Report summary transportation

Contents

1. Uses / Applications

Products and articles used in the transportation sector containing PFAS are very diverse. There are several large and small components which itself are already high-tech devices. A large amount of PFAS containing products are articles which are subjected to extreme conditions like exposure to seawater, heat, UV-radiation or aggressive chemicals. In other cases, PFAS in products are necessary for a defined performance like in fire fighting foams or as part of fuels and lubricants. The PFAS containing products and articles in the transportation sector are divided into subgroups. The subgroups should be applicable to the different sectors of transportation: automotive, shipping, aviation and railway. The subgroups are presented in table 1.

Table 1: Uses and applications of PFAS in transportation products and articles

Transportation - subgroup	Examples
Body-, hull-, and fuselage construction	• Industrial feedstock for body-, hull-, and fuselage construction; • Surface tension modifiers in plating processes during the body-, hull-, or fuselage construction (minimizing the generation of chromium mists); • Release film for mold components from the manufacture of plastic parts (e.g. PTFE, ETFE).
Sealing applications	Sealing applications with fluoroelastomers (e.g. PTFE) (60% or more of the fluoroelastomers produced are used in sealing applications in the transportation sector (information received by stakeholder). • O-rings; • Seals in valves and gaskets; • Shaft or piston seals; • Seals for electronic devices such as NOX- and oxygen sensors in the exhaust monitoring; • Seals for battery electrodes in Li-Ion or dry cell batteries.
Combustion engine system	• Sealing and coating applications • Non-woven textiles as cover in the engine bay area as acoustic insulation inside the vehicle engine compartment (treated with PFAS to achieve oil repellence and high temperature resistance i.e. make them non-flammable).
Lubricants	Lubricants based on fluoroelastomers (e.g. PTFE, PFPE) are used in transportation vehicles, mainly to reduce friction in a wide range of applications and over a wide range of temperatures. • Bearings; • Chain guide in automotive engines; • Bushings (e.g. engine mount bush, stabilizer bush); • Fill-for-life lubricant in small gearboxes, actuators, or hydraulic cylinders (e.g. clutch systems); • Electric & Thermal protection of connectors in electronic systems; • Weather strips; • Sunroof guiderail.
Hydraulic fluids	• Steering systems; • Brake systems; • Systems for lifting and lowering of vehicle parts or cargo.
Electrical engineering and information technology	PFAS play an important role in all electrical engineering and information technology in the transportation sector as they are an integral part of the manufacturing processes for semiconductors and in some cases also of the semiconductor itself.

Transportation - subgroup	Examples
	• Computer-based systems e.g. control systems, telecommunication, safety systems; • Data transmission: Optical Fibres from fluoropolymers are used for data transmission where electromagnetic interference is a concern. The fluoropolymer serves as a low refractive index layer (potentially growing use with regard to vehicles getting "smarter", self-driving cars etc.); • Batteries: fluoroelastomer seals are used to protect electrodes from aggressive electrolytes and achieve corrosion inhibition. F-Gases are used in HVAC-systems to cool down/heat traction batteries of electric vehicles. Fluoroelastomers are used as coating for the separator film in Li-Ion batteries; • Fuel cells: Perfluoropolymeric Sulfonyl Fluoride Ionomers act as a binder and proton conductor in the catalyst layers in fuel cells. PTFE is part of the gas diffusion layer and controls the hydrophobicity of the components, which in turn regulates the water management of a fuel cell; • Lighting; • Electric propulsion engines; • Other electricity-based processes specific to the transportation sector (e.g. disinfection of ballast water using UV-radiation).
Fire prevention and protection	No information is available to the dossier submitters.
• Coating and finishings	• Mainly fluoroelastomers are used in the transportation sector for coating applications e.g. PTFE, ETFE, Perfluoroalkoxy alkane (PFA), or Fluoroethylene vinyl ether (FEVE) • General: Coating applications in the transportation sector; • Coating of cables in the Selective Catalytic Reduction system for diesel engines (ad blue); • Coating of diesel and gasoline particle filter hoses; • Turbo charger hoses and coolant lines, engine coolant lines and oil cooler lines; • UV-stable coatings (e.g. paint protection for transportation vehicles for cosmetic and protective reasons e.g. FEVE is used as coating for car wrappings); • Automobile Brightness Enhancement Film matte films to achieve good matte coating quality and optics and also other trim materials in transportation vehicles are coated with fluoroelastomers to achieve good optics; • Coating of insulation materials to lower their thermal conductivity resulting in better insulating properties; • Glass surface treatment with fluoroalkylsilanes for non-stick properties to achieve permanent water and stain repellence and thus improve the visibility for the vehicle operator in bad weather conditions; • High abrasion resistance in windshield wipers or brake pads.
HVACR-systems in transportation vehicles (see also F-Gases summary)	Heating, ventilation, air conditioning and refrigeration (HVACR)-systems. • Use of F-Gases in the various HVACR-systems in transport vehicles for passenger cabin air conditioning or transport refrigeration; • Special heat transfer fluids (e.g. Methoxyheptafluoropropanes) for the immersion-cooling/heating of electronic equipment; • Use as processing aids in the fluoropolymer production; • Use as cleaning fluids; • Use as blowing-agents.

