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PFASs and alternatives in cosmetics: report on commercial availability and current uses

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PFASs and alternatives in cosmetics: report on commercial availability and current uses

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Executive summary

This report examines the commercial availability and current uses of PFASs and alternatives in cosmetics, as well as their market penetration, feasibility, effectiveness and cost.

Thirty-six PFASs (polymeric and non-polymeric) were identified as intentionally added to cosmetics. PFASs provide a wide range of functions in cosmetic products, acting as hair and skin conditioning agents, emulsifiers, stabilisers, oil and water-resistant agents, lubricants, bulking agents and/or oil-resistant surfactants.

Technically and economically feasible alternatives to intentionally used PFASs in cosmetic products are widely available on the market, which implies a high substitution potential. However, stakeholders have indicated that substituting PFASs in cosmetics often requires the entire product reformulation to provide the same functionalities to the product, and like-for-like 'drop-in' replacements are unlikely to happen.

Based on a review of chemical ingredient databases, it is suggested there are hundreds of alternative (non-fluorinated) chemical substances that provide the same function as PFASs in cosmetic products.

The overall market share for PFASs-containing cosmetics is relatively low. This has been confirmed by the cosmetics industry, which has further indicated that producers have been moving away from the use of PFASs for several years already. This suggests that PFASs can be replaced by other ingredients relatively easily as they do not impart any specific technical functions that can't be provided by non-fluorinated alternatives. However, very few studies have demonstrated this experimentally. Also, very little information, either quantitative or qualitative, has been identified on the costs of substituting PFASs with non-fluorinated alternatives.

Many of the PFASs that have been identified in cosmetic products through laboratory analysis, are not listed in the reported ingredients. This indicates that in many cases PFASs can be present in cosmetic products as unintentional impurities or degradation products. While this is a separate issue to the intentional use of PFASs, this nevertheless represents a technical challenge for companies who wish to phase out or substitute PFASs in their products lines.

Abbreviations

BB/CC cream	Beauty balms/colour correctors cream
CPV	Coating, Paint and Varnish
CTPA	The Cosmetic, Toiletry and Perfumery Association
EWG	Environmental Working Group
FEP	Fluorinated ethylene propylene
FP	Fluoropolymer
FTOH	Fluorotelomer alcohol
HFPO-DA	Hexafluoropropylene oxide dimer acid
ICCM	International Conference on Chemicals Management
INCI	International Nomenclature Cosmetic Ingredient
IPEN	International Pollutants Elimination Network
LC	Long Chain
PAP	Polyfluorinated alkyl phosphate ester
PASF	Perfluoroalkane sulfonyl fluoride
PBT	Persistent, bioaccumulative and toxic
PFA	Perfluoroalkoxyl polymer
PFAS	Per- and polyfluoroalkyl substance
PFBS	Perfluorobutanesulfonic acid
PFCA	Perfluoroalkyl carboxylic acid
PFHpA	Perfluoroheptanoic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexane sulfonic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PFSA	Perfluoroalkane sulfonic acid
PIGE	Particle-induced gamma-ray emission spectroscopy
PPIE	Polyperfluoromethylisopropyl ether
PTFE	Polytetrafluoroethylene
PVDF	Polyvinylidene fluoride
SC	Short Chain
SME	Small and medium sized enterprise

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Overall Summary

This report gathers information on alternatives to per- and polyfluoroalkyl substances (PFASs) in cosmetic products, examining in particular the commercial availability and current uses of PFASs and alternatives to PFASs, as well as their market penetration, feasibility, effectiveness and cost.

PFASs are a family of synthetic chemicals that have been extensively used in a wide number of different industrial and consumer applications since the 1950s due to their unique physical and chemical properties. On the one hand, such properties provide PFAS containing products valuable characteristics, such as high versatility, strength, resilience, and durability. On the other hand, they can produce negative impacts on the environment and human health, as PFASs can be, or can degrade to, extremely persistent chemicals that accumulate in humans, animals and the environment.

Health effects in humans associated with exposure to certain PFASs include increased cholesterol levels, impact on infant birth weights, effects on the immune system, increased risk for certain types of cancers, and thyroid hormone disruption. The use of PFASs in cosmetic products may be of concern due to their direct contact with the skin. Some of these cosmetics are applied close to the eyes and the mouth, which could further increase exposure due to enhanced absorption and ingestion.

The report is based upon a review of publicly available information supplemented by information from the members of the Organisation for Economic Co-operation and Development (OECD)/ United Nation Environmental Program (UNEP) Global Perfluorinated Chemicals (PFC) Group, and direct consultation with stakeholder including national authorities, individual companies, industry associations and research organisations.

PFASs in cosmetic products

This report has identified 36 different PFASs (polymeric and non-polymeric) intentionally added to cosmetics (see Annex C). This list was assembled from the EWG Skin Deep database, peer-reviewed literature, and government documents and databases.

The presence of PFASs in cosmetic products can be as the result of intentional use as a chemical ingredient or unintentional presence as a degradation product or impurity. The main focus of this report is on intentionally added chemical constituents and specific alternatives to those components. The unintentional presence of PFASs is also addressed in the report, as this is significant in the wider context of the phase out of PFASs in cosmetics.

PFASs provide a wide range of functions in cosmetic products, acting as hair and skin conditioning agents, emulsifiers, stabilisers, oil and water-resistant agents, lubricants, bulking agents and/or oil-resistant surfactants. Analysis indicates that skin and hair conditioning are the most common functions in products on the European market.

Alternatives to PFASs are widely available on the market, although since there is very little information on like-for-like replacement, very few specific chemicals have been identified in the literature as being a specific 'alternatives'. Based on a review of chemical ingredient databases, it is suggested there are hundreds of alternative (non-fluorinated) chemical substances that provide the same function as PFASs in cosmetic products.

PFASs are intentionally added in different cosmetic product categories, with the main one being decorative (appearance enhancers) cosmetics, followed by skin care, hair care, and toiletries products in 2020 in Europe. A negligible fraction of perfumes and fragrances contained PFASs among their listed ingredients. The overall market share for PFASs-containing cosmetics is relatively low. This has been confirmed by the cosmetics industry, which has further indicated that producers have been moving away from the use of PFASs for several years already.

Availability and feasibility of alternatives to PFASs in cosmetics

Alternatives to PFASs in cosmetics are widely available.

Studies on the technical feasibility of using alternatives to PFASs in the cosmetics sector is generally lacking. Stakeholders have indicated that substituting PFASs in cosmetics often requires the entire product reformulation to provide the same functionalities to the product, and like-for-like 'drop-in' replacements are unlikely to happen.

A broad range of non-PFASs ingredients can potentially perform the same functions associated with the use of PFASs. PFASs provide multiple functions in the same product. Hence, to achieve a comparable technical performance, it can be expected that a larger-scale product reformulation would be required. Given this, and the wide range of different products and functions involved, it is not possible to provide a detailed discussion of technical feasibility for specific chemical alternatives compared with PFASs.

There are significantly more non-fluorinated ingredients in cosmetic products within the same product categories as the PFAS-containing products. This suggests that PFASs can be replaced by other ingredients relatively easily as they do not impart any specific technical functions that can't be provided by non-fluorinated alternatives. However, very few studies have demonstrated this experimentally.

The cosmetics industry indicated that the issue of substituting PFASs in cosmetics is seen as a relatively low priority or concern, given that PFASs-containing products do not make up a significant proportion of the total market of cosmetic products and that this sector is already relatively advanced in the phase-out of PFASs.

Very little information, either quantitative or qualitative, has been identified on the costs of substituting PFASs with non-fluorinated alternatives.

- Capital costs would primarily be borne by the cosmetics producers in the form of lower producer surplus. These are estimated to be €27.2 million (of which €18.4 million affect large companies and €8.9 million small and medium-sized enterprises), between 2025 and 2026 in the form of reformulation costs of an estimated 244 PFAS-containing cosmetic products that would be reformulated in the European Economic Area.
- Operating costs: The only aspect of operating costs that has been covered in the literature is related to the potential differences in product performance. Such costs are considered non-existent or negligible, as there are economically feasible alternatives available for all uses of PFASs in cosmetics.
- Additional costs: No information on the other costs such as employment, health, remediation/clean-up has been identified.

Uptake and market penetration of alternatives

Since PFASs in cosmetics rarely have direct chemical substitutes, it is not possible to provide detailed information on the market share of cosmetics products containing alternatives. Furthermore, many of the alternatives have been used widely in cosmetics over time without being labelled or marketed as ‘PFASs alternatives’.

Notably, the global demand for products based on naturally derived ingredients has been increasing. These products can be considered much less likely to contain intentionally added PFASs in their ingredients as they are based on naturally derived ingredients and are typically required to be free of toxic chemicals to receive specific labels to be marketed as ‘natural’ or ‘environmentally friendly’ products. The increasing consumer demand has been followed by a strong commitment from cosmetics brands to be PFASs-free – of intentionally added PFASs – leading to a large-scale manufacturing of cosmetics products without PFASs.

Overall, UK and EU markets are dominated by PFASs-free cosmetic products (with less than 1.5% of all cosmetic products on the market estimated to contain PFASs in their ingredients), while the situations in the other geographic areas are less clear, because of different regulations and different levels of PFASs manufacturing. It is noted that many OECD countries have implemented legislation and wider policy measures targeted at PFASs that is driving a move away from their use across a wide range of different sectors, potentially including uses in the cosmetics industry.

In terms of the expected time frame to completely substitute PFASs in cosmetics, the EU restriction proposal suggests that PFASs can be eliminated quickly. However, the time estimated for product reformulation and testing varies and ranges from six months to over two years. Given that alternatives are already used widely, and withdrawal of PFASs-containing cosmetic products from the market is the easiest way to eliminate PFASs in cosmetics, elimination of PFASs could be potentially achieved rapidly. Whether this elimination will happen in practice will most likely depend on market and regulatory drivers in certain regions of the world.

Challenges to the shift to alternatives

Technically and economically feasible alternatives to intentionally used PFASs in cosmetic products are widely available on the market, which implies a high substitution potential. However, it is also noted that one-for-one substitution of PFASs in cosmetic products with non-fluorinated alternatives is not common, instead the removal of PFASs is usually achieved through a full product reformulation. The entire reformulation might be both resource and time consuming.

The large number of different potential alternatives available to replace PFASs in the cosmetics sector makes it necessary to distinguish between ‘alternatives’ and ‘suitable alternatives’ to avoid potential negative environmental consequences resulting from regrettable substitution, which is not addressed in this report. However, PFASs are not believed to impart any unique technical function in cosmetic products that can’t be achieved through non-fluorinated alternatives. Therefore, very few, if any, technical challenges have been identified in terms of achieving the required functionality in cosmetic products for the substitution of intentionally used PFASs for non-fluorinated alternatives in those products.

Many of the PFASs that have been identified in cosmetic products through laboratory analysis, are not listed in the reported ingredients. This indicates that in many cases PFASs can be present in cosmetic products as unintentional impurities or degradation products. While this is a separate issue to the intentional use of PFASs, this nevertheless represents a technical challenge for companies who wish to phase out or substitute PFASs in their products lines.

This reflects a lack of transparency both to different actors in the supply chain, and towards consumers regarding the actual chemical constituents present in cosmetic products, which is a barrier to further development of alternatives. Therefore, stronger regulations and government oversight of harmful chemicals in personal care products are potentially needed. In addition, there is clearly a need for stronger communication and better access to information for different industry actors on the chemical constituents in cosmetic products across the full supply chain.

The challenges around the detection and assessment of PFASs (both intentionally added and unintentionally present) in cosmetic products also raises the issue of the availability of suitable analytical techniques (and reference standards) to carry out a reliable screening of PFASs in cosmetic products. While a number of different techniques have been utilised, there is currently not a single screening approach available to allow a consistent and comparable analysis.

1 Introduction

Background, aims and scope of the study

The OECD/UNEP Global Perfluorinated Chemicals (PFC) Group

The OECD/UNEP Global Perfluorinated Chemicals Group (OECD, 2023a[1]) was established in 2012, in response to the International Conference on Chemicals Management (ICCM) - ICCM Resolution II/5 (Strategic Approach to International Chemicals Management, 2012[2]). The group brings together experts from OECD members, non-member countries, and representatives from other international organisations, with the aim of continually facilitating the exchange of information regarding PFASs and to support a global transition towards safer alternatives.

One of the key work streams of the group is to gather information on alternatives to PFASs to understand what they are, what they are used for, their market penetration, feasibility, effectiveness, and cost. To this end the PFC group manages an online portal of information on PFASs and has produced a number of reports on PFASs and their alternatives, including the 2013 synthesis report on the use, potential adverse effects, and alternatives to PFASs (OECD/UNEP Global PFC Group, 2013[3]); a set of 15 fact cards on the major groups of PFASs (OECD, 2022a[4]); and reports on the use of PFASs and alternatives in specific sectors, including Coatings, Paints and Varnishes (CPVs) (OECD, 2022b[5]) and Food Packaging (OECD, 2022c[6]).

The current study is intended to support and further advance this work stream by looking at the commercial availability and current uses of alternatives to PFASs in cosmetic products.

PFASs, their uses, hazards and risks

PFASs are a family of synthetic chemicals that have been extensively used in a wide number of different industrial and consumer applications since the 1950s due to their unique physical and chemical properties (such as water-, oil- repellence and high chemical and thermal stability).

The definition and chemical structure of what constitutes 'PFASs' differs between different authors, and is discussed comprehensively elsewhere, for example in OECD/UNEP Global PFC Group (2013), OECD (2021), Buck, et al. (2011) (Buck et al., 2011[7]), and Buck, Korzeniowski, Laganis, & Adamsky (2021) (Buck et al., 2021[8]).

The OECD definition, derived in 2021, reads as: "PFASs are defined as fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), i.e. with a few noted exceptions, any chemical with at least a perfluorinated methyl group ($–CF_3–$) or a perfluorinated methylene group (–CF_2–) is a PFASs." (OECD, 2021[9]). It is noted that the EU restriction proposal for PFASs (ECHA, 2023b[10]) uses a similar broad definition[1].

The term 'PFASs' is a broad term used to cover at least 10,000 specific chemical substances (ECHA, 2023b[10]). A number of estimates for the precise number of individual chemical substances in the PFASs family have been derived by different authors, depending on the specific definition used. For example, in 2018, the OECD/UNEP Global PFC Group prepared a list identifying 4,730 PFASs[2] that may have been on the global market, while others estimate that closer to around 6,000 substances belong to this group (Concawe, 2016[11]). The EU restriction proposal[3] (ECHA (2023a))[4] estimated that there are over 8,000 chemical substances that could be classed as PFASs. The US EPA has a consolidated 'master' list of PFASs which in 2019 contained 6,330 different PFASs, while in August 2022 it contained 14,735 PFASs[5]. While clearly there are several thousand chemical substances that can be considered PFASs, a study by Buck, Korzeniowski, Laganis, & Adamsky (2021) suggested that 256, (< 6%), of the 4,730 PFASs presented in the 2018 OECD/UNEP Report are commercially relevant globally.

