KEMI
Swedish Chemicals Agency

PFASs in Cosmetics

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kemikalieinspektionen.se

The Swedish Chemicals Agency is supervisory authority under the Government. We work in Sweden, the EU and internationally to develop legislation and other incentives to promote good health and improved environment. We monitor compliance of applicable rules on chemical products, pesticides and substances in articles and carry out inspections. We review and authorise pesticides before they can be used. Our environmental quality objective is A Non-toxic Environment.

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Preface

PFASs (short for per- and polyfluoroalkyl substances) constitute a group of thousands man-made chemicals that are widely used in various technical applications in society due to their unique physical and chemical properties. Since they are chemically and thermally stable as well as repellent to water and oil, they are used in products such as water- and stain repellent textiles, fire-fighting foams, food contact materials (FCMs) and cosmetics.

PFASs are used in various hygiene and cosmetic products for different technical functions. These cover a broad range of uses, such as skin conditioners, binders, anticaking agents, emulsifiers, film formers, and solvents. Many PFASs can be used for a variety of different functions.

REACH (EC 1907/2006) is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry. Restrictions are an instrument to protect human health and the environment from unacceptable risks posed by chemicals. Restrictions are normally used to limit or ban the manufacture, placing on the market or use of a substance, but can impose any relevant condition, such as requiring technical measures or specific labels. A restriction may apply to any substance on its own or in an article, including imported articles.

The dossier proposing the restriction contains background information such as the identity of the substance and justifications for the proposed restrictions. It includes the identified risks, any information on alternatives to the substance and the costs, as well as the environmental and human health benefits, resulting from the restriction.

IVL Swedish Environmental Research Institute and Stockholm University have conducted this study on PFASs in cosmetic products by contract of the Swedish Chemical Agency as part of the Agency’s preparatory work on a broad PFAS restriction under the REACH regulation.

The following persons have been involved from IVL and Stockholm University:

- Kerstin Winkens Pütz – principal investigator, main author, experimental design, sampling, data(base) evaluation, emission calculations
- Jonathan P. Benskin – experimental design, analysis, quality control, report writing
- Shahla Namazkar – sampling, analysis, data processing
- Merle Plassmann – analysis and quality control
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Content

Glossary

Abbreviation	Written out form
CIC	Combustion ion chromatograph
CosIng	Cosmetic ingredient database (from the European Commission)
CMR	Carcinogenic, mutagenic, reprotoxic
CRM	Certified reference material
diPAPs	Polyfluoroalkyl phosphoric acid diesters
EDC	Endocrine-disrupting chemical
EEA	European Economic Area
EOF	Extractable organic fluorine
EU	European Union
INCI	International Nomenclature of Cosmetic Ingredients
KEMI	Swedish Chemicals Agency
KoHF	Swedish Cosmetics, Toiletries and Detergents Association
LC-MS/MS	Liquid chromatography, tandem mass spectrometry
LOD	Limit of detection
MPA	Swedish Medical Products Agency
N.a.	Not analysed
N/A	Not applicable
OECD	Organisation for Economic Co-operation and Development
PAPs	Polyfluoroalkyl phosphoric acid esters
∑PAP	Sum polyfluoroalkyl phosphate esters
PFAAs	Perfluoroalkyl acids
PFASs	Per- and polyfluoroalkyl substances
∑PFAS	Sum perfluoroalkyl carboxylic acids
PFBA	Perfluorobutanoic acid
PFC Group	Perfluorinated chemicals Group (OECD/UNEP Global PFC Group)
PFCAs	Perfluoroalkyl carboxylic acids
∑PFCA	Sum perfluoroalkyl carboxylic acids
PFDA	Perfluorodecanoic acid
PFDoDA	Perfluorododecanoic acid
PFHxA	Perflurorohexanoic acid
PFSAs	Perfluoroalkyl sulfonic acids
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid

PTFE	Polytetrafluoroethylene
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RSD	Relative standard deviation
RSP	Retail Sales Price (includes VAT)
SD	Standard deviation
S/N	Signal-to-noise ratio
SSNC	Swedish Society for Nature Conservation
SVHCs	substance of very high concern
TF	Total fluorine
UNEP	United Nations Environment Programme
WWTP	Wastewater treatment plant

Sammanfattning

IVL Svenska Miljöinstitutet och Stockholm Universitet har på uppdrag av Kemikalieinspektionen genomfört en studie om högfluorerade ämnen (PFAS) i kosmetiska produkter. PFAS är en grupp på över 4700 ämnen[1] med varierande egenskaper, som sedan 1950-talet har använts i både industriella processer och i konsumentprodukter. Det finns en växande oro kring PFAS, då dessa ämnen är mycket svårnedbrytbara, sprids lätt i naturen, anrikas i organismer och har negativa effekter på miljö och människor. Därför förbereder flera av EU:s medlemsländer ett brett begränsningsförslag för PFAS inom ramen för förordningen om registrering, utvärdering, tillstånd och begränsningar av kemiska ämnen (REACH-förordningen). Denna rapport ska stödja detta arbete genom att ge bakgrundsinformation om PFAS i kosmetiska produkter, ett användningsområde som uppmärksammats det senaste årtiondet.

I projektet undersöktes olika databaser för att få en uppfattning om identitet och förekomst av PFAS (d.v.s. substanser med minst ett -CF_2 element) i kosmetiska produkter. Ungefär 170 olika möjliga namn på innehållsämnen i kosmetiska produkter kunde identifieras i kosmetikaingrediensdatabasen (CosIng). 42 av dessa ämnen förekom i tre olika europeiska kosmetika-databaser. Polytetrafluoreten (PTFE; en PFAS-polymer) och C9-15 fluoroalkohol fosfat förekom mest frekvent. Dataanalysen visar att tre av de tio främst använda PFAS i produkter från de undersökta kosmetika-databaserna redan omfattas eller kommer att omfattas av stundade begränsningsregler.[2]

Denna studie visar att produktkategorin med flest PFAS-innehållande produkter var *Dekorativa kosmetika* (3,7 %), följd av *Hudvård, Hårvård och Toalettartiklar* (0,78; 0,65 respektive 0,27 %). Förekomsten av PFAS i produktkategorin *Parfym och Doftämnen* var försumbar, med 0,03 % PFAS-innehållande produkter.

Vidare genomfördes ett antal kemiska analyser, där parametern total-fluor (TF), som ger en uppskattning på den totala PFAS-halten, mättes i 43 köpta kosmetiska produkter med PFAS som listad ingrediens. Ett mindre antal av produkterna valdes även för analys av extraherbart organiskt fluor (EOF) samt av ämnes-specifika PFAS som ger en bild på innehåll av icke-polymera och metanollösliga PFAS. TF och EOF uppmättes i koncentrationer med upp till 13,8 mg F/g (exfoliator/skrubb) respektive 4,93 mg F/g (foundation/BB-kräm), vilket också är i samma storleksordning som i tidigare studier. Ämnes-specifika analyser visade på en hög förekomst av den kort-kedjade PFAS, perfluorbutansyra (PFBA) i proverna, och det hittades en synbar högre andel av kort-kedjade perfluoralkylkarboxylsyror (PFCAs) i jämförelse med tidigare studier. Koncentrationen av ämnesspecifika PFAS var alltid högst i de fall då produkten hade PFAS med i innehållsförteckningen (t.ex. för polyfluoralkylfosfatestrar, PAPs). Två av femton kosmetiska produkter (båda foundation/BB-krämer) överskred EU:s gränsvärden för perfluoroktansyra (PFOA) och PFOA-relaterade ämnen.

Baserat på uppmätta koncentrationer, andel av produkter med PFAS-innehåll, försäljningsdata från Cosmetics Europe, samt andra parametrar och antaganden, kunde en uppskattning av PFAS-utsläppen från användningen av kosmetiska produkter inom Europeiska ekonomiska samarbetsområdet (EES) göras. Den uppskattade totala emissionen (i.e. summan av

[1] Enligt OECD-databasen från 2018 (https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/). Databasen omfattar ämnen med beståndsdelen $–C_nF_{2n}–$ (n ≥3) eller $–C_nF_{2n}OC_mF_{2m}–$ (n and m ≥1).

[2] Exklusive PTFE. PTFE ingår i den kommande mikroplastbegränsningen om det är i både partikelform och fast form (<5 mm partikelstorlek). Detta inkluderar om PTFE finns som en beläggning runt ett annat "oorganiskt material". Partiklar i vätskeform (kolloider) omfattas inte.

emissioner till avloppsvatten och avfallsflöden) utifrån TF (inklusive polymerer) och EOF var 11000 respektive 1300 kg F/år, baserat på genomsnittsscenariot, samt 38000 respektive 5100 kg F/år i värsta-fall scenariot. För summan av enskilda PFCA (d.v.s. orenheter) uppskattades de totala utsläppen till 2,7 och 21 kg ∑PFCA/år, baserat på genomsnitts- respektive värsta-fall scenariot. Dessa resultat pekar på vikten av att använda flera olika analysmetoder som datakällor för att återspegla det breda utbudet av PFAS som man annars riskerar att missa om endast ämnes-specifika kemiska analyser genomförs. Produktkategorin *Hudvård* identifierades som den produktkategorin som bidrar mest till emissioner av TF och summa PFCA, medan *Hårvård* (baserat på bästa-fall och genomsnittsscenariot) och *Dekorativa kosmetika* (baserat på värsta-fall scenariot) bidrar mest till emissionerna av EOF. Den tidigare dataluckan gällande PFAS i hårvårdsprodukter kunde åtgärdas med hjälp av nya mätningar och uppskattade emissioner.

Emissionsdata och övriga data framtagna i denna studie visar, trots att de förknippas med många osäkerheter, på att kosmetiska produkter bidrar till spridning av PFAS i miljön, både via avloppsvatten och via avfallsflöden.

Summary

IVL Swedish Environmental Research Institute and Stockholm University have conducted a study on per- and polyfluoroalkyl substances (PFASs) in cosmetic products by contract of the Swedish Chemical Agency (KEMI). PFASs are a diverse group of approximately 4700 chemicals[3], which have been widely used since the 1950s in industrial processes and consumer products. However, there is increasing concern due to their persistence, mobility in the environment, bioaccumulation and negative effects on environmental and human health. Therefore, some EU member states are preparing a broad restriction proposal of PFASs under the Registration, Evaluation, Authorisation and Restriction of Chemicals regulation (REACH). This report seeks to support this work by providing background information on PFASs in cosmetic products, an area which came into focus during the last decade.

In this project, three different databases were consulted to get an overview of the identity and frequency of occurrence of PFASs (i.e. compounds with at least one -CF_2) in cosmetic products. About 170 unique PFAS ingredients potentially occuring in cosmetic products were identified within the cosmetic ingredient database (CosIng). 42 of these were present in products within three European cosmetic databases, among which polytetrafluoroethylene (PTFE; a PFAS polymer) and C9-15 fluoroalcohol phosphate were most frequent. Analysis of the data shows that three out of the top ten listed PFASs among all considered cosmetic databases are under current or pending restriction.[4]

An analysis of the market share of PFAS-containing products revealed that most occurred in the product category *Decorative cosmetics* (3.7 %), followed by *Skin care, Hair care* and *Toiletries* (0.78, 0.65 and 0.27 % respectively). The occurrence of PFASs in *Perfumes and Fragrances* was negligible with 0.03 %.

Further, several chemical analyses were carried out; among which the total fluorine (TF) content, giving an estimate for the total PFAS content, was measured in 43 purchased cosmetic products listing PFAS(s) as ingredients. A sub-set of these samples was selected for extractable organic fluorine (EOF) and targeted PFAS analyses to obtain a clearer picture of non-polymeric and methanol-soluble PFASs. TF and EOF concentrations of up to 13.8 mg F/g (exfoliator) and 4.93 mg F/g (foundation/BB cream), respectively, were observed in the same range as in previous studies. Targeted analysis revealed a high frequency of the short-chain PFAS perfluorobutanoic acid (PFBA) among the samples, along with an apparent shift towards short-chain perfluoroalkyl carboxylic acids (PFCAs) compared to previous studies. Targeted PFAS concentrations were always highest when a listed PFAS ingredient was included in the target list (e.g. for polyfluoroalkyl phosphoric acid esters, PAPs). Two out of fifteen cosmetic products (both foundation/BB creams) exceeded the EU limit values for perfluorooctanoic acid (PFOA) and PFOA-related substances.

Based on measured PFAS concentrations, the share of products containing PFASs, sales data from Cosmetics Europe, as well as other parameters and assumptions, the total emission of PFASs from cosmetic products after use was estimated for the European Economic Area (EEA). Total emissions (i.e. sum of the emissions to wastewater and solid waste) based on TF

[3] According to the OECD database from 2018 (https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/). The database includes substances that have a $–C_nF_{2n}–$ (n ≥3) or $–C_nF_{2n}OC_mF_{2m}–$ (n and m ≥1) moiety.

[4] Excluding PTFE. PTFE is included in the pending microplastics restriction if it is in both particulate and solid form (<5mm particle size). This includes if it is present as a coating around another ‘inorganic material’. Liquid particles (colloids) would be excluded.

(including polymers) and EOF were approximately 11000 and 1300 kg F/year in the average-case scenario, and 38000 and 5100 kg F/year in the worst-case scenario, respectively. For the sum of the targeted PFCAs (i.e. impurities), the total emission estimates were 2.7 and 21 kg ∑PFCA/year, respectively. The results indicate the importance of using several analytical methods to capture the wide range of PFASs, which would otherwise be missed if only specific PFASs were measured during chemical analysis. The Skin Care product category contributed the most to the TF and sum PFCA emission estimates, while Hair Care (best- and average-case) and Decorative cosmetics (worst-case) contributed the most to the EOF emissions. A previously identified data gap in Hair Care products was also filled by measurements and emission estimates.

Emission estimates and other collected data in this study show, while subject to several uncertainties, that cosmetic products contribute to the occurrence of PFAS in the environment, both via wastewater and via solid waste.

1 Introduction

The Swedish Chemicals Agency (KEMI) together with the REACH competent authorities in the Netherlands, Germany, Denmark and Norway are preparing a proposal for a broad restriction of per- and polyfluoroalkyl substances (PFASs) under the Registration, Evaluation, Authorisation and Restriction of Chemicals regulation (REACH) (European Parliament and Council 2006). REACH is a regulation of the European Union adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry. Restrictions within REACH are used to protect human and environmental health from unacceptable chemical risks and are normally used to limit or ban the manufacture, sale or use of a substance, but can impose any relevant condition, such as technical measures or specific labels. A restriction may apply to any substance on its own or in an article, including imported articles. The dossier proposing the restriction contains background information such as the identity of the substance and justifications for the proposed restrictions. It includes the identified risks, any information on alternatives to the substance and the costs, as well as the environmental and human health benefits, resulting from the restriction.

This report seeks to support the work of KEMI on the restriction proposal for PFASs in cosmetic products by providing a detailed overview of the occurrence of PFASs in cosmetics (both via database searching and empirical measurements), as well as emissions estimates based on empirical data and assumptions.

PFASs are a large and diverse group of synthetic chemicals that have been produced in increasing quantities since the 1950s (Buck et al. 2011). While the exact definition of PFAS is still under discussion, the present work adopted the definition proposed by the OECD/UNEP Global PFC Group, which defines PFASs as fluorinated substances that contain 1 or more C atoms on which all the H (hydrogen) substituents have been replaced by F-atoms (fluorine), in such a manner that they contain at least one aliphatic perfluorocarbon moiety (i.e. $-C_nF_{2n}-$; $n \geq 1$). The perfluorocarbon moiety imparts unique chemical stability and amphipathic properties, which make PFASs useful in a wide range of industrial processes and consumer products (Glüge et al. 2020). Despite their extensive use, the environmental and human health risks of PFASs have been of increasing concern since 2001(Ahrens & Bundschuh 2014, Fenton et al. 2021), when perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) were discovered for the first time in humans and wildlife globally (Giesy & Kannan 2001, Giesy et al. 2001). Regulatory initiatives over the last decade have led to the phase out of several long-chain perfluoroalkyl sulfonic acids (PFSAs) and perfluoroalkyl carboxylic acids (PFCAs). However, numerous replacement PFASs are developed annually and a recent survey from the OECD identified 4730 PFAS-related CAS numbers on the global market (OECD 2018).