Transportation - subgroup	Examples
Interiors	• Use of fluoroelastomers for the coating of trim materials of transportation vehicles to achieve stain protection and give surfaces a valuable feel and look; • Use in the treatment of textiles e.g. for seats, carpets, roof linings, to give the textiles water and dirt repellent properties (for the treatment of textiles usually side-chain fluorinated polymers are applied).
Health protection and lifesaving equipment	• airbags • seatbelts (?) • life jackets (?) • life raft
Other uses related to transportation	• Reflective and protective coatings for traffic signs / roads o Surface-treated pavement marking tapes and beaded retroreflective sheetings (used for driver and pedestrian safety); o ETFE Film is used as an anti-graffiti overlay for traffic signage; • Adhesive tape as paint replacements (e.g. for marking of aircrafts) product provides a chemical resistant surface for the aircraft, as well as reduces the aircraft's surface energy; • Flotation fluids in gyroscopes (mainly used in aircrafts ("artificial horizon") but also in trains (inclination sensors), and road vehicles (Navigation system and control systems); • Wheel weights: AFT (Acrylic Foam Tape; PFAS are used as stabilizing agent in production of tape) layer is used to affix the weight to the wheel surface. A fluoropolymer incorporated into in the weight provides weatherability and reduces the potential of the weight to corrode.

2. Main PFAS substances

Substance information in table 2 is based on information collected in the Call for Evidence (CfE), via stakeholder disclosure and via publicly available information.

Table 2: PFAS substance used in tranportation products and articles

Group/substance	EU market for transport (Tpa)	Source
Fluoroelastomers e.g. • PTFE • ETFE • PFPE • Perfluoroalkoxy alkane (PFA) • Fluoroethylene vinyl ether (FEVE)	Unknown	Information gathered by the dossier submitter
Perfluoropolymeric Sulfonyl Fluoride Ionomers	Unknown	Information gathered by the dossier submitter
Fluoroalkylsilanes	Unknown	Information gathered by the dossier submitter
F-Gases • R1234yf (Tetrafluorpropen) • R134a (Tetrafluorethan) • R-407C (blend of R-32 (difluoromethane), R-125 (pentafluoroethane), and 1,1,1,2-tetrafluoroethane)	Unknown	Stakeholder disclosure and publicly available information (e.g. web pages of HVACR-system manufacturers).
Methoxyheptafluoropropanes	Unknown	Information gathered by the dossier submitter
C6SFP	Unknown	Information gathered by the dossier submitter

3. Manufacturing & Market price + market development

No information on manufacturing or market development and very little information on market prices is available to the dossier submitters. It is reported that the production of fluorine containing materials usually is more expensive compared to most other materials (e.g. PE ≈1€/kg and PTFE ≈ 12.75 €/kg, information received from stakeholder).

4. Emissions

Limited information is available to the dossier submitter on the emission of PFAS from transport products and articles. The reported information for HVACR-systems is summarized in table 3. For more details please see the F-Gases summary report.

Table 3: Emission information for PFAS substances used in transportation products and articles

Subgroup	Emission information	Source
HVACR-systems in transportation vehicles (F-Gases)	9,000 t F-Gases to air#	Stakeholder information https://www.acea.be/statistics/tag/category/report-vehicles-in-use
HVACR-systems for transport refrigeration	495,8 t/a F-Gases to air##	Information gathered by the dossier submitter on F-Gases

Based on amounts of PFAS in HVACR-systems (ca. 0.6 kg/personal vehicle, ca. 1 kg / unit per truck and ca. 6 kg / unit per bus) and taking into account the total number of registered passenger cars (242,727,242), trucks (sum of light and heavy commercial vehicles: 34,340,233) and busses (692,207) in the EU (ACEA 2019) it can be assumed that a total amount of approx. 180,000 t of F-Gases are used in HVAC-systems for passenger comfort in road traffic. Assuming an emission of 5 % to air (ERC 9b Widespread use of functional fluid (outdoor), ECHA 2015), leads to an estimated total emission of 9,000 t/a of F-Gases from HVAC systems for passenger comfort in road traffic.