PFASs can be divided into subgroups in several ways, e.g. based on the chemical moieties present, the carbon chain length and non-polymeric vs polymeric structures (ECHA, 2023a). The definition of 'PFASs' is typically divided into two key categories:

- **Non-polymeric PFASs** comprise a range of diverse molecules and include two broad sub-groups defined by their fluorinated carbon chain length, either short-chain (SC) or long-chain (LC). As outlined in OECD (2013), these can be described as follows:
  - Long chain (LC) includes:
    - Perfluoroalkyl carboxylic acids (PFCAs) with 7 and more perfluoroalkyl carbons, such as perfluorooctanoic acid (PFOA) (with 8 carbons or C8 PFCA) and perfluorononanoic acid (PFNA) (with 9 carbons or C9 PFCA);
    - Perfluoroalkane sulfonic acids (PFSAs) with 6 and more perfluoroalkyl carbons, such as perfluorohexane sulfonic acid (PFHxS) (with 6 perfluoroalkyl carbons, or C6 PFSA) and perfluorooctane sulfonate (PFOS) (with 8 perfluoroalkyl carbons or C8 PFSA); and
    - Substances that have the potential to degrade to long-chain PFCAs or PFSAs, i.e. precursors such as perfluoroalkane sulfonyl fluoride- (PASF) and fluorotelomer-based compounds.
  - Short-chain (SC) includes: PFCAs with 6 or fewer perfluoroalkyl carbons, and carbon chain lengths of less than C7, and PFSAs with carbon chain lengths of less than C6.
- **Polymeric PFASs**. As described in OECD (2013), these can be divided into three categories:
  - **Fluoropolymers (FPs)**: fluorinated polymers consisting of carbon only backbone with fluorine atoms directly attached to this backbone (e.g., polytetrafluoroethylene (PTFE); polyvinylidene fluoride (PVDF); fluorinated ethylene propylene (FEP); perfluoroalkoxyl polymer (PFA); etc.). FPs

[1] ECHA (2022) definition: substances that contain at least one fully fluorinated methyl (–CF_3–) or methylene (–CF_2–) carbon atom, without any H/Cl/Br/I attached to it.

[2] OECD PFAS definition: –CnF2n– where n>3

[3] ECHA PFAS definition: all substances with –CF_3– or –CF_2–

[4] This reference along with ECHA 2023b and 2023c denote a restriction proposal that has been submitted to the European Chemicals Agency from Germany, the Netherlands, Sweden, Norway and Denmark and is referred to as the EU restriction proposal throughout this text.

[5] Derived from: https://comptox.epa.gov/dashboard/chemical-lists/PFASSTRUCT

are not made from PFCAs or their potential precursors (except that perfluorobutylethylene (PFBE) can be used as a comonomer). PFCA homologues are, however, used as processing aids in the polymerisation of some FPs.

- **Side-chain fluorinated polymers**: fluorinated polymers consisting of variable compositions of non-fluorinated carbon backbones with polyfluoroalkyl (and possibly perfluoroalkyl) side chains. The fluorinated side-chains, including PASF- and fluorotelomer-based derivatives, are potential precursors of PFCAs.
- **Perfluoropolyethers**: fluorinated polymers consisting of backbones containing carbon and oxygen with fluorine atoms directly attached to carbon. They are not made from PFCAs or their potential precursors; and PFCAs or their potential precursors are not involved in the manufacturing of perfluoropolyethers.

In general, the highly stable carbon-fluorine bond and the unique physicochemical properties of PFASs make these substances valuable ingredients for products with high versatility, strength, resilience and durability. PFASs are used to fulfil a wide range of functions across industrial, professional and consumer settings, including applications in textiles and leather; cosmetic products; food contact materials; paper and board; firefighting foams; household articles and consumer mixtures; construction products; lubricants and greases; industrial chemicals used in chrome plating; semiconductors; mixtures for treatment of skis; medical devices and apparel; inks, dyes, and paint coatings, applications within the oil, gas and mining industry; refrigeration and cooling applications; transportation (automotive, aviation etc.); and photographic surface layers (Glüge et al., 2020[12]).

The human health and environmental implications resulting from exposure to PFASs and their alternatives are outside of the scope of this report. However, in the past 25 years, there have been growing concerns that the unique physicochemical properties of PFASs that have made them so useful and popular in their wide-ranging uses can also result in negative impacts on the environment and human health (ECHA, 2023a); (OECD, 2023b[13]). An environmental concern for PFASs and/or their degradation products is their very high persistence (ECHA, 2023b[10]). PFASs can be, or can degrade to, extremely persistent chemicals that accumulate in humans, animals and the environment (European Environment Agency, 2022[14]). Their resistance to degradation, and high mobility in the environment mean that PFASs are now ubiquitous in the environment, including remote environments such as the Arctic. PFASs have been observed to contaminate water and soil, for example in most European Union (EU) countries, and it is extremely difficult and costly to clean up such contamination (Nordic Council of Ministers, 2019[15]).

With regard to human health effects, a number of PFASs are known to display potentially toxic and/or bioaccumulative effects. These PFASs are primarily unintentional PFASs in the context of cosmetics. Health effects in humans associated with exposure to certain PFASs include increased cholesterol levels, impact on infant birth weights, effects on the immune system, increased risk for certain types of cancers, and thyroid hormone disruption (Ministers of Denmark, Luxembourg, Norway and Sweden, 2019[16]). Some PFASs are classified in the EU as toxic for reproduction, for the liver, and as suspected carcinogens (HBM4EU, 2022[17]); (ECHA, 2023b[10]) . However, it should also be noted that, while there are several thousand known PFASs chemicals (as discussed above), a relatively small number have been assessed for their health effects.

Some OECD countries have therefore taken the first steps to address all PFASs as a class. For example, the Canadian Government (2021)[6] has published a notice of intent, outlining several actions to assess and address PFASs as a class, and subsequently collected and examined information on PFASs, and published a draft State of PFASs report (Government of Canada, 2023[18]). The European Commission has recommended that actions at the EU level should be taken to ensure that the use of PFASs is phased out unless proven essential

[6] See: https://canadagazette.gc.ca/rp-pr/p1/2021/2021-04-24/html/notice-avis-eng.html#nl5.

for society (European Commission, 2020[19]). In February 2023, an EU restriction proposal was published of around 10,000 PFASs compounds across a wide range of different sectors and uses (including cosmetic products), prepared by authorities in Denmark, Germany, the Netherlands, Norway and Sweden, with the aim of reducing PFASs emissions into the environment and make products and processes safer for people (ECHA, 2023a[20]).

PFASs in cosmetics

The scope of this report includes both non-polymeric PFASs and polymeric PFASs, as well as their non-fluorinated alternatives used in cosmetic products. It is noted that the term 'cosmetic product' may be defined differently across regulatory jurisdictions or different literature sources. Cosmetics Europe, for example, define seven categories of cosmetics and personal care products - oral care, skin care, sun care, hair care, decorative cosmetics, body care and perfumes. This report, therefore, looks to identify where PFASs and polymeric PFASs are used in products covering these categories, and the commercial availability and feasibility for alternatives to PFASs in these uses.

PFASs have been used in a wide range of different cosmetics and personal care products (Gaines, 2022[21]). However, compared to other uses of PFASs such as in fire-fighting foams and textiles, relatively limited amount of research into the presence of PFASs in cosmetics has been conducted, until relatively recently, and this sector has been considered one of the 'lesser known 'uses for PFASs (Schultes et al., 2018[22]); (Nordic Council of Ministers, 2019[15]). More recently, a number of studies have detected and quantified PFASs in off-the-shelf cosmetic products in Sweden (Schultes et al., 2018[22]); (Putz et al., 2022[23]), Denmark (Danish Environmental Protection Agency, 2018[24]), Japan and Republic of Korea (Fujii, Harada and Koizumi, 2013[25]), Canada (Harris et al., 2022[26]) and Canada and the US (Whitehead, Venier and Wu, 2021[27]). These studies highlight that cosmetics and personal care products can contain a range of different PFASs and FPs, which can result in human and environmental exposure to these substances (Harris et al., 2022[26]).

The use of PFASs in cosmetic products may be of concern due to their direct contact with the skin (e.g. hair products, powders, sunscreens, etc), and of particular concern is that the classes of cosmetics listed above are applied close to the eyes and the mouth, which could further increase exposure due to enhanced absorption and ingestion (Whitehead, Venier and Wu, 2021[27]).

PFASs have been reported in cosmetics and personal care products both as intentionally added ingredients, but also as possible impurities in the raw material manufacturing process, or degradation products. For example, Danish Environmental Protection Agency (2018) noted that PFASs detected in cosmetic products (for example the relatively simple fluorinated alkyls), occur both as intentionally added ingredients in cosmetic products and as unintentional degradation products and impurities from the production of the PFASs precursors used in certain cosmetic products.

The main focus of this report is on the intentionally added chemical constituents – i.e. in the ingredients list of the cosmetic products, and specific alternatives to those components. Information on the chemical ingredients of cosmetic products, including PFASs, is compiled and made publicly available through online databases; two such examples include:

- The European Commission's public database with information on substances (based on INCI Name/Substance Name) that may be found in cosmetic products (Cosmetic Ingredient Database - CosIng); https://ec.europa.eu/growth/tools-databases/cosing/index.cfm
- The Skin Deep Database is a database of cosmetic products developed by the US Non-Profit Organization Environmental Working Group (EWG); https://www.ewg.org/skindeep/

An overview of specific PFASs identified as being intentionally added, currently or in the past, to cosmetic products is provided in Annex C and was assembled from the above databases, peer-reviewed literature, and additional government documents and databases.

However, the ‘unintentional’ presence of PFASs in these products is also considered in the broader discussion of how to successfully phase out PFASs (including FPs) from cosmetic products and the key challenges that need to be overcome to achieve this in practice.

Structure of the report

This report presents the overall findings of the present study into PFASs and alternatives in the cosmetics sector.

The objective of this work is to develop a report on the commercial availability and current uses of alternatives to PFASs, specifically focusing on products and articles[7] in cosmetics.

The report is set out in the following sections:

- Introduction (this section);
- Commercial availability and market trend of alternatives to PFASs in cosmetics (Chapter 2);
- Technical and economic feasibility of alternatives to PFASs in cosmetics (Chapter 3);
- Uptake and market penetration of alternatives (Chapter 4);
- Challenges to the shift to alternatives (Chapter 5);
- Status of the shift to alternatives and its sustainability (Chapter 6);
- Policy recommendations and areas for further work (Chapter 7);
- Uncertainties and limitations (Chapter 8);

Methodology

The report is based upon a review of publicly available information supplemented by information from the members of the Global PFC Group, including from national authorities, individual companies, industry associations and research organisations. This has included reports and papers published by national and international authorities, academic institutions and industry, as well as information on individual company websites, and media articles, and information derived either directly or indirectly (i.e. information has been used in references cited) from publicly accessible cosmetic ingredient databases.

A systematic search of peer-reviewed literature was also conducted using the search tool Scopus.

This was further supplemented through interviews and targeted information requests to Global PFC Group members as well as key stakeholders identified through the information gathering process. It should be noted that where information is presented based on inputs to this further consultation, specific opinions or information are not attributed to named individuals or organisations in the report text. A list of contributors to the report is available in Annex A.

[7] As defined under Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures: ‘article’ means an object which during production is given a special shape, surface or design which determines its function to a greater degree than does its chemical composition.

2 Commercial availability and market trend of alternatives to PFASs in cosmetics

Types of cosmetic products containing PFASs and PFASs functions in cosmetics

Overview

The presence of PFASs in cosmetic products has been discussed in several recent reviews in the literature (see for example Glüge, et al. (2020); Gaines, (2022)), as well as in the EU restriction proposal (ECHA, 2023b[10]) and the research and analysis that informed that report (e.g. (KEMI, 2021[28])).

The review by Glüge, et al. (2020) identified 76 individual PFASs in cosmetic products including in shampoo, eye makeup, foundation, facial cleansers and moisturisers. As discussed by Glüge, et al. (2020), the uses of PFASs in cosmetics include anti-aging, anti-frizz, bar soap, beauty balms (BB) / colour correctors (CC) cream/foundation, blush/highlighter, body lotion/body cream, body oil, brow products, concealer/corrector, cream/lotion, cuticle treatment, eye cream/eyeshadow, eye pencil/eyeliner, face cream, facial cleanser, hair creams and rinses/conditioning , hair spray/mousse, hair shampoo, hand sanitiser, highlighter, lip balm/lip stick/lip gloss, lip liner, manicure products, makeup remover, mask, mascara/lashes, moisturiser, nail polish/nail strengthen/nail treatment, powder, primer/fixer, scrub/peeling, shaving cream/shaving foam/shaving gel, sunscreen, sunscreen makeup and several oral hygiene products including toothpicks and dental floss.

The presence of PFASs can be the result of either intentional addition of these substances as a chemical ingredient to a cosmetic formulation, where they provide a required or desirable function (see below), or can also be present ‘unintentionally’, for example as a degradation product or impurity. The primary focus of this report is on intentionally added PFASs and their alternatives in cosmetic products, but the issue of unintentional presence of PFASs in cosmetics is covered in the report also, as this is important in the wider context of phasing out PFASs in these products. These aspects are discussed separately in this section.

It is often difficult to ascertain whether the presence of a PFASs in cosmetics is intentional or unintentional. In practice, this can be indicated by viewing the chemical ingredient list for the product, however, as will be discussed in this report, this is not always and accurate or reliable means of knowing if PFASs are present. Glüge, et al. (2020) identifies if the substance is in current use (U*), used (U), detected (D) or is patented (P) to be used in cosmetic products. This means that U* and U substances are intentionally added and currently used within cosmetic products. P substances indicates that the use was intentional however, does not elaborate on whether the substances use is ongoing or if the patent has expired. Detected substances (D) indicate that it is not known whether the substance was intentionally added as it could be a detection of an impurity or degradation product.

Intentionally added PFASs in cosmetics

PFASs added in cosmetic products

PFASs have been added intentionally to a range of cosmetics and personal care products including lotions, cleansers, nail polish, shaving creams, foundation, lip products, eye products, hair products, foundations and powders.

An overview of specific PFASs identified as being intentionally added, currently or in the past, to cosmetic products is provided in Annex C[8]. This report has identified 36 different PFASs (polymeric and non-polymeric) intentionally added to cosmetics. This list was assembled from the CosIng database, EWG Skin Deep database[9], peer-reviewed literature, and government documents and databases. However, it should be noted that the ingredients and functions listed in some databases are not always reliable (see Chapter 8)

Research by IVL Swedish Environmental Research Institute and Stockholm University (as reported in KEMI (2021) and ECHA (2023b)) has investigated the key uses of PFASs in cosmetics, based on what were considered as the most reliable cosmetic databases, e.g. Kemiluppen and CosmEthics. The total number of cosmetic products (number of units) and share of products containing PFASs were estimated (this is discussed in more detail in Chapter 4). The PFAS-containing product share was estimated for different categories of cosmetic products. It was found that in 2020 the highest proportion of PFAS-containing products within defined product categories[10] on the European market was for decorative cosmetics (appearance enhancers) (3.7%), followed by skin care (0.8%), hair care (0.7%) and toiletries (shampoos, soaps and toothpastes) (0.3%) (KEMI, 2021).

Based on this assessment, it can be concluded that the overall market share of PFAS-containing cosmetics is relatively low. Furthermore, the cosmetics industry has provided further indication that PFAS-containing products do not represent a significant fraction of the market and producers have been moving away from the use of PFASs for several years already.

Some studies have additionally tried to understand which PFAS are more widely used in cosmetics. A recent risk assessment of cosmetic products on the Danish market showed that a wide variety of fluoroalkyl substances and other fluorinated compounds are used in cosmetics, and PTFE was most often found in different product types, followed by $C_{9\text{-}15}$ fluoroalcohol phosphates (CAS RN 223239-92-7) (European Environment Agency, 2021[29]). According to the Cosmetic Ingredient Review, PTFE is used in concentrations of up to 13% in such leave-on products as mascara, up to 3% in face powders and at concentrations of up to 2.4% in such rinse-off products as hair bleaches in the United States (Cosmetic Ingredient Review, 2018[30]).