PFAS are used intentionally in cosmetics as emulsifiers, antistatics, stabilizers, surfactants, film formers, viscosity regulators and solvents. The diverse range of chemistries includes: per/polyfluorinated acrylate polymers, naphthalenes, alkanes/alkenes, alcohols, siloxanes, sulfonamides, ethers, esters, phosphate esters (PAPs), and acids (The Swedish Chemicals Agency (KEMI) 2015). Ingredients in cosmetics and personal care products are regulated by Cosmetics Regulation (EC) No. 1223/2009, which stipulates that cosmetic manufacturers must ensure the safety of their products for human health. However, this regulation does not contain requirements on the use of substances that may impact the environment, such as PFAS. Instead, these substances are addressed by REACH (European Parliament and Council 2006), which also regulates that polymers and low molecular weight substances imported or manufactured in quantities of <1 ton/year do not require hazard and risk assessments. In

Sweden, an addition to the regulation which came into force in February 2020 (KEMI 2017) requires manufacturers and importers (with a yearly turnover of more than five million SEK) to register the occurrence of PFASs in products in the Swedish Chemicals Agency products register, regardless of the concentration used in the product. However, in other EU countries, such regulations are not in place and some PFASs may be completely overlooked in consumer products.

Food, dust, air, and drinking water are regarded as the major exposure pathways for known PFASs in the general population (Trudel et al. 2008, Vestergren et al. 2008). Dermal exposure to PFASs has thus far been considered negligible, probably due to a lack of data on occurrence and dermal permeation of PFAS from cosmetic products (Winkens et al. 2017). Nevertheless, dermal penetration of PFOA was confirmed in vitro in both mouse and human skin and statistically significant increases in serum PFOA levels were observed in mice following dermal PFOA exposure (Franko et al. 2012). However, it remains unclear whether this result can be extrapolated to other PFASs, or if transformation of ingredients in cosmetic products (e.g. PAPs) to PFCAs on the skin could occur. However, phase 1 and phase 2 enzymes are known to be present on the surface of the skin (Pannatier et al. 1978, Oesch et al. 2014), which, combined with possible photolytic processes (Sayre et al. 2005), may facilitate such transformation. Given the large surface area of the skin (~22 m^2; Godin & Touitou (2007)) and the liberal application of some cosmetic products, dermal uptake may represent an important route of PFAS exposure that has to be further investigated.

In addition to the potential risks following human exposure (Fenton et al. 2021), there may be environmental risks associated with PFAS in cosmetic products (Ahrens & Bundschuh 2014). PFASs may be released to the environment from cosmetics during product manufacturing use and disposal., PFAS-containing cosmetics that are removed from the skin or body will enter wastewater streams or be directed to solid waste. It is unclear how these substances behave during wastewater treatment. However, wastewater treatment plants (WWTPs) have been identified as a significant sources of PFASs, either to receiving water (via effluent outfalls), air (via off gassing from settling tanks), and fields (via application of sludge as fertilizer) (Ahrens et al. 2011, Lee et al. 2014, Yeung et al. 2017). A recent fluorine mass balance study of Swedish WWTPs reported that 42-82 % of extractable organic fluorine in sludge and 5-21 % in the effluent water were unaccounted for (Yeung et al. 2017). Notably, diPAPs, which are among the known ingredients in some cosmetic products, contributed a major proportion (63 %) to the total targeted PFASs in sludge samples (Yeung et al. 2017).

The overarching aim of this project is to improve knowledge about the occurrence of PFAS in cosmetics on an EEA scale in order to support regulatory activities. The report can be broken down into the following specific objectives:

- Establish an overview of the occurrence of PFASs in cosmetic products on the EEA market (PFAS structures, functions, product shares, market trends, replacements etc.);
- Quantify PFASs in current cosmetic products and fill data gaps on product categories from previous studies;

- Evaluate the use of different analytical methods to assess compliance with current and future PFAS restrictions on cosmetic products;
- Quantify emissions of PFAS to wastewater and solid waste from cosmetics within the EEA.

2 Earlier research

In the first report on PFAS in cosmetics by Fujii et al. (2013), PFCAs were measured in 24 products listing PFAS among their ingredients (20 products from Japan, two from France and each one from Korea and the USA). 88 % of the products contained PFCAs, with sum PFCA concentrations up to 19 µg/g in sunscreens and up to 5.9 µg/g in other cosmetic products. PFHxA, PFOA, PFDA, and PFDoDA tended to occur at the highest concentrations (Fujii et al. 2013).

In 2017, the Danish Ministry of Environment and Food conducted a survey of cosmetic products containing PFAS as listed ingredients using the Kemiluppen App. Chemical analyses (including total fluorine, TF) was performed on selected products, and the combined data were used as part of a health hazard and risk assessment (Danish EPA 2018). The results of the survey showed that PTFE was the most common PFAS, followed by C9-C15 fluoroalcohol phosphate. PFAS occurred in a wide range of products, but particularly in creams, lotions, and powders. A large variation of PFAS concentrations were observed among the 17 analysed products, with the highest concentration observed for PFHxA in foundation (3340 ng/g) and for the sum of PFASs in concealer (10700 ng/g). Notably, two products contained PFOA concentrations exceeding the EU limit value of 25 ng/g (ECHA 2017), while 6 products exceeded the REACH EU sum limit value for C9-C14 PFAAs or PFCAs (Danish EPA 2018). TF, which provides an estimate of the concentration of the listed PFAS ingredient, was detectable in all analysed products except one control (hair spray; no PFAS listed). TF concentrations in PFAS-containing products ranged from 3.3 µg F/g (Facial Scrub containing perfluorononylethyl carboxydecyl PEG-10 dimethicone) to 740 µg F/g (cream/lotion containing PTFE) (Danish EPA 2018). A subsequent risk assessment concluded that the measured PFCA concentrations in cosmetic products do not pose a risk to consumers, but that a risk cannot be completely ruled out in their worst-case scenario, i.e. if several PFAS-containing products are used at the same time (Danish EPA 2018). In addition, this risk assessment is based on EFSA, 2008 Tolerable daily intake. The picture would likely be different if EFSA, 2020 Tolerable daily intake or Tolerable weekly intake is used.

In Sweden, Henricsson (2017) carried out the first inventory of PFASs in cosmetics on the Swedish market and confirmed 59 different products (4.4 % of those surveyed) listing PFAS(s) among their ingredients. Thereafter, IVL Swedish Environmental Research Institute, in collaboration with the Swedish Society for Nature Conservation (SSNC) analysed a suite of PFCAs and PFSAs in 22 cosmetic products from nine different brands. These same products were subsequently re-analysed including additional samples using a larger target list (including PAPs) along with total and extractable organic fluorine (TF and EOF, respectively) by Schultes et al. (2018). TF concentrations ranged from below the detection limit (<LOD, cream) to 19200 µg F/g (powder), while EOF concentrations – representing contributions from low molecular weight fluorinated ingredients and residuals – ranged from <LOD (powder) to 1720 µg F/g (cream). A total of 39 out of 50 analysed PFASs were detected by targeted analysis, with sum concentrations up to 479 µg/g (foundation) (Schultes et al. 2018). The 6:2 mono- and 6:2/6:2 diPAPs (the latter detected at up to 405 µg/g) were the major PFASs, particularly in foundations listing ingredients such as ammonium C6-16 perfluoroalkylethyl phosphate or C9-15 fluoroalcohol phosphate (Schultes et al. 2018). Longer chain-length PAPs were also observed. PAPs are known precursors to PFCAs, which are environmentally persistent and of concern for both humans and the environment (Lee et al. 2014, Dagnino et al. 2016, Zabaleta et al. 2017).

3 Methods

3.1 Terminology

Per- and polyfluoroalkyl substances (PFASs) are defined in this report as fluorinated substances that contain one or more C atoms on which all the H substituents have been replaced by F-atoms, in such a manner that they contain at least one aliphatic perfluorocarbon moiety (i.e. -C_nF_{2n}-). The terminology used for PFASs in this report is based on Buck et al. (2011), especially within the chemical analytical parts, with the exception to PFASs listed on products' ingredients lists or in the databases.

International Nomenclature of Cosmetic Ingredients (INCI) names are used throughout the report for PFAS(s) in cosmetic databases and on product ingredients lists. It is pertinent to note that one INCI name may comprise several PFASs, such as "C9-C15 fluoroalcohol phosphate", which is a mixture of at least 7 different PFASs. For practical reasons, each INCI name was considered to be one PFAS for the database analysis.

Both the cosmetic databases and Cosmetics Europe have their own (unique) terminology and classification for cosmetic products and their (sub-)categories. Especially for ToxFox, the classification might be flawed, because consumers/app users are requested to enter the product's category (chapter 3.2.3). The terminology and classification therefore also vary in the report, depending on which data are being used. However, it was used to refer to the applied classification system in the different chapters. For the emission calculations, the cosmetic products were classified into the five major product categories of Cosmetics Europe: "Decorative Cosmetics", "Skin Care", "Hair Care", "Toiletries" and "Perfumes and Fragrances".

3.2 Cosmetic Databases

For this report, we applied information from several databases or platforms, of which three are European cosmetic databases based on consumer data collected via smartphone applications (apps), i.e. CosmEthics (Finish), Kemiluppen (Danish), ToxFox (German). With these apps, consumers scan cosmetic product barcodes and receive information on ingredients and their potential hazards to make conscious purchase choices or submit new products and product information to the databases. For all databases, information could be wrong due to faults by the manufacturers on the labels, which can contain errors such as typos (including the ingredients) or misinformation. Further, transcript errors may occur in the label digitalisation process, regardless of quality control. All databases (CosmEthics, Kemiluppen, ToxFox) stated that some products running still under the same barcode and name, might have updated formulations, i.e. altered ingredient lists, compared to the registered ingredient lists in the databases. Additionally, consumers might still have products with former formulations/ingredients in use, because of which a pure replacement of the product information would not give all users the correct information either.

For this report, database extracts on cosmetic products containing PFASs and summary information of all three databases were received. The PFAS names searched for were based on a list provided by KEMI, adapted by IVL and forwarded to the databases. The databases included partly additional PFAS names into the search based on their experience with PFASs and the products in their databases (for more details consult chapter 3.2.4). The Kemiluppen database extract was received on the 10th of July 2020, with an update on the 5th of August, after adding four more PFAS compound names to the search. The ToxFox database extract was received on the 17th of August 2020 and an updated version with a minor change, i.e. the addition of two products, was received on the 28th of August 2020. The CosmEthics database extract was received on the 28th of August 2020.

3.2.1 CosmEthics

CosmEthics is a company founded in 2013, which launched its corresponding app in 2014. The app exists in English, French and Finnish languages and has been downloaded by more than 300 000 EU users. The company's headquarters are in Helsinki, Finland. CosmEthics provides app users with a traffic light system (suitable/safe product, potential allergen, high concern) after scanning a cosmetic product's barcode, which is based on the product ingredients (INCI names). The basic app is for free but can be customised and upgraded for a fee with more functions and alerts (e.g. specific substance class-free products, individual allergens, vegan products etc.). Approximately half of the product data in the database was obtained from manufacturers, retailers and importers, and half from consumers by means of crowdsourcing digital data submissions via the app. In case a scanned barcode does not exist in the database, the app user is asked to take pictures of the product and its ingredient list and presses a submission button within the app. The raw data is then sent to the backoffice system, which links the submission to the scanned barcode. CosmEthics' data processing team then inputs the digital raw data by transcribing the ingredients on the product label into their database (ingredient names from a predefined internal list to minimise typing errors).

In 2020, app users contributed to approximately 60 % of the database increase (i.e. addition of information into the database). According to CosmEthics, it is the biggest machine-readable cosmetic ingredient database worldwide, with a product scanning hit rate of approximately 77 % from within the EU. The company provides research institutions and agencies with database extracts. Quality checks are conducted as part of the transcription process, whereby each submission is controlled for input errors. A second quality check is conducted in the report/database extract generation stage. Margins of error are reported by CosmEthics for different parameters and years during which the products got scanned/registered into the database (INCI label: 2016 <21 %, 2017 <15 %, 2018-2020 <10 %; Category classification: 2016 <25 %, 2017 <25 %, 2018-2020 <15 %). Data from 2014-2015 have higher margins of error. Information on product versions, i.e. products with the same name, but different barcodes due to e.g. country/region-specific formulations (i.e. ingredients) or altered formulations is given as well in this database. (In case the barcode is different in the newly formulated product, it will show up as a new product.) Information on versions originates from manufacturers, but also consumers (via the "add new version" button in the app). The products of the CosmEthics database were even split for some of our analyses into EU/EEA countries and non-EU/EEA countries based on the barcode starting sequence (i.e. GS1 country prefix within the EAN-13) of the scanned product (country code). The country code indicates the country where the manufacturer is registered. As EU/EEA countries in the database extract counted the barcodes of: Austria, Belgium/Luxembourg, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark/Faroe Islands/Greenland, Estonia, Finland, France/Monaco, Germany, Greece, Hungary, Iceland, Ireland, Italy/San Marino/Vatican City, Latvia, Lithuania, Malta, Netherlands, Norway, Poland, Portugal, Rumania, Slovakia, Slovenia, Spain/Andorra, Sweden. Note that Lichtenstein was not included as it has the same barcodes as Switzerland (non-EU/EEA country), which was assumed to have the higher product and registered company share.

(All information on the app and database beyond the publicly available information received by personal communication with Katariina Rantanen, CEO CosmEthics, between July and December 2020.)

3.2.2 Kemiluppen

The app Kemiluppen was developed by the Danish Consumer Council THINK Chemicals (Forbrugerrådet Tænk Kemi), which is an initiative under the Danish Consumer Council. The free consumer app is in Danish and was launched in December 2015. It provides three different product evaluation labels of cosmetic and personal care products based on their ingredients. An A-flask label stands for non-problematic ingredients, a B-flask label for perfume and perfuming substances, including plant extracts, that are potential allergens and/or potential harmful to the environment and, a C-flask label for problematic ingredients, e.g. potential endocrine disrupting chemicals, allergenic preservatives and the carcinogenic, mutagenic, reprotoxic (CMR) substances that are not banned in cosmetics as well as substances of high concern for the environment. In the rare case where a prohibited substance is used in a product, the app points this out as well. If scanned product barcodes are non-existent in the database, the user is asked to take pictures of the product and its ingredient lists. The information is then manually added (ingredient names from a predefined list to minimise typing errors) by the Danish Consumer Council THINK Chemicals into the database, including the products' categorisation into a product category and its' ingredients evaluation (A- to C-flasks). The Danish Consumer Council THINK Chemicals receives updates on products that are newly placed on the market, on existing products were formulations have changed or on products that are discontinued from several producers. It sends ingredient lists to manufacturers before the first publication of a product in their app and thereafter contacts the manufacturers once a year, to give them the chance to inform about changed product formulations. Furthermore, consumers can warn the Danish Consumer Council THINK Chemicals, if they notice different INCI names on a product compared to Kemiluppen's information on which the product evaluation was based. Especially before testing/analysing cosmetic products for certain ingredients within investigations and research projects, the Danish Consumer Council THINK Chemicals even investigates if certain products have changed formulations or are discontinued themselves. However, the division into current and discontinued products is not faultless. Firstly, a product that is already listed as current might not be moved to discontinued due to missing information on its' newly discontinuation. Secondly, although very unlikely, as around 10 product scans are needed before an evaluation by THINK Chemicals starts, already discontinued products that have long been present in a consumer's home could be scanned for the first time and could be falsely counted as current.

(All information on the app and database beyond the publicly available information received by personal communication with Stine Müller, Forbrugerrådet Tænk Kemi, between July and December 2020.)

3.2.3 ToxFox

The free ToxFox app was launched in 2016 by Friends of the Earth Germany (BUND, Bund für Umwelt und Naturschutz Deutschland) and is a consumer app in German that has been downloaded by more than 1.5 million users. Friends of the Earth is a non-profit and politically independent organisation that dates several decades back. ToxFox provides users with information based on the scanned barcodes on ingredients in everyday life products (such as cosmetics, personal care products, electronics, toys, furniture, shoes, textiles etc.). In case a new barcode is scanned, it allows the user to directly request information from the producer on any ingredient that potentially is classified as substance of very high concern (SVHC, request according to Article 33.2 in the REACH legislation). This is the so-called “Giftfrage” function, which only can be used if the contact information of the producer is registered in ToxFox. The “Giftfrage” function is not available for cosmetic products, though. For cosmetic products, the app user gets a notification if any ingredient of a scanned cosmetic product is an endocrine-disrupting chemical (EDC) and/or nanoparticles. The ingredients of cosmetic products are received from a database by Codecheck AG (Switzerland). The data mostly originates directly from consumers, who add data themselves (among which ingredients etc.) and who also choose the product categories for new registered products. A minor extent of the data origins from companies/brands that directly provide data to Codecheck. Therefore, the data quality is highly dependent on each single consumer’s entry. The ToxFox database contains 442 000 products that are uncategorised, among which a lot are cosmetic products according to ToxFox. Even if a categorisation was done by the consumer, some of the predefined product categories, e.g. hygiene products, could be easily confused with cosmetic products. Therefore, the cosmetic product database extract from ToxFox used in this study could be missing cosmetic products or could wrongly count non-cosmetic products as cosmetic products. However, ToxFox is aware of this problem and currently working on an update of the current version and on improving their classification.