The amount of F-Gases used in refrigeration transport are estimated as follows: 1,010 t/a filled into newly manufactured products and 9,916 t in operating systems. Following the same assumption as for the HVACR-systems for passenger comfort a total emission of 495,8 t/a of F-Gases from transport refrigeration is assumed (considering only the amount from operating systems).

5. Exposure (workers, consumers)

Limited information is available to the dossier submitter on the PFAS concentrations and therefore also on the exposure to PFAS in transport products. The reported information on the concentration of PFAS substances or total amount used in road vehicles transportation products and articles is summarized in table 4.

Table 4: Information on the concentration of PFAS substances or total amount used in road vehicles transportation products and articles

Subgroup	PFAS concentration information / amount used	Source
Lubricants	• 0.1 – 0.2 g per component • Concentration of fluoroelastomer in greases: 1 – 15% • Concentration in lubricating fluids: 50 – 100%	Information gathered by the dossier submitter
HVACR-systems in transportation vehicles (F-Gases)	• Ca. 0.6 kg / personal vehicle • Ca 1 kg / Unit per truck • Ca 6 kg / Unit per bus Total use: 180,000 t F-Gases[#]	Stakeholder information https://www.acea.be/statistics/tag/category/report-vehicles-in-use
HVACR-systems for transport refrigeration	Total use: 10,926 t F-Gases[##]	Information gathered by the dossier submitter on F-Gases
Sealing applications	111,104 t Fluoroelastomers[#]	Feedback member states Stakeholder information https://www.acea.be/statistics/tag/category/report-vehicles-in-use

[#] Taking into account the total number of registered passenger cars (242,727,242), trucks (sum of light and heavy commercial vehicles: 34,340,233) and busses (692,207) in the EU (ACEA 2019). For, ships trains and aircrafts no information on the amounts of F-Gases/fluoroelastomers used for HVACR-systems of passenger cabins/sealing applications was provided during the CfE.

[##] The amount of F-Gases used in refrigeration transport are estimated as follows: 1,010 t/a filled into newly manufactured products and 9,916 t in operating systems.

6. Alternatives

The manufacturers of transportation vehicles usually do not prescribe the use of individual substances to their suppliers but rather stipulate performance requirements the individual parts have to meet. Performance requirements are laid down for example in industrial standards (e.g. DIN, EN, ISO), individual company standards, but may also be dictated by legal frameworks (e.g. Regulation (EU) 2018/858 or 2013/168). In an economically driven and competitive sector, such as the manufacture of transportation vehicles, suppliers are incited to provide the most cost effective solutions that still meet the performance requirements. Since the production of fluorine containing materials usually is more expensive compared to most other materials (e.g. PE ≈1€/kg and PTFE ≈ 12.75 €/kg, information received from stakeholder) it could be assumed that fluorinated materials are used only where performance requirements leave no other option.

Information on alternatives is virtually non-existent. Information on alternatives is only available for a few subgroups to the dossier submitter. The subgroups with reported description of use and reported alternatives are presented below. The reported alternatives are subsequently summarized in table 5.

6.1. Sealing applications

Description of the use of the restricted substances:
Fluoroelastomers are used in sealing applications due to the following properties:

- durability against lubricants, fuels, diesel, cooling agents and/or other fluids
- good performance over wide range of temperatures
- good sealing properties (avoidance of permeation, impermeability to gasses)

Function:

- protect from dust and aggressive chemicals (lubricants, fuels, diesel). Ensure functionality, reduce service intervals
- prevent leakage (Emission reduction)

6.2. Combustion engine system

Description of the use of the restricted substances:
In the core engine as well as in the exhaust system conditions regarding heat and pressure are extreme. Above that, petrol-based fuels and, partially also exhaust gases are aggressive and corrosive chemicals. So, the fuel system with storage tanks and fuel pipes as well as seals and valves have to be protected from destruction by fuels. PFAS containing materials are robust materials which are resistant against heat, pressure and corrosive chemicals. Further, these materials are much lighter than e.g. using metal-based materials. Therefore, these materials are used in large quantities in combustion engine systems. The main use of PFAS containing materials in combustion engines are in sealing and coating applications (see other sections in this summary report). Non-woven textiles are applied as cover in the engine bay area of many vehicles as acoustic insulation inside the vehicle engine compartment. They are treated with PFAS to achieve oil repellence and high temperature resistance i.e. make them non-flammable.

Alternatives:

- Lines and hoses: Alternative construction with Nylon fails to fulfil the emission requirements, and all-metal fuel lines did not meet crash test standards (information received from stakeholder).