[8] It is noted that in some cases, it is not certain if PFASs detected in cosmetic products are present as the result of intentional addition (as indicated in Glüge, et al., 2020). This is clearly denoted in Annex C.

[9] The EWG Skin Deep database reviews and analyses products which are currently on the market and rates them depending on the safety of their ingredients. The database also allows for a search by ingredient function, which provides a range of information and the number of products within which that the ingredient is found. The database is regularly updated and therefore, the number of products containing PFASs is up to date and relevant. This information was cross-referenced with the INCI database to outline any potential data gaps.

[10] The proportion was assessed based on the total number of products on the market in an individual products category and the number of those products indicated to contain PFASs based on the CosmEthics database.

The US Food and Drug Administration (US FDA, 2022b[31]) reported that PTFE, 1*H*,1*H*,2*H*,2*H*-perfluorooctyl triethoxysilane (CAS RN 51851-37-7), perfluorononyl dimethicone, perfluorodecalin and perfluorohexane (CAS RN 355-42-0) are commonly added PFASs in cosmetics available on the US market.

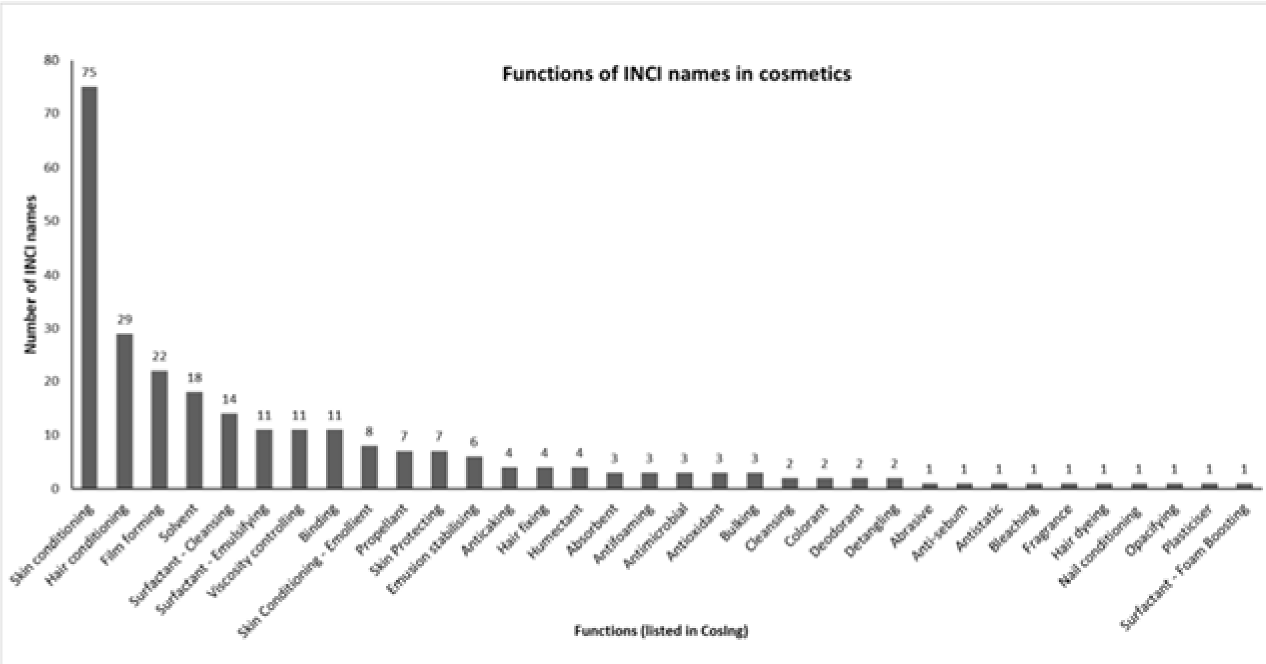
What function(s) do PFASs provide in cosmetic products?

In cosmetic products, PFASs typically act as emulsifiers, antistatics, stabilisers, surfactants, film formers, viscosity regulators and solvents, amongst others, and their properties enable the production of water- and oil-repellent and weather resistant products (Glüge et al., 2020[12]); (Gaines, 2022[21]); (European Environment Agency, 2021[29]). PFASs are also commonly utilised as emulsion stabilisers, bulking agents, and for their ability to repel oil and water, enabling the product to be more durable and resistant against weathering. Other common functions cited are as a skin conditioning /toner allowing the skin to look brighter and in hair conditioning products as an accelerant for hair dyes.

Research by the IVL Swedish Environmental Research Institute and Stockholm University (as reported in KEMI (2021) and ECHA (2023b)) has indicated the main functions provided by PFASs in cosmetic products in Europe, based on a review of INCI names in cosmetics using the CosIng database. An overview of results outlining the most frequently found functions within cosmetic products when the INCI database was searched. is provided in Figure 2.1. It can be seen that the CosIng database identifies the main functions of PFASs as skin and hair conditioning, film forming, solvent, cleansing and emulsifying surfactant, viscosity controlling and as a binding agent. PFASs can have multiple functions in cosmetic products (see Annex C).

For a description of terms for each of the function presented in Figure 2.1 a table defining the specific functions is provided in 8Annex B.

Figure 2.1. Overview of main functions of PFASs in cosmetics – based on CosIng database.



Source: IVL Swedish Environmental Research Institute and Stockholm University 2021

Unintentionally present PFASs in cosmetic products

A number of studies have found several PFASs that were not listed in the ingredient lists of the tested products. This was highlighted by KEMI (2021) which states there is a likelihood of underestimation of the total number of PFASs in cosmetic products due to the risk of missing substances that occur unintentionally as impurities not listed in the ingredients lists.

Impurities not listed on the ingredients list is commonly the main cause of detection of unintentional PFASs (KEMI, 2021[28]). Other reasons that could lead to the unintentional presence of PFASs within cosmetic products is that one INCI name can include several PFASs, such as a range of alkyl chain lengths. Some ingredient names on the labels of cosmetic products may not yet be in the CosIng database, depending on the last update from the INCI Database. In other words, CosIng does not reflect all the ingredient names and is not a complete list (KEMI, 2021[28]). Multiple authors have reported that the degradation of PFASs precursors used in certain cosmetic products has led to the unintentional presence of PFASs and impurities in cosmetic products e.g. (Danish Environmental Protection Agency, 2018[24]); (Fujii, Harada and Koizumi, 2013[25]); (KEMI, 2021[28]); (Putz et al., 2022[23]); (Schultes et al., 2018[22]); and (Whitehead, Venier and Wu, 2021[27]).

There is a lack of information in existing studies in the literature investigating the sources of impurities and the mechanism of degradation of PFASs in cosmetic products, or if there are any PFASs that are more susceptible to degradation. It is noted that the manufacturing process can also add PFASs unintentionally to cosmetic products. This aspect is further discussed in Chapter 5.2.

Chemical alternatives to PFASs in cosmetic products

Overview

Alternatives to PFASs have been used widely in cosmetic products for many years. It is important to emphasise the nuance in the term 'alternatives', between instances where PFASs have been used historically in products and then replaced, and where cosmetic products are developed without the use of PFASs in the first instance. The relatively low market share for PFASs (see Chapter 4) would imply that the latter is already a common practice in many, indeed most, cosmetic products currently on the market. As discussed in Chapter 2.1, for the key product types and functions identified to involve the use of PFASs, the overall proportion of products within defined product categories is indicated to be very low.

Consultation with the cosmetics industry has indicated that PFASs are not widely used in cosmetics and are relatively more costly to produce and procure, therefore are only used in products when the functionality required can be achieved with much smaller amounts when compared with non PFASs. This is mainly due to their functional efficiency over other substances (Glüge et al., 2020[12]). This would indicate that a wide range of alternatives are either being used instead of PFASs, or capable of replacing them in cosmetic products. This section presents the available information identified on the identity and commercial availability of alternatives to PFASs in cosmetic products.

Short chain PFASs

In terms of substitution, the literature suggests that the cosmetics industry has focused on switching from LC PFASs to SC PFASs in recent years. While not alternatives to PFASs in general, this follows an overall trend to shift to alternative PFASs when LC PFASs have been used. As explained below, this type of 'drop-in' substitution is not the predominate approach for PFASs and cosmetics.

The definitions of LC and SC PFASs are provided in Chapter 1. It has been reported that, in general across many sector of uses, there has been a shift to move away from longer chain PFASs in recent years, which was initiated by the 3M manufacturing company voluntarily phasing out production and use of PFOSs and

PFOS related chemicals (Glüge et al., 2020[12]), which was then extended to the PFOA substances through the global PFOA Stewardship Program (US EPA, 2006[32]).

The KEMI (2021) report identified a potential trend from long to short chain PFCAs in current cosmetics compared to historical studies such as Fujii, Harada, & Koizumi (2013) and Schultes, et al. (2018). The report by Schultes et al. (2018) reported just one long chain PFCA within the products tested, whereas almost all of the other products contained shorter chain substances. The shift to shorter chain PFCA substances is likely to be the most common change, in cases where 'drop-in' substitution occurred, however, this may vary depending on the product type.

Non-fluorinated chemical alternatives

In terms of 'alternative' chemicals to be used instead of PFASs in cosmetic products, the vast majority of chemical substances identified as providing the key functions associated with PFASs (see Chapter 2) in cosmetic products are non-fluorinated. This observation has been made by assessing the EU's CosIng database. For example, for the function of 'bulking agent', associated with the use of PTFE, there are ~200 identified non-fluorinated chemicals that provide that function. In the case of 'skin conditioning', identified above as being the main function identified for PFASs-containing products (75 INCI names), it is noted there are several thousand chemicals in the database that provide that function.

In terms of the process of 'substitution' of existing uses of PFASs in cosmetics, in most cases, it is indicated that whole product reformulations have occurred to remove remaining PFASs. Therefore, identifying a clear like-for-like 'drop-in' replacement is difficult. More commonly, multiple chemicals are used to replace the different functions provided by PFASs.

Furthermore, it is noted that very limited information is available in the publicly available literature on specific chemical alternatives used to replace PFASs on a one-for-one basis. The Research Institutes of Sweden (RISE, 2022) POPFREE report and the EWG Skin Deep database have identified several specific alternatives. Table 2.1 below provides an overview of several alternatives to PFASs identified in the literature or in cosmetics databases, providing the same functionality as PFASs in cosmetic products. These include naturally derived chemicals from coconut or rapeseed oils. All the substances within the table are non-fluorinated alternatives that are commercially available on the cosmetics market.

One example, where specific alternatives have been investigated is the RISE (2022) POPFREE stage two project. Non-fluorinated alternatives were investigated in pressed powders and lip pencils. Fatty acid salts like magnesium stearate (CAS RN 557-04-0) or sodium myristate (CAS RN 822-12-8) were identified as the fluorine-free alternatives to PTFE, the most common PFASs used in pressed powders. Such alternatives had to be used in higher amounts (>1%) compared to the PFASs (<1 %) (RISE 2022). Non-fluorinated silicones and fats were identified as the main alternatives to perfluorononyl dimethicone, the PFASs used in lip pencils. In both cases the non-fluorinated alternatives had comparable level of performance to PFASs and were already commonly produced. The same report does state that there are already a number of PFAS-free products on the market and therefore, the risk of PFASs exposure to humans and environment in products bought today would be negligible.

Additional chemical alternatives to PFASs include glycols, esters and a range of other non-fluorinated alternatives, including a number of alternatives derived from naturally occurring oils within nuts, seeds and plants. For example, there are several surfactants that have been derived from coconut and rapeseed oils (Pengon et al., 2018[33]). Other naturally derived oils such as argan oil are commonly used in hair and skin products. Argan oils are naturally derived from the seed of the Argan tree, native to Morocco (deLeeuw, 2022[34]). Similarly, shea butter is a regularly used emollient within a range of moisturiser, shampoos and sunscreens (Akihisa et al., 2010[35]). There is a large demand for shea butter with over 750,000 tonnes of butter produced in 2019 (Netherlands Centre for the Promotion of Imports from Developing Countries (CBI), 2022a[36]).

There is limited information and data on the exact naturally derived alternatives that are being used in cosmetic products currently on the market. The consultation with manufacturers of products based on naturally derived ingredients has highlighted that products based on these ingredients have similar performance as PFASs containing products.

There is already good evidence to suggest that the naturally derived ingredients mentioned in the previous paragraph are commercially available (Gentile, 2021[37]).

The literature reviewed indicated that the geographical regionality of naturally derived ingredients does not impact the ability to use these substances. However, concerns have been raised over the overall sustainability of some of these substances. For example, there are several sugar-based surfactants that are derived from palm oil which is associated with deforestation and poor social conditions for those living and working near or in the plantations (International Union for Conservation of Nature, 2018[38]).

It is noted that caution is needed in the use of naturally derived ingredients as a substitute for PFASs. In practice, the term “PFAS free” can mean the substance contains no PFASs or the PFASs levels are under the detection limit of analysis. As PFAS is very persistent and widely present in the environment, some naturally derived ingredients may still contain traces of PFASs, therefore using such substances may lead to the unintentional addition of PFASs to cosmetics.

Table 2.1. Alternative non-fluorinated chemical substances identified for use within cosmetic products[11]

Name	CAS no.	Type of Product(s)	Functions	Notes	Number of Products (as indicated in the EWGs Skin Deep Database)	Source
Magnesium stearate	557-04-0	Powders, lip and eye liners	Oil resistant, water resistant and lubricating properties	Naturally derived substance	Eye shadows = 582 Bronzer = 136 Blush = 116 Foundation = 112 Facial powder = 96 Lipstick = 51 Brow liner = 37 A number of other products including moisturiser, mascara, toothpaste, hair sprays and suncreams	POPFREE
Sodium myristate	822-12-8	Exfoliant scrubs, shaving cream, bar soaps and eyebrow liners	Anticaking, emulsion stabiliser, hair conditioning, skin conditioning and a cleansing and emulsifying surfactant	Data from the Environment Canada Domestic Substance list states that this substance is suspected to be an environmental toxin Naturally derived substance	Exfoliant = 14 Shaving cream = 2 Bar soap = 2 Brow liner 2	POPFREE

[11] It should be noted that the list of substances in Table 2.1 is not presented as an exhaustive list, and information presented should be viewed with caution, as the INCI Decoder database is not always a reliable reflection of the INCI Named ingredients.

