Organisation for Economic Co-operation and Development

ENV/CBC/MONO(2023)22

Unclassified English - Or. English

9 January 2024

ENVIRONMENT DIRECTORATE
CHEMICALS AND BIOTECHNOLOGY COMMITTEE

Cancels & replaces the same document of 20 December 2023

Report on Per- and Polyfluoroalkyl Substances and Alternatives in Coatings, Paints and Varnishes (CPVs): Hazard Profile

Series on Risk Management
No. 80

JT03535483

OECD Environment, Health and Safety Publications
Series on Risk Management
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Report on Per- and Polyfluoroalkyl Substances and Alternatives in Coatings, Paints and Varnishes (CPVs): Hazard Profile

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INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS
A cooperative agreement among FAO, ILO, UNDP, UNEP, UNIDO, UNITAR, WHO, World Bank and OECD

Environment Directorate
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Paris 2023

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Acknowledgements: The report was prepared under the framework of the OECD/UNEP Global PFC Group who reviewed and input to the report. The report was also reviewed and endorsed by the Working Party on Risk Management and is published under the responsibility of the OECD Chemicals and Biotechnology Committee.

Executive Summary

As part of the collaborative work of the OECD/UNEP Global PFC Group, a report on "Per- and Polyfluoroalkyl Substances and Alternatives in Coatings, Paints and Varnishes (CPVs)" was published in 2022. It summarised the commercial availability and current uses of Per- and Polyfluoroalkyl Substances (PFASs) and non-fluorinated alternatives to PFASs in CPVs. Both fluoropolymers (FPs) and short-chain (SC) PFASs are used in coatings, paints and varnishes but they carry out different functions. Typically, FPs are added to CPVs to provide resistance to corrosion, weathering, abrasion and scratching, Ultraviolet (UV) and overall provide durability, while SC PFASs that are used generally act as levelling and wetting agents, have anti-blocking properties or confer oil and water repellence. The report highlighted that for the most closely examined uses in CPVs, non-fluorinated alternatives account for a large majority of market share. It is more cost-effective to use the non-fluorinated alternatives and therefore FPs and SC PFASs are typically used only where specific high- performance attributes are sought.

Given the technical suitability and high market penetration of the alternatives highlighted by the OECD (2022) report, it is important to also understand their hazard profiles. The likelihood of regrettable substitution could be high if the health and environmental hazards are not understood and communicated. This study aims to complement the 2022 report by compiling information on the hazard profile of the FPs, SC PFAS and non-fluorinated substances identified in terms of hazard classifications from authorities and industry and available assessments from authorities on persistence, bioaccumulation, environmental and health hazards. The main search for this study was conducted during January – July 2022, and the report was revised based on feedback from the stakeholders during January – March 2023.

This study demonstrates that the hazard profiles of many of the FPs, SC PFASs and non-fluorinated alternatives used in CPVs are not available. Out of the 45 substances identified in the OECD (2022) report and examined here, only nine substances have been classified by authorities and 30 by industry, while published assessments by authorities were available for just over half of the fluorinated substances and a significantly lower proportion of the non-fluorinated alternatives. No classifications or hazard assessments were identified for 15 substances.

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List of Abbreviations and Acronyms

BAuA	Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (German Federal Institute for Occupational Safety and Health)
CEPA	Canadian Environmental Protection Act, 1999
CLP	Classification, Labelling and Packaging (Regulation (EC) No 1272/2008)
CMR	Carcinogenic, Mutagenic or Reprotoxic
CoRAP	Community Rolling Action Plan
DSL	Canadian Domestic Substances List
ECCC	Environment and Climate Change Canada
ECHA	European Chemicals Agency
EEA	European Environment Agency
EFSA	European Food Safety Authority
EU	European Union
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
IARC	International Agency for Research on Cancer
IFA	Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance)
METI	Japanese Ministry of Economy, Trade and Industry
NICNAS	Australian National Industrial Chemicals Notification and Assessment Scheme
NITE	Japanese National Institute of Technology and Evaluation
OECD	Organisation for Economic Co-operation and Development

OSHA	US Occupational Safety and Health Administration
PBT	Persistent, Bioaccumulative and Toxic
PFASs	Per- and Polyfluoroalkyl Substances
PFC	Perfluorinated Chemicals
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation (EC) No 1907/2006)
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (Dutch National Institute for Public Health and the Environment)
RPA	Risk & Policy Analysts
SDS	Safety Data Sheet
UNEP	United Nations Environment Programme
USA	United States of America
US EPA	United States Environmental Protection Agency
US FDA	United States Food & Drug Administration

Chapter 1. Introduction

1.1. Background

In 2012, the OECD/UNEP Global Perfluorinated Chemicals (PFC) Group was established in response to the International Conference on Chemicals Management (Resolution II/5), which invited intergovernmental organisations, governments and other stakeholders to develop regulatory approaches to reduce the concentration and emissions of perfluorinated chemicals of concern in products, and to work toward global elimination where appropriate and technically feasible. The objectives of the Group are to facilitate the exchange of information on per- and polyfluoroalkyl substances (PFASs) and to support the global transition to safer alternatives.

As part of the collaborative work of the OECD/UNEP Global PFC Group, a report on "Per- and Polyfluoroalkyl Substances and Alternatives in Coatings, Paints and Varnishes (CPVs): Commercial availability and current uses" was published (OECD, 2022) and summarised the commercial availability and current uses of short-chain (SC) PFASs and non-fluorinated alternatives in CPVs. The report highlighted that, because of the cost-effectiveness of non-fluorinated alternatives, their market share is much higher than for Fluoropolymers (FP) and SC PFASs. FP and SC PFASs containing products are only chosen where performance requirements necessitate their use (e.g. fire safety) or for a specific market segment (e.g., touch screen coatings for upper end smart phone models).

Given the technical suitability and high market penetration of the alternatives highlighted by the OECD (2022) report, it is important to also understand their hazard profiles. The likelihood of regrettable substitution could be high if the health and environmental hazards are not understood and communicated. The aim of this study was to complement the 2022 report by compiling information on the hazard profile of the FPs, SC PFASs and non-fluorinated alternatives identified. To achieve this aim, this study focused on collecting information on the following aspects for each substance in Annex A:

- Task 1 – GHS[1] classifications, including:
  - Authority classifications (1st Tier)[2]
  - Non-authority/industry classifications (2nd Tier)

[1] GHS stands for Globally Harmonized System of Classification and Labelling of Chemicals. The GHS system addresses the classification of chemicals by separating them into types of hazard and proposes harmonised hazard communication elements, including labels and safety data sheets (SDS).

[2] Authority classifications refer to classifications made by the competent authorities responsible for enforcing GHS or its equivalent.

- Task 2 – Outcomes of persistence and bioaccumulation assessments published by authorities
- Task 3 – Outcomes of environmental and human health hazard assessments published by authorities.

1.2. Scope

The scope of the OECD (2022) report included FPs, SC PFASs and non-fluorinated alternatives used in CPVs. These chemical and material alternatives to long-chain PFASs are listed in Annex A.

Short-chain PFASs are distinguished from long-chain PFASs using the OECD's definition, which defines long-chain PFASs as:

- Perfluorocarboxylic acids (PFCAs) and their precursors with carbon chain lengths ≥ C7 (including perfluorooctanoic acid (PFOA)); and
- Perfluoroalkane sulfonic acids (PFSAs) and their precursors with carbon chain lengths ≥ C6 (including perfluorohexane sulfonic acid (PFHxS) and perfluorooctane sulfonate (PFOS)).

Short-chain PFASs[3] are defined as:

- PFCAs with carbon chain lengths < C7; and PFSAs with carbon chain lengths < C6.

The substances listed in Annex A were compiled in the OECD (2022) report with a focus on substances used for: Coatings (i.e., power coatings for architectural and chemical industry, radiation curable coatings for electronics, and other coatings for cable and wiring, anti-reflective coatings, anti-graffiti coatings and renewable energy), Paints (i.e., aerosol spray paints for automotive, architectural and chemical industry, and water/solvent-based paints), and Varnishes (i.e., floor and surface finishes/lacquers and stains for domestic, construction and printing use). PFOA and PFOS were also identified as having limited use in the 2022 report but are not included here due to their already widely recognised hazard profile, including international phase-out under the Stockholm Convention (see Stockholm Convention, n.d.).

In total, there are 27 fluorinated substances (16 of which have CAS numbers) and 18 non-fluorinated alternatives (nine of which have CAS numbers) within the scope of this study (see Annex A).

