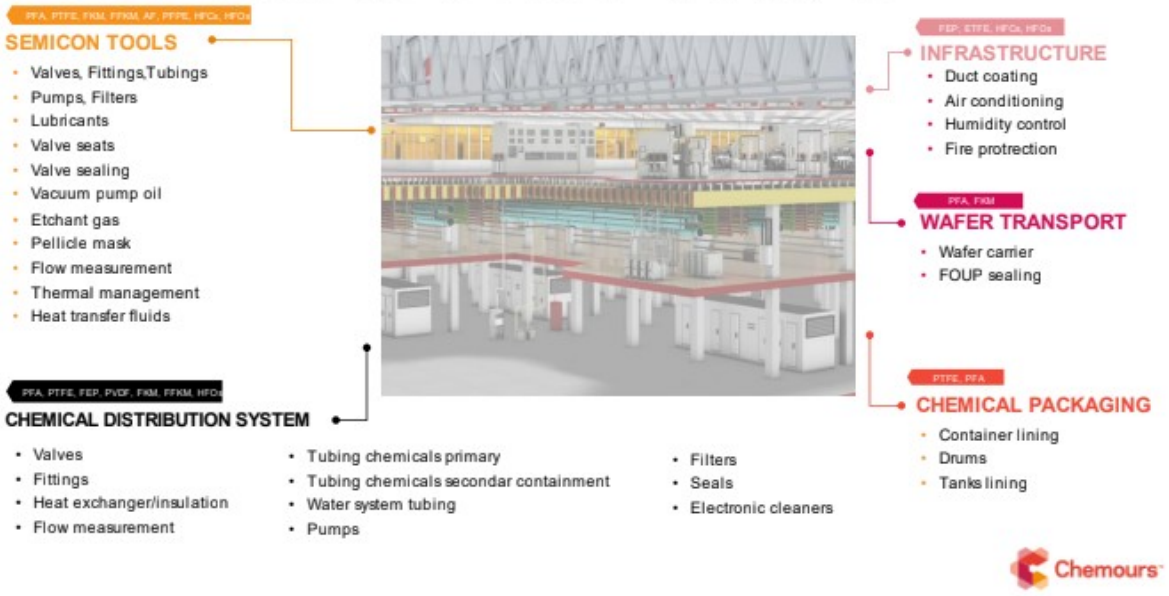
[4] https://www.ft.com/content/76979768-59c0-436f-b731-40ba329a7544

[5] ESIA submission, doc 18 ref 4449

chemicals used throughout the production process, is key for the manufacture of semiconductors. Fluoropolymers also have the advantage of ensuring high durability and reliability, which is critical for operational safety. To date, no alternatives have been found that can meet the range of performance requirements on a par with fluoropolymers. Hence, to maintain and promote a competitive semiconductor industry in Europe, the use of fluoropolymers remains indispensable.

In addition, the risks of banning all PFAS do not apply just to the fabrication plants themselves. Semiconductor chips are essential in virtually all sectors that require advanced electronics, including internet connectivity, communications, computing, aerospace, national security, and transportation—to name only a few. Fluoropolymers help enable 5G transfer speeds and digitization, with implications in medicine, finance, education, entertainment, connected household devices, and beyond. They increase the capacity to improve signal quality over a wide frequency range and increase the durability of 5G systems. The future of 5G will require more cables, antennas, and data centers—fluoropolymer-based components are integral to a connected future.

Semiconductor manufacturing components containing fluoropolymers



As such, fluoropolymers are key to achieve the EU's 10% global market share in semiconductor manufacturing and to meet or even expand the policy objectives set out in the EU CHIPS Act. Otherwise, industries would become entirely reliant on semiconductor supply sources in North America and Asia—to the extent importation was not also affected.

Moreover, it is likely that companies currently investing hundreds of billions in European manufacturing sectors would stop making those investments or re-route them elsewhere around the globe if fluoropolymers would be banned. Tens of thousands of jobs would be lost, not just in direct manufacturing but up and down the supply chain. In fact, it has been projected that the broader European supply chain could suffer economic losses of up to €63.4 billion.