Name	CAS no.	Type of Product(s)	Functions	Notes	Number of Products (as indicated in the EWGs Skin Deep Database)	Source
Polylactic acid	26100-51-6	Exfoliant, lip gloss, facial cleansers	Exfoliating, foam forming	Naturally derived substance	Exfoliant = 12 Lip gloss = 8 Mascara = 4 SPF moisturiser = 4 Anti-aging cream = 4 Beard care, eye shadow, body wash = 1	EWG Skin Deep Database
Silica	7631-86-9	Skin care, Sunscreen, Makeup	Abrasive, absorbent, anti-caking, bulking and opacifying		Foundation = 1812 Lipstick = 1438 Eye shadow = 1,301 Concealer = 733 Bronzer = 594 Lip gloss = 545 Nail polish = 408 Eye liner = 397 Mascara = 202 Exfoliant/scrub = 158 Shampoo = 127 Toothpaste = 50	EWG Skin Deep Database
Polyurethane 35	No CAS no. CosIng ref = 85975	Foundations, mascaras, eye shadows, brow liner, eye liner	Binding agent, water resistance, film forming, improved texture	Sythetic polymer	Foundation = 40 Mascara = 24 Eye shadow = 11 Sunscreen = 8 Brow and eye liners = 6 Setting powder = 3 Primer, baby sunscreen, moisturiser and serum = 1	Cosmetic Ingredient Review

Name	CAS no.	Type of Product(s)	Functions	Notes	Number of Products (as indicated in the EWGs Skin Deep Database)	Source
Acrylates copolymer	25133-97-5	Shampoos, body lotions, nail polish	Skin conditioning and smoothing, film forming, detangling and smoothing hair		Nail polish = 408 Lipstick = 213 Body wash = 171 Shampoo = 154 Mascara = 125 Facial cleanser = 113 Eye liner = 107 Liquid hand soap = 46 Foundation, exfoliants, tooth whitening = 30	EWG Skin Deep Database
Paraffin	8002-74-2	Baby lotions, cold creams, ointments, and others	Emollient, moisturising, skin conditioning	Naturally derived substance	Lipstick = 307 Mascara = 223 Eye liner = 177 Lip balm and liner = 267 Foundation = 71 Moisturiser = 16 Hand cream = 13 and multiple other products	EWG Skin Deep Database
Titanium dioxide	13463-67-7	Sunscreens, pressed and loose powders	UV filter and whitening agent	Naturally derived substance	Foundation = 3,127 Lipstick = 2,821 Eye shadow = 2,038 Concealer = 1,420 Lip gloss = 1,265 Sunscreens = 28	EWG Skin Deep Database
Bis-PEG-18 methyl ether dimethyl silane	No CAS no.	Moisturiser, facial cleaners, shampoos and body washes	Emollient, foam boosting, hair conditioning,		Facial moisturiser = 19 Toner = 15 Bath oil/salts = 7	EWG Skin Deep Database

Name	CAS no.	Type of Product(s)	Functions	Notes	Number of Products (as indicated in the EWGs Skin Deep Database)	Source
	CosIng ref = 54713		skin conditioning, surfactant		Sunless tanning = 4 Facial cleanser = 4 Around eye creams = 2 Shampoos = 2	
Decyl glucoside	58846-77-8	Shower gel, shampoos, face washes and bath foams	Emulsifier, foam forming Enhance the skin and adds skins conditioning properties	The product is derived from a fatty acid in coconut oil and therefore is completely biodegradable	Shampoo = 360 Facial cleanser = 234 Body wash = 209 Exfoliant scrub = 49 Concealer = 48 Conditioning = 28 Foundation 25	INCI decoder 2023
Lauryl glucoside	59122-55-3	Bath products, shower gels and shampoos	Increases the foaming ability of the product and adds skin conditioning properties	Derived from coconut oil as above	Shampoo = 179 Body wash = 144 Facial cleanser = 100 Conditioning = 33 Bubble bath = 30 Toothpaste = 21 Moisturiser = 14	INCI decoder 2023
Sodium lauryl glycol carboxylate	119793-28-1	Face washes, shampoos, shower gels, bath products and shaving creams	Surfactant used for its cleaning, emulsifying, foam boosting and skin		Shampoo = 34 Body wash = 27 Facial cleanser = 26 Exfoliant = 5 Sunscreen = 3	INCI decoder 2023

Name	CAS no.	Type of Product(s)	Functions	Notes	Number of Products (as indicated in the EWGs Skin Deep Database)	Source
			conditioning properties			
Isopropyl myristate	110-27-0	Aftershaves, face washes, hair products and skin creams	Emollient, lubrication, strengthens the skin barrier, enables moisture uptake	Naturally derived substance	Eye shadow = 324 Lipstick = 219 Moisturiser = 160 Shampoo/conditioning = 155 Lip balm = 48 Body firming lotion = 36 Eye liner = 28	INCI decoder 2023
Shea butter	194043-92-0	Moisturisers, lip balm, shampoos, hair styling products, concealers and foundation	Emollient properties that smooths and moisturises the skin	Produced from the Shea nut, produced predominantly in Northern Africa Oleic acid C18, Stearic acid C18, Palmatic acid C16 Naturally derived substance	Moisturiser = 1,287 Lip products = 1,200 Conditioning s = 520 Shampoo = 262 Concealer/foundation = 406 Also included in hundreds of other cosmetic products	INCI decoder 2023
Argan oil	223747-87-3	Shampoos and conditioning and some moisturisers	Skin and hair hydration and elasticity	Produced from the argan tree, native to Morocco Oleic acid C18 Linolenic acid C18:2	Conditioning = 323 Shampoo = 275 Lipstick = 243 Moisturiser = 140 Body wash =49	INCI decoder 2023

Commercial availability of non-fluorinated chemical alternatives

Non-fluorinated PFAS alternatives are being used across the cosmetics industry and the literature review points to a good commercial availability for these alternatives. Furthermore, the cosmetics industry has indicated that alternatives to PFASs are widely available and represent a much greater market share than PFAS-containing products (see Chapter 4).

While a study by Cousins et al. (2019) (Cousins et al., 2019[39]) suggests that drop-in replacements for PFASs are commercially available and provide similar performance and properties to that of PFASs, it is emphasised that the main focus in the cosmetics sector is on product reformulation (see Chapter 3). There is very little available information in the public domain that presents information on one single chemical replacement for a specific PFAS ingredient in cosmetic products. The RISE (2022) report states that unlike with other product categories such as textiles, a specific PFAS may offer multiple functions in a cosmetics product rather than just one function in textiles such as water repellence. Annex XV of the EU restriction proposal (ECHA, 2023b[10]) outlines that PFAS alternatives within cosmetics are available and commercially and economically feasible.

Furthermore, as discussed above, many of the alternatives identified in this report have been used widely in cosmetics over time without being labelled or marketed as ‘PFASs alternatives’ (i.e. they were in use for these products already instead of PFASs). For example, silicones have been increasingly used in cosmetic products (to improve the consistency of formulations) since their first use in the 1940s (Pawar and Falk, 2021[40]) (see Chapter 3). Additionally, paraffins and mineral oils have reportedly been used for decades as common ingredients for similar functions in a range of products (CoSmile Europe, 2023[41]). Magnesium stearate is also a common ingredient in a wide range of cosmetics (INCI Beauty, 2023[42]).

Cosmetics containing naturally derived alternatives are readily available and economically viable for manufacturers across the EU. Cosmetic products cannot be defined as ‘natural’ unless they contain at least 70% of natural substances (excluding water and salt) and cannot contain any fragrance ingredients other than those natural ingredients or derived from natural sources, as defined by the Cosmetics, Toiletries and Perfumery Association (CTPA). The literature reviewed indicates that there is wide availability of naturally derived alternatives to PFASs in cosmetic products (KEMI, 2021[28]). However, in general, products based on naturally derived ingredients are slightly more expensive than their ‘conventional’ counterparts, which could represent an initial barrier to their penetration into the market.

Information on the ‘natural’ cosmetics market provides some insight into the overall demand for, and trend in the market for these products, which can indicate their potential to replace PFAS-containing cosmetic products. The demand for ‘natural’ cosmetic products has been steadily growing globally (see Chapter 4 for further discussion). Steady growth in the market had been seen up until the COVID-19 pandemic in 2021. The number of stores selling products based on naturally derived ingredients has been rapidly growing in the last five years. Germany had the largest market for ‘natural’ cosmetics within Europe with roughly 35% of sales in 2018 (Netherlands Centre for the Promotion of Imports from Developing Countries (CBI), 2022b[43]). There is a drive for certification of natural products predominantly in Western Europe ((Netherlands Centre for the Promotion of Imports from Developing Countries (CBI), 2022b[43])), which could allow consumers to better understand the origins of substances. Furthermore, it is indicated that in the EU, skincare is reported to be the largest product category containing naturally derived ingredients, contributing to nearly 75% of the total EU cosmetics industry.

Summary of PFASs and alternatives used in cosmetics

Thirty-six different PFASs (polymeric and non-polymeric) are identified as being used in cosmetic products. The presence of PFASs in cosmetic products can be the result of intentional use as a chemical ingredient or unintentional presence as a degradation product or impurity. Where intentionally added as chemical ingredients, PFASs provide a wide range of different functions, with analysis from products currently available on the European market indicating skin and hair conditioning being the two most common.

Alternatives to PFASs are widely available on the market, although since there is very little information on like-for-like replacement, very few specific chemicals have been identified in the literature as being a specific 'alternative'. Based on an assessment of chemical ingredient databases, it is suggested that there are hundreds of alternative (non-fluorinated) chemical substances that provide the same function as PFASs in cosmetic products. However, as discussed in Chapter 3, evidence on direct substitution of PFASs in cosmetic products is extremely limited.

The hazard profile of these alternatives is not considered in this report.

3 Technical and economic feasibility of alternatives to PFASs in cosmetics

Overview

This section presents information on the overall technical and economic feasibility of alternatives to using PFASs in cosmetic products.

In general, very limited information is available in the public domain on specific chemical alternatives to PFAS ingredients in cosmetic products. It does not appear that individual ‘drop in’ chemical alternatives have been very widely studied or reported, either in research published by academic or industry organisations (manufacturers, suppliers, retailers), rather this is considered within the sector in terms of wider-scale product reformulation. The cosmetics industry has indicated that the issue of substituting PFASs in cosmetics is seen as a relatively low priority or concern, compared for example to other sectors of use covered by the EU restriction proposal (ECHA, 2023a[20]) or compared to the challenges associated with substituting other restricted or prohibited substances, such as microplastics.

This observation can be largely attributed to the fact that PFASs-containing products do not make up a significant proportion of the total market of cosmetic products (see Chapter 4 for detailed discussion), and the indication from the cosmetics industry that this sector is already relatively advanced in the phase-out of PFASs from the cosmetics supply chain and has been actively phasing out the use of PFASs for the past 5 years.

The use of PFASs in cosmetics, and the feasibility of alternatives is discussed in the EU restriction proposal (ECHA (2023a)). This is largely based on earlier studies, including those by KEMI (2021) and IVL Swedish Environmental Research Institute and Stockholm University (Putz et al., 2022[23]) and provides the most in-depth overview of PFASs and alternatives in this sector, although it should be noted that this is based solely on the situation in Europe. Less information has been identified for this aspect in other markets. It is also noted from the ECHA (2023a) report, that the amount of published literature outlining specific assessments of alternatives – their availability, market penetration, and feasibility (technical and economic) – is lacking.

Technical performance of alternatives to PFASs in cosmetics

Strictly speaking, the ‘feasibility’ of one alternative substance over another substance in cosmetic products has not been investigated specifically in many assessments available in the public domain. There is a strong indication from industry, NGOs and research stakeholders that in the cosmetics sector, the emphasis is not on the identification and use of ‘drop in’ chemical replacements for individual PFASs, as commonly observed in other sectors using PFASs, but rather the broader-scale reformulation of the product itself. Indeed, as noted by KEMI (2021), in order to make existing products that currently contain PFASs non-fluorinated, it might require a completely new formulation of the product, as direct substitution of PFASs by one or several compound(s) might only work in specific cases.

The broad range of available non-PFAS ingredients that can potentially perform the same specific function(s) that are commonly associated with the use of PFASs (see Chapter 2) is cited as an indication that alternatives that provide the required functionality with required performance and cost-effectiveness are available. As noted in KEMI (2021), while a substitution is usually made based on the choice of a new compound that can replace a specific function of the previous compound in the product, in the case of cosmetic products, the kind of PFASs and their functions seem so diverse that making general claims about them seems harder in cosmetics than for instance in the textile sector. In very few cases have specific 'non-fluorinated' alternatives been identified as used directly as a replacement for a PFASs in a specific cosmetic product (e.g. see KEMI (2021); ECHA (2023b)).

In this context, it is important to emphasise the difference between the equivalent chemical function of a substance and the comparable performance of a product. Chapter 2 outlined a broad range of different technical functions provided by PFASs in different types of cosmetic products (e.g. skin conditioning, hair conditioning, film forming, bulking agent, etc). It is indicated that in many cases, PFASs could be expected to provide multiple useful functions in the same product (KEMI, 2021[28]). Indeed, of the 160 chemical ingredients (INCI names) identified in the KEMI (2021) report, 86 (54%) had listed one function, 52 (33%) two and 22 (14%) had three or more different functions.[12] Hence, to achieve a comparable technical performance it can be expected that a larger-scale product reformulation would be required and it must be considered if the overall technical performance (e.g. durability) of the whole PFASs containing product is comparable to that of a PFASs-free product[13]. Industry has noted that, while for PFASs in cosmetics, technically this is an achievable and realistic prospect, there are requirements to conduct appropriate testing and assessments to ensure a required level of performance and safety. In general, it was indicated this can be 6-12 months per product, but could be much longer depending on the product.

Given the above discussion, and the wide range of different products and functions involved, it is not possible to provide a detailed discussion of technical feasibility for all specific chemical alternatives compared with PFASs in this sector.

One example where specific alternatives have been investigated is the RISE (2022) POPFREE stage two project where a specific case study highlighting PFASs in cosmetics is presented. This was developed in collaboration with the cosmetics retailer H&M. They investigated examples of potential non-fluorinated alternatives for PFASs in two types of cosmetic product:

- **Pressed powders** – the most common PFAS used in pressed powders is PTFE. Since PTFE is not used in all pressed powders, it was inferred that the use of PTFE could be related to specific-coloured pigments. The fluorine-free alternatives are fatty acid salts (e.g. magnesium stearate or sodium myristate). The key required performance/function in these products was to create low friction powder. The frictions measurements were assessed, and no differences could be observed in the level of performance.

[12] However, it should be noticed that the reported functions of INCI Name ingredients may not strictly reliable, as they are indicated by the manufacturer without associated demosntrations. Therefore, such information should be taken with caution.

[13] With PFASs-free product it is intended a product that does not contain PFASs according to the list of ingredients (Putz, Namazkar, Plassmann, & Benskin, 2022), that is intentionally added PFASs.

- **Lip pencils** – The specific PFAS observed in the products previously was perfluorononyl dimethicone. The fluorine-free alternatives used here were alternate silicones and fats. The claims associated with perfluorononyl dimethicone by the suppliers are that base formulations are easy to level off, soft, not 'gunky'. Products free from PFASs also had this claim, providing the same performance, and were long lasting in humid conditions.

The RISE (2022) POPFREE report stated that in both product type cases, non-fluorinated alternatives with comparable technical performance were already commonly produced. For powders, the fluorine-free alternatives had to be used in higher amounts in the product than the PFASs (alternatives few percent, PFASs <1 %)[14]. This is the only example identified in publicly available literature where the assessment of alternatives in comparison with specific PFASs has been carried out at a substance-for-substance level.

The cosmetics industry has indicated that there are very few, if any, technical barriers to phasing out (and/or avoiding their use in the first instance) intentionally added PFASs from products and that product reformulation to remove PFASs as an intentional ingredient is already in progress.

Overall, the fact that there are far more non-fluorinated cosmetic products within the same product categories on the market[15] as the PFASs containing products, suggests that PFASs can be replaced by other ingredients and do not have unique functions in cosmetic products. However, very few studies have demonstrated this experimentally.

It should also be noted that the relative feasibility of specific alternatives to a PFAS-containing cosmetic product, depending on the function, may be different in different geographical locations. For example, the needs for cosmetics differ in hot and humid areas.

Costs of using alternatives to PFASs in cosmetics

Overview

Very little quantitative or qualitative information has been identified on the costs of substitution of PFASs with non-fluorinated alternatives in the cosmetics sector. An assessment of potential economic impacts for the cosmetics sector of the PFASs restriction in Europe, has been presented in the EU restriction proposal (ECHA (2023b)). This section is based on the information reported in that study, supplemented by further information provided through consultation with stakeholders.