(All information on the app and database beyond the publicly available information received by personal communication with Ulrike Kallee, BUND, between July and December 2020.)

3.2.4 Number and identity of PFASs/INCI names in cosmetic products

PFASs searched from the databases were based on an INCI name list that IVL received from KEMI (based on compilation after a CosIng database search in May 2020) and partly additional INCI names that the cosmetic databases identified as such and shared with us and based on the PFAS definition given in the start. Approximately 170-190 different PFASs (varying among the databases) were searched from the different databases. Some databases decided to include PFASs that were not official INCI names and/or PFAS names that are not listed within CosIng (i.e. non-INCI and non-CosIng). These “non-CosIng name” PFASs were included due to the database owner’s or other employees’ experience with cosmetics and or their presence on internal PFAS lists that they use and continue since years. For more details on the databases searches, such as dates etc. consult chapter 3.2.

To provide an overall summary and ranking of PFASs/INCI names found within each database, the number of products containing a certain PFAS/INCI were listed. Each PFAS/INCI then received a rank based on the frequency in products within the database, starting with one for the most frequent PFAS/INCI. In case of several PFAS/INCI with the same frequency within a database, i.e. number of products with the PFAS/INCI, so called fractional ranks were calculated. As an example: Two different PFASs/INCI names occurred in each 5 products in Kemiluppen. The previous compound (in 6 products) had a rank of 10. The following two PFASs/INCI names with the same frequency each received a rank of 11.5 (i.e: rank 11 plus rank 12 equals 23, which is divided by two for the number of PFASs with same frequency). The ranks following fractional ranks continued in the same manner, i.e. in case there was only one PFAS with a unique frequency, the next compound would receive a rank number of 13, in case of three numbers with the same frequency, the PFASs would receive a rank number of 14. All PFASs/INCI names that did not occur in one database but did occur in others, received the next rank number following the last PFASs/INCI names found in this particular database. Finally, all ranks were summed and the PFASs were rearranged based on the rank sum (from low to high). PFASs with the lowest rank sum were considered as most frequent throughout the databases and are presented in this report.

3.3 Databases for PFAS functions in cosmetics and commercial availability of PFAS-containing technical products

The Cosmetic ingredient database (CosIng) is the European Commission's database for information on cosmetic substances and ingredients. The online search function in the CosIng database was used for the identification of PFAS functions as cosmetic ingredients. The INCI names were searched for in the CosIng database (https://ec.europa.eu/growth/tools-databases/cosing/index.cfm?fuseaction=search.simple, searched in July and August 2020) and their functions were recorded. For more details on the results consult chapter 4.4.

Additionally, the material selection platform SpecialChem for producers (https://cosmetics.specialchem.com/) was searched for the INCI names to identify technical products with PFASs for cosmetics production. For each INCI, the technical product name(s) were recorded, their functions, recommended applications for products as well as the producers and the commercial availability of the technical products. The searches were done between July and October 2020. In this report, the number of the technical products containing PFASs and their commercial availability is presented in chapter 4.6.2.

3.4 Sampling for cosmetic products with PFASs

3.4.1 Sampling strategy and sampling

The following approach was used to maximize sampling of sub-categories containing a high share of PFAS-containing products: First, summary statistics on PFAS-containing products received from CosmEthics (EU/EEA barcode product database extract only) were reviewed and the share (%) of PFAS-containing products was calculated for each product sub-category. The most relevant sub-categories were identified as those with both the largest share of PFAS-containing products and the largest total number of products. Thereafter, a total number of 50 anticipated samples was distributed among the most relevant product categories and sub-categories according to the number of PFAS-containing products in a given sub-category (i.e. percent distribution). Sampling aimed to collect the number of products identified from each of the targeted sub-categories.

The first sampling attempt involved in-person, targeted shopping for specific PFAS-containing products from the cosmetic databases among the relevant sub-categories (mainly CosmEthics). However, listed brands/products were partly not available and a few products did not list PFAS anymore when consulting the products' ingredients lists. Therefore, a second attempt was made via an online shop search but was ultimately dismissed as a suitable sampling option (see chapter 4.8 for the reason). Thereafter, a more random sampling approach in several physical shops was chosen, i.e. checking labels of random products (mostly within relevant sub-categories according to the systematic sampling approach), which followed a final targeted sampling for products of companies and brands without any previous purchased product based on the Surfejs list (https://www.surfejs.se/varstingjakten/, latest access 5th of September 2021). This list represents a blacklist of cosmetic products containing PFASs compiled by the Swedish Society for Nature Conservation (SSNC) based on reports by (Swedish) consumers.

At the conclusion of sampling, the coverage of purchased products from the relevant PFAS-containing sub-categories was deemed satisfactory. For more information on the sampling and occurring difficulties, see chapter 4.8.

3.4.2 Purchased cosmetic product samples

The sampling campaign obtained 43 different cosmetic products containing PFAS as listed ingredients and two without PFAS as blank samples (one blank within Decorative Cosmetics, one within Hair Care, Table 1). One cosmetic product was purchased online from a Swedish shop while the remaining products were bought from several different stores in Stockholm during September 2020. For more information on the country barcode, i.e. where the manufacturer is registered, or the product is made in etc., consult the Table 25. In total, 24 of the purchased cosmetic products fall within the product category Decorative Cosmetics, 6 within Hair Care and 15 within Skin Care (out of which 2 products were for males). One product contained two, three products three and one product six different INCI names/PFASs. No product was purchased within the product categories Toiletries or Perfumes and Fragrances (Table 1).

Among the purchased PFAS-containing products, eight products listed PFASs/INCI names that fall under current or pending restrictions. A total of six different PFASs were listed as ingredients that fall under current or pending restrictions: Perfluorooctyl triethoxysilane, Perfluorononyl dimethicone, Polyethylene perfluorononyl dimethicone, C9-15 fluoroalcohol phosphate, Ammonium C6-16 perfluoroalkylethyl phosphate, C4-18 perfluoroalkylethyl thiohydroxypropyltrimonium chloride (Table 1).

Table 1: Overview cosmetic product samples purchased (September 2020 in different stores in Stockholm, Sweden) for the analysis of TF, EOF and targeted PFASs with triggering ingredient on the ingredient list; PFAS INCI names in bold are under existing or pending PFAS restriction.

Sample name (Sub Category (ID))	Triggering Ingredient
Decorative Cosmetics	N/A
Blush/Bronzer/Contour 1	**PTFE***
Blush/Bronzer/Contour 2	**PTFE***
Blush/Bronzer/Contour 3	POLYPERFLUOROMETHYLISOPROPYL ETHER
Blush/Bronzer/Contour 4	**PTFE***
Concealer 1	**PERFLUOROOCTYL TRIETHOXYSILANE**
Concealer 2	PERFLUORODECALIN, PERFLUOROHEXANE, PERFLUOROMETHYLCYCLOPENTANE
Eye liner, pen 2	**PERFLUORONONYL DIMETHICONE**
Eye shadow 1	**PTFE***
Eye shadow 2	**PTFE***
Eye shadow 3	**PTFE***
Eye shadow 4	**PTFE***
Eye shadow 5	POLYPERFLUOROMETHYLISOPROPYL ETHER
Eyeliner liquid/gel	POLYPERFLUOROMETHYLISOPROPYL ETHER
Foundation/BB Cream 1	**PERFLUOROOCTYL TRIETHOXYSILANE**
Foundation/BB Cream 2	TRIFLUOROPROPYL DIMETHICONOL
Foundation/BB Cream 3	**C9-15 FLUOROALCOHOL PHOSPHATE**
Foundation/BB Cream 4	**AMMONIUM C6-16 PERFLUOROALKYLETHYL PHOSPHATE**
Lip liner, pen 1	**PERFLUORONONYL DIMETHICONE**
Lip liner, pen 2	**POLYETHYLENE PERFLUORONONYL DIMETHICONE**
Loose powder	POLYPERFLUOROMETHYLISOPROPYL ETHER
Mascara	**PTFE***
Pressed Powder 1	POLYPERFLUOROMETHYLISOPROPYL ETHER
Pressed Powder 2	POLYPERFLUOROETHOXYMETHOXY DIFLUOROETHYL PEG PHOSPHATE
Hair Care	N/A

Hair spray 1	OCTAFLUOROPENTYL METHACRYLATE (OFPMA)
Hair spray 2	HYDROFLUOROCARBON 152a
Shampoo	OCTAFLUOROPENTYL METHACRYLATE (OFPMA)
Styling cream	**C4-18 PERFLUOROALKYLETHYL THIOHYDROXYPROPYLTRIMONIUM CHLORIDE**
Treatment 1	OCTAFLUOROPENTYL METHACRYLATE (OFPMA)
Skin Care	N/A
After shave	POLYPERFLUOROMETHYLISOPROPYL ETHER
Anti-age cream 1	ACETYL TRIFLUOROMETHYLPHENYL VALYLGLYCINE
Anti-age cream 2	PERFLUOROHEXANE, PERFLUOROPERHYDROPHENANTHRENE, PERFLUORODECALIN
Anti-age cream 3	POLYPERFLUOROMETHYLISOPROPYL ETHER
Exfoliator	PERFLUOROHEXANE, PERFLUORODECALIN, PERFLUOROMETHYLCYCLOPENTANE
Eye moisturiser 1	**PTFE***
Eye moisturiser 2	TRIFLUOROACETYL TRIPEPTIDE-2
Facial moisturiser	POLYPERFLUOROMETHYLISOPROPYL ETHER
Mask 1	ETHYL PERFLUOROBUTYL ETHER, ETHYL PERFLUOROISOBUTYL ETHER
Mask 2	METHYL PERFLUOROBUTYL ETHER, METHYL PERFLUOROISOBUTYL ETHER, PERFLUOROHEXANE, PERFLUOROPERHYDROPHENANTHRENE, PERFLUORODECALIN, PERFLUORODIMETHYLCYCLOHEXANE
Mask 3	METHYL PERFLUOROISOBUTYL ETHER
Moisturiser/Face cream 1	ACETYL TRIFLUOROMETHYLPHENYL VALYLGLYCINE
Moisturiser/Face cream 2	POLYPERFLUOROMETHYLISOPROPYL ETHER
Serum and treatment 1	TRIFLUOROACETYL TRIPEPTIDE-2
Serum and treatment 2	ACETYL TRIFLUOROMETHYLPHENYL VALYLGLYCINE
Blank samples (no PFAS on the ingredient list)	N/A
Eye liner, pen 1	N/A
Treatment 2	N/A

* Included in the pending microplastics restriction if PTFE is in both particulate and solid form (<5mm particle size). This includes if it is present as a coating around another ‘inorganic material’. Liquid particles (colloids) would be excluded.

3.5 Analysis of cosmetic products

Characterisation of PFASs in cosmetic products is analytically challenging, due to the large diversity of PFASs occurring in these products, as well as concentrations varying by several orders of magnitude between listed PFAS ingredients and PFAS impurities. For example, polymeric PFASs are not typically extractable by the same methods that are used to extract low molecular weight PFASs. Similarly, appropriate dilutions of a sample extract to measure listed ingredients, is more likely to result in residual PFASs dropping below limits of detection.

To address these difficulties, three different analytical methods were chosen. The analytical procedures were carried out at the Department of Environmental Science, Stockholm University, Sweden. The 45 purchased samples (including two blank samples, i.e. without any PFAS on the ingredient list) were analysed for their total fluorine (TF) content and a subset of 15 samples was analysed for extractable organic fluorine (EOF) and individual (target) PFAS content. Samples analysed for EOF and target PFAS are denoted with an asterisk (*) in Table 19.

Each of the three aforementioned analytical techniques have advantages and disadvantages. TF is rapid and captures all organofluorine substances (including polymers), but has the potential to overestimate PFAS content due to the presence of inorganic fluorine. EOF can capture a wide range of organofluorines and removes inorganic fluorine, but the type of PFAS captured by this approach is ultimately dependent on the extraction solvent. Polar solvents (such as methanol used here) are effective at capturing low molecular weight, polar PFAS, but not fluoropolymers. Targeted PFAS analysis, on the other hand, is highly specific and sensitive, but does not capture PFASs not specifically included in the method (which is most listed PFAS ingredients, see Table 2).

Table 2: Overview of the different analytical methods (Total fluorine (TF), extractable organic fluorine (EOF) and targeted PFAS analysis) applied on the samples in this report and their prerequisites, potential to detect different compounds, advantages and disadvantages. CIC=combustion ion chromatography; LC-MS/MS=liquid chromatography coupled to a triple quadrupole mass spectrometer; PTFE=Polytetrafluoroethylene.

	TF (CIC)	**EOF (CIC)**	**Targeted PFAS (LC-MS/MS)**
Description of analysis	Direct instrumental analysis (no extraction)	Extraction followed by instrumental analysis	Extraction followed by instrumental analysis
Concentration includes inorganic fluorine	Possibly; If inorganic fluorine is present, it will contribute to TF.	Unlikely; Spike/ recovery tests show that sodium fluoride is removed by extraction. It is assumed that other inorganic species will behave similarly.	No; Likely removed by extraction and not measured by instrumental analysis
Concentration includes polymers	Possibly; If polymers are present, they will contribute to TF	Unlikely; Most large polymers are removed during extraction. Unclear for small polymers.	No; Likely removed by extraction and not measured by instrumental analysis.
Compounds detected	Anything containing fluorine	Anything containing fluorine that is not removed by the extraction	Only low molecular weight PFASs specifically targeted by the method (existing standards and known mass to charge ratio)
Advantages / PFASs detected	Detects all PFASs (incl. PTFE and any polymer); Most rapid and convenient of all methods	Detects mostly non-polymeric, polar PFASs soluble in methanol	Detects specific PFASs (matching standards and specific mass to charge ratio, i.e. MS/MS method required)
Disadvantages	Potential overestimation of total PFAS content, due to contribution from inorganic fluorine (if present).	Likely underestimation of PFAS content, i.e. missing PTFE, polymeric and/or non-polar/non-ionisable PFASs.	Underestimation of total PFAS content. Most listed PFAS ingredients not included.

By comparing the analytical results of the different methods to each other, some of the disadvantages can be ruled out. For example, if the TF and EOF signals are similarly high, inorganic fluorine can be assumed to be negligible. On the same hand, if there is a difference between TF and EOF, the difference might be due to the presence of inorganic fluorine, polymers, and/or non-polar organic fluorine species which are removed by the sample extraction step prior to EOF instrumental analysis (as well as due to analytical uncertainties).

3.5.1 Sample extraction for EOF and targeted PFAS analysis

Samples analysed for EOF and targeted PFAS were subjected to a methanolic extraction procedure previously reported in Schultes et al. (2018). Briefly, sodium hydroxide solution (NaOH, 0.5 mL of 0.2 M) and methanol (5 mL) were added to approximately 0.1 g of the cosmetic product sample. Thereafter, samples were vortexed and extracted in an ultrasonic bath at room temperature for 30 minutes. After centrifuging at 2000 rounds per minute (rpm) for 5 minutes, the supernatant was transferred into a new test tube. The extraction was repeated a second time with 5 mL methanol and the extract was centrifuged (20 min at 3000 rpm). The supernatants were combined and neutralised with hydrochloric acid (HCl, 50 µL of 2 M). Thereafter, the methanol was evaporated under a gentle stream of nitrogen to about 1 mL and 500 µL of the concentrated extract were transferred to a 1.5 mL Eppendorf tube containing 25 mg graphitized carbon (Supelclean ENVI-carb) and 50 µL glacial acetic acid. The tubes were vortexed and centrifuged at 10000 rpm for 10 minutes before transferring the supernatant to a new Eppendorf tube. At this point, the extract was divided into two portions: about 500 µL was kept aside for EOF analysis and 100 µL of the extract was spiked with 50 µl of an isotopically labelled standard solution (20 pg/µL) for targeted analysis (see Table 26 for a full list of internal standard compounds). 10 % of the samples were replicated and all sample extracts were stored in a freezer until the day of analysis.