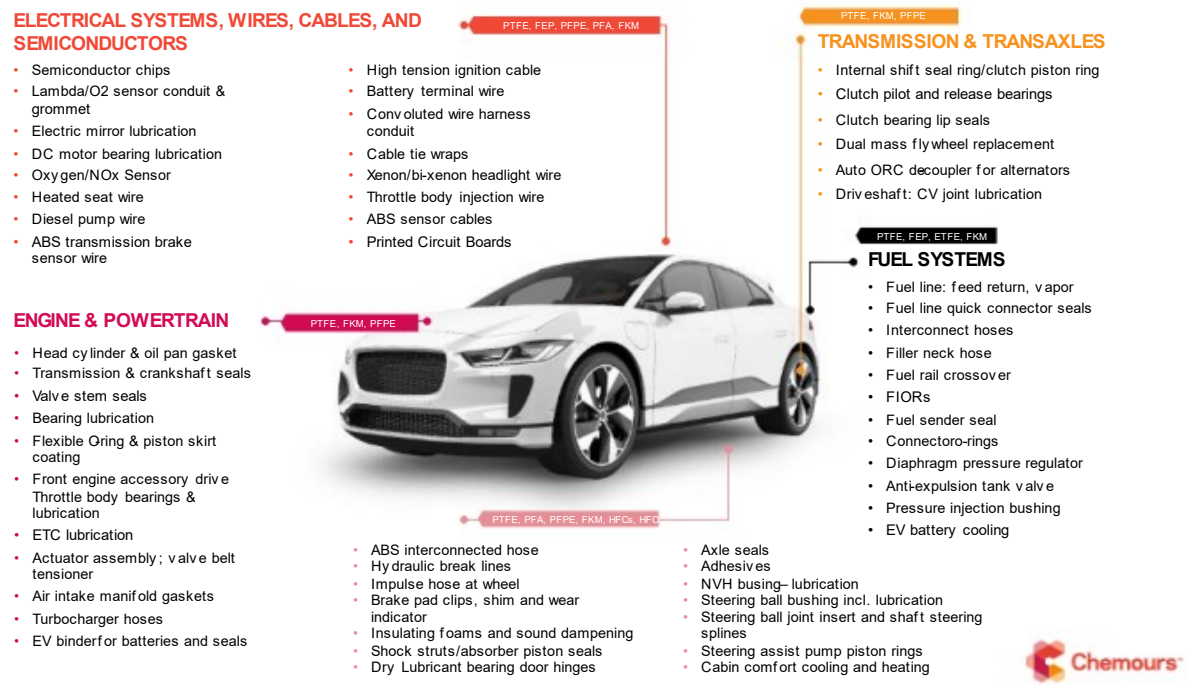
Based on the ubiquity of semiconductors within a massive range of high-impact industries, it is an economic imperative for the ECHA to grant a time-unlimited derogation for fluoropolymers in semiconductor manufacturing from the proposed PFAS restriction.

Advancing the Next Generation of Transportation

Due in part to their role in advanced electronics and communications, fluoropolymers are also vital in the transport sector.

In the automotive industry, for instance, machinery and equipment often have to withstand harsh (outdoor) environments and extreme operating conditions, while also providing a high level of reliability and safety. In this context, fluoropolymers, with their unique set of properties and characteristics, are used to ensure that different automotive components meet their respective quality and performance requirements to ultimately allow for safe and efficient operations.