Capital costs of alternatives to PFASs in cosmetics

This section has considered estimates for the capital costs of non-fluorinated chemical alternatives and of naturally derived ingredients, that is any long-term investment that will be required to introduce alternatives in the cosmetic sector, for example in terms of reformulation. The only aspect of capital costs associated with substitution of PFASs in the cosmetics sector that has received attention in the literature, is related to product reformulation. The ECHA (2023b) report presents an assessment of reformulation costs for PFASs in

[14] Specific values (or range) were not quoted in the RISE(2022) report

[15] Based on the European market data.

cosmetics (for Europe)[16]. The key aspects of estimating the reformulation costs for PFASs-containing products in the cosmetics sector are summarised in the table below.

Table 3.1. Overview of reformulation costs estimate for PFASs in cosmetics in Europe (based on ECHA, 2023b)

Aspect of costs	Costs/assumptions
Total number of cosmetic formulations on the EEA market	• The European Commission impact assessment on simplification of the Cosmetics Directive estimated that there were 300,000 cosmetic product formulations on the EEA market in 2008 (EC, 2008) – updated to 520,000 formulations in present day based on information from Cosmetics Europe. • 520,000 total formulations (of which 100,000 from large companies and 420,000 from small and medium sized enterprises (SMEs)).
Number of cosmetic formulations on the EEA market containing PFASs	• The market share of PFASs containing products, i.e. the percentage of total cosmetic products that contain PFASs in the CosmEthics database was 1.4 % (extracted in August 2020). This is based on the European cosmetic database CosmEthics (Finish) by the Authors to be the one most representative of the EEA market. • It was noted that a substantial share of the PFASs-containing products in the three cosmetic product databases consulted for this study contain PFASs that are or are about to be restricted. In the CosmEthics database this share was 33 %. These cosmetic products need to be reformulated anyway even in the absence of the restriction proposed. • The number of cosmetic formulations on the EEA market containing PFASs by the time the restriction will be implemented is estimated to be 4,878 (520,000*1.4%*(100-33)%), of which 938 are in large companies and 3,940 in SMEs.
Number of reformulations expected due to a restriction of PFASs in cosmetics	• Assumed by the authors that 5% of the relevant products are reformulated (based on previous D4/D5/D6 restriction). • It was considered by the authors that this could be considered an overestimation, since the assumption in the restriction proposal for D4, D5 and D6 was based on a total market share below 30% while the share of formulations with PFASs is noted to be substantially lower (see Chapter 4) than that for all subcategories of cosmetics in the CosmEthics database. • The number of reformulations expected as a result of this restriction proposal are (5%*4,878=) 244, of which 47 belong to large companies and 197 to SMEs.

[16] The method and assumptions for the estimation largely follows the approach taken for the previous ECHA restriction proposal D4, D5 and D6, as the process was considered to be broadly very comparable.

Aspect of costs	Costs/assumptions
Cost per reformulation	• Estimated that the cost per major reformulation done by large companies in the cosmetics industry was assumed to be €365,000 in 2017, while a major reformulation by an SME was assumed to cost €42,000. These estimates were based on the D4, D5, D6 restriction proposal. • Adjusting these costs for inflation to 2021 values implies that a major reformulation costs €391,000 for large companies and €45,000 for SMEs. • Assumed by the authors that all reformulation required due to this restriction proposal can be considered as major reformulations. • The authors note that this could imply an overestimation of the true reformulation costs since all expected reformulations might not be major.

Based on the assumptions described in Table 3.1, the proposed EU PFASs restriction leads to major reformulations of 244 cosmetic products (in the EEA), of which 47 belong to large companies and 197 to SMEs. These reformulations are expected to cost (undiscounted) €27.2 million (of which €18.4 million affect large companies and €8.9 million SMEs) in 2025 and 2026. It was also noted that, since the profit margins in the market for manufacture of cosmetic products are relatively high, the Dossier Submitters assume that the product reformulation costs primarily will be borne by the cosmetics producers in the form of lower producer surplus.

It should also be noted, that, as discussed above, the total number of product reformulations for PFASs-containing products is expected to be relatively low, compared to other chemical substances such as microplastics, where the number of total reformulations required is expected to be substantially higher (tens of thousands). Hence the relative overall costs associated with reformulation to remove PFASs can be seen as being very low compared to those related to other chemical substances.

The cosmetic industry has indicated that, in general, 'major' product reformulation is not required to remove PFASs from existing formulations. It was further indicated that, because manufacturers will typically reformulate their product on a regular basis, some of the costs associated with reformulation for restricted substances (like PFASs) can be 'recaptured' as reformulation is happening anyway under 'business as usual' conditions.

Operating costs of alternatives to PFASs in cosmetics

This section discusses the operating costs of non-fluorinated chemical alternatives and of naturally derived ingredients, that is any daily expense that the industry will face in operating with alternatives in the cosmetic sector, including both technical costs (e.g. for additional testing, installing new equipment etc.) and organisational costs (e.g. training of workers, occupational safety measures, regulatory costs).

The only aspect of operating costs that has been covered in any literature source identified in this report, is related to the potential differences in product performance. The ECHA (2023b) report noted that, while substitution away from PFASs could still, in theory, lead to some loss of product performance, even if this performance loss would not be critical. Very little, if any information is available to indicate that such losses will occur as a result of a restriction of PFASs in cosmetic products, and therefore it was assumed (in ECHA (2023b)) that the associated consumer [economic] losses are non-existent or negligible. The cosmetics industry has noted that this may not necessarily be the case for all cosmetic products and there may be some types of products for which it is more challenging to replace PFASs than it is for others. However, no specific examples have been provided.

The assumption of low or negligible operating costs was primarily based on the information that the share of PFASs containing cosmetic products is very low (1.4%) in over 100 cosmetic product subcategories included in the CosmEthics database, which, according to the authors of the ECHA (2023b) report indicates that there are economically feasible alternatives available for all uses of PFASs in cosmetics. This adds to the information presented in earlier sections, suggesting that cost-effective or cost-equivalent PFASs-free products are already on the market, but it also emphasised that limited information has been identified in the literature on specific alternatives in most uses.

Additional costs of alternatives to PFASs in cosmetics

No information on other types of costs (for example related employment, health, remediation/clean up) and a comparison for the use of PFASs compared to alternatives has been identified in this study.

Summary of the technical and economic feasibility of alternatives

In the cosmetics sector, substitution of PFASs with alternatives is generally not approached in terms of ‘drop in’ replacements, rather this is seen more in the context of full product reformulation. There is very little data available on the assessment of alternatives on a substance-for-substance basis.

In general, for all identified functions provided by PFASs in cosmetic products, it is shown to be technically and economically feasible to substitute the intentionally added PFASs with alternatives that provide the same function, and many non-fluorinated alternatives are available on the market that can provide the main functions identified for PFASs in these cosmetic products. Specific quantitative assessments have only been identified in Europe, however. In general, the cosmetics industry does not foresee there being any significant technical or economic challenges to substitute PFASs for alternatives in the vast majority of cosmetic products. It is noted, however that very few specific feasibility assessments of PFAS-containing vs PFAS-free products are available in the literature to demonstrate feasibility of alternatives explicitly.

While in some cases, it is noted that it could be challenging and costly to replace PFASs and achieve the same level of overall performance, no specific examples have been provided that demonstrate this, and in many cases the costs associated with PFAS phase-out may be ‘recaptured’ by reformulation that would occur anyway under ‘business as usual’ operations.

4 Uptake and market penetration of alternatives

Overview of the market for cosmetics

In 2020, global sales of cosmetic products[17] totaled at $484 billion (USD) according to Euromonitor International (2021) (Euromonitor International, 2021[44]).[18] Considering decorative cosmetics alone, sales are forecast to continuously increase between 2023 and 2027 by 20%, to a maximum value of $125 billion (USD) in 2027 (Statista, 2023a[45]).

The global market share of different cosmetic products has remained relatively stable between 2011 and 2022 (Statista, 2023b[46]). Skin care products dominated the market over this time period and made up 41% of the global cosmetics market in 2022. In the same year, hair care products made up 22% of the market, followed by make-up (16%), perfumes (11%), and hygiene products (10%). Chapter 2.1 of this report highlighted that PFASs may be present in cosmetic products under each of these categories.

The largest global brand in 2021 was L'Oréal, with a revenue of $35.6 billion (USD) (Statista, 2023c[47]). Other global leaders in the sector include Estée Lauder (revenue of 17.7 billion USD), Unilever (revenue of $12.3 billion (USD) in the beauty and wellbeing sector), and P&G (revenue of $3.3 billion USD in the beauty sector) (Estée Lauder., 2022[48]); (Statista, 2023d[49]); (Business Quant, 2023[50]). The cosmetics sector is made up of a mixture of large companies and SMEs, for example, in Europe there are nearly 7,000 SMEs in the cosmetics industry (CTPA, 2023a[51]).

Europe and the US are the largest markets for cosmetics. In 2021, both regions had cosmetics markets worth nearly $90 billion USD each (CTPA, 2023a[51]). China had a market of approximately $75 billion USD, followed by Japan ($30 billion USD), Brazil ($20 billion USD), India ($15 billion USD), and South Korea ($10 billion USD). While the European cosmetics market is anticipated to remain a similar size over time (ECHA, 2023b[10]), the US and Chinese markets are expected to increase in value (Statista, 2023e[52]); (Statista, 2023f.[53]). In Europe, the highest consumption of cosmetics is in Germany, followed by France, Italy, the UK, and Spain (Cosmetics Europe, 2023[54]).

Between 2018 and 2019, global sales of natural cosmetics increased by 8.8% (Alioze, 2022[55]). Increasing global demand for natural cosmetics is expected to continue, with projected growth of 33% between 2023 and 2027 (Statista, 2023h[56]).

[17] Product categories including baby care, bath/shower, colour cosmetics, deodorants, fragrances, hair care/colour, hair removal, men’s grooming, oral care, skin care, sun care.

[18] As cited by the Personal Care Products Council 2021 Sustainability Report.

In Europe, the market for natural cosmetics grew continually between 2014 and 2019 (from 2.8 billion EUR[19] to 4 billion EUR[20]) (Netherlands Centre for the Promotion of Imports from Developing Countries (CBI), 2022a[36]). In Western Europe, organic certification and fair-trade certifications are increasingly demanded by consumers. In the US, a 6.6% annual growth rate is expected in the natural skin care market up until 2030 (Grand View Research, 2023[57]). In Asia, revenue of the natural cosmetics sector is predicted to grow by 8% annually until at least 2027 (Statista, 2023i[58]), compared to 4% for the wider beauty and personal care market (Statista, 2023j[59]).

Market share of PFAS-containing vs PFAS-free cosmetic products and geographical spread

The market share for PFAS-containing products is quite modest. Investigating the market share of cosmetics products containing alternatives to PFASs is challenging because PFASs in cosmetics rarely have direct chemical substitutes (see Chapter 2 and Chapter 3). However, the cosmetic industry[21] has indicated that there is a large and growing market for products using alternatives to PFASs, which are widely used and available on the market. Therefore, PFASs are not commonly used in cosmetics. This can be at least partly attributed to growing demand for cosmetic products based on naturally derived ingredients (discussed in further detail below).

It is notable that the global market for cosmetics and personal care products based on natural ingredients was worth 37 billion USD in 2022 (Statista, 2023g[60]), reflecting nearly 8% of the total cosmetics market. Products based on naturally derived ingredients are of increasing demand and therefore increasingly penetrating the wider cosmetics market (see also Chapter 4). These products are unlikely to contain intentional PFASs ingredients as they are based on naturally derived ingredients.

PFASs are not common ingredients in cosmetic products, at least in the UK and EU cosmetics markets. Cosmetic databases in the EU indicate that only 1.1 to 1.4% of cosmetic products contain PFASs ingredients (ECHA, 2023b[10]). Across all categories of cosmetics products, PFASs-containing products make up less than 10% of the products on the market (ECHA, 2023c[61]). Similarly, in the UK, a 2020 survey by the Cosmetic, Toiletry and Perfumery Association (CTPA) (representing 85% of the UK cosmetics market) found that only 1.5% of member companies reported use of PFASs as cosmetic ingredients (CTPA, 2023b[62]). The CTPA also report that only nine PFASs ingredients are used within cosmetics in the UK and the use of PFASs in cosmetics in the UK is declining rapidly. In discussions with the CTPA, the organisation highlighted that PFASs have never been standard ingredients for cosmetic products and are only found in a small number of high-performance products, but the level of performance provided is not critical, and the same functions can be provided by other ingredients.

Commitments of cosmetics brands to be PFASs-free also suggest that manufacturing of cosmetics products without PFASs / with alternatives is taking place on a large scale. For example, global brands H&M and Sephora are included in the Green Science Policy Institute's list of PFASs-free cosmetic brands (Green Science Policy Institute, 2023[63]). Furthermore, the largest global cosmetics brand L'Oreal committed to not

[19] Converted from 3 billion USD, using conversion rate of 1 USD = 0.93 EUR https://www.xe.com/currencyconverter/convert/?Amount=3&From=USD&To=EUR

[20] Converted from 4.3 billion USD, using conversion rate of 1 USD = 0.93 EUR https://www.xe.com/currencyconverter/convert/?Amount=3&From=USD&To=EUR

[21] Insight for Europe only

using PFASs in their products in 2018 (Chemical Watch, 2018[64]),[22] and given the breadth of their portfolio across multiple product categories, this might suggest that a large number of products on the global market contain PFASs alternatives. However, recently, PFASs were detected in several L'Oreal mascara products in the US (Verdant Law, 2022[65]), and in L'Oreal eye shadows in the UK (BBC, 2023[66]). Some sources suggest that cosmetics brands may be struggling to eliminate PFASs due to a lack of transparency from ingredient suppliers and manufacturers (Environmental Health News, 2022[67]), which could lead to accidental occurrence of PFASs in cosmetics. This problem cannot be addressed by reviewing ingredient lists for PFASs and substituting them if listed, but through improved supply chain communication and transparency as well as analytical testing of the composition of cosmetic products.

Estimates for market share of PFAS-containing products were not identified for regions other than Europe. However, there are concerns regarding the level of use of PFASs in cosmetics in the US and in Canada, particularly after a study recently detected PFASs in 29 cosmetic products on the market (Whitehead, Venier and Wu, 2021[27]). In the same study, where targeted PFASs were measured in 29 foundations, lip products, and mascaras, the sum of 53 PFASs were present at a median of 99 ng/g and an average of 591 ng/g product weight, including products from the US and Canada. Each of the 29 cosmetic products contained between 2 and 13 different PFASs. PFAS was only listed as an ingredient in one of those 29 products. The anticipated / proposed regulatory provisions in some countries such as the US, EU, UK, and New Zealand are likely to result in the elimination of PFASs (and therefore full uptake of alternatives or withdrawal of products) from the cosmetics markets in these countries. These provisions are further explored in Chapter 4.5.2.

Countries in Asia may have a different distribution of PFASs and PFASs alternatives in cosmetic products on the market due to different regulations and likely different product formulations. The International Pollutants Elimination Network (IPEN) investigated PFASs pollution in the Middle East and Asia[23] and raised concerns that PFASs are largely unregulated (IPEN, 2019[68]).

Overall, UK and EU markets are dominated by PFASs-free cosmetic products (with less than 1.5% of cosmetic products on the market containing PFASs ingredients), while the situations in other geographical areas are less clear (based on publicly available estimates of the proportion of cosmetics containing PFASs).

