Report summary petroleum & mining

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1. Uses / Applications

1.1. Uses of non-polymeric PFAS in petroleum industry

The uses of PFAS in the oil and gas industry, as discussed by Glüge et al. (2020), and defined according to the OSPAR[1] categorisation of chemicals used in the oil and gas sector, are the following:

1. Drilling fluids: Fluorinated surfactants (fluorosurfactants) act as a foaming agent that initiates and extends the fractures in the formation. PFAS-based products are commonly used as anti-foaming agents.
2. Simulation chemicals: Fluorosurfactants have become more commonly used in 'chemically-driven oil and gas production' as foaming agent to support the displacement of the oil.
3. Production chemicals: PFAS-based products are commonly used as anti-foaming agents.
4. Water and gas tracers: PFAS-based tracers are used as water and gas tracers to map oil and gas reservoirs. They are considered low risk and can be detected at extremely low concentrations.
5. Other uses: PFAS-based chemicals are used to prevent evaporation of liquid fuels in oil and gas storage or the containment or clean-up of oil spills.

1.2. Uses of non-polymeric PFAS in mining

In the mining sector, PFAS (including both PFCA salts and PASF compounds) are reported to have been used, for example to increase the extraction efficiency in copper and gold mining. Based on the Glüge et al. (2020) review, the specific functions provided by PFAS in the mining sector include the following:

1. Use as an acid mist suppressing agent in mineral recovery;
2. Agents to increase wetting of the sulfuric acid or cyanide used to leach ore, enhancing the amount of metal recovery;
3. Use as hydrocarbon foaming agent;
4. Fluorinated surfactants used in ore floating to create stable aqueous foams to separate the metal salts from soil; and
5. Use in the recovery of metal salts from aqueous solutions.

It is unclear to what extent these practices are currently required/utilised in Europe and hence if/which PFAS compounds are currently being used for these applications. It has been indicated, based on input by industry, that non-polymeric PFAS are not being used widely in the mining sector in Europe. However, no further input has been received to definitively confirm the level of ongoing use, and the specific application of PFAS in this sector.

1.3. Uses of fluoropolymers in the petroleum industry

A wide range of fluoropolymers such as fluoroplastics and fluoroelastomers are identified as being used in the oil and gas industry, predominantly in the application of oil and gas transport. This refers to use in the equipment and piping used in extraction machinery or infrastructure.

1) Oil and gas transport and storage equipment

Pipes and tubes used in the production and transportation of oil are generally large and for economic reasons are typically manufactured from carbon steel rather than more expensive corrosion resistant alloy (Glüge et al. 2020). Lining the interior surface of oil well pipes with fluorocarbons can help prevent or reduce oil-induced corrosion, caused by its acidic nature. Lining the exterior of offshore pipes also protects them from corrosion through sea water.

[1] The Oslo and Paris convention for the Protection of the Marine Environment of the North-East Atlantic

Fluoropolymers are widely used in the equipment and piping used in extraction machinery or infrastructure. Based on the input from industry (manufacturers, suppliers, and downstream users, through CfE responses and further consultation), the main uses for fluoropolymers include the production of the following components used in oil and gas extraction equipment:

- Lining of piping, flowmeters and fittings, fluid-handling components, process vessels, tanks, storage and transport containers
- Flexible risers and flowlines
- Liners in the high pressure lines used in offshore choke and kill systems
- Seals used in downhole drilling operations (e.g. flange sealing applications)
- Valve bodies
- Valve packing
- Valve seals
- O-rings
- Pipe gaskets
- Capacitive sensors and their connecting cables
- Filtration equipment (e.g. HEPA filters - a synthetic composite with 'expanded' PTFE membrane)
- Vibration dampers
- Packer elements
- Pneumatic actuators, pneumatic regulating devices
- Blow-out preventors
- Stators and "mud motors"
- Submersible pumps
- Pump liners
- Packaging vents – leaking and rupturing

The key functional property ability for PFAS-based materials used here is the extreme durability and capability of maintaining their form and mechanical strength and corrosion resistance under the extreme environments.

2) Cables

Polymeric PFAS are used in the cable insulation for communication cables in oil and gas drilling. For example, the resistance of a number of fluoropolymers to harsh chemicals and heat have allowed them to be used and marketed in numerous wire and cable applications in the onshore and offshore oil and gas sector, including electrical downhole cables, fibre optic downhole cables and hybrid electric/fibre cables.

1.4. Uses of fluoropolymers in mining

It is expected that there will be current use of fluoropolymers (fluoroplastics and fluoroelastomers) in the mining sector in Europe. It is indicated (through a review of literature and commercial sites) that use of fluoropolymer in the cables, pipelines and conveyor belts used at mining installations will be occurring. The specific products, uses, functions, and desired properties of fluoropolymers in the mining sector can be expected to be broadly similar to this in the oil and gas sector.

However, very limited input from the mining industry (e.g. individual operators, suppliers, or industry associations) has been provided as part of this study. Direct consultation with the mining industry, including the main associations representing the European industry, has been conducted, but minimal information on the specific uses in the mining sector has been received.

1.5. Summary

The key applications for which PFAS-based chemicals are used in the petroleum and mining industries are summarised in the Table 1. While it is expected that PFAS will be used in refineries of petroleum products, no data was available on current products, or their volumes of use in Europe.