Automotive components containing fluoropolymers

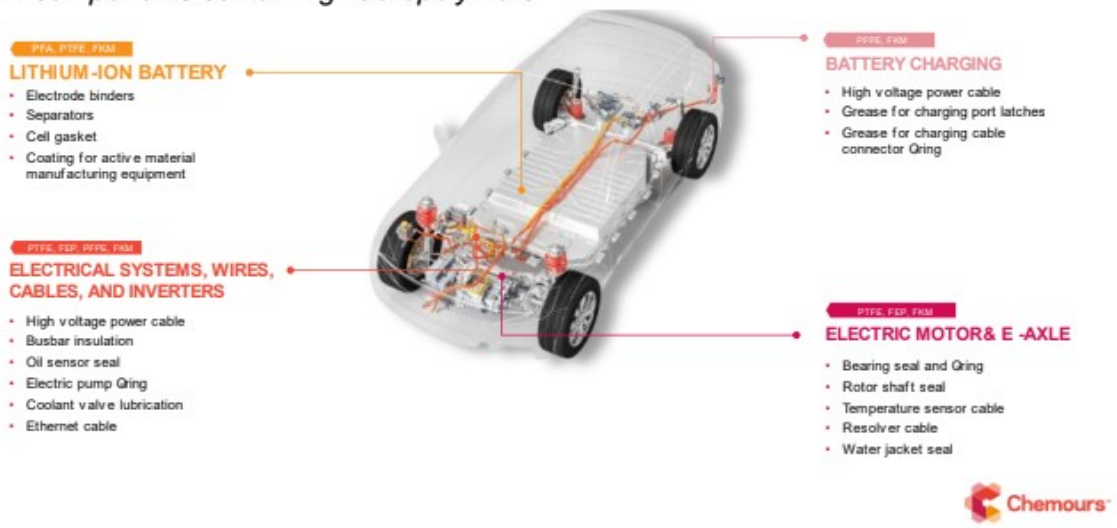


In other words, fluoropolymers keep cars running smoothly and efficiently and contribute to overall safety, performance, sustainability, and durability, thus increasing efficiency and extending their lifespan.

For instance, today's internal combustion engines and hybrids vehicles rely on fluoropolymers for their high-temperature and chemical resistance, which helps to reduce emissions, and meet Euro6 Norm for example. Among others, fluoropolymers make lambda sensors highly temperature and fire resistant, provide high insulation strength and a low water vapor permeability. They are used in seals such as O-rings and fuel hoses to prevent unwanted fuel leaks throughout the life of the product, as well as dry lubricants to lower friction to achieve higher efficiency and lower emissions.

The same importance holds true for fluoropolymers in electric vehicles (EVs), the demand for which is projected to grow 5-10X in the next decade.[6] At the heart of the growth of EVs—including the promise they bring to fundamental energy transition in transportation—are lithium-ion batteries. Fluoropolymers are used in key components for all high performance and lithium-ion battery technologies as they provide high chemical resistance and tolerance to a wide range of operating temperatures, both of which are critical for batteries. To be more precise, in batteries fluoropolymers are used in active material compounds, electrolytes, valves, seals, washers and membranes, and battery coatings.[7] No alternative chemistry can be used that offers the same advantages without significantly affecting safety and performance.

EV components containing fluoropolymers



Without a time-unlimited derogation for fluoropolymers from a potential PFAS restriction, the automotive industry in Europe would collapse. EV manufacturing would be curtailed and investment in innovation and manufacturing—including significant resources devoted to battery gigafactories—would diminish substantially. The EU would be unable to rely even on imports of any fluoropolymer-based components required for EVs and other transportation manufacturing. As a result, costs would significantly increase for manufacturers and consumers, resulting in lower adoption and dramatically reduced net benefit of more EVs on the road. Industrial deployment would be hamstrung by a lack of EU-based solutions.

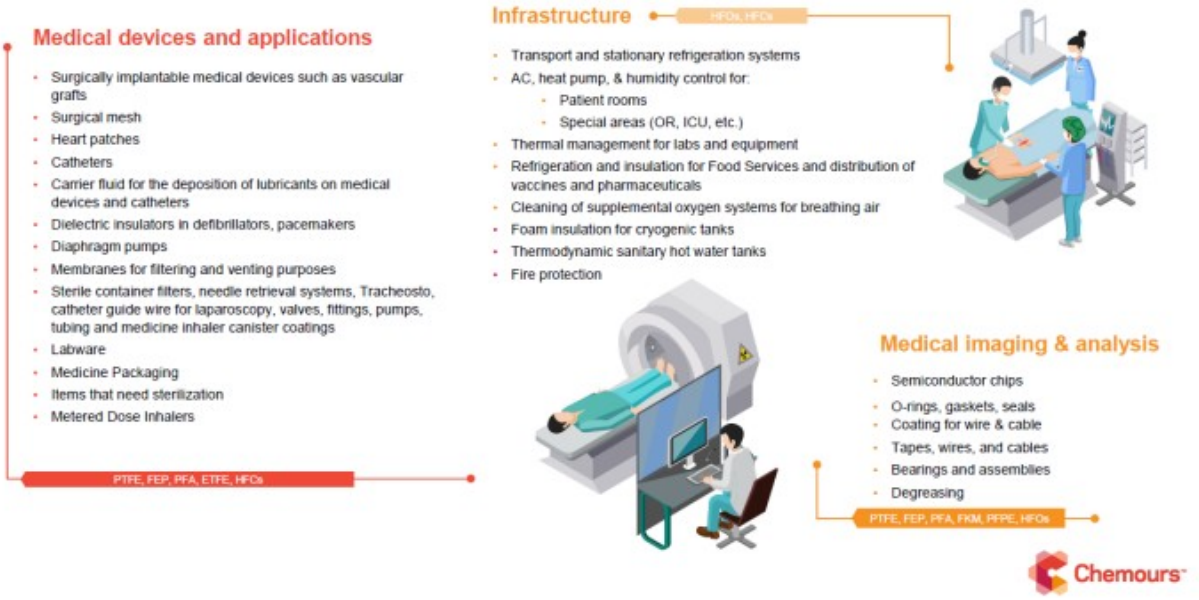
Fortifying Medical & Healthcare Technologies