The scope of the Tier 1 classification search of Task 1 was limited to GHS classifications from countries with publicly available GHS classification databases. An example of an excluded country is the US, where GHS classifications are made by industry and the competent authority (US OSHA) does not maintain a database of classifications. However, the literature search for industry classifications was not limited in geographical scope. The scope of Tasks 2 and 3 included assessments published by authorities, but not assessments published in scientific journals. The literature review for Tasks 2 and 3 was limited to assessments published in the English language, however countries that are part of the Global PFC Group were requested to supplement

[3] It should be noted that the distinction of "long-chain" and "short-chain" PFASs based on chain length is only applicable to PFCAs, PFSAs and their precursors.

the desk review findings. As the focus of this study was on the collection of hazard properties, assessments reporting risk values, such as Tolerable Daily Intakes (TDIs), health advisory values, cancer risk values, were excluded.

1.3. Methodology

1.3.1. Task 1 – Identification and review of GHS classifications

The United Nations' Globally Harmonised System of Classification and Labelling of Chemicals (GHS) provides a basis for globally uniform information on physical, health, safety and environment aspects of hazardous chemical substances and mixtures. The first edition of GHS was published in 2003 and has been updated with a new edition every two years, in light of experience gained from its implementation. The ninth edition was published in 2021[4].

The GHS system addresses the classification of chemicals by separating them into types of hazard and proposes harmonised hazard communication elements, including labels and safety data sheets (SDS). Its purpose is to ensure that information on physical hazards and toxicity of chemicals is available during handling, transport and use to enhance the protection of human health and the environment. The GHS also provides a basis for harmonisation of rules and regulations on chemicals at national, regional, and global levels in order to assist in facilitating trade.

The identification of classifications was limited to authority classifications and industry classifications. For authority classifications, the intent was to identify where an authority had examined the available information and made a classification conclusion. In several countries, GHS implementation is the legal responsibility of industry, so available industry classifications were also included. Other potential sources of classifications were not considered within the scope of the report (e.g. from scientific literature or non-governmental organisations) as additional verification would be required.

Authority classifications

The collection of authority classifications (1st Tier GHS classifications) primarily involved reviewing the main national and regional legislation implementing GHS and searching their associated GHS classification inventories and databases. The search was limited to those countries and regions with publicly accessible classification inventories and databases. These are listed in Table 1.1 below.

[4] https://unece.org/ghs-rev9-2021

Table 1.1. Publicly available classification databases accessed for Task 1

Country / Region	Inventory / Database	Link
Australia	Hazardous Chemical Information System (HCIS)	http://hcis.safeworkaustralia.gov.au/HazardousChemical
Canada	Workplace Hazardous Materials Information System (WHMIS)	https://www.canada.ca/en/health-canada/services/environmental-workplace-health/occupational-health-safety/workplace-hazardous-materials-information-system/hazardous-substance-assessments.html
	Quebec Provincial Committee on Standards, Equity, Health and Safety at Work (Commission des normes, de l'équité, de la santé et de la sécurité du travail – CNESST)	https://reptox.cnesst.gouv.qc.ca/Pages/recherche-produit.aspx
China	NRCC National Internet Service Platform for Hazardous Chemicals	http://hxp.nrcc.com.cn/hc_safe_info_search.html
Chinese Taipei	GHS Classification Reference List	https://ghs.osha.gov.tw/CHT/intro/AnnounceData4Detail.aspx?id=282 (original source) Found also at: https://safety.nchu.edu.tw/web/tadnews.php?bar=6&Site_ID=17&title_id=&action=list&of_ncsn=12&ncsn=26&nsn=1049
European Union	Classification and Labelling (C&L) Inventory	https://echa.europa.eu/information-on-chemicals/cl-inventory-database
Japan	National Institute of Technology and Evaluation (NITE) classifications	https://www.nite.go.jp/chem/english/ghs/ghs_index.html
Malaysia	Chemical Information Management System (CIMS)	https://cims.dosh.gov.my/
New Zealand	Chemical Classification and Information Database (CCID)	https://www.epa.govt.nz/database-search/chemical-classification-and-information-database-ccid/
South Korea	National Chemicals Information System (NCIS)	https://ncis.nier.go.kr/en/main.do

In addition to the information sources in Table 1.1., the GESTIS Substance Database[5], the information system on hazardous substances of the German Social Accident Insurance, was searched. The GESTIS Substance Database contains information for the safe handling of hazardous substances and other chemical substances at work and is maintained by the Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA, Institute for Occupational Safety and Health of the German Social Accident Insurance).

Non-Authority / Industry Classifications

To identify industry classifications (2nd Tier GHS classifications), an internet search using Google was performed to identify published SDSs, from which GHS classification information was extracted. The search was performed using the CAS numbers of each substance listed in Annex A in combination with each of the following search strings: "*SDS*", "*safety data sheet*" and "*material safety data sheet*". For substances without CAS numbers, searches

[5] https://www.dguv.de/ifa/gestis/index-2.jsp

were performed using the substance name in combination with the above search strings. Industry classifications are presented when they differ from the authority classifications of the country/region in which the company resides, or when that authority classification was not available. Where multiple industry classifications were identified for a single country or region, these were amalgamated to present a worst-case classification. In addition to industry classifications obtained via SDS, the most frequently notified classifications under the EU CLP Regulation are provided. Locations vary, including Europe, North America and Asia but identification could have been limited by language as only searches in English were conducted.

Under the EU Classification, Labelling and Packaging (CLP) Regulation ((EC) No 1272/2008), manufacturers and importers who place any quantity of a hazardous substance (i.e. a substance meeting any of the physical, health and environmental hazards under GHS) on the market are obliged to notify the classification and labelling of the substance to ECHA. The notification obligation also applies to manufacturers and importers placing on the market a substance that is subject to registration under REACH (i.e. in quantities ≥ 1 tonne/year), regardless of whether the substance is hazardous or not. Notifications made by manufacturers and importers can differ for the same substance, due to different impurity profiles, interpretation differences in the process of evaluation of available data, or in the application of the classification rules for CLP. The CLP Regulation encourages agreement between notifications made by registrants and non-registrants. The most common notified classification has been reported for this Task, and in cases where there are two classifications with an equal number of notifications, both have been reported.

1.3.2. Task 2 – Review of Persistence and Bioaccumulation Assessments

To collect information on the persistence and bioaccumulation of the substances listed in Annex A, assessments published by national, regional, and international authorities were identified. Assessments published in scientific journals or by other third-parties were out of scope of this study. To identify published assessments, the websites and webpages of the authorities listed in Table 1.2 were reviewed and searched using the CAS numbers of each substance. Searches were conducted using CAS numbers as this identifier is unique to each substance, whereas substance names can be numerous and vary in spelling and structure across different regions. For substances with no CAS number, the substance name was used to perform the search.

Table 1.2. Authority websites and webpages accessed for Task 2

Organisation / Authority	Website / Webpage
Australian Industrial Chemicals Introduction Scheme (AICIS)	https://www.industrialchemicals.gov.au/chemical-information/search-assessments
Food Standards Australia New Zealand (FSANZ)	https://www.foodstandards.gov.au/code/Pages/default.aspx
Environment and Climate Change Canada (ECCC)	https://www.canada.ca/en/environment-climate-change.html
	https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/substances-list/domestic.html
	https://pollution-waste.canada.ca/substances-search/Substance?lang=en
European Chemicals Agency (ECHA)	https://echa.europa.eu/
ECHA PBT Assessment List	https://echa.europa.eu/pbt
European Food Safety Agency (EFSA)	https://www.efsa.europa.eu/
European Public Health Association (EUPHA)	https://eupha.org/
Japanese Ministry of Economy, Trade and Industry (METI)	https://www.meti.go.jp/english/
New Zealand Environmental Protection Administration (EPA)	https://www.epa.govt.nz/industry-areas/hazardous-substances/
US Environmental Protection Agency (US EPA)	https://www.epa.gov/
US Food & Drug Administration (US FDA)	https://www.fda.gov/
Stockholm Convention	http://www.pops.int/

In addition to the information sources in Table 1.2., the OECD's eChemPortal Database[6] was searched and an internet search using Google was performed using the CAS numbers, or substance names listed in Annex A in combination with each of the following search strings: "*assessment*", "*persistence assessment*" and "*bioaccumulation assessment*".