6.3. Lubricants

Description of the use of the restricted substances:

- Reducing friction over a wide range of temperatures
- Offer extended lifetime performance in particular at elevated temperatures
- Combustion prevention at contact points
- Reduce or avoid the need for lubrication of the finished components
- Good material compatibility to elastomer, plastics

Alternatives:

- No information on alternatives regarding transportation applications was provided so far

6.4. Coating and finishings

Description of the use of the restricted substances:
Fluoroelastomers are used in coating applications in the transportation sector because of their good performance over a wide range of temperatures (anti crack resistance), abrasion resistance, fire resistance and resistance to aggressive chemicals. In some special coating applications fluoroelastomers are used due to their dielectric properties, low thermal conductivity, non-stick properties and UV-stability. As coating of cables in the Selective Catalytic Reduction (SCR) system for diesel engines (ad blue) or coating of diesel and gasoline particle filter hoses fluoroelastomers also function as part of the emission reduction systems.

Examples for coatings to achieve heat resistance, and resistance to aggressive chemicals are turbo charger hoses and coolant lines, engine coolant lines, or oil cooler lines. UV-stable coatings are used for example as paint protection for transportation vehicles for cosmetic and protective reasons e.g. FEVE is used as coating for car wrappings. Similarly, fluoroelastomer coatings are used as automobile Brightness Enhancement Film (BEF) matte films to achieve good matte coating quality and optics and also other trim materials in transportation vehicles are coated with fluoroelastomers to achieve good optics.

Insulation materials are coated with fluoroelastomers to lower their thermal conductivity resulting in better insulating properties. For non-stick properties glass surfaces are treated with fluoroalkylsilanes to achieve permanent water and stain repellence and thus improve the visibility for the vehicle operator in bad weather conditions. The fluoroalkylsilanes form a chemical bond with the glass surface while the perfluorinated alkylchain provides the water and stain repellence. An example for coatings to achieve high abrasion resistance are windshield wipers or brake pads. According to stakeholder information fluoroelastomers provide better brake efficiency and help absorb pressure compared to non-fluorinated brake pad coatings.

Alternatives:
There are some fluorine free materials available which can be used to achieve a protective coating

- Silicone based chemicals
- Sulfosuccinates
- Propylated aromatics
- Fatty alcohol polyglycol ether sulphates
- Alkyl acrylates
- Polyurethanes and -acrylics
    - A disadvantage is their higher layer thickness and that they can´t be used for applications with high temperatures because of cracking (information received from stakeholder).

6.5. HVAC-systems in transport vehicles (see also the summary report for F-Gases)

Description of the use of the restricted substances:
F-Gases are commonly used as heat-exchange media in HVAC-systems of transport vehicles due to their following properties:

- Good thermal capacity
- Wide range of operating temperatures
- Low-/Non-flammable
- Lower global warming potential (GWP) and toxicity than chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs)
- Zero ozone depletion
- Chemical inertness
- Non-corrosivity

For the immersion-cooling/heating of electronic equipment the dielectric properties of the heat exchange medium are of high relevance. For such applications special heat transfer fluids are used (e.g. Methoxyheptafluoropropanes).

<u>Alternatives</u>:
A discussion on the alternatives to F-Gases as heat transfer media is provided in the separate summary report on F-Gases. This includes also alternatives for vehicle air-conditioning, transport refrigeration and electronics cooling. Thus, only a brief overview over the available alternatives and possible advantages and disadvantages will be given here:

The following non-PFAS heat transfer agents are available for the uses described above:

- Air
- Water
- Ethylene glycol
- Mineral oils
- Silicone oils
- Alcohols
- Natural gases: HC-600 (n-butane), R-717 (Ammonia), R-744 (CO_2)

Non-PFAS heat transfer agents can have one of the following disadvantages (According to stakeholder information):

- Electrically conductive
- Create corrosion
- More energy necessary to reach low temperatures
- Flammable and/or explosive
- Higher levels of toxicity
- Higher global warming potential (GWP) levels
- Not thermally stable
- High working pressure
- Water reactive
- Require periodic replacement and need to be disposed of

However, there are also some advantages associated with the use of non-PFAS alternatives, especially regarding the use of “natural” alternatives i.e. air, water, CO_2 etc. They are widely available, cheap, have no or only a low GWP and are easier to handle during service and end of life. Modern HVAC-solutions with natural alternatives may even be more energy-efficient than the use of F-Gases. An air-cycle system for a train HVAC-system was reported to render up to 28 % of annual energy savings compared to R-134a systems (UBA, 2019). Another UBA report shows, that the use of R-744 instead of R134a can reduce the fuel consumption of a passenger car HVAC-system from 14-54 %, depending on the ambient temperature (UBA, 2009).