In the medical industry, fluoropolymers are used in a number of different applications in different medical segments, including medical devices, medical and pharmaceutical infrastructure, and medical imaging and analysis. In this context, fluoropolymers' low surface energy and barrier properties, lubriciousness, temperature and chemical resistance, mechanical strengths, flexibility and high product purity help to create a highly sterile environment and protect medical devices, equipment, and drugs against contaminants.

[6] National Blueprint for Lithium Batteries

[7] RECHARGE (2023). *Comments on the Annex XV report*. PFAS Restriction Proposal Consultation. Doc 13 ref 4276, appendix page 7.

Medical components containing fluoropolymers



For example, fluoropolymers' high product purity is specifically critical in equipment used in vaccine and medical production because impurities or contact with other materials risk the possibility of contamination. Similarly, during the COVID-19 crisis, fluoropolymer-based manufacturing played a major role in meeting the needs of the medical industry, including the production, effectiveness, and transport of vaccines, ventilators, test kits, and inhalers. Fluoropolymers also play an essential role in catheter tubing that are used for endoscopic procedures which, compared to traditional operating practices, significantly increase patient comfort, reduce risk of complication, and reduce the duration of hospital stays.

As such, patient therapies, lab equipment, and prescription drugs—to name only a few—all require fluoropolymers within their manufacturing cycles. Yet, it goes further than that: fluoropolymers also increase the lifespan of components, in large part by reducing the risks of failure, replacements, and cross-infections. They also help lower cleaning and maintenance costs and lead to decreased levels and risk of workforce exposure, relative to inefficient or less chemically secure alternatives.

Companies around the world have invested in the next generation of healthcare technologies that rely on fluoropolymers, and a total ban would present a significant disruption to the European economy. If fluoropolymers were eliminated through regulation, the availability of equally high-performing and durable medical device components produced in the EU would be dramatically reduced, forcing hospitals and medical providers to seek solutions elsewhere around the globe. Any components manufactured without the use of fluoropolymers run the risk of being meaningfully less durable, reliable, affordable, or safe.

An Interconnected Network of Fluoropolymer Dependence

The sector and industry applications detailed above are just some of the many examples of the critical uses of fluoropolymers. In fact, there are many more essential applications throughout other sectors of the EU and global economy, including chemical, aerospace,

marine, industrial machinery, food production, electronics—to name just a few.

When looking at these numerous uses of fluoropolymers in different applications, it is important to consider the links between industries as well as cross-industry dimensions of these uses.

First, there are many common fluoropolymer applications in industrial and professional uses across different sectors. For instance, fluoropolymers are used for valves, O-rings, seals, fittings, pumps, pipes, filters, and vessels in numerous contexts in all sectors described above. Chemours alone provides fluoropolymers to over 1,400 different combinations of different sectors and their applications in the EMEA region. Where these applications are used, they generally provide important safety and performance benefits, as downstream users have an inherent economic incentive to use comparatively cheaper alternative materials wherever possible.

Second, a number of applications that require the use of fluoropolymers are used in products which in turn are part of another product, and which are indispensable in this second product. In other words, fluoropolymers are often used at the beginning of a value chain, but the downstream value chain relies on this initial use of fluoropolymers – at least to a certain degree. For instance, cars and electronic equipment rely on semiconductors. And hydrogen-powered heavy-duty vehicles partly rely on electrolysis.

As such, it is misleading to assess the functions and benefits of fluoropolymers within the scope of individual applications. Instead, it is important to also consider the use of specific fluoropolymer-containing applications within and across industries and value chains. For this reason, the only practical way to regulate the use of fluoropolymers in the restriction dossier is to exempt them or, if this is not possible, to provide a very broad derogation for fluoropolymers in industrial and professional use.