Table 1: Summary of PFAS used in the petroleum and mining industries.

Parent Level	**Sub – Level[1]**	**Application**
Petroleum exploration and production	Drilling fluid/production chemicals[2]	Fluorosurfactants and anti-foaming agents
	Stimulation chemicals	Enhanced oil/gas recovery stimulation products
	Water and gas tracers	Tracers used to map oilfields
	Other	Chemicals used in the storage or containment of oil and gas
		Fluoropolymer used in pipeline, valves, gaskets, O-rings, seals, cable and wiring insulation
Mining applications[3]	Extraction of ores and minerals	Acid mist suppressing agent
		Wetting agents
		Hydrocarbon foaming agent (Flotation)
		Fluorinated surfactants used in ore floating (Flotation)
	Equipment	Fluoropolymer used in pipes, cable, hoses, conveyor belts

[1] For petroleum extraction, as defined under the Harmonised Mandatory Control System under OSPAR Decision 2000/2. This does not apply to mining.
[2] Referred to as 'Chemicals used in the actual production and processing of hydrocarbons' under OSPAR
[3] Uses not covered under OSPAR Decision 2000/2

2. Main PFAS substances

A variety of PFAS (non-polymer PFAS, fluoropolymers) are in use in petroleum and mining . Around 100 substances (with and without CAS numbers) are identified in this sector. The list of PFAS used in this sector is not provided here as it is partly reported in the Glüge et al. (2020) recent publication and partly due to confidential Business Information (CBI). Please note that the use of PFAS as containment and/or transport chemicals has not been confirmed as being in active use in Europe through the information gathered from industry (manufacturers, suppliers, downstream user associations and national authorities) in the Call for Evidence (CfE) during the period May-July 2020 and further consultation as part of this assessment. In addition, data collected during the consultation indicated minimal use of PFAS for enhanced oil/gas recovery stimulation products in Europe. There are no identified products currently on the market for this application.

3. Manufacturing & Market price + market development

To our knowledge, there are no specific sites for the manufacturing of polymeric or non-polymeric PFAS for the petroleum and mining industry. For the forward-looking trends (2020-2050), it is noted that petroleum production is expected to decline significantly in Europe over this time period (Table 2). It is, however, noted that the demand for PFAS-based tracer and anti-foaming agents is expected to increase in future years.

Table 2: Baseline projections (excluding the UK) for volumes of PFAS and fluoropolymer used (in t) in the petroleum and mining sector

Group	PFAS compound	Unit	Estimated volume of PFAS used						
			1990	2000	2010	2020	2030	2040	2050
Water and gas tracers	PFAS-based tracers	t	0.0	0.3	0.6	1.0	1.1	1.2	1.3
Production chemicals	Fluorosiloxane-based antifoaming agents	t	0.0	1.1-2.8	2.3-5.6	3.4-8.5	3.7-9.4	4.1-10.3	4.6-11.4
Fluoropolymers (all)	-	t	2000-4300	2500-5400	3000-6400	3500-7500	3900-8500	4300-9150-	4700-10100

Water and gas tracers

The input provided by one supplier suggests that, for the seven tracer products considered in this analysis, the total sales in Europe for this sector represent a total value of ~€300 000 to 400 000 per year[2]. However, if only the volume of product expected to be used each year in the oil and gas sector in Europe is considered, this represents <€10 000 per year[3].

Fluorinated benzoic acid compounds are known to be used in tracers for oil and gas, do not meet the criteria of PFAS used in the current restriction proposal.

Drilling/production chemicals

Information on the volumes of production/sales of fluorinated polysiloxane-based anti-foaming agent products in Europe has been provided by only a small number (two) suppliers as part of the CfE. In the absence of information of the current market share of these suppliers, it has not been possible to produce an estimate for total levels of production and sales of these products on the European market, based only on the input of suppliers.

Simulation chemicals

Very little information on specific oil/gas well stimulation products currently being marketed and sold in the EU has been obtained in this assessment. Information on current production or use of these products in Europe was not divulged in any responses to the CfE, and manufacturers or suppliers known to either to previously market such products did not indicate these products were currently being marketed or used, when contacted in direct consultation. The use of PFAS-based products for well stimulation is likely to be minimal in Europe.

Fluoropolymers

It has not been possible to derive unit prices, either for the fluoropolymer sold for use in the petroleum and mining sector, or for the products containing fluoropolymer sold to downstream users, due to a lack of information provided by suppliers, and the large number of products on the market for this sector.

[2] Based on a (confidential) unit price provided by the supplier, and an estimate from the supplier that 1/3 of sales are to the European market.

[3] https://publik.tuwien.ac.at/files/publik_267896.pdf

Based on the estimated range of the tonnage for fluoropolymer used annually in the petroleum and mining sector in Europe, a very approximate estimate of €5.25 to €11.25 million of sales per year has been derived[4]. It is emphasised that this value is subject to significant uncertainty and is based only on input from one supplier. This estimate is therefore indicative and should be used with caution.

4. Emissions

The manufacture of the PFAS and fluoropolymers themselves is not within the scope of this study and is the subject of a separate assessment in this restriction proposal.In total, the emissions of PFAS in 2020 from the different use categories by life-cycle stage were as follows:

- Non-polymer PFAS : 1,111-3,925 tonnes/a
- Fluoropolymers: 3,347-10,561 tonnes/a
- Side-chain fluorinated polymers: 475-3,617 tonnes/a

An overview of the total emissions (baseline 2020) of non polymer-PFAS to the environment from the petroleum and mining industry in EEA is provided in Table 3.