3.5.2 TF and EOF analysis (CIC)

Since the structures are known from the products' ingredient lists, quantification can be performed directly on the product using combustion ion chromatography (CIC). During CIC, all fluorine-containing substances are converted to inorganic fluorine, which is then measured by ion chromatography. Because all fluorine-containing substances produce a fluoride signal, quantification can be performed on PFASs which lack authentic standards. Briefly, CIC analysis is carried out as follows: samples (approx. 0.1-1 mg of cosmetic product for TF analysis and 10-100 µL of extract for EOF analysis) were weighed into a ceramic boat containing glass wool. To minimise background contamination, all boats were baked out prior to analysis of real samples. The samples were combusted at 1100°C under a flow of oxygen (400 L/min) and argon mixed with water vapor (200 L/min) for about 6 minutes. Combustion gases were collected in MilliQ water in an absorber unit (GA-210, Mitsubishi), after which an aliquot of the absorption solution (100 mL) was injected onto the ion chromatograph (IC, Dionex Integrion HPIC, Thermo Fisher Scientific), which was equipped with an anion exchange column (Dionex IonPac AS19 2 × 50 mm guard column and 2 × 250 mm analytical column, 7.5 mm particle size) operated at 30°C. Chromatographic separation was achieved by running a gradient of aqueous hydroxide mobile phase ramping from 8 mM to 60 mM at a flow rate of 0.25 ml/min. The fluoride was detected by a conductivity detector.

3.5.3 Targeted PFAS analysis (LC-MS/MS)

Extracts were injected (5 µl) onto an Acquity ultra performance liquid chromatography (UPLC) (Waters Corp., Milford, MA) equipped with a BEH C18 guard (5×2.1 mm, 1.7 mm particle size) and an analytical (50×2.1 mm, 1.7 mm) column operated at 40°C. The composition of the mobile phase and details on the gradient and the flow rate can be found in Table 27. Detection of PFASs was carried out using a triple quadrupole mass spectrometer (MS/MS) (Xevo TQ-S, Waters Corp, Milford, MA) operated in negative electrospray ionisation mode. The capillary voltage was set to 1.0 kV, and the desolvation and source temperature were set to 350˚C and 150˚C, respectively. The desolvation and cone gas flows were set to 150 L/h and 650 L/h, respectively. Precursor and product ions and further information on MS parameters are presented in Table 26. Quantification of individual PFASs was performed using MassLynx 4.1 (Waters), via an 8-point calibration curve ranging from 0.02 to 100 pg/µl. Analytes lacking an analogous labelled standard were quantified using the internal standard with the closest retention time (Table 26). In cases where a sample contained polyfluoroalkyl phosphates (PAPs), a ten-fold fortification of internal standard was performed and the concentrations were adjusted by dilution prior to analysis, to prevent the samples' concentration to exceed the standard curve.

For comparison (i.e. mass balance, chapter 4.9.4) to TF and EOF data, targeted PFAS concentrations were converted to fluorine equivalents (C_{F_PFAS}; ng F/g) using Equation 1:

Eq. 1
$$\boldsymbol{C_{F\_PFAS}} \left[\frac{ng\ F}{g}\right] = \frac{C_{PFAS}\left[\frac{ng}{g}\right] \times n_F \times A_F}{MW_{PFAS}}$$

where C_{PFAS} and n_F are the concentration and number of fluorine atoms for a given target, A_F is the atomic weight of fluorine (19.0 g/mol), and MW_{PFAS} is the molecular weight of the target (g/mol). Once the concentrations were converted to fluorine equivalents (i.e. ng F/g), they were summed to obtain ΣC_{F_PFAS} concentrations (concentrations below the limit of detection (<LOD) were replaced with 0), which were directly comparable to EOF and TF measurements. This approach was done to assess the fluorine mass-balance, i.e. determine how much of the TF and EOF concentration can be explained by the sum of the targeted PFAS concentration (chapter 4.9.4).

3.5.4 Quality assurance and quality control

The accuracy and precision of TF measurements were assessed through triplicate combustions of a certified reference material (CRM) (BCR®-461, fluorine in clay). The average percent recovery of these measurements 90% (2.5% relative standard deviation, RSD) Boat blanks and a mid-level calibration standard were run intermittently to monitor potential carry-over and instrumental stability, respectively. All TF data were blank-subtracted and limits of detection (LODs) were calculated as 3 times the standard deviation of the blanks. Intra-sample variability of TF was assessed by analysing 10 % of samples in triplicate.

For EOF measurements, accuracy and precision were assessed using replicate spike/recovery experiments, consisting of a PFAS-free cosmetic product which was extracted and analysed with and without fortification of a suite of PFASs (277 ng F fortification level; n=3). Average percent recovery from these experiments was 61 % (14 % RSD). Furthermore, an additional spiking experiment was performed using 250 ng sodium fluoride (NaF i.e. inorganic fluorine; n=3), which confirmed that inorganic fluorine was removed during the extraction procedure. In addition to analysing 10 % of samples in triplicates, three procedural blanks were handled in the same way as the samples to check for potential contamination introduced during the extraction procedure. Finally, during instrumental analysis, boat blanks and a mid-level calibration standard were run intermittently to monitor potential carry-over and instrumental stability, respectively. All EOF concentrations were blank-corrected. Limits of detection were calculated based on three times the standard deviation of the procedural blanks.

For LC-MS/MS measurements, accuracy and precision were assessed using the same replicate spike/recovery experiments as used for EOF, i.e. a PFAS-free cosmetic product which was extracted and analysed with and without fortification of a suite of PFASs. The fortification level was 10 ng PFAS. In addition to analysing 10 % of samples in triplicates, three procedural blanks were handled in the same way as the samples to monitor for potential contamination introduced during the extraction procedure. Finally, during instrumental analysis, instrumental blanks and a mid-level calibration standard were run intermittently to monitor potential carry-over and instrumental stability, respectively. Procedural blanks did not show detectable contamination for any target PFAS. Therefore, limit of detection (LODs) were determined using the concentration obtained from the lowest calibration point with a well-shaped peak with an intensity >1000 and a signal-to-noise (S/N) ratio of >3 and converted to weight per weight (ng/g) units using the average sample weight. Replicate spike/recovery experiments with target PFAS revealed an average percent recovery of 83 % (range 30-106 %; n=3) and an average RSD of 13 %. Considering that internal standards were added after extraction (necessary because a portion of the same extract is used for EOF analysis), these recoveries are reasonable, and reflect some losses incurred during the extraction procedure and/or matrix effects arising from the absence of exactly matched, isotopically labelled internal standards. Detections limits ranged from 1 to 18 ng PFAS/g cosmetic product sample. A contamination of the samples during sample treatment could be ruled out, as procedural blanks showed concentrations of <LOD for all targets.

As a final QC measure, a sample previously analysed in Schultes et al. (2018) was re-analysed in the present study for TF, EOF, and target PFAS concentrations (Figure 4). TF and EOF concentrations measured here were in good agreement with previous measurements (3100 ng F/g vs 2900 ng F/g and 1260 ng F/g vs 1380 ng F/g, respectively). For target analysis, sum PFCA (∑PFCA) concentrations were in good agreement (6.27 ng F/g vs 8.11 ng F/g, respectively), but higher diPAP concentrations were observed in the present work compared to Schultes et al. (2018) (487 ng F/g vs 72 ng F/g, respectively). This is perhaps not surprising considering that a different method was used for diPAP determination in Schultes et al. (2018) and because challenges were noted in that study for determination of PAPs in these samples due to their extremely high concentrations.

All analytical values are rounded to three significant figures, except for in a few figures and tables in the appendix, were un-rounded values are presented for the purposes of auditing, but no more than 3 values should be considered significant.

3.6 Emissions - input data, assumptions and calculations

Generally, four parameters have to be considered calculating a chemical's emission, in this case for PFAS (E_{PFAS} in kg/year) from products (see Equation 2):

- the concentration of a chemical in the products (C_{PFAS} in µg PFAS/g product),
- the total amount, or tonnage of the products sold per year ($A_{products}$ in tons/year),
- the share of products containing the chemical ($f_{PFAS\ products}$) and
- the fraction of the chemical released from the product into a certain compartment ($f_{release}$), (e.g. wastewater or solid waste etc.).

Eq. 2 $$E_{PFAS}\left[\frac{kg}{year}\right] = C_{PFAS}\left[\frac{\mu g}{g}\right] \times A_{products}\left[\frac{t}{year}\right] \times f_{PFAS\,products} \times f_{release} \times 10^{-3}$$

The factor 10^{-3} in Equation 2 is a conversion factor from g/year to kg/year. The $f_{release}$ part can be neglected (i.e. set equal to one) in order to calculate the total emission or total content of PFASs in the products. In the following subsections, each parameter will be described more closely.

Due the availability of Retail Sales Prices per product category only, the entire emission calculations were made on the level of the five defined product categories from Cosmetics Europe (Decorative Cosmetics, Hair Care, Skin Care, Perfumes and Fragrances as well as Toiletries). In the following subsections the derivation of each of the four parameters going into the emission calculations is more closely explained. All results of the final emission estimates are rounded to two significant figures.

3.6.1 The concentration of PFASs in the cosmetic products

The concentration of PFASs in the products was derived by measuring total fluorine (TF), the extractable organic fluorine (EOF) and individual PFASs (targeted analysis) in purchased cosmetic products with at least one PFAS on the ingredient list (see chapters 3.4 and 3.5 for more details on the sampling and the analytical methods).

TF concentrations were grouped according to the type of cosmetic product, e.g. all eye shadows were considered one subgroup. Within each subgroup, the average, minimum and maximum concentration was determined. Based on these values, the overall average, minimum and maximum for each product category (Decorative Cosmetics, Hair Care and Skin Care) was calculated (note that there were no samples among the product categories "Perfumes and Fragrances" or "Toiletries"). This approach was chosen over calculating the overall averages based on all single products (within one product category), to avoid discriminating certain subcategories that were comprised of fewer products than other subcategories.

For EOF data, the aforementioned approach was applied to determine the overall average, minimum and maximum concentrations each for Decorative Cosmetics, Hair Care and Skin Care. For each sample of cosmetic product all measured PFCA concentrations were combined to give a sum concentration i.e. ∑PFCAs (in ng ∑PFCAs/g product). The ∑PFCA concentrations per cosmetic product were applied to the average, minimum and maximum concentration calculation (as described above for TF and EOF).

The derived overall average, minimum and maximum concentrations for the three product categories were used as the product concentration in the emission calculations of the average-, best- and worst-case scenario to wastewater, respectively. These scenarios were separately calculated for TF, EOF and ∑PFCA concentrations, respectively.

None of the analysed samples belonged to the product categories "Toiletries" or "Perfumes and Fragrances". The average concentrations of Hair Care in the different scenarios and measurements were assumed to be valid for Toiletries as well. This assumption was made, as Toiletries (with subcategories such as shower gel/ body wash) seemed more related to Hair care (with subcategories such as shampoo) than to any other of the cosmetic product categories. Hair styling products that were sampled as well within the Hair Care product category had lower concentrations than shampoo, therefore the average concentrations for Hair Care were assumed to be suitable for Toiletries as well and this approach was deemed the best estimate. However, given the high market share associated with Toiletries (~25 %; Table 5; resulting from recalculation into the highest total amount (metric tonnes) of products, see chapter 3.6.2, Table 4), this category might have an impact on the total emissions, even though only 0.27 % of Toiletries contain PFASs (chapter 3.6.3, Table 8). Therefore, future measurements of products within the product category Toiletries could update these emission estimates.

For "Perfumes and Fragrances", the concentrations were assumed to be equal to zero for all measurements (TF, EOF and PFASs) and scenarios. Only one in 3637 products (i.e. 0.027 %) in the "Perfumes and Fragrances" product category contained a listed PFAS as an ingredient (CosmEthics database). Therefore, emissions were assumed to be negligible, i.e. product category concentrations in all emission scenarios (best-, average- and worst-case) were assumed to be zero.

Concentrations below the limit of detection (LOD) were treated differently in the emission calculations for the different parameters (i.e. TF, EOF, ∑PFCAs). For the ∑PFCA concentrations <LOD were set equal to zero and for the TF and EOF equal to the value of the actual LOD (Table 3).

In case one of the PFCAs had a concentration below the limit of detection (<LOD), the single PFCA's concentration went into the ∑PFCA calculation as equal to zero. This might be an underestimation of the ∑PFCAs. However, taking the actual value of the LOD would likely be an immense overestimation. The overestimation would likely be of a much greater and even more unrealistic extent than the underestimation due to three major reasons:

a) None of the PFCAs was listed as an ingredient, so the PFCAs occur as impurities. They are unlikely to occur in all products and concentrations are expected to be low;
b) In cases where several PFCA concentrations in the same sample were <LOD, the sum of the LOD concentrations would result in an overestimate for the emissions calculations; so in this case the ∑PFCAs would be fully driven by the actual LOD values (dependent on the method and instrument) and not by measured concentrations;
c) The minimum, average and maximum ∑PFCA concentration per product category (which in the extreme case would be equal to the ∑LOD-values, if all PFCAs have concentrations <LOD) will be set off against tonnes of products in the emission calculations. So even low LOD (ng/g) values (especially their sum) would contribute greatly to the final calculated emitted ∑PFCA amounts.

Table 3: Treatment of sample concentrations below the limit of detection (LOD) for the different analytical methods and its effects on the minimum, average and maximum concentrations per product category that go in the emission calculations for total fluorine (TF), extractable organic fluorine (EOF) and ∑PFCAs.

	TF	**EOF**	**∑PFCAs**
Concentrations <LOD treated as	Equal to the LOD value	Equal to the LOD value	Equal to zero (0)
Reasoning	To prevent underestimation, as intended PFAS on the ingredient list, which should in theory give a signal	To prevent underestimation, as intended PFAS on the ingredient list, which should in theory give a signal	To prevent extreme overestimation when taking the sum of several PFCAs, also PFCAs were not on the ingredient list and occur as impurities
Impact on emission calculations of using LOD	Negligible; except for minimum concentration value for Hair care equal to LOD value	Negligible; except for minimum concentration value for Skin care and for Decorative Cosmetics equal to LOD value	None (set equal to zero)

For TF and EOF, the actual value of the LOD was taken instead of zero and went into the average calculation for the sub-categories (Table 3) and the product categories. This was done in order to prevent an underestimation. At least one PFAS was listed as intended ingredient in these products and thus, in theory will result in a signal for TF and EOF, i.e. bigger than zero, even though it was lower than the LOD (Table 3). Further, hardly any sample concentrations fell below the LOD (for TF only one hair spray and one mask <LOD; for EOF one eye shadow and one exfoliator <LOD). Therefore, the influence of assuming zero or taking the LOD values was negligible for the total averages of the cosmetic product categories. For TF, only within the product category Hair Care, the minimum concentration was equal to the LOD value of one hair spray product and taken as the minimum concentration for the best-

case scenario (Table 3). For EOF, the value of the LOD was taken as the minimum concentration for both Skin Care and Decorative Cosmetics in the best-case scenario (Table 3).

For the overall average, minimum and maximum of the TF, EOF and ∑PFCA concentrations per product category (Decorative Cosmetics, Hair Care and Skin Care) that went into the emission calculation, see Table 28, Table 29, Table 30.

3.6.2 The total amount of cosmetic products sold per year

Ideally, emission calculations would include yearly tonnages of the considered products within the trading market of interest. However, to our knowledge, this data is not available and even Cosmetics Europe does not have this kind of information (personal communication with John Chave, December 2020), neither the Swedish Cosmetics, Toiletries and Detergents Association (KoHF, personal communication with Peter Jansson, December 2020), nor the Swedish Medical Products Agency (MPA, personal communication with Josefin Liljeteg, December 2020). Therefore, the yearly tonnage of produced cosmetic products (Table 4) was indirectly derived based on the following data and assumptions:

- the European cosmetic products market Retail Sales Price from 2019 (RSP in Euro) Table 5 Cosmetics Europe (2020);
- the market share of the different product categories, Table 5 (Cosmetics Europe 2020);
- an assumed average product price per product category, Table 6 (assumptions);
- an assumed average product size per product category Table 7 (in g, based on limited data of the CosmEthics database and assumptions).