Moreover, considering the very high amount of individual uses of fluoropolymers as well as their relevance within and across industries, the approach of use-specific derogations is not appropriate to provide for an effective regulatory framework.

Such an approach would result in a need for potentially thousands of individual use-specific derogations. Evaluating and implementing such a large number of specific use or sector-specific derogations would require significant time and administrative effort on the side of both industry as well as enforcement authorities, which in turn would be likely to create high regulatory uncertainty within industries, which could result in investment decisions being delayed and hindering innovation within the EEA.

LACK OF FLUOROPOLYMER ALTERNATIVES

There are currently no viable alternatives to fluoropolymers that offer the same unique combination of properties, uses, and societal benefits. Some alternatives have similar performance for a very particular parameter or property—but it is precisely the combination and range of properties that make fluoropolymers so uniquely useful in a vast range of industries and sectors. It is important to note that fluoropolymers are expensive and complex

to handle, making them materials of last resort. For this reason, it goes without saying that if alternatives that met industry requirements were already available, they would be used.

As high molecular weight molecules with unique properties attributable to the strong Carbon– Fluorine bonds, the strongest bond in organic chemistry, fluoropolymers are unlikely to be replaced by an alternative material, regardless of the resources invested. Applications requiring a combination of these properties, fluoropolymers are the superior and, often, only solution.

Notably, the proposal's own assessment notes that there is uncertainty in understanding of alternatives.[8] But the known downside risks of eliminating fluoropolymers are very clear: Any alternatives, while they will differ across specific applications, have the potential to suffer from a range of performance and quality issues ranging from reduced efficiency, durability, compatibility, and versatility to higher initial investment costs and maintenance costs. There would also likely be uncertainties around the safety of product breakdown, given that any alternatives with the same chemical resistance and persistency as fluoropolymers have the potential degrade into toxic substances when they become unstable. If an alternative were to exist or be invented, it would be able to handle the extreme environments and durability, meaning that, like fluoropolymers, it would also be very persistent.

Moreover, the production and design process to produce any viable alternatives will require significant time, effort, and resources, with the potential for major product qualification issues, a narrower band of operating condition requirements, higher risk of exposure to hazardous substances, or higher safety risk and increased emissions from technical regression.

Additionally, information about alternatives is extremely limited and lacks expert vetting and full testing before commercialization. That means alternatives, if they can be produced in the first place, will require extensive time and effort if they are to clear legal or regulatory barriers, let alone reach industry-leading safety, emissions control, and recycling standards.[9]

In many cases, there simply is no alternative. To elevate the most prevalent example: Semiconductor chips cannot be manufactured without fluoropolymers; in other words, every industry, sector, and consumer in the EU that relies on semiconductor technology will be put at a significant disadvantage.

There are currently no viable alternatives to fluoropolymers in many other important applications, especially when it requires high-speed, high-volume transmission of data (data centers, radar systems, 5G, etc.), miniaturization (computers and electronics), and extremes in temperature (like air travel, space applications, or high-hazard manufacturing). From aerospace and defense to advanced electronics and clean energy, there is often no domestically manufactured alternative replacement.

Simply put, replacing these fluoropolymers in their most critical applications would require an outsized investment of time, energy, and resources across the EU—if doing so is even

[8] Annex XV Restriction Report

[9] Plastics Europe: Socio-economic Analysis of the European Fluoropolymer Industry – Executive Summary

possible. No other polymers, plastics, or metals can match fluoropolymers' capabilities. When their unique properties, categorically different safety profile, irreplaceable role within entire sectors, and responsible management of manufacturing and end of life emissions are taken as a whole, the only viable, sensible, and science-backed solution is that fluoropolymers must be exempted from the proposed PFAS regulations.

ENVIRONMENTAL & HUMAN HEALTH AND SAFETY

Fluoropolymers are now subject to restriction merely because they fit the PFAS structural definition of PFAS as described by the OECD, meaning they are persistent.

However, backed by a substantial body of scientific data, fluoropolymers have been demonstrated to meet the requirements of "polymers of low concern" as defined by the Organization for Economic Cooperation and Development (OECD). Based on in-depth data and scientific rigor, the "polymer of low concern" criteria were developed over time, within regulatory frameworks from around the world.[10]

Along those lines, fluoropolymers have documented safety profiles and are thermally, biologically, and chemically stable, negligibly soluble in water, nonmobile, nonbioavailable, nonbioaccumulative, and non-toxic.[11] They do not degrade into other PFAS and have been proven safe during their intended use phase.