[4] Based on Plastics Europe (2017) Socio-economic analysis of the European fluoropolymer industry, https://www.plasticseurope.org/application/files/7315/1708/4052/Final_SEA_Fluoropolymers_summary2017.pdf

Based on an estimated € 780 million total revenue from fluoropolymer across all sectors and an estimated 52 000 tonnes sold (2015 value).

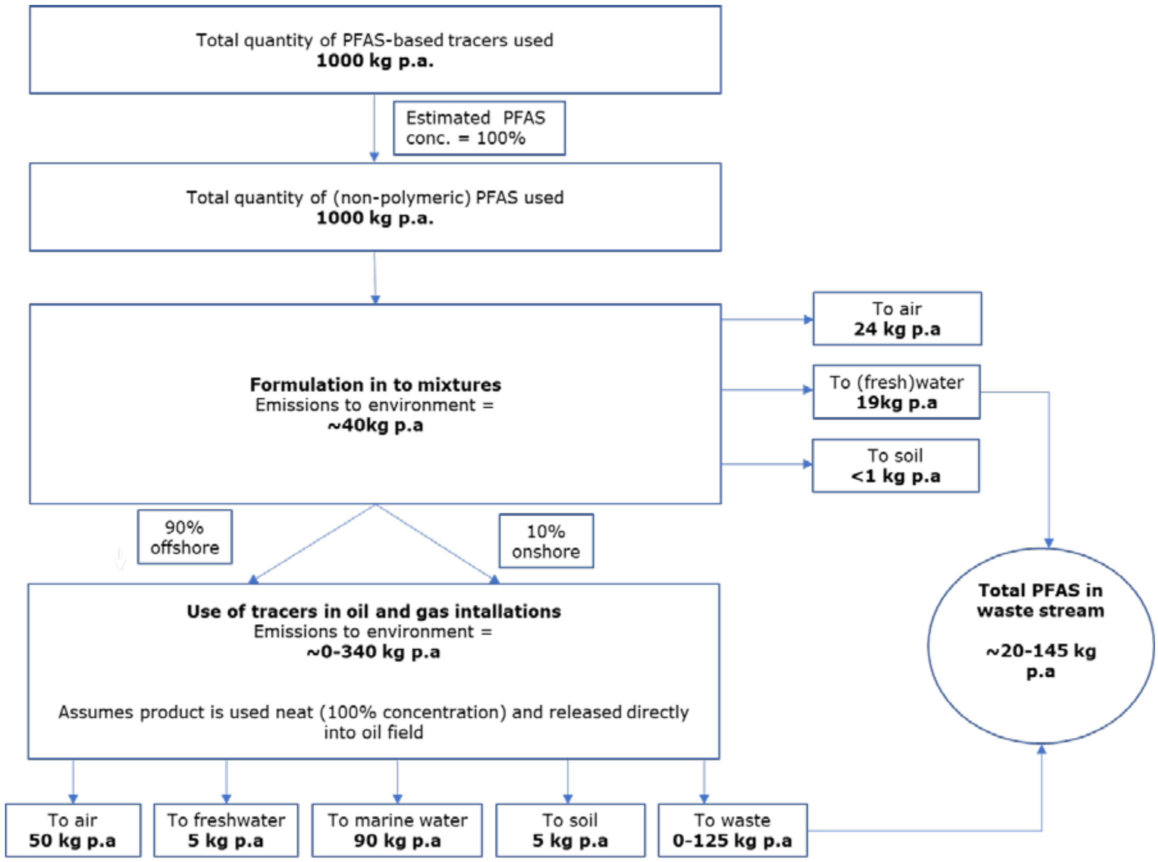
Table 3: Overview of estimated emissions of non-polymeric PFAS for 2020 (baseline) by receiving environment from the petroleum and mining industry

Group	PFAS compound	Quantity of product used (kg)	Quantity of PFAS (kg)	Emissions to air (kg)	Emissions to freshwater (of which transferred to waste) (kg)	Emissions to marine water (kg)	Emissions to land (kg)	Total Emissions (kg)	Total quantity entering waste (kg)
Water and gas tracers	Fluoro-alkane tracers + other PFAS-containing tracers	1000	1000	25-70	20-25 (20)	0-110	0-5	165-185	20-145[1]
Drilling/ Production chemicals	Fluoro-siloxane antifoaming agents	170 000	3 400 – 8 500	85-635	70-210 (15-40)	20-760	0-45	170-1650	15-230[2]
Fluoro-polymers (all) **Low scenario**	Monomeric PFAS (not specified)	3 500 000 – to 7 500 500	4-8	1-2	<1 (<1)	<1	<1	1-3	<1 (formulation) 1-3 (end of life)
Fluoro-polymers (all) **High scenario**	Monomeric PFAS (not specified)	3 500 000 – to 7 500 500	900-1900	270-580	3-6 (2-4)	20-40	20-45 (1-2)	310-670	3-6 (formulation) 310-670 (end of life)

[1] ~20 kg from the formulation phase (freshwater and soil) ; 0-125 kg from the use phase (recaptured at surface)

[2] 15-40 kg from the formulation phase (freshwater and soil) ; 0-190 kg from the use phase (recaptured at surface)

For tracer and anti-foam products, the levels of emissions estimated in table 3 are expected to be directly proportional to volumes of production and use of these products. Therefore, the pattern of emission levels (relative to the 2020 baseline) from 1990 to 2050 period, is expected to follow the same trend as presented in the baseline scenario for expected tonnage of sales and use for these products presented in table 2.
Flow diagrams for estimated emissions from tracer products, anti-foaming agents products and fluoropolymer products (low and high scenarios) can be found in figure 1-4.