For each product category the following equation resulted into the total amount of cosmetic products sold per year ($A_{products}$):

Eq. 3 $$A_{products}\left[\frac{t}{year}\right] = \frac{RSP_{market}\,[Euro] \times f_{market}}{RSP_{product}\,[Euro]} \times M_{product}\,[g]$$

By assuming an average product price per product category ($RSP_{product}$ in Euro) and relating this to the Retail Sales Prices (including VAT) per product category (based on the total market Retail Sales price (RSP_{market} in Euro) and the market share (f_{market}), the number of sold products within each product category could be calculated. This, in combination with the average product size per product category ($M_{product}$ in g), translated into the tonnage of products produced within each product category per year in the EEA, although without Lichtenstein and Iceland, because the Cosmetics Europe Retails Sales Prices did not include these two countries ($A_{products}$ in t/year, Table 4).

Table 4: Calculated total amount (metric tonnes) of cosmetic products sold per year in 2019 in the EEA; data based on assumptions and Retail Sales Price, as well as market share from Cosmetics Europe as well as assumptions and data from the CosmEthics database.

Product category	Total amount of products (thousand tonnes/year in 2019)
Skin Care	273
Toiletries	1110
Hair Care	838
Perfumes and Fragrances	77.6
Decorative Cosmetics	18.8
Total EEA market*	2320

**EU27 and Norway (i.e. EEA without Lichtenstein and Iceland).*

It is pertinent to note that the assumed values for the parameters “product size” and “product price” have a considerable influence on the data and are therefore highly sensitive parameters. An increase of all average product sizes by 10 % would result in a 10 % increase in the total quantity (i.e. mass in t) of products and hence the total emissions. The same sensitivity is true for the product price: An increase of the average product price by 10 % would result though in a 10 % decrease in both the total number of products and the corresponding mass of products and the emissions.

Even though the tonnages were partly based on estimates, the calculated tonnages fitted the estimated amounts of a previous report by Amec Foster Wheeler (2017, pages 26-27). Their estimated total volume of 3-5 million tonnes for the European market (EU28, in 2015), agreed well to the here estimated total volume of 2.64 million tonnes (removing both Norway and Switzerland from the EU28 Norway and Switzerland data for 2019, Cosmetics Europe). (Note that the value of total tonnes differs from Table 4 due to the inclusion and exclusion of different countries, mainly the United Kingdom, which was included for the comparison to the Amec Foster Wheeler (2017) report, but not for any other part of this current report and neither for calculating the emissions within the EEA.)

3.6.2.1 Retail Sales Prices and market share per product category

The total European cosmetic products Retail Sales Prices (RSP) in 2019 was 79.84 billion Euro (including VAT, for EU28 Norway and Switzerland). In order to retrieve an approximation for the EAA cosmetic products market only, the RSP from both the United Kingdom (10.657 billion Euro) and Switzerland (1.965 billion Euro) were subtracted. This resulted in an EEA Retail Sales Price volume of 67.218 billion Euro for the cosmetic products in 2019 (i.e. EU27 and Norway, Table 5). Note that this value misses Iceland and Lichtenstein, as the European cosmetic products market RSP did not include these countries. However, those countries' cosmetic products' Retails Sales Prices likely makeup a minor portion compared to the other EEA countries.

Table 5: EEA cosmetic products market 2019, Retail Sales Prices (RSP including VAT) and market share by product category; data from Cosmetics Europe (2020) on European market (70.84 billion Euros, EU28 Norway and Switzerland) subtracting the RSP from the United Kingdom and Switzerland (10.657 and 1.965 billion Euros); the percentages are also based on Retail Sales Prices.

	Product category	Percent (%)	Retail Sales Price (bn Euro)
Market share 2019 by product category	Skin Care	27.1	18.22
	Toiletries	24.8	16.67
	Hair Care	18.7	12.57
	Perfumes and Fragrances	15.4	10.35
	Decorative Cosmetics	14.0	9.41
Total EEA market*	All product categories	100.0	67.22

**EU27 and Norway (EEA without Lichtenstein and Iceland).*

Out of the total EEA cosmetic products Retail Sales Prices in 2019 (67.22 billion Euro, including VAT) and the market share of the different product categories (both Cosmetics Europe 2020), the Retail Sales Price per product category was calculated (Table 5). An identical market share of the different product categories (%) was assumed even after the exclusion of the national Retail Sales Price from Switzerland and the United Kingdom from the European cosmetic products market.

3.6.2.2 Product price

There was no information available on product prices, confirmed by the Swedish Cosmetics, Toiletries and Detergents Association (KoHF) (personal communication with Peter Jansson, December 2020), Cosmetics Europe (personal communication with John Chave, December 2020). Therefore, estimates were necessary. Firstly, the average product price assumptions from a previous report (Hansson et al. 2020) in Sweden per product category were considered (assumed 100 SEK, i.e. approximately 10 Euros as average product price for Decorative Cosmetics, Hair Care, Toiletries and Skin Care products). Cosmetic products in Sweden are generally more expensive than in many other EEA countries. Assuming a more expensive product price will result in a lower number of products sold per product category, because the product price is related to the overall Retail Sales Price (Eq. 3). A lower number of products will generally result in lower emissions (Eq. 2), because of which the assumed Swedish prices were taken for the best-case scenario only (Table 6). Perfumes and Fragrances were not considered in the previous report but were assumed to cost 30 Euro per product in the best-case scenario (Table 6).

Table 6: Estimated average product price (Euro) per product category for the emission calculations for the best-, average- and worst-case scenario; price including VAT.

Product category	Estimated average product price (Euro) for the emission calculations Best-case	Estimated average product price (Euro) for the emission calculations Average-case	Estimated average product price (Euro) for the emission calculations Worst-case
Decorative Cosmetics	10	5	5
Hair Care	10	3	3
Perfumes and Fragrances	30	10	10
Skin Care	10	5	5
Toiletries	10	3	3

For the average and worst-case scenario, the same prices, but lower than in the best-case scenario were assumed. The assumptions were based on personal experience and after screening prices on a webpage of one popular drugstore in Germany (https://www.dm.de/ beginning of January 2021). The drugstore has a price filter option that lists the number of products in different price categories. The search was done for different sub-product categories (e.g. shampoo, eyeshadow etc.) within the different product categories. However, the frequency of products in the different price categories and for the different sub-categories were not recorded and no mathematical averages were calculated among the products to obtain the average price per product category. Anyhow, the assumed average prices were based on these insights and after weighing e.g. probable frequently big sellers within the product categories.

3.6.2.3 Product size

To our knowledge no information is available on average product sizes, even confirmed by the Swedish Cosmetics, Toiletries and Detergents Association (KoHF) (personal communication with Peter Jansson, December 2020) and Cosmetics Europe (personal communication with John Chave, December 2020). In order to obtain the product size (in g), the database extract of CosmEthics for the PFAS containing products was consulted (both EU/EEA and non-EU/EEA barcode products, 2016-2020 data). Within each product category and product sub-category, the products' sizes were extracted. However, many products and entire sub-categories did not have any product size information. The sub-categories and size information were sorted into the major product categories according to Cosmetics Europe (i.e. Skin Care, Hair Care, Decorative Cosmetics, Perfumes and Fragrances, as well as Toiletries). The product sizes of products in sub-categories that existed in serval main product categories were treated as belonging to one sub-category (e.g. for Toiletries: sub-category Deodorant existed in both CosmEthics product categories Bath and Body (female) and in Male grooming and was considered as an overall Deodorant sub-category within Cosmetics Europe's Toiletries product category). Product sizes given in mL were assumed to be the corresponding size in g (i.e. assumption 1 mL=1 g) and one oz was treated as 30 mL and then accordingly expressed in grams. For products with size information like 5×1.2 g (i.e. products such as eyeshadow pallets containing e.g. 5 different coloured products of each 1.2 g), the actual value was calculated (i.e. 6 g) and given for this product.

The average of the product size was calculated for each sub-category. For each of the big five Cosmetics Europe product categories, several averages of the product sizes were calculated (Table 7):

a) the average [g] over all single products

b) the average [g] based on the different sub- categories' size averages

c) the average [g] including all products only in the sub-categories in which samples for chemical analysis existed

d) the average [g] based on the different sub-categories' size averages in the sampled sub-categories only.

Table 7: Average product sizes [g] for the different product categories; final average product size for the emission calculations assumed after considering different averages based on product sizes from the CosmEthics database (PFAS INCI containing products 2016-2020 with listed product size information only) and making assumptions on product sub-categories with missing product size data.

Product category	**Final average product size [g] for emission calculations**	average [g] (over all products with sizes)	average [g] (over the different categories' size averages)	average [g] (including all products in the sampled categories only)	average [g] (over the different categories' size averages in the sampled categories only)	number of products (with PFAS INCI) with product size in the CosmEthics database
Decorative Cosmetics	**10**	13.5	8.8	14.0	9.9	673
Hair Care	**200**	189	166	197	171	79
Skin Care	**75**	47.2	76.8	38.6	41.9	181
Perfumes and Fragrances	**75**	152	152	N/A	N/A	1
Toiletries	**200**	167	158	N/A	N/A	21

As the frequency of products with information on product sizes differed greatly within the sub-categories and considering that all sub-categories were not sampled exhaustively, the aforementioned product size averages within the same product group partly varied (Table 7). Therefore, further assumptions were required to determine the final average product size per product group for the emission calculations. For Decorative Cosmetics, an even number of 10 g was chosen as the final product size for the emission calculations as this roughly approximated the averages (Table 7). Furthermore, many products contained fairly small volumes, except for foundations, for which a large number displayed a registered sample size, explaining why the averages based on all single products were higher than 10 (13.5 g, see Table 7). For Hair Care, 200 g was chosen, being close to several of the averages and assuming that large volume products like shampoo, conditioner, hair spray and holding or styling foam or mousse are frequently sold extensively within this product category. For Skin Care, 75 g was chosen as the final product size for the emission calculations (Table 7). In this case, considering the widely varying products sizes among the different sub-categories, an average weight derived from all category averages seemed most appropriate (see 76.8 g in Table 7). Further, even for Skin Care, it was assumed that larger volume products are the most frequent sellers (e.g. body lotions, sunscreens etc.), further supporting an average value of 75 g for this product category. For the last two categories ("Toiletries" and "Perfumes and Fragrances"), the data availability was scarce, or non-existent. For Perfumes and Fragrances, the product size was assumed to be 75 g. A product size was only available for one product within Perfumes and Fragrance, but the volume (152mL) seemed too large considering that many Perfumes and Fragrances come in 30, 50, 60 and 75 mL sizes. For Toiletries, a larger size (200 g) than the averages was assumed, as product sizes for body wash were non-existent (presumably a large product size sub-category and popular selling item). The product size of 200 g for Toiletries is also in accordance with a previous assumption (Hansson et al. 2020).

3.6.3 The share of products containing PFASs

Only the share of the PFAS-containing products within each product category was considered for the emission calculations in order to avoid an overestimation of emitted PFAS amounts. The share of PFAS-containing products within each category was derived from the CosmEthics database (PFAS-containing products in the entire database, including product versions related to total number of products, including product versions; for more information see chapter 3.2.1). The sub-categories from CosmEthics were regrouped into the product categories from Cosmetics Europe, in order to match the products with the sales statistic categories. Sub-categories named "other" within CosmEthics different product categories were removed, as a correct assignment of the products to a specific Cosmetics Europe product category was not possible. The sub-categories "antiseptic", "hand sanitizer" and "wipes" were not clearly mentioned in the nomenclature and categorisation list that was received from Cosmetics Europe and therefore, the products within these sub-categories were removed from the data as well.[5] Further, the total number of products with and without PFASs in the sub-category "Make up remover" (CosmEthics) was each split half into Decorative cosmetics and Skin care. The reason for this is that Cosmetics Europe differentiates CosmEthics' overall "Make up remover" sub-category into the sub-categories "Eye-make up remover" and "Make up remover" and counts them as Decorative cosmetics and Skin care, respectively. Data on "After Shave" (CosmEthics) was treated in the same way and further split into "After shave balms and creams" (Skin care) and "Pre and aftershave lotions" (Perfumes and Fragrances) in Cosmetics Europe's classification. After the rearrangement of the sub-categories into the product categories, the share of PFAS containing products was calculated per product category based on the total number of products including versions, and the total number of products containing PFAS including versions. The PFAS-containing product share did hardly differ (≤0.03 %) when including or excluding all the above-mentioned ambiguous sub-categories. The final PFAS-containing product share included into the emission calculation

[5] Antiseptics and hand sanitizers are not cosmetic products but instead biocidal products. Wipes itself are not cosmetic products either, as the wipe is considered an article. However the substance on the wipe can possibly be a cosmetic product.

was based on the data excluding the ambiguous sub-categories (Table 8). The PFAS containing share of products is highest for Decorative cosmetics (3.67 %) and lowest for Perfumes and Fragrances (0.03 %, Table 8). For more details on the product share with PFASs by categories according to the CosmEthics database consult Table 12 and by sub-categories according to CosmEthics consult Table 31.

Table 8: Share of cosmetic products and product versions that contain PFAS (%) sorted according to the Cosmetics Europe categories for the emission calculations; data based on the total number of products and product versions containing and not containing PFAS from the CosmEthics database (entire database information included, i.e. product and product versions, EU/EEA and non-EU/EEA); Note: the CosmEthics product sub-categories were rearranged into Cosmetics Europe product categories and ambiguous product sub-categories such as "other" were removed.

Product category (Cosmetics Europe)	**Total number of products and product versions**	**Total number of cosmetic products and product versions containing PFAS**	**Share of cosmetic products and product versions containing PFAS (%)**
Decorative cosmetics	29 118	1068	3.67
Hair care	21 938	142	0.65
Perfumes and Fragrances	3637	1	0.03
Skin care	40 103	314	0.78
Toiletries	17 844	49	0.27
Total	112 639	1574	1.40

3.6.4 The fraction of PFASs released from cosmetic products

For the emission estimates, the entire quantity of PFASs in cosmetic products sold within the EEA region (not including Lichtenstein and Iceland) was calculated. Additionally, the quantity of PFASs from cosmetic products that are emitted into wastewater were estimated. The difference between the total amount of PFASs in cosmetics and the amount that is emitted via wastewater was considered to end up in solid waste (i.e. disposal of cosmetic products removal pads/tissues etc. into waste, leftover product amount in the package, disposal after a product's lifetime).

PFAS emissions during the production of cosmetic products are not considered in this report. Furthermore, potential releases of volatile PFASs into the air from the products themselves or the consumers' body surfaces following the product application were not considered. The volatile PFASs were rather considered going into wastewater or solid waste, to avoid introducing a great uncertainty based on several additional unknown parameters for the air emission calculations.

For the PFAS emission estimates into wastewater, the habits of consumers when removing cosmetic products after the application/use were considered, based on summary statistics received from Cosmetics Europe (communication with John Chave, December 2020) originating from a Kantar TNS (2018) report. Kantar TNS carried out a survey commissioned by Cosmetics Europe among 8000 female and male consumers in eight European countries (1000 participants per country). The cosmetic products removal categories involved 1) using water (i.e. "wash-off") or 2) using cotton, pads, wipes and/or the alike, or 3) neither of the first two choices, i.e. "other". Following the cotton/wipes answer, participants could provide an answer on if these were thrown into the municipal trash or disposed into the toilet (or other). For the cosmetic products fraction released into the wastewater, we considered the total percentage of both, the percentage of the wash-off answers and the cotton/pads/wipes that were discarded into the toilet (see column Total release into wastewater, in Table 9). The removal question was asked for different product subcategories or product categories (Table 9).

Table 9: Consumer habits for the removal of different cosmetic products and calculated total release into wastewater; data based on Kantar TNS (2018) commissioned by Cosmetics Europe; calculated release into wastewater considered wash-off and the share of cotton, pads and wipes disposed into the toilet.