In fact, an in depth-assessment of the fluoropolymers which accounting for approximately 96% of the global commercial fluoropolymer market against thirteen widely accepted polymer hazard assessment criteria, showed that these polymers are of low concern (PLC) and pose no significant risk to human health or the environment.

Moreover, as high molecular weight molecules with unique properties attributable to the strong Carbon–Fluorine bonds, fluoropolymers' highly stability is not an intrinsic hazard—in fact, it provides an immeasurable value for sustainability and durability.

These characteristics remain true for fluoropolymers throughout their life cycle and even when industrial or consumer use has ceased. There is considerable data demonstrating that, at this "end-of-life" period, where fluoropolymers are typically disposed via landfill, incineration, or recycling, they do not degrade in the environment or release substances of toxicological or environmental concern. Industry observes stringent end-of-life requirements and is continuing to invest in research into the safest conditions for disposal of fluoropolymers.[12]

Based on a thorough review and assessment of fluoropolymer toxicity data, human clinical data, and physical, chemical, thermal, and biological data, research has concluded that—for these reasons—fluoropolymers are distinctly different from other polymeric and nonpolymeric PFAS and should be separated from them for hazard assessment or regulatory purposes.

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[10] A critical review of the application of polymer of low concern and regulatory criteria to fluoropolymers

[11] A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers

[12] A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers

RESPONSIBLE MANUFACTURING

Guided by existing regulation, industry already employs robust responsible manufacturing practices, including control of gaseous, aqueous, and solid emissions throughout manufacturing and processing, stringent emissions abatement technology and waste disposal methods, and end of life management. Leading fluoropolymer manufacturers have invested in state-of-the-art emissions control facilities and have already demonstrated significant emission reduction, including fluorinated polymerization aid recovery for reuse, 99% reduction of air/water process emissions, and 99% plant emission reductions.[13]

As such, every stage of fluoropolymer manufacturing—from the earliest stages of raw materials and monomers to the creation of polymers—can be completed responsibly, with thorough management of raw materials, polymerization aids, and the resulting polymers that are used in various product applications. The vast majority of fluoropolymers are manufactured in a manner that enables them to meet the OECD's criteria for polymers of low concern.[14]

Moreover, numerous recycling, incineration, and landfill processes and methods are existing, well suited to address end-of-life concerns associated with fluoropolymers. Similarly, existing waste directives as well as recycling, incineration, and landfill standards and practices demonstrate that effective mitigation measures are already in place or can be amended to address potential risks associated with the end of life of applications containing fluoropolymers.

Along those lines, fluoropolymer manufacturers in Europe committed to the highest standards for manufacturing worldwide. The industry-led program includes a concrete commitment to minimize emissions of non-polymeric PFAS residues from polymerization aids, a platform to promote the adoption of commercially available state-of-the-art technologies to minimize non-polymeric PFAS emissions in manufacturing, as well as the commitment to inform downstream users of fluoropolymers on their safe handling and use in the Guide for the Safe Handling of Fluoropolymer Resins. In addition, R&D investments have increased recyclability and re-use, core to the goal of a circular economy. In other words, fluoropolymers can be manufactured and used safely and responsibly.

THE PATH FORWARD: GOVERNMENT & INDUSTRY PARTNERSHIP TO ACHIEVE A SCIENCE-BASED REGULATORY OUTCOME

As demonstrated, attempting to regulate all PFAS in a broad and general way as currently proposed would discard decades of accepted regulatory assessment practice and drive unintended, adverse consequences resulting in a regulatory precedent that will stifle the European economy, make Europe more dependent on third countries for critical materials, and—above all—undermine EU's clean energy, technology, and economic goals. Moreover, fluoropolymers' safety profile (including designation as "polymers of low concern," existing regulatory approval, and aggressive goals with respect to responsible manufacturing), unique

[13] A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers

[14] A critical review of the application of polymer of low concern and regulatory criteria to fluoropolymers

combination of characteristics, and critical industry applications require this exemption. Grouping all PFAS together doesn't accurately reflect the actual risks, uses, and related management measures for each substance.

Instead, to regulate PFAS in a way that benefits regulators, industry, and modern society, it needs a time-unlimited derogation for manufacturing, sale, import, and use of fluoropolymers—underpinned by an unwavering commitment to responsible manufacturing of fluoropolymers and responsible life-cycle management.