1.3.3. Task 3 – Review of Human Health and Environmental Hazard Assessments

To collect information on the human health and environmental hazards of the substances listed in Annex A, assessments published by national, regional, and international authorities were identified. Assessments published in scientific journals or by other third-parties were out of scope of this study as the aim was to identify authoritative assessment conclusions for these substances. To identify published assessments, the websites and webpages of the authorities listed in Table 1.3 were reviewed and searched using the CAS numbers of each substance. Searches were conducted using CAS numbers as this identifier is unique to each substance, whereas substance names can be numerous and vary in spelling and structure across different regions. For substances with no CAS number, the substance name was used to perform the search.

[6] https://www.echemportal.org/

Table 1.3. Authority websites and webpages accessed for Task 3

Organisation / Authority	Website / Webpage
Australian Industrial Chemicals Introduction Scheme (AICIS)	https://services.industrialchemicals.gov.au/search-assessments/
Food Standards Australia New Zealand (FSANZ)	https://www.foodstandards.gov.au/code/
Environment and Climate Change Canada (ECCC)	https://www.canada.ca/en/environment-climate-change.html
Canadian Environmental Protection Act (CEPA) – List of Substances	https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/substances-list.html
European Chemicals Agency (ECHA)	https://echa.europa.eu/
European Food Safety Agency (EFSA)	https://www.efsa.europa.eu/
European Public Health Association (EUPHA)	https://eupha.org/
Japanese Ministry of Economy, Trade and Industry (METI)	https://www.meti.go.jp/english/
New Zealand Environmental Protection Administration (EPA)	https://www.epa.govt.nz/industry-areas/hazardous-substances/
US Environmental Protection Agency (EPA)	https://www.epa.gov/
US Food & Drug Administration (US FDA)	https://www.fda.gov/
International Agency for Research on Cancer (IARC) Monographs	https://monographs.iarc.fr/
United Nations Environment Agency (UNEP)	https://www.unep.org/

In addition to the information sources in Table 1.3., the OECD's eChemPortal Database was searched and an internet search using Google was performed using the CAS numbers and substance names listed in Annex A in combination with each of the following search strings: "assessment", "hazard assessment", "health assessment" and "environment assessment".

Chapter 2. Report Findings

Annex C presents the available authority and industry GHS classifications of each substance listed in Annex A. Industry classifications are presented when they differ from the authority classifications of the country/region in which the company resides, or when that authority classification was not available. Where multiple industry classifications were identified for a single country or region, these were amalgamated to present a worst-case classification. In addition to industry classifications obtained via SDS, the most frequently notified classifications under the EU CLP Regulation are provided.

Annex C also presents the outcomes of published persistence and bioaccumulation assessments and human health and environmental hazard assessments conducted by authorities. The outcomes of published assessments are displayed for the individual endpoints included in each assessment.

2.1. Task 1 – Identification and review of GHS classifications

Classification information was available for 15 of the 27 fluorinated substances in scope of this project; both authority and industry classifications were available for five, while only industrial classifications were available for ten (see Annex B).

Classification information was available for 15 of the 18 non-fluorinated alternatives in scope of this project; both authority and industry classifications were available for four, while only industry classifications were available for 11 (see Annex B).

2.2. Task 2 – Review of Persistence and Bioaccumulation Assessments

Persistence and bioaccumulation assessments by authorities were available for 12 of the 27 fluorinated substances, and three of the 18 non-fluorinated alternatives (see Annex B). Of the 12 fluorinated substances for which data on persistence and bioaccumulation were available, nine were identified as being persistent or very persistent and two were identified as being bioaccumulative. Of the three non-fluorinated alternatives, two were identified as being persistent or very persistent; none of these three alternatives were identified as bioaccumulative.

2.3. Task 3 – Review of Human Health and Environmental Hazard Assessments

Human health hazard assessments by authorities were available for six of the 27 fluorinated substances, and for four of the 18 non-fluorinated alternatives. Environmental hazard assessments by authorities were available for 11 of the 27 fluorinated substances, and for three of the 18 non-fluorinated alternatives (see Annex B).

The human health and environmental hazard types identified in this study included:

- Acute toxicity;
- Sub-chronic and chronic toxicity;
- Corrosion / Irritation;
- Sensitisation;
- Repeated dose toxicity;
- Carcinogenicity;
- Genotoxicity;
- Reproductive and developmental toxicity;
- Aquatic toxicity; and
- Terrestrial toxicity.

For the majority of substances considered in this study for which human health hazard and environmental hazard data were available, there was generally a lack of adverse effects observed. However, the availability of information for each substance should be considered to draw any conclusions, particularly in light of the data-gaps and lack of assessment for many substances. Grouping approaches could also be applied.

Chapter 3. Data Gaps and Limitations

The findings of this study have demonstrated that the hazard profiles of the majority of FPs, SC PFASs and non-fluorinated alternatives used in CPVs are poorly understood and/or not publicly available. Only three out of the 45 substances are fully registered under REACH (34455-00-0; 55184-72-0; 577-11-7), and one component of a used mixture (CAS 375-73-5) noting that polymers are exempt from reporting under REACH. Outside of Europe, information may be more widely available to regulators in some of the countries as, for example, 18 out of the 45 substances are listed on the US TSCA Inventory.

Only nine substances have been classified by authorities and 30 by industry, while published assessments by authorities were available for less than half of the fluorinated substances and non-fluorinated alternatives. No classification or hazard assessments were identified for 15 substances (see Annex B and Table 3.1 below).

A study limitation was the lack of available CAS numbers for some substances. The literature searches were conducted primarily by CAS number as these are unique to each chemical substance, whereas there are inconsistencies in the preference, structure and spelling of chemical substance names across different regions. Of the 45 substances included in the scope of this study, 19 did not have a CAS number available. However, substance names were used as search terms where CAS numbers were not available, so it is not expected that a substantial amount of critical information was missed.

It is also uncertain whether there is classification information held by industry that is not publicly accessible. In addition, due to the scope of the study, the general scientific literature was not considered.

Despite the limitations of this study, the findings are considered to accurately represent the level of currently available evidence on the hazard profile of SC PFAS, FPs and non-fluorinated alternatives obtainable from authority or industry classifications or from assessments by authorities.

Table 3.1. Level of data availability for each substance

		Authority Classifications	Industry Classifications	Human Health Hazard Assessments	Environmental Hazard Assessments	Persistence & Bioaccumulation Assessments
Fluorinated substances	Data available	5	15	6	11	12
	Data unavailable	22	12	21	16	15
Non-fluorinated alternatives	Data available	4	15	4	3	3
	Data unavailable	14	3	14	15	15
Total	Data available	**9**	**30**	**10**	**15**	**15**
	Data unavailable	**36**	**15**	**35**	**31**	**30**

Chapter 4. Conclusions and Recommendations

This study examined the availability of classifications and assessment by authorities of the persistence, bioaccumulation and human health and environment hazards posed by 45 FPs, SC PFASs and non-fluorinated alternatives in coatings, paints and varnishes. Based on the data available, in general, the human health hazard data for the substances included in this study show a lack of adverse effects, and the same is true for aquatic and terrestrial toxicity. However, there are potential human health and environmental risks for certain substances, and in many cases current evidence is insufficient or too inconsistent to draw solid conclusions. Therefore, each substance should be considered within the context of data availability and data concordance. Grouping approaches could also be applied. The major concern surrounding fluorinated substances is persistence, as the majority of the fluorinated substances that have been assessed for persistence, are considered to be persistent or very persistent. This is not unexpected given the persistent nature of fluorinated substances.

This study identified no classification or authoritative hazard assessments of any kind for 15 substances. Therefore, significant data gaps exist in terms of classification and assessment. As this study only focused on where a classification conclusion or authoritative hazard assessment had been conducted, it is uncertain as to the level and nature of the individual studies available on these substances in the public domain and how much unpublished information is in the private domain. However, further assessment of the potential health and environmental effects is required, given the lack of classification/assessment highlighted by this study. As already recommended by the OECD (2022), any scientifically robust information on intentionally used fluorinated substances and non-fluorinated PFAS alternatives in CPVs should be shared publicly. In order to support the shift towards safer substitutes, the elaboration of classification conclusions and assessment of the available persistence, bioaccumulation and hazard information on alternatives and their dissemination is needed. When authorities elaborate these, they can be shared with other stakeholders, industry and authorities in order to reduce duplication of work and to leverage the analysis that has been conducted. Guidance is available from the OECD on Key Considerations for the Identification and Selection of Safer Chemical Alternatives (OECD, 2021). Screening approaches could also be employed using high-throughput methods and in vitro models. These could be paired with grouping approaches to create efficiencies in the generation of information to support assessment.