Product category	**Product sub-category**	Wash-off (%)	Cotton, pads, wipes (%)	Other (%)	Cotton etc. dispose d into bin (%)	Cotton etc. dispose d into toilet (%)	**Total release into wastewate r (%)**
Decorative Cosmetics	Make-up	24	75*	1	93	5	**27.8**
Decorative Cosmetics	Nail varnish/ remover	15	76	9	95	4	**18.0**
Decorative Cosmetics	Lip stick	29	69	2	94	5	**32.5**
Decorative Cosmetics	Lip balm	52	37	11	93	6	**54.2**
Skin Care	Skin Care	75	20	5	94	4	**75.8**
Skin Care	Sun lotion	86	13	2	93	6	**86.8**
Hair Care	Hair styling	91	6	3	88	8	**91.5**
Toiletries	Deodorant/ antiperspirant	89	8	3	89	8	**89.6**

**Out of the consumers removing their Make up with cotton/wipes/tissues (75 %): 48 % remove their make up with cotton/pads/wipes only and 27 % use both, cotton/pads/wipes and water.*

For the three different emission scenarios, i.e. best-, average- and worst-case, different assumptions were made based on the consumer removal habits (Table 9) for the overall product categories on the total release into wastewater (Table 10). For the average-case scenario, the removal statistics from Kantar TNS (2018) were taken. In cases where removal statistics for several product subcategories within one product category were available, the presumably largest and most relevant subcategory's data were used for the entire product category (compare Table 9 to best-case scenario in Table 10). No removal statistics were available for Perfumes and Fragrances, therefore assumptions were made for the different cases (average-case 90 % release into wastewater, best-case 80 % and worst-case 100 %, Table 10). For the average-case scenario of Decorative cosmetics, all consumers among the ones using cotton, pads and/or wipes (27 % out of 75 %, Table 9), but still washing their face, were counted as purely "wash-off", i.e. assuming 100 % removal with water (therefore release of 53.4 % in Table 10).

For all best-case emissions it was assumed that the average-case emission into wastewater could be lowered by 10 %, i.e. assuming that some of the products are disposed before they are used up and that some fraction of the cosmetic products stays inside the package and is thus disposed into solid waste. For Decorative cosmetics in the best-case scenario, the consumers using cotton, pads or wipes, but still washing their face, were counted into the statistics as purely cotton, pads and wipe users, i.e. assuming 100 % removal with the aid and no removal by water (27.8 % Table 9 and removing 10 % as for all other product categories resulted in 17.8 %, Table 10).

Table 10: Release case scenarios of cosmetic products into the wastewater for emission calculations in the best-, average- and worst-case scenario after cosmetic product use; data are based on Kantar TNS (2018) and assumptions.

Product category	Release scenarios for emission calculations after product use Best-case (%)	Release scenarios for emission calculations after product use Average-case (%)	Release scenarios for emission calculations after product use Worst-case (%)
Decorative Cosmetics	17.8	53.4	100
Skin Care	65.8	75.8	100
Hair Care	81.5	91.5	100
Toiletries	79.6	89.6	100
Perfumes and Fragrances	80.0	90.0	100

For the worst-case scenario, the emission to wastewater was assumed to be 100 % for all product categories, as it seems more likely that a bigger fraction than in the average scenario is still washed off (washing the according body parts, taking a shower/bath or washing cloths), although applying cotton pad etc. that are disposed into waste (Table 10).

4 Results and Discussion

In the following, the results of the cosmetic databases investigation (chapter 4.1, 4.2 and 4.3) and the functions of PFASs (chapter 4.4), as well as general cosmetic products and PFAS specific cosmetic product market trends are presented (chapter 4.5 and 4.6), partly also including information from the cosmetic databases investigation. This is followed by a chapter on substitution of PFASs in cosmetic products (chapter 4.7) and an experience report from the sampling of cosmetic products (chapter 4.8). The analytical results of TF, EOF and the targeted PFAS analysis are presented in chapter 4.9. The results chapter is concluded by the outcome of the emission calculations (chapter 4.10).

4.1 Market share of cosmetic products containing PFASs

The market share of PFAS containing products, i.e. the percentage of total cosmetic products that contain PFAS in the cosmetic databases (CosmEthics, Kemiluppen, ToxFox), ranges between 0.33 and 1.4 % depending on the database (Table 11). The variability in the data may be due to difference in a) the scanned products; b) app-user-groups and product preferences; c) geographical differences; or d) the age of the database (in case of market changes, older databases reflect likely a bigger portion of historical products, although the date of scanning does not reflect the day of purchase or market placement). Another reason for ToxFox having a much lower share of PFAS-containing cosmetic products than the other databases might be that the categorisation of products is done by the person scanning the product, i.e. the app user, which contrasts with the other databases. ToxFox includes a large variety of different product categories, such as electronics, but even hygiene articles and other categories that might be confused with cosmetic products. Additionally, the database contains 442000 products that are uncategorised and according to ToxFox, many of these are cosmetics. Therefore, cosmetic products may be either missed in the database extract, as they were classified as something else or not categorised at all, or mistakenly counted as cosmetic products when they were not. We did not include products of the hygiene articles category, as this category could include products that would not be counted as cosmetic products, such as diapers etc.

Table 11: Total number of cosmetic products and market share of PFAS-containing products in the databases, Note for Kemiluppen: information on current and discontinued products might contain misinformation, Note for CosmEthics: products including unique products and different product versions, division into EU/EEA and non-EU/EEA countries based on the barcodes (i.e. country where the manufacturer is registered).

Database	Total number of cosmetic products	Cosmetic products containing PFAS	Share of cosmetic products containing PFAS (%)
ToxFox	213000	696	0.33
Kemiluppen (entire database)	18518	212	1.1
Kemiluppen (current products)	12932	169	1.3
Kemiluppen (discontinued products)	5554	43	0.77
CosmEthics (entire database)	121246	1658	1.4
CosmEthics (EU/EEA)	78929	838	1.1
CosmEthics (non-EU/EEA)	42317	820	1.9

For the CosmEthics database, the PFAS-containing product share was 1.4 %. Summary statistics based on CosmEthics was even available for the country of registration of the manufacturer based on the barcode information (EU/EEA and non-EU/EEA countries). This revealed a higher share of PFAS containing products for manufactures registered in non-EU/EEA countries (1.9 %) compared to EU/EEA countries only (1.1 %, Table 11). The total share of INCI names in the CosmEthics database that are identified as PFAS(s) is 0.061 % (entire database).

In Kemiluppen, information on current and discontinued products was available. Considering only the current products, i.e. removing products that are discontinued, the share of PFAS containing products is higher than considering the entire registered products in Kemiluppen (1.3 % compared to 1.1 %, Table 11). This is owed to the low share of discontinued products containing PFAS (0.77 %, Table 11). However, this information is only as good as the information that Kemiluppen receives on discontinued products (see 3.2). Nevertheless, the percentage of current products in Kemiluppen that contain PFAS is nearly identical to the percentage of PFAS containing products in the entire CosmEthics database (1.3 and 1.4 %, respectively). Generally, these two databases seem to match well in their overall PFAS-containing product share statistics.

4.2 Occurrence of PFASs in different product categories

The CosmEthics database has about 10 times the product amount compared to the continued products of Kemiluppen, therefore, the entire CosmEthics database (products and product versions, EU/EEA and non-EU/EEA barcode products) was chosen as the information source on the share of PFAS containing products in different product categories.

Make-up contained the highest percentage of products with PFAS INCI names (4.1 %), followed by Facial care products and Male grooming products (each 1.2 %). Baby and children’s products had a share of 0.03 % PFAS containing products and the two main product categories Fragrances and Foot care, had not a single product listing any PFAS INCI that we searched for.

Table 12: PFAS containing products and product versions by product categories and share of PFAS containing products/versions in % (i.e. products with PFAS INCI names on ingredient lists); data in the table sorted by PFAS share from high to low; classification and product categories based on the CosmEthics database, entire database information included (product and product versions, EU/EEA and non-EU/EEA).

Main product category (CosmEthics)	Total number of products and product versions	Total number of cosmetic products and product versions containing PFAS	Share of cosmetic products and product versions containing PFAS (%)
Make up	26 899	1102	4.1
Facial care	23 059	285	1.2
Male grooming	4394	52	1.2
Hair care	22 135	145	0.65
Hands and Nails	7869	26	0.33
Bath and Body Products	25 089	38	0.15
Tanning	2717	7	0.25
Mouth	2081	2	0.09

Baby and Children's Products	2610	1	0.03
Fragrances	3455	0	0
Foot care	931	0	0

After the rearrangement of the sub-categories from CosmEthics into the product categories from Cosmetics Europe, the PFAS containing share of products turned out to be highest for Decorative cosmetics (3.7 %), followed by Skin care, Hair care and Toiletries (0.78, 0.65 and 0.27 %, respectively) and to be lowest for Perfumes and Fragrances (0.03 %, Table 8). These are the final PFAS containing product shares applied in the emission calculations, which were based on the product category definition of Cosmetics Europe.

For more details on the subcategories' PFAS share within each main product category of CosmEthics (Table 12), see Table 31 in the Annex.

4.3 Number and identity of PFASs in cosmetic products

Over the course of the project, 169 different INCI names were generally identified as PFAS(s) potentially occurring in cosmetics in addition to 12 different INCI substances within the CosIng database. For the full list of INCI names see Table 32 and Table 33.

Based on the PFASs/INCI names searched for in the different databases, 45 different PFASs/ INCI names were found in the three databases, out of which three were no INCI names, i.e. not listed in the CosIng database. Trifluoromethyl dechloro ethylprostenolamide, which is a PFAS, but not included in CosIng, occurred in two products in Kemiluppen. A search of CosmEthics revealed the PFASs (but non-INCI names) perfluoropolymethylisopropyl ether were found in six products and perfluoropolymethylisopropylether in one product (note same compound, different notation). These non-INCI names were included in the PFAS search among the products in the Kemiluppen and CosmEthics databases due to the experience of the databases on the existence of these PFASs in products.

A total of 40 different PFASs/INCI names appeared in CosmEthics (counting the two non-INCI name PFASs separately, although they are identical compounds as mentioned above), 26 appeared in Kemiluppen and 12 in ToxFox. The entire list of PFASs found in cosmetic products and the number of products containing the different PFASs can be found for each database in the appendix (Table 34, Table 35 and Table 36). These data should be consulted besides Table 13 when evaluating the importance of different PFASs, because the number of products with certain PFASs/INCI names might partly be more relevant than the actual rank, considering the low number of overall PFAS/INCI name hits, especially among ToxFox in comparison to the other databases. PFASs/INCI names with a lower rank in the bigger databases, might be overall more relevant due a higher number of hits in cosmetic products. However, ranks were the best choice for the evaluation to avoid biasing the use of any one database based on its' size/product amount or the number of hits. Furthermore, it is worth noting that some products occurring in the databases may no longer be present on the market.

The fluoropolymer PTFE was the most frequent PFAS/INCI name in all databases and occurred in more than 500 products in CosmEthics, in more than 300 products in Toxfox and in 64 products in Kemiluppen (i.e. in 33, 46 and 30 % of all products containing PFAS(s) respectively, Table 13 and Table 11). C9-C15 fluoroalcohol phosphate was the third most frequent PFAS/INCI name in each database and overall, comprising all PFASs/INCI names and databases, the second most frequent. These two INCI names were also found to be the most frequent in an earlier investigation (Danish EPA 2018). All remaining PFASs/INCI names varied in their rank and/or their presence/absence in the different databases. Perfluorodecalin (bicyclic fully fluorinated carbon ring; $C_{10}F_{18}$) was the third most frequent PFAS/INCI name considering all databases. Some PFASs that occurred most frequently in both CosmEthics and Kemiluppen, did not occur in ToxFox (Table 13). Some of the less frequent compounds occurring in ToxFox, did not occur in any of the two other databases (Table 13).

Among the top 10 ranked PFASs/INCI names among all databases, only 3 are covered by restrictions. Among the top 20 (Table 13), 5 PFASs/INCI names are covered or about to be covered by restrictions and for one compound it is unclear due to the unknown chemical structure. Considering the top 10 PFASs/INCI names, a substantial share of PFAS-containing products (about 1/5 up to 1/3) in the databases contain PFASs that are or are about to be restricted (for CosmEthics about 550 out of 1658 products, Kemiluppen about 46 out of 212 and Toxfox about 136 out of 696, see Table 11 and Table 13).

Table 13: PFAS INCI names found in cosmetic products in the different databases, shown are only the most frequent found PFASs among all databases and the top ten ranked PFASs within each database (CosmEthics (entire database), Kemiluppen and ToxFox), rank within database (the number of products in which the according PFAS was found), "N/A" equals not found in this database, grey cells represent the top 10 ranked substances of all databases and/or within a database. Note: fractional ranks are applied, therefore e.g. ToxFox's Top 10 has three PFASs/INCI names with a rank value of 11, as their occurrence in the number of products was the same, otherwise they would have received arbitrarily the ranks 10-12.

PFAS INCI names	CAS No	EC/List no	Fluorinated carbons	Covered by any existing or pending PFAS restriction	Rank CosmEthics (number of products)	Rank Kemiluppen (number of products)	Rank ToxFox (number of products)
PTFE	9002-84-0	618-337-2	fluoropolymer	**Unclear*[1]**	1 (541)	1 (64)	1 (321)
C9-15 fluoroalcohol phosphate	223239-92-7	N/A	C9-C15	Existing, included in PFOA restriction in the Stockholm Convention/ POPs Regulation	3 (208)	3 (27)	3 (76)
Perfluorodecalin	306-94-5	206-192-4	C10/fully F	**No**	6 (64)	5 (13)	4 (70)
Perfluorooctyl triethoxysilane	51851-37-7	257-473-3	C6	Existing, included in 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)silanetriol and any of its mono-, di- or tri-O-(alkyl) derivatives	2 (232)	4 (14)	N/A
Perfluorononyl dimethicone	N/A	N/A	C9	Existing, included in PFOA restriction in the Stockholm Convention/ POPs Regulation	4 (111)	11.5 (5)	5 (60)
Polyperfluoromethylisopropyl ether	69991-67-9	615-044-1	C4	**No**	8 (55)	7 (9)	6 (55)
Hydrofluorocarbon 152a	75-37-6	200-866-1	C1	**No**	5 (103)	16.5 (3)	2 (86)
Octafluoropentyl methacrylate	355-93-1	206-596-0	C4	**No**	12 (31)	2 (31)	N/A
Acetyl trifluoromethylphenyl valylglycine	379685-96-8	609-497-4	C1	**No**	7 (63)	7 (9)	N/A
Methyl perfluorobutyl ether	163702-07-6	N/A	C4	**No**	11 (34)	7 (9)	N/A
Polyperfluoroethoxymethoxy difluoroethyl PEG phosphate	N/A	N/A	C1+C2	**No**	9 (47)	11.5 (5)	N/A
Ammonium C6-16 perfluoroalkylethyl phosphate	65530-72-5 / 65530-71-4 / 65530-70-3	685-094-7 / 809-881-3 / 809-882-9	C6-C16	Existing PFOA and C9-C14 PFCAs	14 (25)	10 (6)	N/A

PFAS INCI names	CAS No	EC/List no	Fluorinated carbons	Covered by any existing or pending PFAS restriction	Rank CosmEthics (number of products)	Rank Kemiluppen (number of products)	Rank ToxFox (number of products)
Methyl perfluoroisobutyl ether	163702-08-7	605-340-9	C4	**No**	16 (23)	9 (7)	N/A
Trifluoropropyldimethyl/trimethylsiloxysilicate	N/A	N/A	C1	**No**	10 (42)	23.5 (1)	N/A
Polyperfluoroisopropyl ether	25038-02-2	626-882-2	C3	**No**	21.5 (7)	19 (2)	11 (1)
Trifluoromethyl C1-4 alkyl dimethicone	N/A	N/A	C1	**No**	25 (6)	N/A	8 (7)
PEG-8 trifluoropropyl dimethicone copolymer	N/A	N/A	C1	**No**	30 (3)	N/A	9 (2)
HC yellow no. 13	10442-83-8	443-760-2	C1	**No*2**	N/A	N/A	7 (16)
Polysilicone-7	146632-08-8	N/A	C8	Existing PFOS precursor	N/A	N/A	11 (1)
Polysilicone-10	N/A	N/A	Unclear	**Unclear**	N/A	N/A	11 (1)

**1 Included in the pending microplastics restriction if PTFE is in both particulate and solid form (<5mm particle size). This includes if it is present as a coating around another 'inorganic material'. Liquid particles (colloids) would be excluded.*
**2 Included in the Cosmetics Regulation provisions: Annex III/261.*

For the Kemiluppen data, the list of the most frequent 10 PFASs in this database did not change when removing the discontinued products. The order of the 8th to 10th most frequent PFAS would change slightly. Considering the low number of hits in cosmetic products for these PFASs, the inclusion of discontinued products is suggested to have an insignificant effect on the frequency of detection Table 13).