It has been shown that risks associated with the use of fluorinated substances in the manufacture of fluoropolymers can be controlled and minimized applying the framework of strictly controlled conditions, including standard emission abatement technologies and very strict manufacturing standards. It has been further outlined that the use of fluorinated polymerization aids in the manufacture of fluoropolymers cannot be entirely substituted with non-fluorinated polymerization aids, and that the use of non-fluorinated polymerization aids generates comparatively higher amounts of unknown emissions, which themselves bear a risk to human health and the environment and limit performance. Hence, Chemours urges ECHA to consider:

- an exemption for the use of transported isolated intermediates in the manufacture of fluoropolymers and fluoropolyethers under strictly controlled conditions.
- an exemption for non-intermediate substances necessary for the manufacture of fluoropolymers and fluoropolyethers under strictly controlled conditions.
- an exemption for the use of fluorinated processing aids in the manufacture of fluoropolymers. If a phase-out is eventually considered by the Scientific opinions to be a more appropriate measure, then Chemours urges ECHA to consider a derogation of at least 12 years with a review period, which will be necessary to ensure that disproportionate socio-economic impacts can be avoided.

We remain committed to working with the appropriate competent authorities to help fill any data gaps or to provide additional information about the safety and socio-economic value of fluoropolymers. In line with this commitment, we participated in ECHA's public consultation and provided substantial data and knowledge on the manufacturing, uses, and end-of-life management of fluoropolymers. We will continue to constructively engage in the regulatory process, and we are confident that we can achieve a coherent, science-based regulatory approach that leads to the use of safer, better-performing chemicals in the EU, and enables the sustainability and success of the EU industrial value chain.

Supporting European Sustainability and Competitiveness: An Alternative Approach to the Proposed EU Restriction on PFAS (F-Gases)

September 2023

Introduction

In February 2023, authorities in Denmark, Germany, the Netherlands, Norway, and Sweden submitted a proposal to the European Chemicals Agency (ECHA) that calls for a complete phase-out of the manufacture, import, sale, and use of per- and polyfluorinated substances (commonly known as PFAS). PFAS are a class of thousands of chemicals, each with different safety profiles and uses.

While Chemours recognizes the concerns raised by the Dossier Submitters with the safety profiles of some PFAS, Chemours does not agree with the proposed restriction or grouping. The Annex XV report does not objectively identify and assess a complete range of potential restriction or regulatory management options (it only assesses the appropriateness of a ban), nor does it clearly demonstrate that the proposed restriction is the most appropriate means to regulate the potential risks of PFASs. Additionally, the proposed restriction—which includes fluorinated gases (F-gases) and specialty fluids—uses a grouping approach based on chemical structure and fails to justify the need of a case-by-case approach for F-gases, making the inaccurate assumption that all PFAS substances, including F-gases, share the same hazard and risk profile.

The EU has proven, science- and risk-based methods to regulate PFAS and other chemicals effectively; however, the current approach by the Dossier Submitters will block effective, safe, and already regulated technologies completely by instituting a widespread ban. For example, F-gases, such as Hydroflurocarbons (HFCs), low global warming potential Hydrofluoroolefins (HFOs), and HFO blends—have the potential to be banned due to the atmospheric degradation profile (trifluoracetic acid (TFA)) of some F-gases. These technologies are safely being used across the EU, are essential to achieving the EU Green Deal goals, and are successfully regulated under the F-Gas Regulation in the EU and the Montreal Protocol globally.

Before discussing alternative restriction options, it is important to understand the critical role F-gases play in our society. F-gas applications go far beyond comfort cooling; F-gases power the world's largest industries and value chain—from automotive, aerospace, and advanced electronics to constructions, HVACR, and data centres. These chemistries are critical for the EU to achieve its ambitions, to realising next generation computing speeds, enabling electric vehicles, fostering circularity, and achieving decarbonisation.

Chemours supports a science-based regulation to PFAS, which recognizes many of the Dossier Submitter and civil societies concerns regarding certain PFAS substances. However, not all PFAS are the same, nor should they be regulated in the same way, given the vast differences in structure and risk. PFAS can and are, safely used across many applications. As experts in the manufacture, properties, and applications of F-gases and specialty fluids, Chemours and its Thermal & Specialized Solutions (TSS) business are committed to take an active, responsible, and constructive role in the proposed restriction process to facilitate the development of a coherent approach to the regulation of PFAS.