Anticipated time frame for alternatives to eliminate the use of PFASs

The technical and economic feasibility of alternatives to PFASs in cosmetic products is covered in Chapter 3. As noted there, the EU restriction proposal indicated that PFASs can be eliminated relatively quickly and easily from cosmetic products in the EU due to "*sufficiently strong evidence pointing to the existence of technically and economically feasible alternatives*" (ECHA, 2023b[10]). As discussed in Chapter 3, the EU restriction proposal concluded that the costs of substituting PFASs with alternatives would be negligible for a number of reasons. The cosmetics market is already dominated by alternatives to PFASs and therefore a relatively low degree of reformulation would be required to completely eliminate intentionally added PFASs. In addition, companies are likely to produce multiple products within the same product category and accept consumers shifting to existing alternative products rather than investing in reformulation. The EU restriction proposal approximates that 47 products by large companies and 197 products by SMEs might need reformulation. The overall number and complexity of reformulations for PFASs are considered very low by the cosmetics industry,

[22] No direct source / statement from L'Oreal was identified, only news articles.

[23] Countries investigated included Bangladesh, Egypt, India, Indonesia, Japan, Jordan, Lebanon, Malaysia, Nepal, Sri Lanka, Thailand, and Vietnam

in comparison with other tens of thousands of reformulations that may be required in the case of proposed restriction of microplastics.

No additional scientific literature on the time required for substitution in the cosmetics sector was identified. There are variable claims from news outlets and web sources for the time required to reformulate cosmetic products. The cosmetics industry has indicated that reformulation and testing could require 6-12 months, but could be longer in some cases, while other sources claim that reformulation may take over two years (e.g. 2.5 to 4.5 years including raw material research and development, product testing and qualification, safety and regulatory requirements, and manufacturing and marketing) (Cosmetics Info, 2023[69]). However, others suggest that products can be developed and launched in as little as 6 months (Brookman, 2019[70]). Product formulation is more challenging for completely new technologies, and therefore reformulation with existing technologies (PFASs alternatives that are already available and feasible) may be quicker than the average product reformulation.

Overall, given that alternatives are already used widely, the elimination of intentionally added PFASs could be achieved very rapidly. Whether this elimination will happen in practice will most likely be dependent on market and regulatory drivers in certain regions of the world (see Chapter 4).

Drivers for the development of alternatives

Market drivers

Concern surrounding PFASs is increasing globally, reflecting increases in the understanding of the risks to human health and the environment from PFASs. A US study showed that between 2017 and 2019, the number of social media posts about PFASs increased by 670% (Tian et al., 2022[71]). During this period, peaks in PFASs posts correlated with media coverage and scientific publications, e.g. related to contamination events. Recent press releases have demonstrated PFASs concerns specifically in the cosmetics sector, at least in the US and UK.[24]

While no information specifically on consumer efforts to purchase PFASs-free cosmetics was identified, there is clear evidence that the demand for more sustainable cosmetics is increasing. Consumers are seeking products with more positive environmental impacts, science-based credentials for health and safety, sustainably sourced ingredients, market segments with fragrance-free products made using natural ingredients, and products which avoid contentious chemicals (Euromonitor International, 2022[72]); (Statista, 2023b[46]); (Netherlands Centre for the Promotion of Imports from Developing Countries (CBI), 2022b[43])). Furthermore, while consumers reportedly have a preference for brands they already use, the main features attracting them to other brands are natural, clean, and sustainable brands (Forbes, 2019[73]).

Several standards – for example the COSMOS-standard[25] and the NATRUE standard[26] have been developed which certify natural cosmetic products (COSMOS, 2023[74]) ; (NATRUE, 2023[75]) and several organisations are advocating for toxic-free and PFASs-free cosmetics (Globalportalen, 2019[76]); (Breast Cancer Prevention Partners, 2023[77]). These standards and campaigns are likely to further drive the market (e.g. a campaign

[24] A Google news search of "forever chemicals in cosmetics" run on 03/05/2023 returned about 228 results, primarily in the UK (which may be due to more media coverage in the UK but also as this search was executed in the UK).

[25] https://www.cosmos-standard.org/en/cosmos-standard/

[26] https://natrue.org/our-standard/natrue-criteria-2/

from the Swedish Society for Nature Conservation (SSNC) triggered the commitment of L'Oreal to cease use of PFASs in cosmetics (described in Chapter 4.2)).

Regulatory drivers

Regulatory drivers are related to global, national or state-level restrictions in the use of PFASs for the production of cosmetics or in the imports/exports of PFASs. Such restrictions could drive the substitution of PFASs in cosmetics with alternatives. Certain PFASs and their salts / related compounds are restricted globally under the Stockholm Convention (UNEP, 2023[78]). PFOA, PFHxS, their salts and related chemicals, are listed on Annex A, meaning that countries who have ratified the Convention must take measures to *eliminate* the production and use of these substances. PFOS is listed on Annex B, meaning that countries who have ratified the Convention must take measures to *restrict* the production and use of these substances. Long-chain PFCAs are currently being reviewed for addition to Annex A or B.

It is noted that many OECD countries have implemented legislation and wider policy measures targeted at PFASs, that go beyond the requirements of the Stockholm Convention and that are driving a move away from their use and substitution to safer alternative across a wide range of different sectors, potentially including uses in the cosmetics industry.[27] Examples of cosmetic-specific regulations with a focus on OECD countries is provided below.

In the US, in 2021, the No PFASs in Cosmetics Act was proposed in Congress, which would ban PFASs in cosmetics products such as make-up, moisturisers, and perfumes (US Congress, 2021[79]). In 2022, the Modernization of Cosmetics Regulation Act (MoCRA) was signed into law. The MoCRA expands the US FDA's authority to regulate cosmetics, expands the reporting requirements for cosmetic ingredients (including PFASs), and requires the US FDA to assess the use of PFASs in cosmetics, including any risks associated with such use[28].

Additional relevant regulation has been passed or proposed at the state level in the US. Some States have signed into law regulations that ban PFASs in a wide range of products (that would cover cosmetics), such as Maine by 2030 and Minnesota by 2032. Some other States have proposed similar regulation (Connecticut, North Carolina, Rhode Island). Several States have enacted specific bans of PFASs in cosmetics, including California, Colorado and Washington (all PFASs), as well as Maryland (certain PFASs). Similar bans of PFASs use in cosmetics or personal care products have also been proposed in Hawaii, Illinois, Massachusetts, New Jersey, and Oregon (Lee, Kindschuh and Brankin, 2021[80]); (Bloomberg Industry Group, 2023[81]).

In New Zealand, in 2023, the Environmental Protection Authority proposed a specific ban on all PFASs in cosmetics from 2026 as part of an update of its Cosmetic Products Group Standard 2020 (New Zealand Environmental Protection Authority, 2023[82]).

A REACH restriction of all PFASs[29] as a class covering a wide range of uses (including cosmetics) has been proposed and is currently being evaluated (OECD, n.d.[83]) (ECHA, n.d.[84]).

[27] https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/countryinformation/

[28] https://www.congress.gov/117/bills/hr2617/BILLS-117hr2617enr.pdf

[29] REACH restrictions apply also in European Economic Area (EEA) countries such as Iceland and Norway.

Summary of market and drivers for alternatives

The overall market for products with alternatives to PFASs dominates. The market share of PFAS-containing products is indicated to be very small, and the market for alternatives is continuing to grow, which is further reducing the relative market for PFASs-containing products. The primary driver for this trend is the stronger public awareness and demand for 'clean' (i.e. naturally derived) cosmetic products and associated response from brands and retailers pledging to phase out PFASs from their products, with a focus on their reputational image and purchasing priorities of their customers. This has been aided by several larger brands \making pledges to phase out PFASs specifically, which has encouraged other brands to follow suit.

The phase out of PFASs within cosmetics is being further driven by increasingly strict legislation restricting or prohibiting PFASs in different global regions, which in some cases is specifically targeted at use in cosmetics. It is indicated that it is technically and economically feasible to substitute the remaining intentional uses of PFASs in cosmetics, with a relatively small timescale and with very little impact or risk to the industry. However, it should be noted that data is more readily available for the EU and UK market, while the situation in other global regions is less clear.

5 Challenges to the shift to alternatives

Technical challenges for substitution

Availability and functionality of alternatives

As discussed in earlier sections, a limited number of studies has been identified that have investigated the compatibility of specific PFASs compounds with non-fluorinated alternatives in terms of their ability to deliver a specific technical function in cosmetic products. As noted in earlier sections and in the RISE POPFREE project (RISE, 2022[85]), in many cases it can be seen that products had been completely reformulated and it was not possible to identify a clear individual ‘substitute’ chemical substance to the original PFASs.

As noted in the EU restriction proposal (ECHA, 2023b[10]), it is expected that the share of PFASs containing cosmetic products is below 10% for over 100 cosmetic product subcategories investigated[30]. Of the most frequently occurring properties for PFASs in cosmetic products identified in the EU restriction proposal (ECHA, 2023c[61]) – skin conditioning, film forming, solvent and surfactant etc– it has been noted in Chapter 2 above, that a very large number of ‘alternative’ (non-fluorinated) substances are available to perform the same function.

On this basis, the EU restriction proposal concluded that the evidence is sufficiently strong that technically feasible alternatives are available for the quantities required for use in cosmetic products and that the substitution potential is high (ECHA, 2023b[10]). However, as noted in KEMI (2021), in order to make existing products with PFASs non-fluorinated might require a completely new formulation of the product, as direct substitution of PFASs by one or several compound(s) might only work in specific cases.

However, it must be considered that this observation has been based predominantly on consulting various online cometic product databases, e.g. CosIng (EU); EWG Skin Deep (US), CosmEthics (Finnish), Kemiluppen (Danish), ToxFox (German). As noted by KEMI (2021), the sheer number of specific functions and products involved means that researchers have not attempted to investigate the feasibility or performance of alternatives, in relation to PFASs, in many specific assessments. Furthermore, the cosmetics industry has noted that these chemical databases for cosmetic products may not always provide accurate or up-to-date information. It was also noted by the cosmetics industry, that while a wide range of alternatives are shown to be available for the chemical functions PFASs provide in cosmetics, a distinction needs to be made between ‘alternatives’ and ‘suitable alternatives’ in this context. For example, it was noted that the overall performance of a cosmetic product (e.g. its overall durability) may be linked to several different functions, of which PFASs may be associated with several simultaneously. This could potentially make the reformulation using ‘suitable alternatives’ more challenging in some cases and requires more detailed reformulation. Therefore, inferences

[30] Based on an assessment of products included in the CosmEthics database

on the availability and technical feasibility of ‘suitable’ alternatives to PFASs based on these chemical databases need to be viewed with some degree of caution. However, no specific examples have been raised where this causes a major problem and overall, the cosmetics industry considers the substitution of PFASs to be achievable.

The only specific case identified is the RISE (2022) POPSFREE assessment of PFASs in cosmetics (as discussed in Chapter 3). It was noted there (echoing observations made earlier in this section) that, looking at two types of cosmetic products (pressed powders and lip pencils) no significant differences were indicated between PFASs and non-fluorinated alternatives. The only potential challenge was that, in lip pencils, the alternatives (fatty acid salts such as sodium myristate or magnesium stearate) used instead of the PFASs (perfluorononyl dimethicone), usually need to be used in higher amount as compared to PFASs (a few percent vs less than 1 percent of the total formulation). However, the authors noted that, as several products free from PFASs are already on the market, it was decided not to spend more effort in trying to understand the function of PFASs and identify new alternatives.

Overall, the cosmetics industry in general has indicated that many companies within this sector are already in the process of phasing out or have already phased out the intentional use of PFASs from their products in favour of non-fluorinated alternatives, indicating that feasible alternatives are available to replace the function provided by PFASs with limited or negligible risk to the industry regarding loss of performance.

Cost and time

The timescales required to reformulate products are not widely discussed in the publicly available literature and various estimates have been provided from different sources. As discussed in earlier sections, the required time for manufacturers to reformulate a cosmetic product could range between 6 months and 4+ years, although it is also noted that this can be highly variable depending on the specific product, and in some cases could be much longer if significant testing (e.g. for safety) is required.

KEMI (2021) highlight the experience of one cosmetic producer, where they indicated that no direct substitution (of PFASs) could be made in cosmetic pens without changing the entire formulation as the function of PFASs was (according to the supplier) unique to the products’ composition. Therefore, the entire formulation was modified successfully, albeit being both resource and time consuming. This was not quantified or elaborated in the KEMI report.

It is indicated that the large number of products and functions PFASs provide (and the low market share of PFASs-containing products) deters researchers from investigating this in further detail – given its low priority compared to other sectors or other chemicals/product groups within the cosmetics sector, where ‘drop in’ substitution is more common, and likely to have greater impact on the industry.

The EU restriction proposal (ECHA, 2023a[20]) concluded, on the basis that the share of PFASs containing cosmetic products is very low (see Chapter 3), there are economically feasible alternatives available for all uses of PFASs in cosmetic products. Furthermore, as discussed above, the cosmetics industry has indicated that, because reformulation of products occurs on a regular basis under ‘business as usual’, it can be considered that the costs of reformulation specifically to phase out PFASs, can be to an extent offset.

The overall conclusion, therefore, is that very few, if any, technical or economic challenges have been identified in terms of achieving or replicating the required performance in cosmetic products for the substitution of PFASs for non-fluorinated alternatives. It is indicated that PFASs do not impart any unique technical function to any cosmetic products. However, the cosmetics industry has noted that the situation could be different for SMEs, which may often fall behind in the actions taken around chemical substitution, as they typically lack the same means of tracking and responding to regulatory changes as large companies do. It must also be emphasised that very few specific studies have been identified that systematically compare the technical performance of PFASs vs non-PFASs containing products.

Practical challenges for substitution

Lack of industry awareness, supply chain transparency and labelling

An important observation in the recent research identifying PFASs in cosmetic products, is that in many cases, the PFASs compounds that are being identified through laboratory analysis, are not listed in the reported ingredients (either on product labels or in the online ingredient databases). This clearly indicates that, while it could be considered that the 'intentional' use of PFASs in cosmetics is being phased out relatively easily by the cosmetics sector, the issue of 'unintentional' presence of PFASs in cosmetic products remains more challenging in practical terms.

This issue has been highlighted in the report of KEMI (2021) and reported in the analytical studies conducted by Fujii, Harada, & Koizumi (2013), Schultes et al. (2018), Whitehead, Venier, & Wu (2021), and Putz, Namazkar, Plassmann, & Benskin (2022). This has also been reported in recent media stories in the UK and US (The independent, 2023[86]). As elaborated below, the reasons for the discrepancy between the chemical substances listed in the ingredients of a cosmetic product and what is detected in the product in practice through analytical measurements has been investigated and discussed in these studies.

As discussed by Whitehead, Venier, & Wu (2021) and Fujii, Harada, & Koizumi (2013), additional bulking agents and/or colorants might be added to cosmetic products, which include substances like mica and talc. It is indicated that mica and talc can often be treated with Polyfluorinated alkyl phosphate esters (PAPs) to provide hydrophobic properties that improve the durability and wear of applied cosmetics. Other potential sources of PFASs include fluorinated versions of methicone and dimethicone, acrylate and methacrylate, and silicone polymers. It is hypothesised that PFASs detected in samples were from these ingredients described on the labels using only their generalised name, as provided by the suppliers, for example, methicone, acrylate, hence, in some cases it may be that cosmetics manufacturers/suppliers are aware that the product contains fluorinated compounds but the use of fluorinated ingredients is poorly disclosed and/or manufacturers are not required to disclose this information.

Another explanation for the presence of PFASs that are not disclosed in the ingredients list, is the presence of impurities or degradation products from PFASs that are intentionally used. For example, several studies have detected PFCAs in cosmetic products, which has been explained by the formation of degradation products from other PFASs. For example, it is noted that fluorotelomer alcohols (FTOHs) are typically used in the synthesis of PAPs, and the FTOHs impurities contained in the PAPs could degrade (e.g. through oxidation/hydrolysis) to PFCAs.