Comparing the PFASs/INCI names within the CosmEthics database of the EU/EEA-barcoded products with the entire databases' barcoded products (i.e. barcode corresponds to the country where the manufacturer is registered), many PFASs/INCI names exist among the top 20 in both rank-lists (Table 37). In fact, the first three most commonly ranked INCI names are the same, i.e. PTFE, perfluoroctyl triethoxysilane and C9-15 fluoroalcohol phosphate (Table 37). However, there are some differences. Most dominantly, hydrofluorocarbon 152a is ranked fifth common in the entire list, whereas it is on rank 17.5 in the EU/EEA list (Table 37). Similarly, ocotafluoropentyl methacrylate and trifluoropropyl dimetioconol are ranked as 12th and 13th most common in products of the entire database, but do not appear in any of the EU/EEA barcode products. For more details consult Table 37.

PFAS-containing products were investigated for the number of PFASs/INCI names in one product based on one database (Kemiluppen). Most products listed one PFAS/INCI name in the product's ingredient list. Only very few listed two or more. The maximum number of different PFASs/INCI names in one product was five. It is pertinent to note that some INCI names may comprise several PFASs as e.g. C9-15 fluoroalcohol phosphate, which covers 7 different PFASs of different chain lengths. These were counted as one based on the INCI name.

Table 14: Number of INCI names/PFASs in current and discontinued products containing PFAS in the Kemiluppen database, "N/A" equals not found in this database.

Number of PFASs/INCI in a product (according to the ingredient list)	Current products containing PFAS	Discontinued products containing PFAS
1 PFAS	159	42
2 PFASs	7	1
3 PFASs	N/A	N/A
4 PFASs	2	N/A
5 PFASs	1	N/A

A yearly summary of the number and identity of PFASs/INCI names in newly scanned products containing PFASs in the CosmEthics database extract, is also available. However, this data are not presented in the report to avoid misinterpretation. For these data, it is germane to note that the year a product was scanned does not reflect the year the product was placed on the market or purchased, as it could have been sitting at a customers' home for a period of time. This ultimately represents a source of uncertainty. Further, the number and identity of PFAS in products scanned also depends on the total number and type of yearly scanned products, which may vary.

4.4 Functions of PFASs in cosmetic products (CosIng)

The number of identified PFAS INCI names with listed function(s) in cosmetics from the CosIng database can be found in detail in Table 15. Out of 169 INCI names (Table 32), 9 had no information available on the function, or indicated function as "not reported". Of the remaining 160 INCI names, 86 had listed one function, 52 two and 22 had three or more different functions (maximum number of functions five, see Table 15).

In order to receive functional information on the INCI names for which no information was available in CosIng, other sources such as https://cosmeticsinfo.org, https://www.ewg.org/skindeep/, or https://skinsort.com/ could be consulted. However, we refrained from doing so in this report, as the function names in CosIng were standardised keywords and thus easier to present and compare statistically.

Table 15: Overview of number of functions listed in CosIng per PFAS INCI name (in total searched for 169 INCI names that are PFAS or PFASs).

Number of functions per INCI name	INCI name
"Not reported"/No information on function	9
1	86
2	52
3	16
4	4
5	2

The identified functions of INCI names in cosmetic products from the CosIng database can be found in detail in Figure 1. Skin conditioning was the major function with 75 hits, followed by hair conditioning (29 hits), film forming (22 hits), solvent (18 hits), surfactant (cleansing 14, emulsifying 11), viscosity controlling (11) and binding (11).

The functions in cosmetics of the most frequent (i.e. highest ranked, chapter 4.3) PFASs among the three databases are shown in Table 16. Most frequently occurring for these PFASs are the functions, skin conditioning, binding and solvent.

Table 16: Functions in cosmetics (according to CosIng) of the most frequent PFASs in the three cosmetic databases.

PFAS	Function from CosIng
PTFE	Bulking
C9-15 fluoroalcohol phosphate	Skin conditioning
Perfluorodecalin	Detangling Skin conditioning Solvent
Perfluorooctyl triethoxysilane	Binding
Perfluorononyl dimethicone	Skin conditioning
Polyperfluoromethylisopropyl ether	Skin conditioning
Hydrofluorocarbon 152a	Propellant
Octafluoropentyl methacrylate	Binding
Acetyl trifluoromethylphenyl valylglycine	Skin conditioning
Methyl perfluorobutyl ether	Solvent Visocity controlling

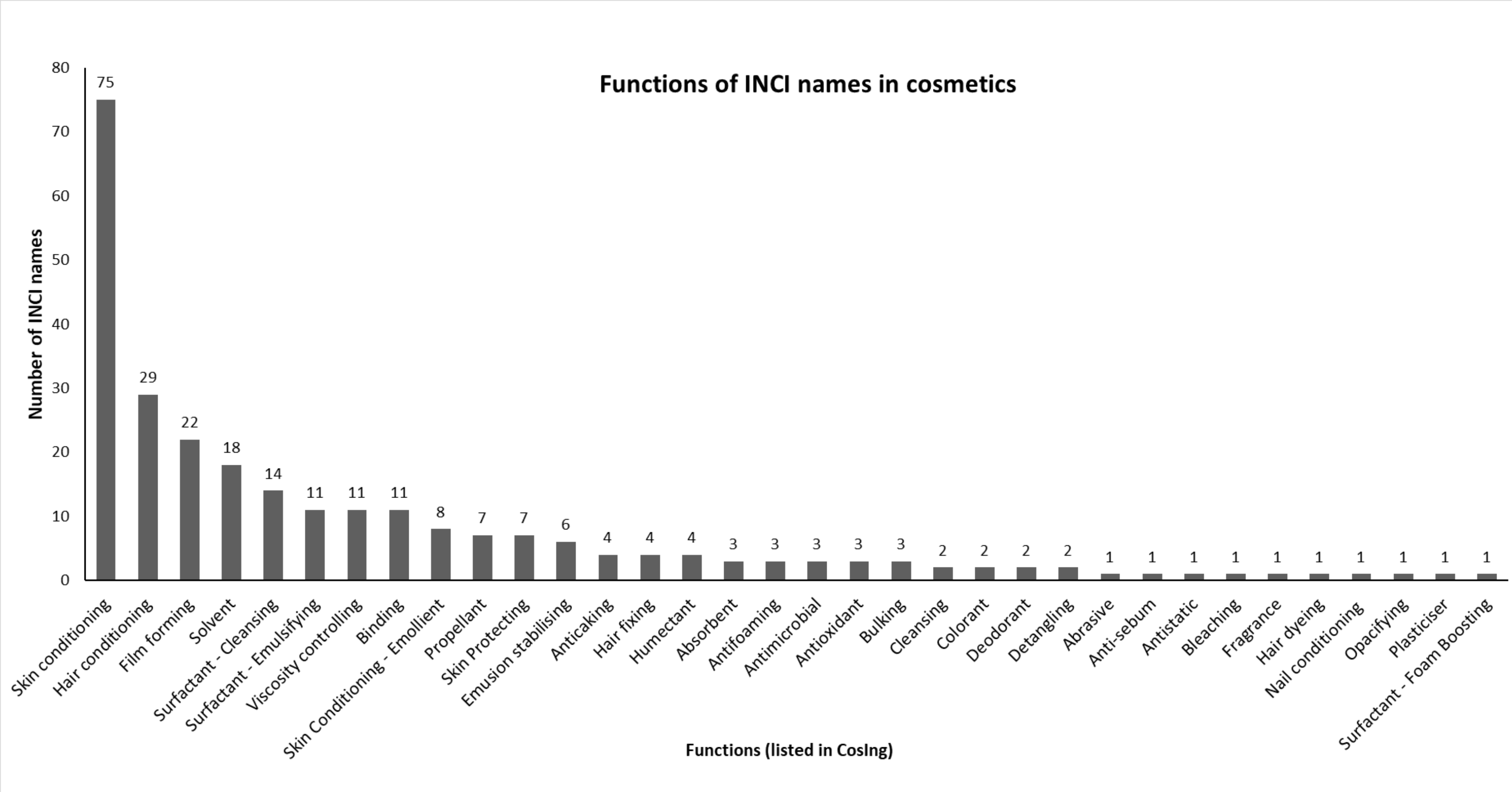

Figure 1: Functions of INCI names in cosmetics, searched for 169 INCI names in total in the CosIng database, for 9 INCI names the function section was empty or "not reported" was given as information, Total function count surpasses 160, as several INCI names have several listed functions.

4.5 General market trends of cosmetic products in Europe

The following section is based on the market performance report from 2019 on European Cosmetic, Toiletry & perfumery data from Cosmetics Europe, the European trade association for the cosmetics and personal care industry (Cosmetics Europe 2020). The European market has with about 80 billion Euro (Retail Sales Price, i.e. including VAT) the biggest industry market share in 2019 compared the other major markets: USA (74 billion Euro), China (55 billion Euro), Japan (33 billion Euro), Brazil (23 billion Euro) India (12 billion Euro) and South Korea (10 billion Euro). The cosmetic product imports from the USA, China, Canada and Japan into European countries amounted in 2019 to 3.8 billion Euro out of the total import volume of 6.5 billion Euro. The total import volume into European countries makes therefore approximately 8 % of the total European markets Retail Sales Price. The socio-economic importance of the cosmetic industry becomes apparent, when considering that in total 1.86 Million people are directly or indirectly employed within the cosmetics industry in Europe.

Among the European countries, the biggest share of the nearly 80 billion Euro Retail Sales Price falls onto Germany (14 billion Euro), followed by France (11 billion Euro), the United Kingdom, Italy and Spain (11, 11 and 7 billion Euro, respectively).

Considering the European cosmetic and toiletry market trend, the annual growth in 2017, 2018 and 2019 was 1.3, 1.1 and 1.4 %, respectively (Retail Sales Prices in billion euro, including VAT and monetary effect £+CHF+NOK/Euro, not inflation-adjusted). However, this increase is lower than the inflation rate in the EU28 (1.7, 1.9 and 1.5 %, respectively, https://ec.europa.eu/eurostat/databrowser/view/tec00118/default/table?lang=en). This might indicate a small decline in retail sales of cosmetics in real terms. Additionally, it has to be mentioned that the RSP and inflation might have changed differently in different countries, so this net-effect has to be taken with caution. The highest per capita consumption in 2019 in Euro (Retail Sales Price) included the Nordic European countries (Norway 232, Sweden 193, Finland 186 and Denmark 175 Euro) and Switzerland (229 Euro). However, considering the market changes from 2018 to 2019 in % (Euro, Retail Sales Price basis), it becomes obvious, that several Eastern European cosmetic markets are on a strong rise (Romania 7.8 %, Bulgaria, Croatia, Hungary, Poland and Latvia all above 5 %) and the increases likely are true increases, as they are clearly exceeding the inflation rates in the respective country (https://ec.europa.eu/eurostat/databrowser/view/tec00118/default/table?lang=en). Further, traditional markets like the United Kingdom (-2.3 %), Switzerland (-1.0 %) and France (-0.6 %) seem to be on a decrease, especially considering the positive inflation rates up to 2.5 % for the UK, but even France with 2.1 % and Switzerland 0.9 %. However, it even has to be mentioned that the price per product in any country might have changed independently from the inflation rate.

Further, the five product categories showed different market changes from 2018 to 2019 (Euro, Retail Sales Price basis): with Skin Care, Hair Care, Toiletries as well as Fragrances on a rise (by 2.3, 1.8, 1.4 as well as 0.5 %, respectively), while Decorative Cosmetics nearly stayed unchanged (-0.1 %). This made for a total market share of 27.1 % Skin Care, 24.8 % Toiletries, 18.7 % Hair Care, 15.4 % Perfumes and Fragrances and 14.0 % Decorative Cosmetics (Euro, Retail Sales Price basis).

The overall market Retail Sales Prices show that there is a need to investigate and regulate chemicals in cosmetic products in general, as the product volume seems to increase, or stay somewhat constant considering the overall inflation rate. The market volume of cosmetic products might even increase overall, as the single product price is likely lower in the Eastern

European countries compared to the countries with decreasing markets. Additionally, the strongly increasing market volumes of cosmetics in several mostly Eastern European countries result in a potential higher human exposure to chemicals from cosmetic products, as well as higher releases of chemicals into the environment in these regions.

4.6 Market trends of PFASs in cosmetic products

An assessment of the products' placement on the market could not be made based on the databases. The reason for this is that the only given date (if given at all) was associated with the scan of product and not the purchase of the product or its release onto the market. The product scan could have happened several years after the product was bought or released.

However, some information on market trends and the discontinuation of products could still be acquired from the cosmetic databases and from SpecialChem, a material selection platform for producers.

4.6.1 Information on discontinuation of PFAS-containing products derived from the cosmetic databases

In total 5554 products are recorded to be discontinued in the Kemiluppen Database, out of which 43 are discontinued products containing PFAS (0.8 % of all discontinued products, Table 17). The discontinued PFAS containing products can be found in the following main product categories: Shaving and hair removal (19 % of the total discontinued products in this category contain PFAS), Facial care (1.3 %), Make-up/cosmetics (1.2 %) Hair care (0.6 %, Table 17).

Table 17: Overview on discontinued products in total, of discontinued products containing PFAS and the share of discontinued products with PFAS based on the Kemiluppen Database information. Note: (sub-)category names directly translated from Danish and based on Kemiluppen's classification.

Main category*1	**Sub-category***2	**Discontinued products**	**Discontinued products with PFAS**	**% products with PFAS within discontinued products**
Facial care (total) *3	N/A	**1184**	**15**	**1.3**
Facial care	BB / CC cream*4	19	4	21
Facial care	Day cream / lotion / gel	273	6	2.2
Facial care	Mask	113	1	0.9
Facial care	Night cream	46	2	4.3
Facial care	Cleaning wipes	60	1	1.7
Facial care	Eye cream / -serum / -gel	38	1	2.6
Shaving and hair removal (total)*3	N/A	**86**	**16**	**19**
Shaving and hair removal	Shaving cream / -gel	50	15	30
	Wax / cream / jelly / oil	11	1	9.1
Hair care (total)*3	N/A	**1136**	**7**	**0.6**
Hair care	Hair cream / -lotion	65	1	1.5

Hair care	Hair lacquer / -spray / heat spray	142	4	2.8
Hair care	Hair mousse	47	1	2.1
Hair care	Shampoo	384	1	0.3
Make-up/cosmetics (total)*[3]	N/A	**401**	**5**	**1.2**
Make-up/cosmetics	Foundation	43	3	7.0
	Eye pencil/ eyeliner	4	1	25
	Eye shadow	61	1	1.6
Total Products*[3]	N/A	**5554**	**43**	**0.8**

*[1]*Only main categories with at least one discontinued PFAS containing product are listed, Main categories excluded are: Baby care, Divers, Body care, Sun care, as well as Soap and hygiene.*
*[2] *Only sub-categories with at least one discontinued PFAS containing product are listed.*
*[3] *The total number of discontinued products per main category even includes the non-listed sub-categories, i.e. the ones without any PFAS containing product, same goes for the total products, the numbers also includes the non-shown main categories, i.e. the ones without any PFASs containing product; see even *[1].*
*[4] *BB cream = synonymous use: Blemish Balm, Beauty Balm or Beauty Benefit (pigmented day cream/foundation/moisturizing/skin care product), CC cream = synonymous use: Colour Correction, Colour Correct, Colour Control (see BB cream, but more covering and often with UV-filters, applied on top of BB-creams or day creams).*

From the CosmEthics database, information was retrieved on if a new product version was found in the database not containing PFAS anymore. 18 Make up products of two brands (2 pressed powders and 16 foundation/BB creams) scanned between 2016 and 2020 were found to be replaced in the database by products no longer containing PFAS. The Make-up category was also among the dominant main categories of discontinued PFAS products within Kemiluppen (Table 17).

However, it must be mentioned that this information requires a) in case of Kemiluppen that information on the discontinuation of a product was received by the producers or their own investigation of certain products and b) in case of CosmEthics that the product with the previous and subsequent formulations are both part of the database and have different barcodes; (if the barcode is different for the newly formulated product, it will show up as a new product). Therefore, the data on discontinuation or version replacement cannot be taken as an overall market representation.

4.6.2 Commercial availability of technical products with PFASs for cosmetic producers (SpecialChem)

The commercial availability of technical products as cosmetics ingredients with PFASs was investigated based on the material selection platform for producers (SpecialChem). In total 168 INCI names were searched for, out of which 36 were at least in one technical product in the database (Table 18). A total of 132 technical products was found with a PFAS INCI name, out of which 117 carried the availability status “commercial” (Table 18). For the other products the status information was missing, or the “availability [was] not confirmed” (12 technical products), or the products was “discontinued” (in three cases, Table 18). In total, 27 different suppliers were found providing PFAS containing technical products for cosmetic producers according to the platform (Table 18). The most frequent INCI in the technical products was PTFE with a presence in 24 technical products.