Baseline year: 2020

Figure 1: Source flow diagram for estimated emissions from tracer products

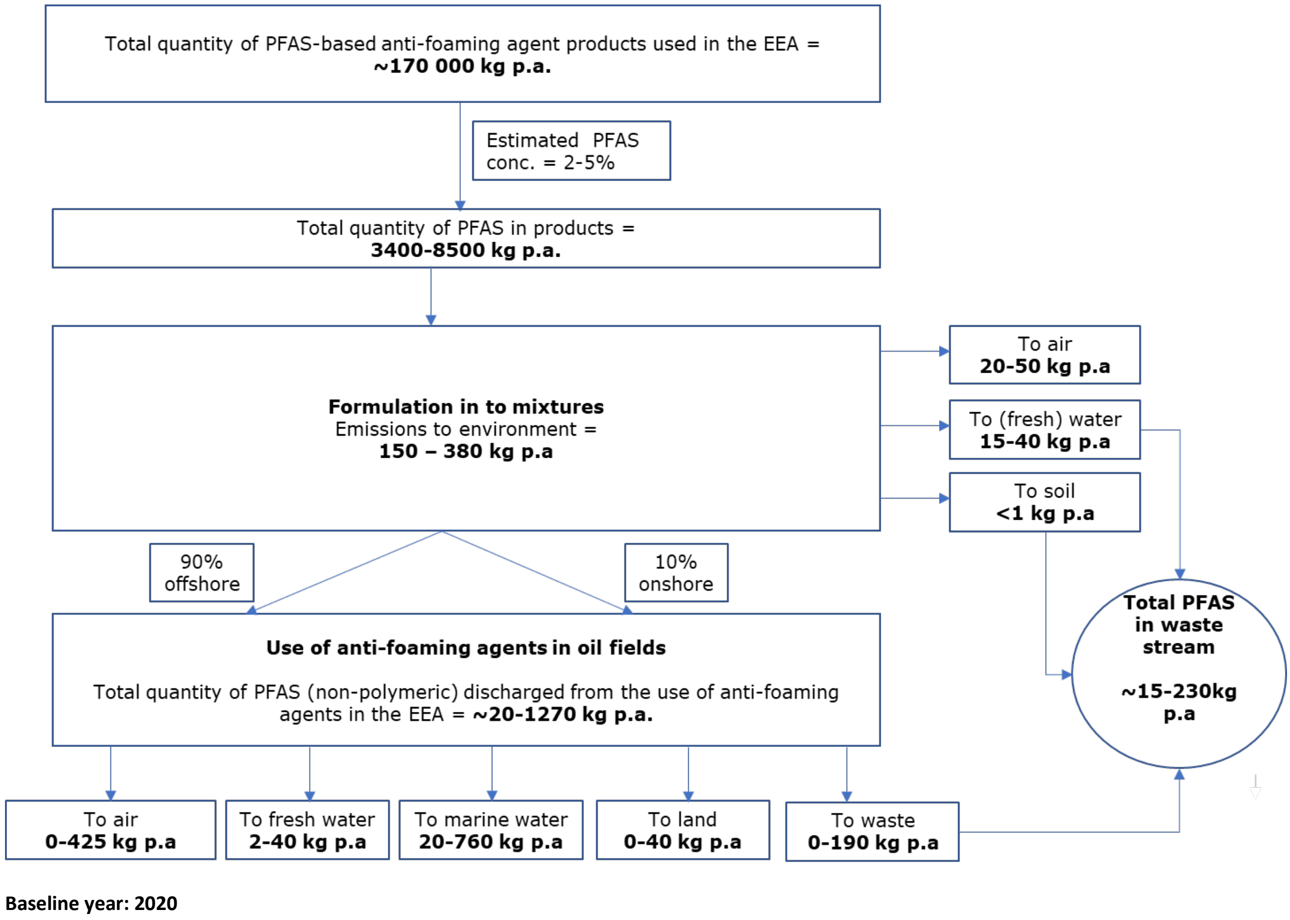
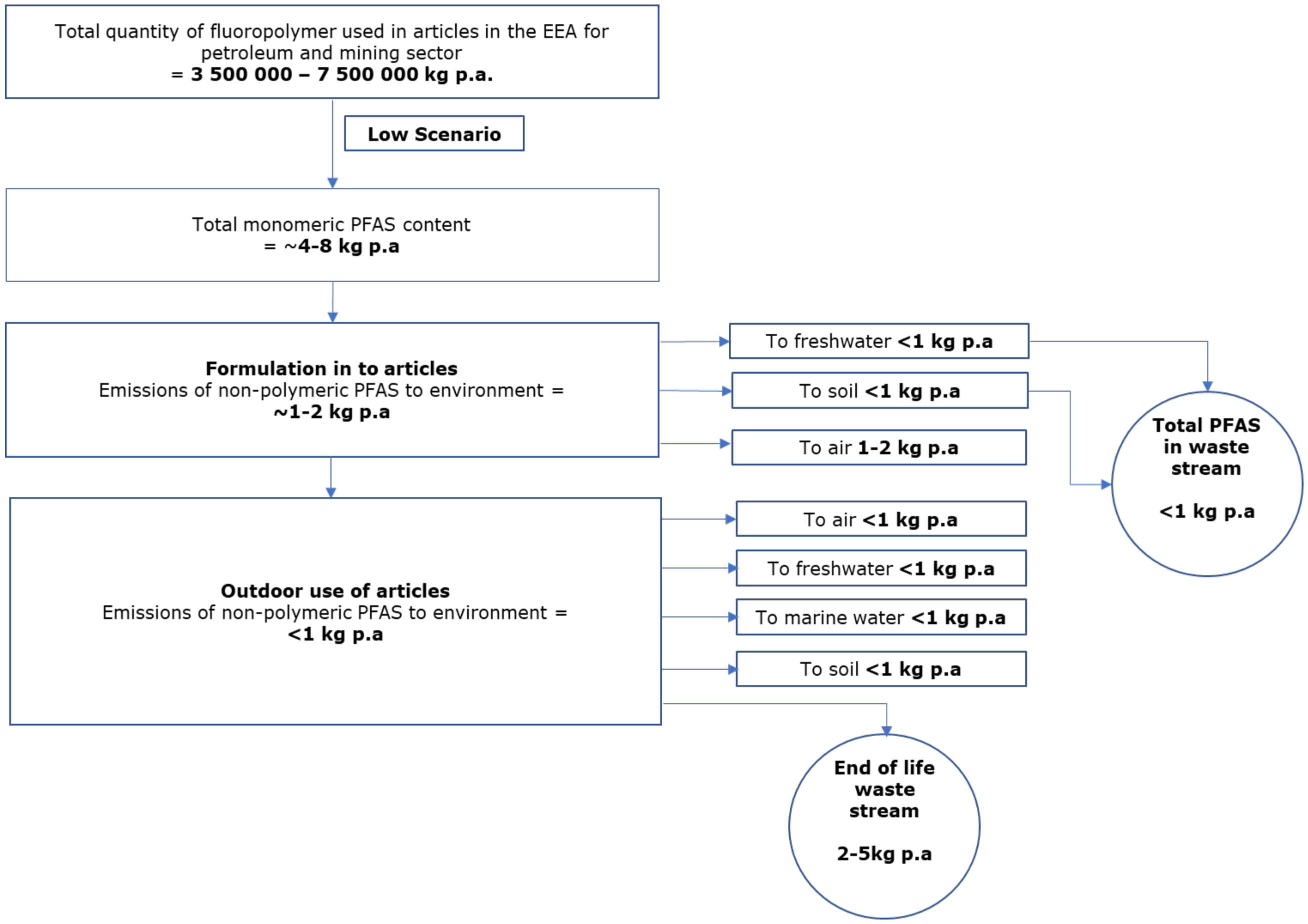
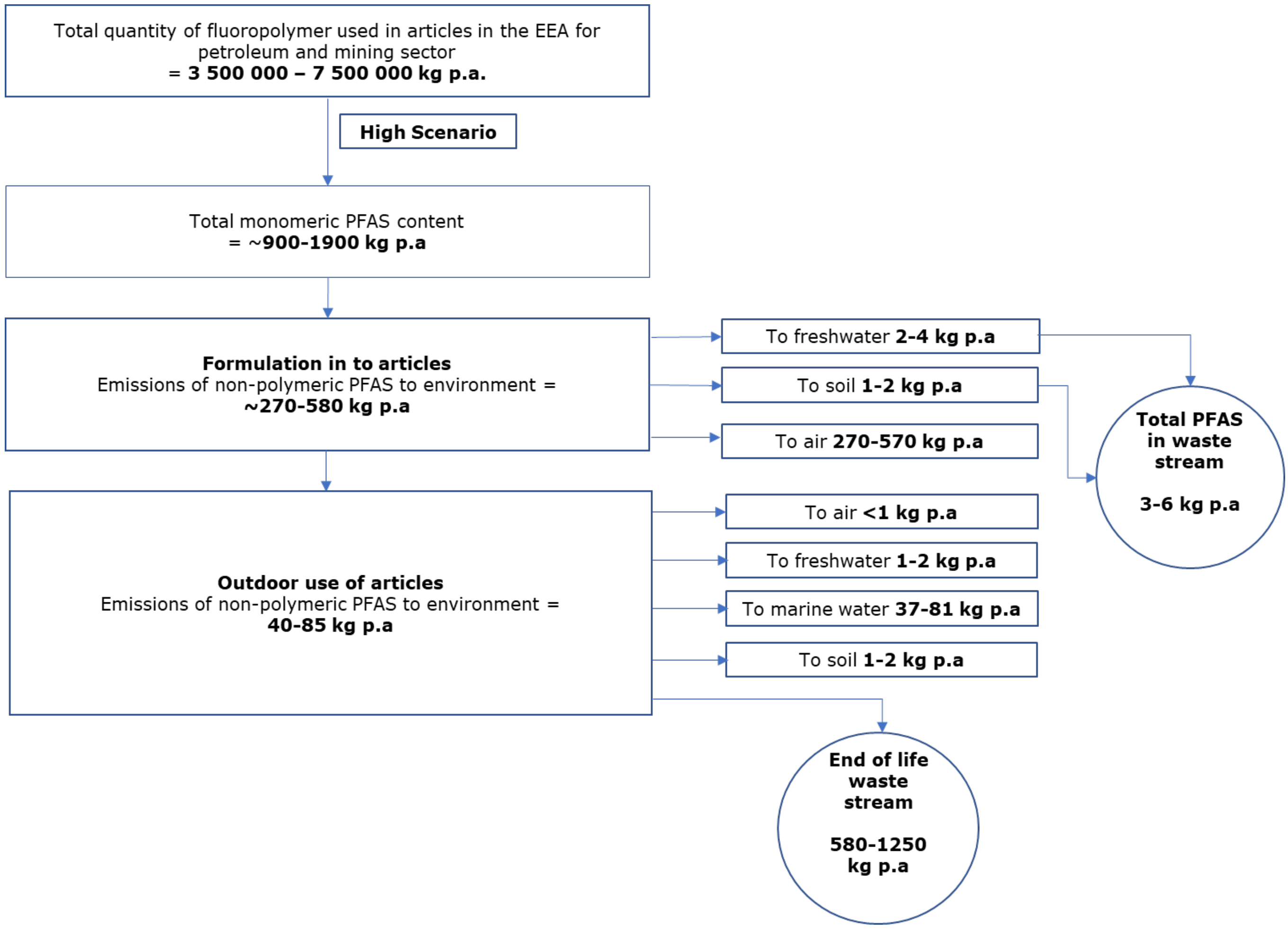