The report on “Per- and Polyfluoroalkyl Substances and Alternatives in Coatings, Paints and Varnishes (CPVs)” (OECD, 2022) identified that non-fluorinated alternatives cover more than 90% of market share for almost all industrial sectors. As chemicals used in CPVs come into direct contacts with a

large number of consumers, improving the understanding PFAS alternatives should be a priority.

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Annex A. Table of Fluorinated and Non-Fluorinated Substances Used in Coatings, Paints and Varnishes

These tables of fluorinated substances and non-fluorinated alternatives were compiled in the OECD report on Per- and Polyfluoroalkyl Substances and Alternatives in Coatings, Paints and Varnishes (CPVs) - Report on the Commercial Availability and Current Uses (2021) with the deletion of common long-chain PFASs (PFOA and PFOS).

Fluorinated Substances (SC PFAS and FPs)

Substance Name	CAS Number
C4-fluorinated polyether	No CAS provided
C4-fluorinated polyethers (Such as methyl nonafluorobutyl ether) - 163702-07-6	Example CAS 163702-07-6
C4-fluorinated polyethers (Such as methyl nonafluoroisobutyl ether) - 163702-08-7	Example CAS 163702-08-7
ECTFE	25101-45-5
ETFE	68258-85-5
FEP	25067-11-2
FEVE (Fluoroethylene vinyl ether)	146915-43-7
Fluorinated acrylic or methacrylic acid esters	No CAS provided
Fluorinated hydrocarbons	No CAS provided
Fluorinated polyether	No CAS provided
Fluoroalkane sulfonic acids	No CAS provided
Fluorotelomer (Such as partially fluorinated alcohol-substituted glycol substances)	No CAS provided
Formulation of fluoro sulphonamides including PBSF and 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-bis(2-hydroxyethyl)butane-1-sulfonamide - 30334-69-1	30334-69-1
Formulation of fluoro sulphonamides including PBSF and 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-bis(2-hydroxyethyl)butane-1-sulfonamide	34455-00-0
PBSF (perfluorobutane sulfonyl fluoride)	No CAS provided (Suggested CAS: 375-72-4)
Perfluoropolyether (PFPE) blend (with polyurethane)	76415-97-9
Perfluoropoly-ether and polyurethane blend	No CAS provided
PFA	No CAS provided
PFBS based fluorosurfactants or additives	Example CAS 1017237-78-3
PTFE	9002-84-0
PVDF	24937-79-9
Salts of fluorinated carboxylic acids	No CAS provided
Short-chain PFAS C2 (ETHENE, CHLOROTRIFLUORO-, POLYMER WITH 1,1-DIFLUOR)	9010-75-7
Short-chain PFAS C6: Hexanoic acid, 2,2,3,3,4,4,5,6,6-undecafluoro-	307-24-4
Short-chain PFAS mixtures (with silicone)	No CAS provided
Short-chain PFAS mixtures with silicones. (For example, silane, siloxane and PFAS < C8 (1-butanesulfonic acid, 1,1,2,2,3,3,4,4,4-nonafluoro-))	Example CAS 375-73-5 for PFAS portion
Short-chain polymeric fluoroalkyl acid ester	661476-43-3

Non-fluorinated Alternatives

Substance Name	Synonyms	Cas Number
Chlorinated polyethylene		No CAS provided
Chlorosulfonated polyethylene		No CAS provided
Epoxy (Bisphenol A-epichlorohydrin copolymer acrylate)		90598-46-2
Ethylene-propylene rubber		No CAS provided
Neoprene		No CAS provided
Nylon		No CAS provided
Polyester		113669-97-9
Polyethylene		No CAS provided
Polymethylmethacrylate powder		9011-14-7
Polyolefin		No CAS provided
Polysiloxane		63148-53-8
Polyurethane		9009-54-5
PVC		9002-86-2
Silica based		No CAS provided
Silicone polymers (made of silanes and siloxanes) (For example, non-ionic modified silicone polyether and a mixture of a silicone polyether and a diocylsulfosuccinate in ethanol and water)		Example: 67674-67-3 (10-15%) and dioctylsulfosuccinate (50-55%)
Sulfosuccinates	Sodium diisotridecyl sulfosuccinate	55184-72-0
Sulfosuccinates (Sulfosuccinate mixed with water and 2,2 dimethylpropane-1,3-diol)		577-11-7
Thermoplastic elastomer		No CAS provided

Annex B. Data Availability of Fluorinated Substances and Non-Fluorinated Alternatives

Fluorinated Substances (Short-Chain PFAS and Fluoropolymers)

Substance Name (from Annex A)	CAS Number	Authority Classifications	Industry Classifications	HH Hazard Assessments	Environmental Hazard Assessments	Persistence & Bioaccumulation Assessments
C4-fluorinated polyether	No CAS provided					
C4-fluorinated polyethers (Such as methyl nonafluorobutyl ether) - 163702-07-6	Example CAS 163702-07-6					
C4-fluorinated polyethers (Such as methyl nonafluoroisobutyl ether) - 163702-08-7	Example CAS 163702-08-7					
ECTFE	25101-45-5					
ETFE	68258-85-5					
FEP	25067-11-2					
FEVE (Fluoroethylene vinyl ether)	146915-43-7					
Fluorinated acrylic or methacrylic acid esters	No CAS provided					
Fluorinated hydrocarbons	No CAS provided					
Fluorinated polyether	No CAS provided					
Fluoroalkane sulfonic acids	No CAS provided					
Fluorotelomer (Such as partially fluorinated alcohol-substituted glycol substances)	No CAS provided					
Formulation of fluoro sulphonamides including PBSF and 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-bis(2-hydroxyethyl)butane-1-sulfonamide - 30334-69-1	30334-69-1					
Formulation of fluoro sulphonamides including PBSF and 1,1,2,2,3,3,4,4,4-	34455-00-0					

Substance Name (from Annex A)	CAS Number	Authority Classifications	Industry Classifications	HH Hazard Assessments	Environmental Hazard Assessments	Persistence & Bioaccumulation Assessments
nonafluoro-N,N-bis(2-hydroxyethyl)butane-1-sulfonamide						
PBSF (perfluorobutane sulfonyl fluoride)	No CAS provided (Suggested CAS: 375-72-4)					
Perfluoropolyether (PFPE) blend (with polyurethane)	76415-97-9					
Perfluoropoly-ether and polyurethane blend	No CAS provided					
PFA	No CAS provided					
PFBS based fluorosurfactants or additives	Example CAS 1017237-78-3					
PTFE	9002-84-0					
PVDF	24937-79-9					
Salts of fluorinated carboxylic acids	No CAS provided					
Short-chain PFAS C2 (ETHENE, CHLOROTRIFLUORO-, POLYMER WITH 1,1-DIFLUOR)	9010-75-7					
Short-chain PFAS C6: Hexanoic acid, 2,2,3,3,4,4,5,6,6-undecafluoro-	307-24-4					
Short-chain PFAS mixtures (with silicone)	No CAS provided					
Short-chain PFAS mixtures with silicones. (For example, silane, siloxane and PFAS < C8 (1-butanesulfonic acid, 1,1,2,2,3,3,4,4,4-nonafluoro-))	Example CAS 375-73-5 for PFAS portion					
Short-chain polymeric fluoroalkyl acid ester	661476-43-3					

Note: Yellow shading indicates no data identified and blue shading represents where data was identified

Non-fluorinated Alternatives

Substance Name (from Appendix 1 of CPV report)	CAS Number	Authority Classifications	Industry Classifications	HH Hazard Assessments	Environmental Hazard Assessments	Persistence & Bioaccumulation Assessments
Chlorinated polyethylene	No CAS provided					
Chlorosulfonated polyethylene	No CAS provided					
Epoxy	90598-46-2					
Ethylene-propylene rubber	No CAS provided					
Neoprene	No CAS provided					
Nylon	No CAS provided					
Polyester	113669-97-9					
Polyethylene	No CAS provided					
Polymethylmethacrylate powder	9011-14-7					
Polyolefin	No CAS provided					
Polysiloxane	63148-53-8					
Polyurethane	9009-54-5					
PVC	9002-86-2					
Silica based	No CAS provided					
Silicone polymers (made of silanes and siloxanes) (For example, non-ionic modified silicone polyether and a mixture of a silicone polyether and a diocylsulfosuccinate in ethanol and water)	Example 67674-67-3 (10-15%) and dioctylsulfosuccinate (50-55%)					
Sulfosuccinates	55184-72-0					
Sulfosuccinates (Sulfosuccinate mixed with water and 2,2 dimethylpropane-1,3-diol)	577-11-7					
Thermoplastic elastomer	No CAS provided					

Note: Yellow shading indicates no data identified and blue shading represents where data was identified

Annex C. Hazard Classifications and Assessments of Fluorinated and Non-Fluorinated Substances Used in Coatings, Paints and Varnishes

This annex contains the findings of Tasks 1, 2 and 3.