In practice, these issues present technical challenges for companies who wish to phase out or substitute PFASs in cosmetic products. As reported in KEMI (2021), based on consultation with cosmetic brands/companies and through the work of the SSNC, some retailers have indicated they have, or intend, to phase out PFASs, but in some cases, it is then observed (either in the ingredient list or through sampling) that they still do in fact contain PFASs.

For example, KEMI (2021) highlight the case of one supplier of eye shadows and cosmetic pens. It was reported that the supplier had self-imposed a ban on PFASs in their products but it was later revealed that some of their products do contain PFASs (in this case PTFE), prompting the company to investigate in more detail. It was revealed that they did not choose to add PTFE themselves, but obtained it as a part of the colour pigment mixtures that they bought and added to formulate the eye shadows. In general, a longer transition period is needed because the cosmetics industry alone cannot prevent impurities and by-products in cosmetic raw materials and unintentional introduction of PFASs into products from the manufacturing process.

The above discussion raises two key practical challenges in terms of substituting PFASs for non-fluorinated alternatives in cosmetic products:

Information available to consumers – both the information on, and the ability to access the information on ingredient labels.

KEMI (2021) noted several issues when trying to view information on the ingredients of cosmetic products, both in-store and online before purchase – for example issues with legibility, or packaging or display practices that restricted visibility of ingredient lists. It is noted in other sections of the report that consumer awareness, engagement and demand are important drivers, exerting pressure on retailers to phase out PFASs in their products. This section has highlighted that in many cases consumers are not being provided sufficient information on the ingredients in cosmetic products before purchase, and this represents a barrier to further development of alternatives.

This potentially indicates the need for stronger regulations and government oversight regarding accessibility of ingredient information for cosmetic products before purchase to ensure that the presence of PFASs in cosmetic products is fully communicated to consumers when making purchasing decisions. Glüge, et al., (2020) argued that the actual number of PFASs employed in Denmark, Finland, Norway and Sweden is underrepresented since these countries exempt cosmetic products from the duty to be declared in the product register. Similarly, Whitehead, Venier, & Wu (2021) indicated lax regulatory requirements for reporting PFASs use in the US and Canada, appears to be causing problems for estimating the actual magnitude of PFASs use in cosmetics. Furthermore, KEMI (2021) suggested that industry compliance with EU cosmetics legislation[31] on labelling seems at least partly questionable. For example, it was indicated by KEMI (2021) that online shops (in Sweden) are not bound to but recommended that information on ingredients should be provided, and suggested this should be considered for future addition into existing regulations.

Supply chain transparency and access to information across the whole value chain

Linked to the above discussion, there is clearly a need for stronger communication and better access to information on the presence of PFASs and possible causes of contamination, between different industry actors across the full supply chain for cosmetic products. In some cases, retailers have the ambition to prohibit use of PFASs in their products, but either been prevented or delayed in doing so, or have continued to market PFASs-containing products inadvertently. It is indicated that a key reason for this is the lack of knowledge of what chemical components are actually present in their products.

For example, the specific case highlighted above in the KEMI (2021) report noted that a producer had the intention of avoiding the occurrence of PFASs as potential impurities, however this work was described as a ‘big challenge’, because tracking raw materials is reportedly often hindered by the producers’ confidential information policies, which lead to non-transparency along the production chain. The cosmetic producer reported that there are a lot of different material production processes in which PFASs are still part of and that this is in general a very demanding task. This indicates that need for improved action and coordination from within the industry itself to help inform and speed up the process of, firstly identifying where PFASs are present, which informs their phase out and substitution in practice.

The cosmetics industry has noted that, while the issue of unintentional presence of PFASs in products needs to be addressed, the presence of intentional contamination is covered by legislation in many areas (e.g. Europe), but in order to ensure compliance, companies must be able to report sufficient information to the authorities. In many cases, this is reported to be lacking, and it is noted the quality and quantity of information shared between manufacturer and retailer is highly variable between bases. This highlights the need for better knowledge sharing and education across supply chains to address this issue.

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[31] Chapter VI Consumer information, Article 19 “Labelling” of the Cosmetics Regulation (European Parliament and Council of the European Union 2009)

In addition, there is the need to adopt a more specific screening method. For example, the fluorine-19 nuclear magnetic resonance spectroscopy (^{19}F NMR) is a straightforward way to screen for organic fluorine.

Analytical constraints

A variety of analytical approaches to the detection and quantification of PFASs in cosmetic products are available.

The EU restriction proposal (ECHA, 2023b[10]) provides a detailed discussion of the available analytical approaches in different sectors, including cosmetic products[32] and this is also discussed in a separate report by the Nordic Council of Ministers (2022).

The analysis of PFASs in cosmetics can be achieved broadly using one of two methods:

- **Targeted analyses** of selected specific PFASs. This can be done by liquid or gas chromatography coupled to mass spectrometry (e.g. using LC-MS, GC-MS GC/ECNI/MS). It is noted, however that laboratories can currently quantify around 40 different PFASs. Given there are many thousands of PFASs that exist, this clearly only covers a small fraction of the total number of PFASs potentially present.
- **Sum parameter** e.g. total fluorine (TF), extractable organic fluorine (EOF) and adsorbable organic fluorine (AOF) methods. For example, TF content can be determined by particle-induced gamma-ray emission spectroscopy (PIGE). In such an analysis all fluorine in the sample will be measured, both inorganic and organic fluorine.

It is also noted in several studies that 19F-NMR is a simple and straightforward method to screen for total organic fluorine (Camdzic, Dickman and Aga, 2021[87]) (Papeo et al., 2007[88]) (Heerah et al., 2020[89]).

The quantity of inorganic fluorine in common products is usually not known. Although some find it convenient to assume that the total fluorine must be organic fluorine, measurements do not support the assumption. This allows a much wider range of PFASs to be detected. An additional advantage of total fluorine methods is that they are significantly faster and cheaper than targeted analyses. Hence, the use of total fluorine methods to quantify PFASs, e.g. for compliance and enforcement purposes, is considered practical (ECHA, 2023b[10]).

In practice, the analytical studies that have detected PFASs in cosmetic products have used a combination of targeted and TF analysis. The Nordic Council of Ministers (2022) report concludes that “there is currently no standard method for determination of PFASs in cosmetics available, but some commercial laboratories offer analysis of some targeted PFASs. In some studies, measurements of total fluorine (TF), total organic fluorine (TOF) or extractable organic fluorine (EOF) showed much higher values than determined by targeted PFASs analysis. Therefore, analysis of targeted PFASs might not disclose the full picture of PFASs used or present in the products”.

Indeed, several of the academic studies investigating PFASs in cosmetic products have noted a difference between the results of the two methods. For example, Whitehead et al. (2021) reported a lack of correlation between the total fluorine concentrations from PIGE and targeted analyses results, attributing this to (1) numerous PFASs are not on the target list, (2) the presence of inorganic or polymeric fluorine, or (3) an effect due to the lack of homogenization or different shades/colours being chosen, or a combination of all three. Moreover, it is necessary to consider the effective application of the analytical methods. For instance, we must

[32] An assessment of the availability of analytical methods for PFASs is provided in Annex E of the ECHA report.

ponder ways to prevent the overestimation of risks, such as determining whether all total fluorine is perceived as organofluoride derived from PFASs.

Clearly, further research is required to better understand and characterise the presence of 'unintentional' PFASs present in cosmetic products, to enable to identity, explain, and ultimately prevent their presence in cosmetic products. Improved analytical methods, and in particular the availability of standards, will help enable this.

To date, a relatively small number of specific analytical studies regarding the detection and characterisation of PFASs in cosmetic products have been conducted. As discussed by Putz, Namazkar, Plassmann, & Benskin (2022), in practice only a relatively small sub-set of products have been tested and the total number of samples analysed represents a small fraction of the total number and variety of products available. Clearly, given the large number of different cosmetic products on the market, and the number of individual PFASs potentially present, it is impractical to do an assessment of every single product on the market.

The extent of PFASs contamination in supposedly PFASs-free (according to listed ingredients) products in the EEA remains unclear (Putz et al., 2022[23]). This is at least partly attributable to the gaps in capacity to conduct 'full' analytical testing. For example, Schultes et al. (2018), note that some of the listed fluorinated ingredients (e.g. fluorinated silanes, polymeric substances) were not quantified due to the lack of MS-based methods and/or authentic standards.

Summary of challenges for substitution

The challenge of phasing out intentionally added PFASs is seen by the cosmetics industry as being achievable and much less complex or costly than for other substances (e.g. microplastics), with a much smaller number of products needing to be reformulate. There are no major technical or cost related issues or practical challenges preventing the full phase out of intentionally added PFASs is cosmetics. However, it is noted that (based on data in the EU), much of the reformulation is carried out by SMEs, where access to the resources (capital and staff) to identify where PFASs are present and how to replace them, may be lacking, and as such the capacity to substitute PFASs may be more limited. The situation is notably different where PFASs are 'unintentionally' present in cosmetic products. In the wider context of phasing out the presence of PFASs in products, this raises the issue of the communication and transparency of information along the supply chain, in order to identify and prevent the causes of inadvertent contamination.

6 Status of the shift to alternatives and its sustainability

This section provides an overall summary, based on the above discussion in Chapter 2-5, on the current picture in terms of the substitution of PFASs in cosmetic products.

Although there are knowledge gaps regarding the extent of use of PFASs in cosmetics globally, it can be summarised that PFASs are not critical or widely used ingredients in cosmetics. The market share of PFASs-containing cosmetics represents a small share of the cosmetics market in Europe (less than 1.5%), and data are lacking from other global regions to compare whether the markets share a similar distribution.

In Europe, it is indicated that the industry is already well-advanced in the phase-out of PFASs from cosmetic products and the market share of PFASs-containing cosmetics is consistently reducing as manufacturers reformulate their products in response to demand from consumers for safer and more sustainable cosmetics and in preparation for the proposed EU PFASs restriction, which covers the cosmetics sector. PFASs do not contribute a unique or critical function to cosmetics and there is good availability of alternatives to replace remaining intentional uses of PFASs.

The predominant way for manufacturers to remove PFASs from their products is through whole product reformulation rather than a like-for-like or ‘drop in’ replacements. Therefore, it may require multiple different alternatives to be used to replicate the same function(s) and achieve the same performance as the product previously containing PFASs. It is also noted that companies do not regularly change the name of the products post reformulation even if they contained PFASs in the previous formulation, so it is not always immediately apparent when or where reformulation of cosmetic products has taken place to remove PFASs (KEMI, 2021[28]).

Naturally derived ingredients in cosmetics appear to be slightly more expensive than chemical alternatives at the product level. However, for other PFASs alternatives, there does not appear to be an economic or production barrier preventing the uptake of these substances. The move away from PFASs has increased the demand for naturally derived products such as shea butter, coconut oil and argan oil.

There is also a lack of understanding of the ‘unknown’ or ‘unintentional’ presence within the supply chain. Also, laboratory analysis of substances within products is still a challenge. Currently chemical analysis of total organic fluorine levels and total oxidisable precursors are the two ways of assessing the PFASs levels within products, However, these two methods often produce different results, meaning the accuracy of the assessment is difficult to know and rely upon (RISE, 2022[85]).

7 Policy recommendations and areas for further work

Overview

This chapter presents recommendations for government and industry, based on the information presented in Chapters 2-6 of this report.

Recommendations for government authorities and international organisations

- To assess the risks of PFASs that are intentionally added to cosmetic products there is a need to better understand the presence of PFASs within these products. This could be advanced by:
    - Improving legislative frameworks and guidance for the labelling of cosmetic products and communicating adequately the ingredients.
    - Investigating possible ways to better align/standardise and update the information presented in cosmetic product databases to ensure that they are accurate, reliable and up-to-date, and facilitate a better cross referencing between different data sources for identifying where intentionally added substances are being used.

Recommendations for industry including associations, cosmetics manufacturers and retailers.

- To conduct a thorough investigation of the full supply chain, to allow a better understanding of where PFASs are being intentionally used (or inadvertently present). This will also allow better identification of impurities/unintentional presence of PFASs in products.
- To investigate possible causes or sources of unintentional presence and take steps to avoid or minimise contamination during the manufacturing process.
- Encourage and facilitate a better understanding of product ingredients throughout supply chains – for example providing a forum or mechanism for improved transparency of information between different actors in the supply chain, to more effectively identify where PFASs are intentionally used and/or present as impurities, and to foster the sharing of information on alternatives, where not confidential or harming competitiveness.
- To investigate if and where SMEs need further guidance and support on where PFASs are present within their products and supply chain, and how to reformulate these products to remove PFASs in favour of safer alternatives.

8 Uncertainties and limitations

Key limitations of this study

It should be noted that this study has been based on a review of publicly available information and information gathered through direct consultation with a relatively small number of stakeholders (See Chapter 1). This is not intended to be an exhaustive analysis of this subject. In many cases, it is expected that information relating to PFASs and alternatives in cosmetics is held by industry (e.g. chemical suppliers, cosmetic manufacturers, retailers) and may not be readily shared due to confidentiality or commercial sensitivity concerns.

It should be further emphasised that, in general, information on specific 'drop in' replacements is lacking in the literature reviewed for this report. It is expected that more specific information on certain specific chemical alternatives is not in the public domain and may only be obtained directly from industry.

Key data gaps/uncertainties

The key areas of uncertainty and data gaps identified from this work include the following:

- Very few studies have been identified that actively investigate the relative difference in performance between PFASs-containing and PFASs-free products for the same function. In general, a hypothesis is made that the sheer number of non-PFASs containing products on the market and that are shown to provide the desired functions, mean that alternatives are available and feasible in all uses. However, this hypothesis has not been explicitly tested in many studies.
- In general, data is more widely available for the European market compared to other markets. This is largely attributed to the ongoing PFASs restriction proposal at EU level which has involved the collection and analysis of data on PFASs in cosmetics. The situation in Europe may not be the same as for other regions, and this is currently an area of uncertainty for this report.
- For the most part, information on PFASs compounds in cosmetic products in key reports and papers (e.g. KEMI, Danish EPA, ECHA etc) has been derived from using ingredient databases. As discussed in KEMI (2021), some limitations of the databases can lead to an underestimation of total number of PFASs occurring in cosmetic products and/or existing as INCI names:
  - Some ingredient names on the labels of cosmetic products may not yet be in the CosIng database, depending on the last update from the INCI Database, i.e. CosIng does not necessarily reflect all ingredient names, so it represents an incomplete list.
  - One INCI name can represent several PFASs, such as a range of alkyl chain lengths.
  - Typing errors of the ingredient names can occur both on the package labels, or when transferring the ingredient names into the database meaning searches in the database will not be an exact match.
- Generally, it is unlikely that all products available on the market are in the databases (reflected by the different number of registered products in the databases). Furthermore, outdated products, both taken

from the market or with changed ingredients might still be part of the databases, even though some databases are actively updating this information.

- There is also the risk of missing PFASs which occur unintentionally (i.e. as impurities not listed among the ingredients), but which are nevertheless detected by targeted PFASs analysis.