Figure 2: Source flow diagram for estimated emissions from anti-foaming agents products



Baseline year: 2020

Figure 3: Source flow diagram for estimated emissions from fluoropolymer products (low scenario)



Baseline year: 2020

Figure 4: Source flow diagram for estimates emissions from fluoropolymer products (high scenario)

5. **Exposure (workers, consumers)**

It is not expected that direct exposure to consumers or the general public would occur. It is expected that direct exposure will only occur potentially for occupational workers across the supply chain. This could include:

- Workers involved in formulation of PFAS/fluoropolymer in products.
- Workers handing PFAS/fluoropolymer products on site.
- Workers involved in handling wastes containing PFAS on site.

Exposure to fluoropolymers and non-polymeric PFAS can occur at various points along the supply chain, but this is expected to be minimal due to the use of adequate PPE, closed equipment and ventilation. Both the landfilling and incineration of fluoropolymer could potentially lead to the release of PFAS to the environment (Lohmann et al., 2020).

6. **General discussion on emissions and exposure**

<u>Summary of existing legal requirements</u>

The petroleum and mining industry is covered under Council Directive 2014/52/EU (on the assessment of the effects of certain public and private projects on the environment). Installations for the extraction of petroleum, natural gas, and mining facilities are therefore subjected to an environmental impact assessment. Chemical substances used in the extraction of oil and gas, and in mining are furthermore Directive 2006/21/EC on the management of waste from the extractive industries (the Extractive Waste Directive) requires that extractive waste must be managed in specialised facilities in compliance with specific rules. The Directive covers the planning, licensing, operation, closure and after-care of waste facilities and provides for a major-accident policy for high-risk facilities. Inventories of closed facilities posing serious risks to the environment and health also have to be drawn up by Member States . Recovered fluid is managed in accordance with the EU Mining Waste Directive (which includes the requirement for a waste management plan setting out methods for re-use and disposal) and local legislation and conditions (IOGP, 2016). Both the oil and gas, and mining industries are covered by existing European-level guidance documents on best available techniques to be applied to protect the environment and human health.

OSPAR Decision 2000/2 on a Harmonised Mandatory Control System for the Use and Reduction of the Discharge of Offshore Chemicals is the main international control for this sector. The purpose of the OSPAR decision is to enable authorities to ensure and promote – through an effective enforcement and control system – the use of less hazardous or non-hazardous substances due to the use and discharge of offshore chemicals.

Summary of effectiveness of operational conditions and risk management measures

Both the oil and gas, and mining industries are covered by existing European-level guidance documents on best available techniques to be applied to protect the environment and human health. For oil and gas, '*the Best Available Techniques Guidance Document on upstream hydrocarbon exploration and production'* is established[5]. This guidance document sets out a 'best available techniques' and 'best risk management approaches' for a number of activities in the onshore and offshore hydrocarbons extraction industry

[5] https://eippcb.jrc.ec.europa.eu/sites/default/files/inline-files/hydrocarbons_guidance_doc.pdf

7. Alternatives

Table 4: Summary of technical and economical feasibility for alternatives in the oil and gas sector