Short-chain PFAS C2 (ETHENE, CHLOROTRIFLUORO-, POLYMER WITH 1,1-DIFLUOR): CAS 9010-75-7

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	USA
Notified Not Classified	"Not classified."	"Not classified."

Source: 3M (2020); Electron Microscopy Sciences (2021); GuideChem (2017); HaloPolymer (2016)

Human Health Hazard Assessments
None found

Environmental Hazard Assessments

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Aquatic Toxicity	Ethene, chlorotrifluoro-, polymer with 1,1-difluoroethene is not inherently toxic to aquatic organisms.

Persistence and Bioaccumulation Assessments

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Persistent	Ethene, chlorotrifluoro-, polymer with 1,1-difluoroethene is persistent.
	Bioaccumulation	Ethene, chlorotrifluoro-, polymer with 1,1-difluoroethene is not bioaccumulative.

PFBS based fluorosurfactants or additives: Example CAS 1017237-78-3

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	USA
Notified Aquatic Chronic 2	Aquatic Chronic 1	Skin Sens. 1B

Source: Carpro (2017); Klein and Company (2015); Tiflex (2011)

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.

Short-chain PFAS mixtures with silicones. (For example, silane, siloxane and PFAS < C8 (1-butanesulfonic acid, 1,1,2,2,3,3,4,4,4-nonafluoro-)): Example CAS 375-73-5 for PFAS portion. The data below was identified for this component.

Authority Classifications

Australia
Eye Irrit. 2A

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	USA	Japan
Registered Met. Corr. 1 Skin Corr. 1 Eye Damage 1	Acute Tox. 4 (Oral) Skin Corr. 1B Eye Dam. 1	Acute Tox. 4 (Oral) Skin Corr. 1B Eye Dam. 1 **Or** Acute Tox. 4 (Oral) Eye Dam. 1 Met. Corr. 1 Skin Corr. 1C **Or** Acute Tox. 4 (Oral) Skin Corr. 1B Eye Dam. 1 STOT SE 3	Acute Tox. 4 (Oral) Skin Corr. 1B Eye Dam. 1

Source: Santa Cruz Biotechnology (2018c); Sigma Aldrich (2018b); Sigma Aldrich (2021a); SynQuest (2017); TCI (2016a)

Human Health Hazard Assessments

Publications	Hazard Assessed	Conclusions on Human Health Effects
NICNAS (2019)	Acute Toxicity	Based on the data available for potassium PFBS and KPBS (direct precursors of PFBS), PFBS has low toxicity following oral and dermal exposure. Inhalation effects were observed at relatively high doses and classification is; therefore, not considered warranted.
	Corrosion/Irritation	PFBS is classified as hazardous with the risk phrase 'Causes serious eye irritation' - Cat. 2A (H319) in HSIS (Safe work Australia).
	Sensitisation	PFBS is not considered as skin sensitiser.
	Repeated Dose Toxicity	PFBS is not considered to cause serious systemic effects from repeated oral exposure and serious damage to health from repeated inhalation exposure.
	Genotoxicity	Based on the results from negative in vitro genotoxicity studies, PFBS is not considered to be genotoxic.
	Reproductive and Developmental Toxicity	Based on the available data on potassium PFBS (direct precursor of PFBS), PFBS is not considered to cause reproductive or developmental toxicity.
US EPA (2021)	Thyroid effects	The available evidence supports a hazard and the thyroid is considered a potential target organ for PFBS toxicity in humans.
	Developmental effects and reproductive effects	The available evidence supports a development hazard, and the developing offspring is considered a potential target for PFBS toxicity in humans. The available evidence for reproductive effects is equivocal.
	Renal effects	The available evidence supports a hazard and indicates the kidney as a target organ of PFBS toxicity.
	Hepatic effects	The available evidence for hepatic effects is equivocal.
	Effects on lipid or lipoprotein homeostasis	The available evidence for effects on lipid or lipoprotein homeostasis is equivocal.
	Immune effects	The available evidence for immune effects is equivocal.
	Cardiovascular effects	The available evidence for cardiovascular effects is equivocal.
EFSA (2020)	Repeated Dose Toxicity	An elevated absolute and relative liver weight was the most sensitive endpoint for PFBS.
	Reproductive Toxicity	Reproductive toxicity was not reported in rats exposed to PFBS up to 1000 mg/kg bw per 3445 day. Delay in development and decrease in body weight gain were seen in mice exposed during 3446 gestation, with a NOAEL of 50 mg/kg bw per day (74 ng/mL serum in the dam at GD 20).
	Genotoxicity	PFBS mutagenicity was judged to be equivocal 3930 in S. typhimirium TA 98, but negative in TA 100 and E. coli WP2 uvrA/pKM101 (NTP, 2019b). A significant decrease in 3934 polychromatic erythrocytes was seen in the peripheral blood of both sexes (NTP, 2019b).
ATSDR (2021)	Respiratory	Oral exposure studies in laboratory animals have not found consistent evidence of histological alterations for PFBS
	Cardiovascular	The laboratory animal studies did not find increases in the incidence of histological alterations in the heart following exposure to PFBS.
	Gastrointestinal	Studies on PFBS have reported some signs of gastrointestinal irritation following gavage administration.
	Hematological	Some laboratory animal studies have reported alterations in hematological indices following exposure to higher doses of PFBS.
	Hepatic effects	Evidence from acute, intermediate, and/or chronic oral studies in rats, mice and monkeys indicates that liver is a sensitive target for PFBS toxicity. The effects include increases in liver weight, hepatocellular hypertrophy, and decreases in serum lipid levels. These effects were considered specific to rodents and were not considered relevant to humans.

	Renal	Laboratory animal studies have not found evidence of impaired renal function or morphological damage following exposure to PFBS.
	Ocular	Ocular effects have not been found following oral exposure to PFBS.
	Reproductive effect	Epidemiological studies provide mixed evidence of impaired fertility (increased risks of longer time to pregnancy and infertility); there is also some evidence for PFBS but the results are not consistent across studies or were only based on a single study. Multigeneration studies on PFBS have not found alterations in reproductive parameters in animals. Studies on PFBS have not found histological alterations.

Environmental Hazard Assessments

Publications	Hazard Assessed	Conclusions on Environmental Effects
NICNAS (2015)	Aquatic Toxicity	PFBS is not expected to have high toxicity to aquatic organisms.
	Terrestrial Toxicity	PFBS is not expected to have high toxicity to birds.

Persistence and Bioaccumulation Assessments

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation
ECHA	Persistence	Short-chain PFAS mixtures with silicones. (For example, silane, siloxane and PFAS < C8 (1-butanesulfonic acid, 1,1,2,2,3,3,4,4,4-nonafluoro-)) is currently undergoing assessment via Public Activities Coordination Tool (PACT) as suspected PBT.
	Bioaccumulation	Short-chain PFAS mixtures with silicones. (For example, silane, siloxane and PFAS < C8 (1-butanesulfonic acid, 1,1,2,2,3,3,4,4,4-nonafluoro-)) is currently undergoing assessment via Public Activities Coordination Tool (PACT) as suspected PBT.
NICNAS (2015)	Persistence	PFBS is persistent.
	Bioaccumulation	PFBS is not bioaccumulative.

C4-fluorinated polyethers (Such as methyl nonafluorobutyl ether): Example CAS 163702-07-6

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	USA
Notified Not Classified	"Not hazardous"	"Not classifiable" **Or** Skin Irrit. 2 Eye Irrit. 2A STOT SE 3

Source: 3M (2012); Sigma Aldrich (2020); Spectrum (2020a); SynQuest (2012); TCI (2014)

Human Health Hazard Assessments

Publications	Hazard Assessed	Conclusions on Human Health Effects
NICNAS (2019a)	Acute Toxicity	The substance is considered to have low acute toxicity following oral and dermal exposure. Acute inhalation toxicity is very low in rats.
	Corrosion/Irritation	Skin irritation studies conducted with the chemical did not provide evidence of skin irritation effects. The chemical produced negative results for eye irritation effects.
	Sensitisation	The substance is not considered as a skin sensitiser.
	Repeated Dose Toxicity	Repeated inhalation exposure to chemicals from this group did not elicit any serious toxicological effects.
	Genotoxicity	The substance is not mutagenic.
	Reproductive and Developmental Toxicity	The substance did not show any effects on reproductive or developmental parameters.