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Annex A. Stakeholders consulted

In addition to the Global PFC Group, the following list of organisations were consulted directly in the production of this report:

- The Swedish Chemicals Agency (KEMI)
- IVL Swedish Environmental Research Institute
- The Research Institute of Sweden (RISE)
- University of Stockholm
- ChemSec
- Cosmetics Europe
- The Cosmetic, Toiletry and Perfumery Association (CTPA)
- Credo

Annex B. Definition of function(s) of chemicals used in cosmetic products

Glossary of chemical functions within cosmetics[33]

Name	Description
Abrasive	Removing unwanted tissue or foreign materials from various body surfaces, including mechanical tooth cleaning and/or gloss improvement
Absorbent	Taking up water- and/or oil-soluble (dissolved or finely dispersed) substances
Adhesive	Tending to unite/bind/bond surfaces together
Anti-sebum	Helping control sebum production
Anticaking	Preventing agglomeration of particulate solids into lumps or hard masses (cohesive cake), thus allowing free flow of particles
Anti corrosive	Preventing and or inhibiting the corrosion of the packaging material
Antimicrobial	Preventing and/or slowing down microbial growth
Antioxidant	Inhibiting reactions promoted by oxygen, thus avoiding oxidation and rancidity
Antiperspirant	Reducing perspiration
Antiplaque	Helping protect against plaque
Antistatic	Preventing and/or reducing static electricity by neutralising electrical charge on surfaces
Astringent	Contracting and/or tightening the skin

[33] Extracted from European Commission: https://ec.europa.eu/growth/tools-databases/cosing/index.cfm?fuseaction=ref_data.functions

Name	Description
Binding	Providing adhesive properties during and after compression in cosmetic tablets and/or cakes
Bleaching	Bleaching or lightening the shade of hair and/or skin
Buffering	Stabilising the pH of an aqueous medium in a narrow range even if an acid or base is added. Altering and/or maintaining a cosmetic product's pH at the desired level
Bulking	Non-reactive (chemically inert), solid ingredients that dilute other solids and/or increase the volume of cosmetic products
Chelating	Forming complexes with metal ions which could affect the stability and/or appearance of cosmetics
Cleansing	Helping to keep the body surface clean
Colorant	Exclusively or mainly intended to colour the cosmetic product, the body as a whole or certain parts thereof, by absorption or reflection of visible light; (precursors of oxidative hair colorants shall be deemed colorants) All authorised colorants are substances in the positive list of Annex IV to the Cosmetics Regulation 1223/2009
Denaturant	Rendering cosmetics unpalatable Mostly added to cosmetics containing ethyl alcohol to make it unsuitable for ingestion
Deodorant	Reducing and/or eliminating unpleasant odour Contributing against the formation of malodour on body surfaces
Depilatory	Breaking down the mechanical strength of hair fibres so that they can be removed by mild scraping/rubbing
Detangling	Reducing or eliminating hair intertwining due to hair surface alteration or damage
Dispersing non surfactant	Facilitating the dispersion of solids in liquids They function primarily by coating the solid through the process of adsorption, thus changing the surface characteristic of the suspended solid
Emulsion stabilising	Helping the process of emulsification and improving emulsion stability and shelf-life

Name	Description
Exfoliating	Initiating and/or accelerating removal of the layers of dead skin cells from the skin surface
Eyelash conditioning	Conditioning and enhancing the appearance of eyelashes Improving the gloss or sheen of eyelashes, coating the eyelash hair to increase the appearance of its diameter and length, or helping with the separation of the eyelash hair
Film forming	Producing (upon application) a continuous film on the skin, hair or nails
Foaming	Trapping numerous small bubbles of air or other gas within a small volume of liquid by modifying the surface tension of the liquid
Fragrance	Imparting an odour or taste Creating a perceivable pleasant smell and/or masking a bad smell
Hair conditioning	Enhancing the appearance and feel of hair Leaving the hair easy to comb, supple, soft and shiny and/or imparting volume, lightness, gloss, texture, etc.
Hair dyeing	Imparting colour to hair Hair dyeing preparations may be temporary, semi-permanent, permanent, depending on the length of time the colorant remains on the hair
Hair waving or straightening	Modifying the chemical structure of the hair, allowing it to be set in the style required (permanent waves or hair straightening)
Humectant	Retaining and/or preserving the moisture in a product during use
Light stabiliser	Protecting the cosmetic product from deterioration effects of light
Moisturising	Increasing the water content of the skin and keeping it soft and smooth
Nail conditioning	Improving and/or enhancing the cosmetic characteristics of the nail (moisturizing, increasing sheen, reducing brittleness and flaking, etc.)
Occlusive	Preventing and/or slowing down the evaporation of water from the skin surface
Opacifying	Reducing transparency or translucency of cosmetics
Oral care	Providing cosmetic effects to the oral cavity, e.g., cleansing, deodorising, protecting

Name	Description
Pearlescent	Imparting a shimmering appearance to cosmetics
Perfuming	Used for perfume and aromatic raw materials
pH adjusters	Controlling the pH of cosmetic products
Plasticiser	Softening and making supple synthetic polymers that otherwise could not be easily deformed, spread or worked out
Preservative	Exclusively or mainly intended to inhibit the development of micro-organisms in the cosmetic product. All authorised preservatives are substances in the positive list of Annex V to the Cosmetics Regulation 1223/2009
Propellant	Generating pressure in an aerosol pack, expelling contents when the valve is opened. Some liquefied propellants can act as solvents
Reducing	Changing the chemical nature of another ingredient by adding hydrogen (or removing oxygen)
Refreshing	Imparting a pleasant freshness to the skin
Skin conditioning	Maintaining the skin in a good condition
Skin protecting	Helping to avoid harmful effects to the skin such as UV, temperature and wind
Slip modifier	Enhancing the flow properties of other ingredients without reacting chemically with them
Smoothing	Seeking to achieve an even skin surface by decreasing roughness or irregularities
Solvent	Dissolving other components of cosmetics. Solvents are usually liquids (aqueous and nonaqueous)
Soothing	Lightening discomfort of the skin or of the scalp
Surface modifier	Applied to other cosmetic components to make them more hydrophilic or hydrophobic, or to modify their physical/chemical properties (in some cases, surface modifiers may form a covalent bond with substrates)
Surfactant	Helping other ingredients that normally do not mix to dissolve or disperse in one another

Name	Description
	Surfactants are also called a surface-active agent as they lower the surface tension of water or reduce the interfacial tension between immiscible components
Tanning	Darkening the skin with or without exposure to UV
UV filter	Exclusively or mainly intended to protect the skin and/or hair against certain UV radiation by absorbing, reflecting, or scattering UV radiation All authorised UV filters are substances in the positive list of Annex VI to the Cosmetics Regulation 1223/2009
Viscosity controller	Increasing or decreasing the viscosity (thickness) of cosmetics

Annex C. Identified PFASs in Cosmetic Products

Name	CAS No.	Number of poly/perfluorinated carbons	Intentional use (Y/ Unclear)	Type of Product(s) and number of products indicated[34]	Function(s)[35]	Additional Information/references
Perfluorohexane	355-42-0	C6	Y	Foundation, skin creams Foundation (1) Anti-age cream (1) Exfoliator (1) Mask (1) Moisturisers	Solvent	References: Putz et al. 2022, (US FDA, 2022b[31]), KEMI 2021
C9-15 fluoroalcohol phosphate	223239-92-7	C9-15	**Y**	Foundation (1)	Skin conditioning	References: Putz et al. 2022, Danish EPA 2018
Polyperfluoroethoxymethoxy difluoroethyl PEG phosphate	N/A	Polymer	**Y**	Pressed powder cosmetics Foundation powder (1)	Hair conditioning Skin conditioning	Complex mixture of polyperfluoroethoxy methoxy difluoroethyl PEG ether (CAS no. 88645-29-8) and phosphoric acid (EWG Skin Deep database) References: Danish EPA 2018, Putz et al. 2022

[34] As indicated in the EWG database and/or cited references

[35] As indicated in CosING database and/or cited references

Ammonium C6-16 perfluoroalkyl ethyl phosphate	65530-72-5 / 65530-71-4 / 65530-70-3 (as part of complex mixture described in last column)	C6-16	**Y**	Foundation	Surfactant – Emulsifying	Ammonium salt of complex mixture of esters of phosphoric acid and C6-16 perfluoroalkylethyl alcohols with CAS no. 65530-72-5 / 65530-71-4 / 65530-70-3 (EWG Skin Deep database) Reference: Danish EPA 2018, Putz et al. 2022
Perfluoromethylcyclopentane	1805-22-7	C6	**Y**	Foundation, exfoliators Foundation (1) Exfoliating scrub and mask (1)	Skin conditioning Solvent	Reference: Putz et al. 2022, US EPA 2023b
Octafluoropentyl methacrylate	355-93-1	C4	**Y**	Hair products Shampoo (6) Hairspray (4) Conditioning (8) Hair styling products (23)	Binding	Reference: NICNAS 2017, Putz et al. 2022
C4-18 perfluoroalkylethyl thiohydroxypropyltrimonium chloride	70983-60-7	C4-18	**Y**	Hair products Hair styling cream (1)	Surfactant Surfactant – cleansing	Reference: Putz et al. 2022, US EPA 2023b
Acetyl trifluoromethylphenyl valylglycine	379685-96-8	N/A	**Y**	Skin cream Skin cream (3)	Skin conditioning	Reference: Putz et al. 2022
Perfluoroperhydrophenanthrene	306-91-2	C14	**Y**	Face mask Face mask (1)	Skin conditioning Solvent	Reference: Putz et al. 2022, US EPA 2023b

Trifluoroacetyl tripeptide-2	64577-63-5	C1	Y	Face cream Face cream (2)	Skin conditioning Skin protecting	Tripeptide composed of valine-tyrosine-valine. Reference: Putz et al. 2022
Ethyl perfluorobutyl ether	163702-05-4	C4	Y	Face masks Face mask (1)	Solvent	Reference: Putz et al. 2022
Ethyl perfluoroisobutyl ether	163702-06-5	C4	Y	Face masks Face mask (1)	Solvent	Reference: Putz et al. 2022
Methyl perfluorobutyl ether	163702-07-6	C4	Y	Face masks Face mask (2) Anti-aging cream	Solvent Viscosity control agent	Reference: Putz et al. 2022, NICNAS 2019a, NICNAS 2019b, Glüge et al. 2020
Methyl perfluoroisobutyl ether	163702-08-7	C4	Y	Face mask (1)	Solvent Viscosity control agent	Reference: Putz et al. 2022
Perfluoro-1,3-dimethylcyclohexane	335-27-3	C8	Y	Face mask (1)	Solvent	Reference: Putz et al. 2022
Perfluoro(methylcyclohexane)	355-02-2	C7	Y	No data in references reviewed, but chemical appears in US EPA 2023b	Skin conditioning Anti-caking agent Binding Absorbent Emulsion stabilising	Reference: US EPA 2023b
Perfluorocyclohexylmethanol	28788-68-3	C6	Y	No data in references reviewed, but chemical appears in US EPA 2023b	Skin conditioning Emulsion stabilising	Reference: US EPA 2023b

Perfluorobutylcyclohexane	374-60-7	C10		**Y**	No data in references reviewed, but chemical appears in US EPA 2023b	Skin and hair conditioning. Anti-static agent	Reference: US EPA 2023b
Perfluoroheptane	335-57-9	C7		**Y**	No data in references reviewed, but chemical appears in US EPA 2023b	Anti-caking agent Skin conditioning	Reference: US EPA 2023b
Perfluoroperhydrobenzyl tetralin	116265-66-8	C17		**Y**	No data in references reviewed, but chemical appears in US EPA 2023b	Skin conditioning	Reference: US EPA 2023b
Perfluoro-2-methylpentane	355-04-4	C6		**Y**	No data in references reviewed, but chemical appears in US EPA 2023b	Emollient Skin conditioning	Reference: US EPA 2023b
Perfluoromethyldecalin	51294-16-7	C11		**Y**	No data in references reviewed, but chemical appears in US EPA 2023b	Skin conditioning Anti-caking agent	Reference: US EPA 2023b
Perfluorohexylethyl dimethylbutyl ether	210896-25-6	C6		**Y**	No data in references reviewed, but chemical appears in US EPA 2023b	Skin conditioning	Reference: US EPA 2023b
Sodium 6:2 fluorotelomer phosphonate	1189052-95-6	C6		**Y**	No data in references reviewed but reported use in cosmetics in NICNAS risk assessment	Not reported	Reference: NICNAS 2018

Potassium 6:2 fluorotelomer phosphonate	1224952-82-2	C6	**Y**	No data in references reviewed, but reported use in cosmetics in NICNAS risk assessment	Not reported	Reference: NICNAS 2018
1H,1H,2H,2H-Perfluorooctyltrimethoxysilane	85857-16-5	C6	**Y**	No data in references reviewed, but reported use in cosmetics in NICNAS risk assessment		Reference: NICNAS 2018
6:2 Fluorotelomer sulfonic acid	27619-97-2	C6	**U**	Body lotion/cream/oil		Reference: Glüge et al. 2020
Polytetrafluoroethylene (PTFE)	9002-84-0	Polymer	**Y**	Is used in dental floss, pressed, and loose powder cosmetics Also used within nail enamel, shaving gels, foundations, skin creams and liquid cosmetic formulations Eye Shadow= 48 Bronzer/highlight = 18 Facial powder = 13 Body powder = 9 Blush = 8 Foundation = 6 Mascara, brow liner, facial moisturiser = 4	Chemical resistance Heat resistance UV filter Strong adhesion Low water absorption	Commonly known as Teflon Reference: Danish EPA 2018, US FDA 2022, De Lima Associates 2023, Putz et al. 2022

				Setting powder = 1		
Polyperfluoromethylisopropyl ether (PPIE)	69991-67-9	Polymer	**Y**	Skin creams and oils, facial cleansers, shampoos, Shaving cream, Sunscreens, setting powder/sprays and makeup primers. Facial moisturiser and lip liner = 6 Serums and essences = 2 Body oil = 1 Lip balm = 1 Facial cleanser = 1 Shampoo = 1	Skin conditioning	Reference: De Lima Associates 2023, US EPA 2023b, Putz et al. 2022
Perfluorooctyl triethoxysilane (FOTS) **1*H*,1*H*,2*H*,2*H*-perfluorooctyltriethoxy silane**	51851-37-7	C6	**Y**	Body lotion/cream/oil Nail enamel Foundation Foundations and skin creams Lipstick = 3 CC creams = 1 Concealer = 1 Mascara = 1	Binding agent UV filter	Reference: Danish EPA 2018, Glüge et al. 2020, US FDA 2022, De Lima Associates 2023 , Putz et al. 2022
Perfluorodecalin (PFDC)	306-94-5	C10	**Y**	Facial cleanser, shampoos and skin creams Facial moisturiser = 11	Skin conditioning Solvent Detangling	Reference: US FDA 2022, US EPA 2023b, Putz et al. 2022

				Eye cream and serums = 5 Masks = 4 Shaving cream and facial cleanser = 3 Moisturiser = 2 Lip balm, exfoliant, body oil, shampoo, body firming lotion, shaving cream (men's) =1	Improves skin barrier function to increase moisture uptake capacity, repair wrinkled skin, and enhance oxygen uptake	
Perfluorononyl dimethicone	259725 -95-6	Polymer	**Y**	Eye and lip pencils Eye liner = 48 Lip liner = 15 Eye shadow = 7 Lipstick = 6 Conditioning Hair spray and sunscreen = 1	Skin conditioning	Reference: Danish EPA 2018, US FDA 2022, De Lima Associates 2023, Putz et al. 2022
Trifluoropropylmet hyl dimethicone	115361 -68-7	Polymer	**Y**	Foundation, Lipsticks Lipstick = 4 Foundation = 1		Reference: De Lima Associates 2023 and Putz et al. 2022
N-Ethyl perfluoroalkane sulfonamidoacetic acid	2991-50-6	C8	**U**	Hair creams/conditioning		Reference: Glüge et al. 2020
HC yellow no. 13	10442-83-8	C1	**Y**	Hair dyes Hair colour and bleaching = 2	Hair dyeing	Reference: ToxPartner, 2023.