PFAS compound (application)	Alternative(s) identified	Technical feasibility		Economical feasibility	
		Comparative use	Critical use/applications	Unit price	Volume and wider costs
Fluorinated alkanes (tracers)	Radioactive tracers	Comparable performance is achievable but higher dose rates are likely to be required due to differences in detection limits.	The very low (parts per quadrillion) levels of detection for PFAS-based tracers may make them suitable for use in some application where alternatives cannot achieve the same level of performance.	PFAS-based tracers are likely to be much more expensive to procure, but no quantitative value provided.	Expected that much higher volumes of alternative may be needed to meet the same performance, but no quantitative estimate is available.
Fluorinated silicones/siloxanes (antifoams)	PDMS-based products as antifoams (note various other possibilities mentioned above)	Comparable performance is achievable but higher dose rates are required.. Non-PFAS based products are more widely used than PFAS-based foams, with the latter used only for a relatively small number of 'niche' locations.	Alternatives may be less efficient with some crude oils so would be less feasible for some installations and would be needed in greater concentrations/quantities.	PFAS-based product will probably be slightly more expensive to procure, but no quantitative value provided.	For some users, a much higher dose rate is required and therefore would be more expensive overall as more product will be required to achieve the same result. Also has implications for storage volumes needed.
PBSF-based compounds/polymers (EOR/EGR fluid;	No specific substance identified	No specific alternative products identified. Indicated to provide adequate level of	PFAS-based surfactants may be needed in some 'extreme' cases at some installations.	No assessment of cost differences was possible	No assessment of cost differences was possible

PFAS compound (application)	Alternative(s) identified	Technical feasibility		Economical feasibility	
		Comparative use	Critical use/applications	Unit price	Volume and wider costs
stimulation chemicals)		performance in EOR/EGR due to widespread use.			
Fluoropolymers e.g. PTFE (pipe linings and other components)	Various, including :Steel, other metal alloys, XL PE, EPDM, HNBR, PEEK)	Some alternatives can meet the required functionality suitable for some applications and conditions. E.g. PEEK has similar heat resistance performance as PTFE ; higher tensile strength, better machinability, better compressive strength.	Alternatives may not be suitable for some applications and may not meet the same functionality in the required conditions. E.g. PEEK has lower chemical resistance (e.g. to sulphuric acid) than PTFE so can be susceptible to corrosion. Not suitable for all applications.	In most cases fluoropolymer is expected to be more expensive to procure than alternatives. Use of fluorine-free components could reduce clean-up and waste-handling costs.	For alternatives in some cases (e.g. with PEEK) unit costs can be higher than conventional fluoropolymer. Key additional costs could be incurred through additional maintenance, more frequent replacement of parts or higher quantities of product needed to perform the same function, and disposal and clean-up costs. Transition to alternatives could take many years or decades to implement in the supply chain and requires investment of resources and capital from manufacturers and suppliers. .

8. Economic impacts in case of a full PFAS ban

For non-polymeric PFAS (tracers and anti-foaming agents) it is indicated on the basis of input from suppliers that alternatives are currently available on the market and can be used in the relatively short-term to achieve broadly the same functionality. However, for fluoropolymers it is indicated that it could be a relatively long (several years to several decades) to transition towards using alternatives that can achieve the same level of performance.

It has not been possible to derive an estimate for the total number of workers impacted by the use of PFAS and/or fluoropolymer in these sectors, due to a lack of data and the relatively large number of steps and complexity in the supply chain.

Overall, it can be expected that the impact of a restriction for PFAS/fluoropolymer in this sector will have relatively minor impact on employment. In terms of manufacture and employment, a restriction would likely have limited impact on both and would be offset by the increased employment associated with the production of alternatives.

Table 5: Overview of economic impacts

Product category	Substitution costs	Transitional costs	Loss of functionality
Tracers	No comparison between PFAS-based tracer and radio-labelled alternatives has been possible in this assessment	Likely to be minimal, as alternatives are available and currently on the market. Expected to be relevant in a relatively small number of installations.	Alternative tracer products (e.g. radio-labelled tracers) can deliver the required functionality. Unclear if alternatives will match the low limits of detection delivered by PFAS-based tracers (implication on dose rate). It is not expected that use of alternative tracers will have a significant impact on the overall production levels of oil and gas in Europe.
Anti-foaming agents	No unit cost data has been made available in this assessment, so costs comparison has not been possible. Indicated that higher dose rate of non-fluorinated product would be required to fulfil the same function and therefore a much higher overall volume of use, and hence overall higher costs can be expected.	Likely to be minimal, as alternatives are available and currently on the market. Expected to be relevant in a relatively small number of installations.	Fluorinated anti-foams are expected to offer a superior functionality. Level of use of PFAS-containing anti-foaming agents compared to the level of use of PDMS-based products is very small (<1%). Overall impact of losing this functionality would be relatively minor and would not result in a significant loss of production or revenue

Fluoropolymers	Transition to using alternatives to fluoropolymer in the oil and gas sector cannot be viewed as a simple 'drop in' replacement of one material for another. For product reformulation, costs can range from tens of thousands of Euros to millions of Euros for any single formulation, so the overall costs could be expected to extend (in total) up to several millions of Euros per company.	Substitutions of new materials for fluoropolymers could take substantial time (years if not decades) and costs. The relative complexity in the supply chains is an important factor Quality assurance, both for the material/formulation supplied by the manufacturer, and of the actual products containing those material supplied to downstream users in the petroleum and mining industry (e.g. need for quality checks to assure adequate performance, efficiency and reliability, as well as a review of potential hazards, toxicology, environmental impacts).	Essential for alternatives to match the high-performance function delivered by fluoropolymer (mechanical strength and stability, high resistance to high temperatures and chemical corrosion, found in the harsh environments associated with deep drilling depths). The potential differences in overall costs between using the fluoropolymers and fluorine-free alternative options are therefore likely to cover the following aspects: • Differences in operational lifetime of components • Overall frequency and costs of maintenance • The production efficiency and amount of operational downtime (e.g. to carry out maintenance) • Difference in clean-up costs (e.g. due to leakage or leaching) • Difference in waste disposal costs