Environmental Hazard Assessments

Publications	Hazard Assessed	Conclusions on Environmental Effects

NICNAS (2019b)	Aquatic Toxicity	The substance is expected to degrade in the environment into one or more of the short-chain PFCAs. Currently available data indicate that short chain PFCAs are not expected to be toxic to aquatic organisms.

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation
NICNAS (2019b)	Persistence	The substance is expected to degrade in the environment into one or more of the short-chain PFCAs including perfluorohexanoic acid (PFHxA), perfluoropentanoic acid (PFPeA), and perfluorobutanoic acid (PFBA). The potential degradants PFHxA, PFPeA and PFBA and their direct precursors have been categorised as Persistent.
	Bioaccumulation	The substance is expected to degrade in the environment into one or more of the short-chain PFCAs including perfluorohexanoic acid (PFHxA), perfluoropentanoic acid (PFPeA), and perfluorobutanoic acid (PFBA). The potential degradants PFHxA, PFPeA and PFBA and their direct precursors have been categorised as not bioaccumulative.

Persistence and Bioaccumulation Assessments

C4-fluorinated polyethers (Such as methyl nonafluoroisobutyl ether: Example CAS 163702-08-7

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	UK
Registered Not Classified ***Notified*** Not Classified	"not classified"

Source: 3M (2012); SynQuest (2016)

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation Effects
METI (2011)	Bioaccumulation	Mixture of 1,1,1,2,2,3,3,4,4-nonafluoro-4-methoxybutane and 1-methoxy-2-(trifluoromethyl)-1,1,2,3,3,3-hexafluoropropane, which consist of 1-methoxy-2-(trifluoromethyl)-1,1,2,3,3,3-hexafluoropropane as a major component is not readily biodegradable and has low bioconcentration (BFC=144).

Persistence and Bioaccumulation Assessments

ECTFE: CAS 25101-45-5

Authority Classifications
None found.

Industry Classifications (SDS)

USA
Not classified

Source: Saint Gobain Performance Plastics (2014)

Human Health Hazard Assessments
None found.

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Aquatic Toxicity	Ethene, chlorotrifluoro-, polymer with ethane is not inherently toxic to aquatic organisms.

Environmental Hazard Assessments

Persistence and Bioaccumulation Assessments

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation
ECCC (2006)	Persistence	Ethene, chlorotrifluoro-, polymer with ethane is persistent
	Bioaccumulation	Ethene, chlorotrifluoro-, polymer with ethane is not bioaccumulative

FEP: CAS 25067-11-2

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	USA
Notified Not Classified	not classified	not classified

Source: 3M (2018); Bohlender (2016); Fibre Glast (n.d.)

Human Health Hazard Assessments
None found.

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Aquatic toxicity	It is uncertain if 1-Propene, 1,1,2,3,3,3-hexafluoro-, polymer with tetrafluoroethene is inherently toxic to aquatic organisms.

Environmental Hazard Assessments

Persistence and Bioaccumulation Assessments

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation Effects
ECCC (2006)	Persistence	1-Propene, 1,1,2,3,3,3-hexafluoro-, polymer with tetrafluoroethene is persistent.
	Bioaccumulation	It is uncertain if 1-Propene, 1,1,2,3,3,3-hexafluoro-, polymer with tetrafluoroethene is bioaccumulative.

FEVE (Fluoroethylene vinyl ether): CAS 146915-43-7

Authority Classifications
None found.

Industry Classifications (SDS)
None found.

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.

Formulation of fluoro sulphonamides including PBSF and 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-bis(2-hydroxyethyl)butane-1-sulfonamide: CAS 30334-69-1

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	USA	UK
Notified Acute Tox. 4 Skin Irrit. 2 Eye Irrit. 2 Acute Tox. 4 STOT SE 3	Skin Irrit. 2 Eye Irrit. 2A STOT SE 3	STOT SE 3 Eye Irrit. 2 Skin Irrit. 2

Source: Apollo Scientific (2017); SynQuest (2016a)

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.

PVDF: CAS 24937-79-9

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (Industry SDS)	USA	Japan
not classified	not classified	not classified

Source: Polysciences (2021); Roth (2015); Santa Cruz Biotechnology (2018d); Sigma Aldrich (2018c; 2022a); Thermo Fisher Scientific (2018)

Human Health Hazard Assessments
None found.

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Aquatic toxicity	Ethene, 1,1-difluoro-, homopolymer is not inherently toxic to aquatic organisms.

Environmental Hazard Assessments

Persistence and Bioaccumulation Assessments

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation Effects
ECCC (2006)	Persistence	Ethene, 1,1-difluoro-, homopolymer is persistent.
	Bioaccumulation	Ethene, 1,1-difluoro-, homopolymer is not bioaccumulative.

Short-chain PFAS C6: Hexanoic acid, 2,2,3,3,4,4,5,6,6-undecafluoro-: CAS 307-24-4

Authority Classifications

Australia
Eye Dam. 1 Repr. 2

Industry Classifications (SDS)

European Union (Industry SDS)	Canada	UK
Skin Corr. 1B Eye Dam. 1	Skin Corr. 1B Eye Dam. 1	Skin Corr. 1B

Source: Apollo Scientific (2016); Sigma Aldrich (2006); TCI (2014a); Toronto Research chemicals (2018)

Human Health Hazard Assessments

Publications	Hazard Assessed	Conclusions on Human Health Effects
NICNAS (2016)	Acute Toxicity	PFHxA is expected to have low to moderate acute toxicity following oral exposure.
	Sensitation	No data is available for skin sensitation. However, based on data for the analogues, PFOA and its ammonium salts, the substance is not considered as a skin sensitiser.
	Repeated Dose Toxicity	Based on the treatment-related effects reported in various repeated dose toxicity studies, repeated oral exposure to PFHxA is not considered to cause serious damage to health.
	Genotoxicity	Based on the weight of evidence from the available data, PFHxA is not considered to be genotoxic.
	Carcinogenicity	There was no evidence of carcinogenicity associated with PFHxA treatment in rats.
	Reproductive and Developmental Toxicity	Foetotoxic effects were observed with PFHxA at relatively high doses (175 mg/kg bw) compared with 5 mg/kg bw/day for PFOA
EFSA (2020)	Repeated dose toxicity	The most consistent and most sensitive endpoint was the increased relative liver weight, especially in male rodents.
	Developmental toxicity	In a 28-days study in male rats orally treated with PFHxA at doses from 62.6 to 1000 mg/kg bw per day did not show significant effects on

		sperm count per g cauda epididymis or serum testosterone, but a slight (5%) decrease in epidydimal weight was reported for the highest dose.
	Genotoxicity	PFHxA did not induce mutations in bacteria.
	Long-term toxicity and Carcinogenicity	There is a long-term study for PFHxA, providing no evidence for any carcinogenicity of this PFAS.
	Metabolic outcomes	There were no associations between total cholesterol and PFHxA.
US EPA (2022)	Hepatic effects	The currently available evidence indicates that PFHxA likely causes hepatic effects in humans under relevant exposure circumstances.
	Developmental effects	The currently available evidence indicates that PFHxA likely causes developmental effects in humans under relevant exposure circumstances.
	Renal effects	The currently available evidence is inadequate to assess whether PFHxA may causes renal effects in humans under relevant exposure circumstances
	Hematopoietic effects	The currently available evidence indicates that PFHxA likely causes hematopoietic effects in humans under relevant exposure circumstances.
	Endocrine effects	The currently available evidence suggests, but is not sufficient to infer, that PFHxA could cause endocrine effects in humans under relevant exposure circumstances.
	Reproductive effects	The currently available evidence is inadequate to assess whether PFHxA might cause male and female reproductive effects in humans under relevant exposure circumstances.
	Immune system effects	The currently available evidence is inadequate to determine whether PFHxA exposure might cause immune system effects in humans under relevant exposure conditions
	Nervous system effects	The currently available evidence is inadequate to assess whether PFHxA might cause nervous system effects in humans under relevant exposure circumstances.
	Carcinogenicity	The evidence is insufficient to make a judgement on whether PFHxA exposure might affect the development of any specific cancers.
ATSDR (2021)	Respiratory	An oral study with PFHxA reported nasal lesions in rats, however, a second study did not find these effects at higher doses.
	Gastrointestinal	Most studies did not report histological alterations in the gastrointestinal tract following exposure to PFHxA.
	Hematological	Some laboratory animal studies have reported alterations in hematological indices following exposure to higher doses of PFHxA.
	Ocular	Ocular effects have not been found following oral exposure to PFHxA.
	Immunological	The small number of studies investigating immunotoxicity following exposure to PFHxA did not find associations.