6.6. Interiors

Description of the use of the restricted substances:

- Car seat fabrics are treated with C6SFP to achieve stain protection.
- Fluoroelastomers are used for coated trim materials

Alternatives:

- For car seat treatment: see summary report of Textiles. In general protection from grease and oil cannot be achieved on the same level as provided by treatment with C6SFPs. Some alternatives provide good water protection.
- Fluoroelastomers are used for coated trim materials: there are no alternatives to fluoroelastomers that provide an equivalent level of performance. However, it is questionable if the high level of performance provided by fluoroelastomers is necessary for the coating of trim materials.

Table 5: reported alternatives for PFAS substances used in transportation products and articles

Sub use	Non PFAS alternative?	Function	Advantage / disadvantage
Combustion engine system (lines and hoses)	Nylon All-metal fuel lines		Nylon fails to fulfil the emission requirements All-metal fuel lines did not meet crash test standards (information received from stakeholder).
Coating and finishings	• Silicone based chemicals • Sulfosuccinates • Propylated aromatics • Fatty alcohol polyglycol ether sulphates • Alkyl acrylates • Polyurethanes and -acrylics	Protective coating	A disadvantage is their higher layer thickness and that they can´t be used for applications with high temperatures because of cracking (information received from stakeholder).

Sub use	Non PFAS alternative?	Function	Advantage / disadvantage
HVAC-systems in transport vehicles	• Air • Water • Ethylene glycol • Mineral oils • Silicone oils • Alcohols • Natural gases: HC-600 (n-butane), R-717 (Ammonia), R-744 (CO_2)	Heat transfer agent	Disadvantages: Non-PFAS heat transfer agents can have one of the following disadvantages (According to stakeholder information): • Electrically conductive • Create corrosion • More energy necessary to reach low temperatures • Flammable and/or explosive • Higher levels of toxicity • Higher global warming potential (GWP) levels • Not thermally stable • High working pressure • Water reactive • Require periodic replacement and need to be disposed of Advantages: • Air, water, CO_2 etc. are widely available, cheap, have non-low GWP and are easier to handle during service and end of life. • Modern HVAC-solutions with natural alternatives may even be more energy-efficient than the use of F-Gases.
Interiors		Stain protection	• General: protection from grease and oil cannot be achieved on the same level as provided by treatment with C6SFPs. Some alternatives provide good water protection. • Fluoroelastomers are used for coated trim materials: there are no alternatives to fluoroelastomers that provide an equivalent level of performance.

7. Economic impacts in case of a full PFAS ban

The economic impact assessment is still in the beginning stages. Information on use quantities is partly available for the automotive industry.

Table 6: Summary table on uses, tonnage, indicative trend and alternatives

Subuses (incomplete)	**Tonnages/y**	**Indicative trend (--/-/0/+/++)**	**Emission (tonnes PFAS)**	**Non PFAS alternative available?**
General	Numbers stated below only refer to road vehicles (cars, trucks, busses)	Unknown	Unknown	Yes, at least partly. <u>For coatings and finishings:</u> Silicone based chemicals Sulfosuccinates Propylated aromatics Fatty alcohol polyglycol ether sulphates Alkyl acrylates Polyurethanes and -acrylics <u>For HVAC systems:</u> Air, Water, -Ethylene glycol, Mineral Oils, Silicone Oils, Alcohols, naturals gases e.g. HC-600 (n-butane), R-717 (Ammonia), R-744 (CO2)
Body-, hull-, and fuselage construction	?			
SEALING APPLICATIONS	111,104			
Lubrication	?			
HYDRAULIC FLUIDS	?			
electrical engineering and information technology	?			
Coatings and finishing (Incl. Interiors and related applications e.g. coating of road signs)	?			
HVACR-Systems	184,130			
Health protection and lifesaving equipment (incl. fire prevention and firefighting)	?			

In general: research is still going on. There is quite some information on cars (and other road vehicles), much less on trains, ships and aircrafts

8. References

ECHA (2015): ECHA Guidance on Information Requirements and Chemical Safety Assessment Chapter R.12 Version 3.0.

UBA Hintergrundpapier (2009): Natural refrigerants – CO2-based air conditioning system put to practical testing. Retrieved from: https://www.umweltbundesamt.de/publikationen/natural-refrigerants-co2-based-air-conditioning

UBA (2019): UBA texte 120/2019 Environmentally friendly air conditioning for trains – Field data measurement and analysis on the ICE 3 air-cycle system.