Table 6: Summary of socio-economic, environmental and health impacts

Product category	Economic	Social	Health/Environmental	Wider economic implications
Tracers	It is expected that much higher volumes of alternatives may be needed to meet the same performance, but no quantitative estimate is available	Expected to be minimal as this should only impact a relatively small number of installations and feasible alternatives exist.	Due to the risks around the potential exposure and environmental risks associated with radioactive substances, the overall risk of these alternatives could be considered higher than that of the PFAS-based products.	Expected to be minimal
Anti-foaming agents	PFAS anti-foaming agents are expected to be more effective at lower doses than conventional anti-foaming agents, so alternatives require higher dose rates and overall volumes of use. Confidential industry estimate is that PFAS-based product will be slightly more expensive to procure, but no quantitative value provided.	Expected to be minimal as this should only impact a relatively small number of installations and relatively few producers/suppliers expected.	Expected to be minimal as there is no major difference in associated risks. Under certain conditions (high temperatures, presence of certain types of fillers), silicone polymers can break down resulting in low concentration of D4, D5 and D6 within the polymer matrix.	Possible loss of revenue associated with possible loss of functionality at specific installations where PFAS-based chemicals are currently used. Expected to be minimal as the PFAS-based compounds are used only in a relatively small number of installations.
Fluoropolymer	For alternatives (e.g. metal alloys, fluorine-free polymers), the unit costs can be higher than conventional fluoropolymer. However, in most cases fluoropolymer is expected to be the more expensive option. Key additional costs could be incurred through additional maintenance, more frequent replacement of parts or higher quantities of product needed to perform the same function, and disposal and clean-up costs. Transition to alternatives could take many years or decades to implement in the supply chain and requires investment of resources and capital from manufacturers and suppliers.	Most petroleum and mining installations expected to use fluoropolymer. Large number of manufacturers and suppliers of fluoropolymers and products in the EEA. Expected that up to 5% of fluoropolymers production in Europe is for petroleum and mining. Loss in productivity or revenue at specific installations could have implications for employment in the oil and gas and mining sectors.	Loss in function that could lead to greater levels of leakage/loss of pollutants has important implications of the environmental and health performance of a specific installation and the sector as whole. In addition, use of stainless steel pipes as alternative would be more carbon intensive.	Possible loss of revenue associated with possible loss of functionality at specific installations where the functionality of fluoropolymer is essential to operations.

9. **Methods used & uncertainties**

The collection of data on the use of PFAS in the petroleum and mining sector comprised the following three main aspects:

- A review and collation of information from the call for evidence.
- A rapid review of relevant literature.
- A direct consultation with key stakeholders.

The assumptions and uncertainties that could most significantly affect the results are discussed briefly below:

- The level of market data (e.g. on tonnage and unit price) of PFAS and fluoropolymer used in the European petroleum and mining sector is very limited. The overall tonnages of use for the PFAS-containing products and their alternatives on the market is therefore subject to considerable uncertainty or is not known. Estimated ranges of tonnages have been estimated where possible based on the input from a small (1-2) number of suppliers.

- In the market analysis, tonnages of use for specific products have been informed based on input provided by a small number manufacturers and suppliers. In some cases (e.g. for fluoropolymer) some indication of market share was provided by the supplier. An overall tonnage of use for Europe as a while was extrapolated from this. A range of values based on an expected minimum and maximum market share is presented.

- For non-polymeric PFAS, information has been provided by national authorities (OSPAR contacting parties) on the levels of use and discharge of specific products used at offshore oil and gas installations. Where data is provided from one country, an overall value for Europe has been extrapolated from this data, on the basis of % oil production in that country (based on the BP Statistical review). Data was provided only for offshore installations, so data presented on total tonnages of use do not take onshore installations into account.

- The assumptions underpinning the estimation of the baseline scenario (1990-2050) estimated the tonnages of production/sales of these products are outlined in Section 1.3.

- The exposure assessment relating to environmental emissions has been based on the following key assumptions:
    - Manufacture of PFAS/fluoropolymer and waste treatment are out of scope of this assessment.
    - Emissions to different environmental compartments have been informed, in the absence of more specific information, on the basis of ECHA (2016) default worst-case release factors resulting from the conditions of use described in the ERCs.
    - For fluoropolymers, the emissions assessment only considers emission of residual non-polymeric PFAS in the polymer matrix. A broad consideration of general 'PFAS' is applied in the absence of specific information on specific compounds or fluoropolymer types.
    - Broad assumptions have been made regarding the residual concentration of PFAS in the fluoropolymer matrix. To capture the level of uncertainty around this aspect, a high and low scenario are presented for the emissions of residual PFAS from fluoropolymer,

10. References

Glüge, J. et al. (2020), An overview of the uses of per- and polyfluoroalkyl substances (PFAS), Environmental Science: Processes and Impacts, Issue 12, 2020.

IOGP (2016) Generic exposure scenario for the use of chemicals in the exploration and production of hydrocarbons using high-volume hydraulic fracturing.