Environmental Hazard Assessments

Publications	Hazard Assessed	Conclusions on Environmental Effects
NICNAS (2015a)	Aquatic toxicity	PFHxA is not expected to have high toxicity to aquatic life.
	Terrestrial toxicity	PFHxA can cause developmental toxicity in some terrestrial organisms at moderate concentrations.

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation Effects
ECHA	Persistence	Short-chain PFAS C6: Hexanoic acid, 2,2,3,3,4,4,5,6,6-undecafluoro- is currently undergoing assessment via Public Activities Coordination Tool (PACT) suspected as PBT.
	Bioaccumulation	Short-chain PFAS C6: Hexanoic acid, 2,2,3,3,4,4,5,6,6-undecafluoro- is currently undergoing assessment via Public Activities Coordination Tool (PACT) suspected as PBT.
NICNAS (2015a)	Persistence	PFHxA is categorised as persistence.
	Bioaccumulation	PFHxA is catagorised as not bioaccumulative.
Stockholm Convention (2012)	Persistence	Perfluorohexanoate (PFHxA) is persistent and is the potential degradation product from short chain (C_6) fluorotelomer-based surfactants.
	Bioaccumulation	PFHxA does not bioconcentrate, bioaccumulate or biomagnify.

Persistence and Bioaccumulation Assessments

Formulation of fluoro sulphonamides including PBSF and 1,1,2,2,3,3,4,4,4-nonafluoro-N,N-bis(2-hydroxyethyl)butane-1-sulfonamide: CAS 34455-00-0

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)
Registered STOT RE 2 Aquatic Chronic 3 ***Notified*** STOT RE 2 Aquatic Chronic 3

Source: Industry Notifications - EU CLP (2022o; 2022c)

Human Health Hazard Assessments

Publications	Hazard Assessed	Conclusions on Human Health Effects
NICNAS (2015b)	Not specified	This chemical is assumed to degrade to PFBS (See assessment result for PFBS, no. 3).

Environmental Hazard Assessments

Publications	Hazard Assessed	Conclusions on Environmental Effects
NICNAS (2015c)	Aquatic Toxicity	This chemical is assumed to degrade to PFBS (See assessment result for PFBS, no. 3). Currently available data indicate that PFBS is not expected to be toxic to aquatic organisms.

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation Effects
NICNAS (2015c)	Persistent	This chemical is assumed to degrade to PFBS. It is noted that direct precursors to PFBS are categorised as Persistent.
	Bioaccumulation	This chemical is assumed to degrade to PFBS. Currently available data indicate that PFBS is not expected to be highly bioaccumulative.

Persistence and Bioaccumulation Assessments

Short-chain polymeric fluoroalkyl acid ester: CAS 661476-43-3

Authority Classifications

South Korea
Acute Tox. 4 (Oral)
Acute Tox. 3 (Dermal)
Skin Corr. 1
Skin Sens. 1

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)
Notified
Acute Tox. 4
Skin Corr. 1A
Skin Sens. 1
Eye Dam. 1

Source: Industry Notifications – EU CLP (2022p)

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.

ETFE: CAS 68258-85-5

Authority Classifications
None found.

Industry Classifications (SDS)

USA
Not classified

Source: Chemours (2017); Dunstone (2015)

Human Health Hazard Assessments
None found.

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Aquatic toxicity	It is uncertain if 1-Hexene, 3,3,4,4,5,5,6,6,6-nonafluoro-, polymer with ethene and tetrafluoroethene is inherently toxic to aquatic organisms.

Environmental Hazard Assessments

Persistence and Bioaccumulation Assessments

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation Effects
ECCC (2006)	Persistent	1-Hexene, 3,3,4,4,5,5,6,6,6-nonafluoro-, polymer with ethene and tetrafluoroethene is persistent.
	Bioaccumulation	It is uncertain if 1-Hexene, 3,3,4,4,5,5,6,6,6-nonafluoro-, polymer with ethene and tetrafluoroethene is bioaccumulative.
METI (2011a)	Bioaccumulation	1-Hexene, 3,3,4,4,5,5,6,6,6-nonafluoro-, polymer with ethene and 1,1,2,2-tetrafluoroethene is not readily biodegradable and has low bioconcentration.

Perfluoropolyether (PFPE) blend (with polyurethane): CAS 76415-97-9

Authority Classifications
None found.

Industry Classifications (SDS)
None found.

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.

PTFE: CAS 9002-84-0

Authority Classifications

China	GESTIS Substance Database
Eye Irrit. 3 Eye Dam. 1	Not a dangerous substance according to GHS.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	USA	India
Eye Irrit. 3 Eye Dam. 1	"Not a hazardous substance"	"not classified"	"Not a hazardous substance"

Source: Acros Organics (2011); Alfa Aesar (2015a); CDH (n.d. c); Sigma Aldrich (2018a; 2019); Thermo Fisher Scientific (2021)

Human Health Hazard Assessments

Publications	Hazard Assessed	Conclusions on Human Health Effects
IARC (1979)	Carcinogenicity	Unclassifiable as to its carcinogenicity to humans due to insufficient data

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Aquatic toxicity	Ethene, tetrafluoro-, homopolymer is not inherently toxic to aquatic organisms.

Environmental Hazard Assessments

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Persistent	Ethene, tetrafluoro-, homopolymer is persistent
	Bioaccumulation	Ethene, tetrafluoro-, homopolymer is not bioaccumulative.

Persistence and Bioaccumulation Assessments

PBSF (perfluorobutane sulfonyl fluoride): CAS 375-72-4

Authority Classifications

Australia
Eye Irrit. 2A

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	USA	Canada	UK	China
Registered STOT SE1	Skin Corr. 1B Eye Dam. 1	Skin Corr. 1B Eye Dam. 1	Skin Corr. 1B Eye Dam. 1 STOT SE 1	Skin Corr. 1B

Source : Alfa Aesar (2015b); Sigma Aldrich (2021b); Thermo Fisher Scientific (2021a); Toronto Research chemicals (2016)

Human Health Hazard Assessments

Publications	Hazard Assessed	Conclusions on Human Health Effects
NICNAS (2019)	Acute Toxicity	PFBSF has low acute toxicity via the dermal route, with dermal LD50 values >2000 mg/kg bw. Based on the available data, inhalation effects were observed at relatively high doeses and classification is; therefore, not considered warranted.
	Corrosion/Irritation	PFBSF is classified as hazardous with the risk phrase 'Causes serious eye irritation' - Cat. 2A (H319) in HSIS (Safe work Australia).
	Sensitisation	PFBSF was non sensitising in the LLNA when tested at concentrations of 10, 25 or 50 % (weight/volume). It was also negative in a GPMT (REACH).
	Repeated Dose Toxicity	PFBSF is not considered to cause serious systematic effects from repeated oral exposure. PFBSF is not expected to cause serious damage to health from repeated inhalation exposure.
	Genotoxicity	Based on the results from negative in vitro genotoxicity studies, PFBSF is not considered to be genotoxic.
	Reproductive and Developmental Toxicity	Both potassium PFBS and PFBSF are structurally related compounds each of which has the potential to hydrolyse and/or dissociate into the environmentally persistent perfluorobutanesulfonate anion (PFBS).

		Based on the available data on potassium PFBS, this chemical is not considered to cause reproductive or developmental toxicity.

Publications	Hazard Assessed	Conclusions on Environmental Effects
NICNAS (2015)	Aquatic Toxicity	This chemical will release PFBS in the environment, which is not expected to have high toxicity to aquatic organisms.
	Terrestrial Toxicity	This chemical is not expected to have high toxicity to birds.

Environmental Hazard Assessments

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation Effects
NICNAS (2015)	Persistent	Based on the expected non-degradability of PFBS, and the expectation that PFBSF will release PFBS in the environment, PFBSF is categorised as Persistent.
	Bioaccumulation	PFBSF is categorised as not bioaccumulative.

Persistence and Bioaccumulation Assessments

Polyester: CAS 113669-97-9

Authority Classifications
None found.

Industry Classifications (SDS)

EU (industry SDS)	USA	Australia	Canada	Korea
Flammable	"Not considered hazardous"	Flammable	"Not considered hazardous"	Flammable

Source: Biosynthetic (2021); Delta (2017); Donjin (2012); Livingstond International Pty Ltd. (2018); Ralmont (2016)

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.

Sulfosuccinates: CAS 55184-72-0

Authority Classifications

GESTIS Substance Database
Skin Irrit. 2 Eye Dam. 1 Aquatic Chronic 2

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)
Registered Skin Irrit. 2 Eye Dam. 1 Aquatic Chronic 2 ***Notified*** Skin Irrit. 2 Eye Dam. 1 Aquatic Chronic 2	Skin Irrit. 2 Eye Dam. 1 Aquatic Chronic 2

Source: Cromology (2020); Robbialac (2021)

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.

Sulfosuccinates (Sulfosuccinate mixed with water and 2,2 dimethylpropane-1,3-diol): CAS 577-11-7

Authority Classifications

Australia	China	Japan	New Zealand		GESTIS Substance Database
Eye Dam. 1 Skin Irrit. 2	Skin Corr. 2 Eye Dam. 2 Repr. 2 Aquatic Chronic 3	Skin Irrit. 2 Eye Irrit. 2 Repr. 2 Aquatic Acute 3 Aquatic Chronic 3	Skin Irrit. 2 Eye Dam. 1		Skin Irrit. 2 Eye Dam. 1

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	USA	UK	Brazil	Japan
Registered Skin Irrit. 2 Eye Damage 1 ***Notified*** Skin Irrit. 2 Eye Dam. 1	Skin Irrit. 2 Acute Tox 4. (Oral) Eye Dam. 1 Aquatic Acute 3	Eye Dam. 1 Acute Tox 4. (Oral)	Skin Irrit. 2 Eye Dam. 1 Acute Tox 4.	Acute Tox 4. (Oral) Eye Dam. 1 Aquatic Acute 3 Aquatic Chronic 3	Acute Tox 4. (Oral) Skin Irrit. 2 Eye Dam. 1 Repr. 2 Aquatic Acute 3 Aquatic Chronic 3

Source: Fagron (2015); Santa Cruz Biotechnology (2017; 2017a; 2017b; 2017c); Sigma-Aldrich (2021c); Thermo Fisher Scientific (2020)

Human Health Hazard Assessments

Publications	Hazard Assessed	Conclusions on Human Health Effects
NICNAS (2016a)	Acute toxicity	Based on the weight of evidence of results from animal tests following oral exposure, the chemical is considered to have low acute oral toxicity. The chemical has low acute toxicity based on results from animal tests following dermal exposure.
	Corrosion/ Irritation	Based on the available experimental data, the chemical is considered to be a skin irritant. Based on the available experimental data, the chemical is considered to be a severe eye irritant.
	Sensitisation	While no skin sensitisation studies in animals are available, several human studies have been conducted. Based on the available information, the chemical is not considered to be a skin sensitiser. However,

		cumulative irritancy effects are reported.
	Repeated dose toxicity	Based on the available information from experimental studies, repeated oral exposure to the chemical is not considered to cause serious damage to health. Based on the limited data available, repeated dermal exposure to the chemical is not considered to cause serious systemic damage to health.
	Reproductive and Developmental Toxicity	The available data on the chemical indicate that the substance is not a specific reproductive or developmental toxin.

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Aquatic toxicity	Butanedioic acid, sulfo-, 1,4-bis(2-ethylhexyl) ester, sodium salt is not inherently toxic to aquatic organisms.

Environmental Hazard Assessments

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation Effects
ECCC (2006)	Persistent	Butanedioic acid, sulfo-, 1,4-bis(2-ethylhexyl) ester, sodium salt is not persistent.
	Bioaccumulation	Butanedioic acid, sulfo-, 1,4-bis(2-ethylhexyl) ester, sodium salt is not bioaccumulative.
METI (1991)	Bioaccumulation	Sodium 1,2-bis(2-ethylhexyloxycarbonyl)ethanesulfonate is determinated to be non or not highly bioaccumulative.

Persistence and Bioaccumulation Assessments

Polysiloxane: CAS 63148-53-8

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	Canada
Notified Not Classified	"Not a hazardous substance"	"Not hazardous"

Source: Corteva (2020); Sigma-Aldrich (2021e)

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.

Silicone polymers (made of silanes and siloxanes) (For example, non-ionic modified silicone polyether and a mixture of a silicone polyether and a diocylsulfosuccinate in ethanol and water); Example CAS 67674-67-3 (10-15%) and dioctylsulfosuccinate (50-55%)

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	USA	Canada
Notified Eye Dam. 1 Acute Tox. 4 Aquatic Chronic 2	Eye Irrit. 2 Acute Tox. 4 Aquatic Chronic 3	"Not classified"	Eye Irrit. 2

Source: Evonik (2021); Gelest (2014); Siltech (2016)

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.

PVC: CAS 9002-86-2

Authority Classifications

China	Chinese Taipei	Japan	GESTIS Substance Database
STOT SE 3 STOT RE 1	Skin Irrit. 2 Eye Irrit. 2 STOT SE 3	STOT SE 3 STOT RE 1	Not a dangerous substance according to GHS

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	USA	Canada
Notified Not Classified	"Not a hazardous substance"	"not considered as hazardous" **Or** Skin Irrit. 2 Eye Irrit. 2A STOT SE 3	Eye Irrit. 2A STOT SE 3

Source: CDH (n.d. a), GuideChem (2017); Santa Cruz Biotechnology (2015; 2015a; 2018); Sigma-Aldrich (2016); Tilflex (2016); Westlake Chemical (2015)

Human Health Hazard Assessments

Publications	Hazard Assessed	Conclusions on Human Health Effects
IARC (1979)	Carcinogenicity	Unclassifiable as to its carcinogenicity to humans due to insufficient data.

Environmental Hazard Assessments

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Aquatic Toxicity	Ethene, chloro-, homopolymer is not inherently toxic to aquatic organisms.

Publications	Hazard Assessed	Conclusions on Persistence and Bioaccumulation Effects
ECCC (2006)	Persistent	Ethene, chloro-, homopolymer is persistent.
	Bioaccumulation	Ethene, chloro-, homopolymer is not bioaccumulative.

Persistence and Bioaccumulation Assessments

Polyurethane: CAS 9009-54-5

Authority Classifications
None found.

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	USA	Australia
Notified Not Classified	"Not classified"	"NOT classified as a hazardous chemical"

Source: 3M (2016); Lapolla (2013)

Human Health Hazard Assessments

Publications	Hazard Assessed	Conclusions on Human Health Effects
IARC (1979)	Carcinogenicity	Unclassifiable as to its carcinogenicity to humans due to insufficient data.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.

Polymethylmethacrylate powder: CAS 9011-14-7

Authority Classifications

Canada	GESTIS Substance Database
Not hazardous	Not a dangerous substance according to GHS

Industry Classifications (SDS)

European Union (REACH registration; C&L - Notified)	European Union (Industry SDS)	USA	UK	India	China
Notified Not Classified	"Not a hazardous substance "	"Not a hazardous substance" **Or** Repr. 2 STOT RE 2	"Based on available data, the classification criteria are not met"	"Not a hazardous substance"	"Not classified."

Source: CDH (n.d. b) ; GuideChem (2017) ; Sigma-Aldrich (2014) ; Spectrum (2020); TCI (2018); Thermo Fisher Scientific (2010)

Human Health Hazard Assessments

Publications	Hazard Assessed	Conclusions on Human Health Effects
IARC (1979)	Carcinogenicity	Unclassifiable as to its carcinogenicity to humans due to insufficient data

Environmental Hazard Assessments

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Aquatic Toxicity	2-Propenoic acid, 2-methyl-, methyl ester, homopolymer is not inherently toxic to aquatic organisms.

Publications	Hazard Assessed	Conclusions on Environmental Effects
ECCC (2006)	Persistence	2-Propenoic acid, 2-methyl-, methyl ester, homopolymer is persistent.
	Bioaccumulation	2-Propenoic acid, 2-methyl-, methyl ester, homopolymer is not bioaccumulative.

Persistence and Bioaccumulation Assessments

Epoxy (Bisphenol A-epichlorohydrin copolymer acrylate): CAS 90598-46-2

Authority Classifications
None found.

Industry Classifications (SDS)
None found.

Human Health Hazard Assessments
None found.

Environmental Hazard Assessments
None found.

Persistence and Bioaccumulation Assessments
None found.