It must be noted that the database does not necessarily reflect the current technical product supply, as the platform requests users to report missing products/suppliers, any errors and updates on the product status. However, this platform was deemed the best source for obtaining any information on the commercial availability of technical products with PFAS for cosmetic products.

Table 18: Technical products as cosmetics ingredients with PFAS in the SpecialChem material selection platform for producers; search results given based on PFAS INCI name search.

Parameter	Frequency in SpecialChem, cosmetic ingredients (absolute number)
INCI names searched for	168
INCI names found in database	36
INCI names not found in database	132
Products with status "commercial"	117
Products without given status, or status "availability not confirmed"	12
Products with status "discontinued"	3
Total number of technical products	132
Total number of suppliers	27

4.7 Substitution of PFASs in cosmetic products and non-fluorinated alternatives

There is a general trend within the fluorochemical industry towards replacing long-chain PFASs with shorter-chain PFASs (i.e. mostly moving from C8 to C6 PFASs) (Buck et al. 2011). Long-chain PFCAs are defined as having 7 and more perfluorinated carbons (i.e. PFOA and longer chain PFCAs) and long-chain PFSAs as having 6 and more perfluorinated carbons (i.e. PFHxS and longer-chain PFSAs) (Buck et al. 2011). This change in manufacturing practice began around 2000-2002, when the 3M company initiated a voluntary phase-out of the production and application of PFOS and PFOS-related chemistries (US EPA 2000) and continued to an even greater extent due to the global PFOA Stewardship Program towards the elimination of PFOA, its precursors and longer chain PFCAs (US EPA 2006). This trend even was accompanied by a geographical shift in the production of PFAS. Especially for long-chain PFASs, production shifted from Western Europe, Japan and North America to China, India, Poland and Russia, including long-chain PFAAs, but especially in China, even perfluorinated ether acids (Wang et al. 2014, Wang et al. 2015).

A potential trend from long- to short-chain length of detected PFCAs in cosmetic products could even be seen comparing the current study’s data to previously, i.e. older reported data in cosmetic products by Fujii et al. (2013), Schultes et al. (2018). Only one product contained measurable long-chain PFCAs in the current investigation, whereas several to almost all samples contained these in the previous studies, although already less though in the more recent Schultes et al. (2018) study (see more detailed discussion in chapter 4.9.3). Nonetheless, the replacement of long-chain by short-chain PFASs cannot be considered a real substitution, because both are still PFASs.

A substitution is usually made based on choosing a new compound that can replace a specific function of the previous compound in the product. However, for PFASs in cosmetic products, the kind of PFASs (see section 4.3) and functions seem so manifold and diverse (see section 4.4) that making general claims seems harder in the cosmetic than for instance in the textile sector. In the textile sector, the functionality of PFASs can be basically broken down to water and stain repellence. To our knowledge there is hardly any information publicly available on non-fluorinated alternatives used as replacing compounds in cosmetics.

The POPFREE stage two project could identify potential non-fluorinated alternatives for PFASs based on their investigated cases and for at least two types of cosmetic product types: in pressed powders (PTFE) the fluorine-free alternatives are synthetic waxes (e.g. magnesium stearate or sodium myristate), for lip pencils (perfluorononyl dimethicone) silicones and fats (RISE 2020). For powders, the fluorinated-free alternatives had to be used in higher amounts in the product than the PFAS (alternatives few percent, PFAS <1 % (RISE 2020, page 17-18 for cosmetics). POPFREE stated that in both product type cases, non-fluorinated alternatives with the same functional product claims were already commonly produced. Further, PTFE is apparently also found as filling or carrier substance in cosmetic products.

The entire following section on PFAS phase out by cosmetic brands/companies is based on the experiences of the Swedish Society for Nature Conservation (SSNC) that was willing to share these during personal communication (Kristina Volkova Hellström, February 2021) for the report. Official PFAS phase-out statements by cosmetic companies/brands are rare, and not usually publicised, if made at all. However, companies/brands that claim to have already no PFASs in their products are a bit more proactive in their communication. Information on an ongoing or planned PFAS phase-out is mostly received by personal communication or email. The other source of information on PFAS phase outs is due to specific customer requests via online forms or emails that thereafter were made publicly available by SSNC. Taking these sources into account, in total 57 different brands of nine different companies were found to have declared their PFAS phase out in cosmetic products so far. This information originates from Surfejs, a youth project of the SSNC, that started an Instagram campaign in 2017 to eliminate the use of PFASs in cosmetic products. Out of the 57 brands, 54 are global players. A full list of the brands and companies can be found on https://www.surfejs.se/varstingjakten/ (latest access 5th of September 2021). However, the seemingly impressive number of brands that in some way stated a PFAS phase-out must be seen with some precaution. All brands included into SSNC's list promised a full PFAS phase-out. The kind of products included into the PFAS phase-out statements varies greatly from only the new products and not changing the formulation of the existing/old PFAS containing products, to reformulating even existing/old products that contain PFAS. Some brands did not comment on the kind of products that are supposed to become PFAS-free, some not on their plans on how to deal with existing or already produced PFAS containing products. Most brands were precautious and refrained from giving a definite time point for the full replacement of all PFAS containing products. Brands with a timeline had delays. Among the resellers and authorised dealers that claimed to stop selling PFAS containing products, some refrained from their promises in the after hand. Noteworthy, some brands that SSNC was in contact with went through a process of firstly promising to phase out restricted or forbidden PFASs only (required by law anyways), moving on to wider PFAS definitions (e.g. such as shared by the Swedish Cosmetics, Toiletries and Detergents Association (KoHF, https://www.kohf.se/om-kohf/kohf-in-english), until finally deciding on a full PFAS phase-out.

Nevertheless, the PFAS phase out declaration of companies/brands might indicate that at least some likely have already actively found new formulations without PFASs that still work for the functionality of their products (see also the cosmetic producer interview in section 4.7.1

below). The interviewed producer for this report clearly said that PFASs have no unique functions in products and that PFAS-free products can be produced. Although, in order to make existing products with PFAS(s) non-fluorinated might require a completely new formulation of the product, as direct substitution of PFAS(s) by one or several compound(s) might only work in specific cases.

The experience from the partly targeted cosmetic product sampling based on the cosmetic databases information showed that several supposedly PFAS containing products did not list any PFAS as an ingredient. A substitution of PFAS or reformulation of the product has obviously happened in these cases. Additionally, we noticed at least for these products that companies did not change the product name after reformulation.

In summary, all the above, but especially the fact that there are far more non-fluorinated cosmetic products within the same product categories as the PFAS containing products, suggests that PFASs can be replaced by other ingredients and do not have unique functions. To this conclusion comes also the POPFREE stage two project (https://www.ri.se/en/popfree/about-popfree/project-results/popfree-stage-two, latest access 22/02/2021) and it was confirmed by the cosmetic producer during the interview (section 4.7.1).

4.7.1 Experiences of the PFAS phase-out by a cosmetic producer

In October 2020, a cosmetic producer was interviewed for this report, to get insights on the experience and challenges of the cosmetic industry with PFASs in their products. The following text summarises the interview.

The cosmetic producer had a self-imposed PFAS prohibition on all their products. However, in 2016, the company was contacted by an NGO, which made them aware of PFASs on the ingredient lists of some of their cosmetic products. Thereafter, the company initiated a larger investigation in collaboration with a governmental agency to identify potential PFASs in cosmetic products, which resulted in a list of about 100 INCI names. The list was directly used as a prohibited ingredient list for the development of new cosmetic products. A further investigation into the occurrence of the PFAS INCI names in former and current products was undertaken, revealing that two product types (different cosmetic pens and eye shadows, in various colours) contained two PFASs (perfluorononyl dimethicone and PTFE). Thereafter, the company’s suppliers were contacted and instructed to remove the PFASs from the products’ formulations.

For the cosmetic pens, no direct substitution could be made without changing the entire formulation because the function of PFAS in these products was (according to the supplier) unique to the products’ composition. Therefore, the entire formulation required modification, which was ultimately successful, albeit both resource and time consuming.

The supplier of the eye shadows knew that the products contained PTFE. However, 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. According to the supplier, PTFE was exchanged with magnesium myristate (although probably not only as a functional replacement, this last part as a comment from the cosmetic producer itself). When asked if PFASs fulfil unique functions in cosmetic products, the producer replied that they do not.

The cosmetic producer also compiled a blacklist of INCI names for which PFASs are used as starting material or during the production process (examples are polyurethane, polysiloxanes and polyacrylates). With this list, the producer wants to avoid the occurrence of PFASs as potential impurities. This work was described as a big challenge, because tracking raw materials is often hindered by the producers' confidential information policies, which lead to non-transparency along the production chain. The cosmetic producer said 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.

4.8 Experiences from the sampling of cosmetic products

During targeted sampling for products with PFAS based on the cosmetic databases' information it became obvious that some products did not list any PFASs anymore on the ingredient lists. The product names did not change in these cases.

Further, there were several issues when trying to receive information on the ingredients of cosmetic products while sampling. Firstly, the cosmetic ingredients on the products themselves are often in small or unusual prints that are difficult to read. Secondly, many products have covered ingredient lists, which the customer can expose by peeling off the top layer of the label on a designated (mostly) marked small edge on the top label. This is, however, highly difficult depending on how the different label layers are stuck together or to the product packaging. Thirdly, several products are sealed by plastic covers to prevent customers from opening the products in the shops for obvious hygiene-keeping reasons. These seals cover sometimes though the ingredient list or the edge where the customer is supposed to peel off the top label in order to access the ingredient list. Fourthly, alarm labels for theft prevention or price tags are stuck on top of the ingredient lists or disable the customer from peeling off the top label to uncover the ingredient lists. Finally, for some cosmetic brands and in some shops, only test products are showcased for in-shop trial by the customers. On some of these test products, no ingredient information is available. The customers have to ask salespersons for the actual product for this information, as the ingredient list is only printed on the packaging of the product for purchase.

All the above identified problems make checking the ingredients of cosmetic products and comparing products for a conscious purchase decision in physical shops extremely difficult. The compliance with Chapter VI Consumer information, Article 19 “Labelling” of the Cosmetics Regulation (European Parliament and Council of the European Union 2009) seems at least partly questionable.

Online shopping for cosmetics revealed other difficulties. After checking four online shops it was decided against online purchases for the sampling (except for one sample) due to the following reasons: Ingredient lists are not given for all brands or products (which even seemed partly random when comparing different shops for the same products) and the webpages claimed often below given ingredient lists that the ingredients might not be matching the delivered product's ingredients and asked the customer to consult the ingredient list on the product after delivery. By communication with the Swedish Society for Nature Conservation (Kristina Volkova Hellström, August 2020), the information was received that the Swedish Medical Products Agency (responsible authority for cosmetics) claimed that only actual shops are legally bound to the ingredient labelling or provision of this information. Online shops are not bound to but recommended to provide this information. This might be a valid future addition into existing regulations.

4.9 Analytical quantification of total fluorine, extractable organic fluorine and PFASs in the cosmetic product samples

In the following subchapters the concentrations of the cosmetic product analyses are presented for the different methods, i.e. TF, EOF and targeted PFAS analysis.[6] The reanalysed sample from the previous Schultes et al. (2018) study showed reasonable consistency (Figure 4); for more detail see chapter 3.5.4. Total fluorine (TF) in cosmetic products

The TF concentrations in sampled cosmetic products that included PFASs in their ingredients list ranged from below the limit of detection (<LOD) up to 13.8 mg F/g sample (Exfoliator) (Figure 2, Table 19). Two products, i.e. one hair spray and one mask with listed PFAS(s), contained TF levels <LOD, meaning that the total fluorine concentration was too low to be detected with this method. All sampled Decorative Cosmetic products contained TF concentrations above the LOD. The two highest double-digit TF concentrations were measured among Skin Care products, i.e. 13.8 mg F/g in Exfoliator and 10.6 mg F/g in Mask 2 (Table 19, Figure 2). The two products with the highest concentrations listed several INCI names belonging to PFASs. However, the number of PFASs listed on the ingredients list cannot be taken as an indication for the TF concentrations, as there were three other products (Concealer 2, Anti-age cream 2 and Mask 1) listing two or three INCI names that resulted in comparably low concentrations (Table 19). Among those samples was even the mask with TF concentrations <LOD.

All product categories displayed considerable variability in TF concentrations. TF concentrations in Skin Care products were the most variable among the analysed samples (<LOD up to 13.8 mg F/g), followed by Decorative Cosmetics (0.02 up to 6.01 mg F/g) and Hair Care (<LOD up to 0.05 mg F/g) (Figure 2, Table 19). Considerable variability was also observed within sub-categories, e.g. Blusher/Bronzer/Contour 0.90-5.14 mg F/g, Foundation/BB Cream 0.02-3.31 mg F/g, Anti-Age Cream 0.08-3.80 mg F/g, Mask <LOD-10.6 mg F/g (Figure 2, Table 19). Generally, the measured TF range of the cosmetic products compared well to a previous study on cosmetic products by Schultes et al. (2018) (TF range <LOD up to 19.2 mg F/g).

Two out of eight products with restricted or pending-to-be-restricted PFASs contained comparably high TF levels (>1 mg F/g). Both products were among the sub-category Foundation/BB Creams.

Out of the two purchased blank samples, i.e. cosmetic products not listing any PFAS as an ingredient, one contained total fluorine at a level above the limit of detection (0.02 mg F/g vs. a LOD of 0.007 mg F/g sample). This supposedly PFAS-free Decorative cosmetics sample, Eye liner pen 1 (Table 19), likely contained fluorine from the listed mica on the ingredient list (or any other source of inorganic fluorine, i.e. not necessary PFAS). Mica treated with PAPs (e.g. polyfluoroalkyl silylated mica) has also been reported to exist in cosmetic products (Fujii et al. 2013), although the ingredient list of the current product just stated “mica”. The other blank sample (Hair Care, Treatment 2) with TF levels <LOD did not contain any mica. Generally, the TF signals or a fraction of the signals in products could also originate from any PFAS as an impurity or contamination. It cannot be ruled out that contamination with PFAS may occur during manufacturing, for example if products containing PFASs are manufactured in a previous production batch with the same equipment. In this case, production residuals

[6] Presented quantities F/year for the TF and EOF analysis can be converted to PFAS/year by using a factor of 1.4-2.0.

from previous products might remain on the equipment and contaminate the following supposedly PFAS-free product batch.

Table 19: Total fluorine (TF) measurement results (mg F/g sample) of different products within the product categories Decorative Cosmetics, Hair Care and Skin Care and PFAS INCI names from the products' ingredient lists; Unique sample names given based on Sub-category and identity (ID) number; PFAS INCI names in bold are under existing or pending PFAS restriction; each letter in parenthesis behind the INCI name corresponds to the chemical structure in Figure 2; LOD = limit of detection, SD = Standard deviation, given if sample was measured n = 3 times, N.a. = not analysed, i.e. sample measured once and not in triplicates, the measured result is given in the average column.

Sub category (ID)	Average TF (mg F/g)	LOD (mg F/g)	SD (mg F/g)	PFAS INCI (letter corresponds to the chemical structure in Figure 2)
Blush/Bronzer/Contour 1	5.14	0.022	N.a.	**PTFE*3**
Blush/Bronzer/Contour 2	3.26	0.012	0.17	**PTFE*3**
Blush/Bronzer/Contour 3	0.90	0.310	N.a.	POLYPERFLUOROMETHYLISOPROPYL ETHER (B)
Blush/Bronzer/Contour 4	2.49	0.014	N.a.	**PTFE*3**
Concealer 1*	0.80	0.002	N.a.	**PERFLUOROOCTYL TRIETHOXYSILANE (I)**
Concealer 2*	0.03	0.016	N.a.	PERFLUORODECALIN (E), PERFLUOROHEXANE (C), PERFLUOROMETHYLCYCLOPENTANE (M)
Eye liner, pen 2*	0.17	0.004	N.a.	**PERFLUORONONYL DIMETHICONE (G)**
Eye shadow 1	2.21	0.021	N.a.	**PTFE*3**
Eye shadow 2	5.35	0.028	N.a.	**PTFE*3**
Eye shadow 3	0.72	0.020	N.a.	**PTFE*3**
Eye shadow 4	0.99	0.011	N.a.	**PTFE*3**
Eye shadow 5*	1.90	0.015	1.05	POLYPERFLUOROMETHYLISOPROPYL ETHER (B)
Eyeliner liquid/gel	0.35	0.028	N.a.	POLYPERFLUOROMETHYLISOPROPYL ETHER (B)
Foundation/BB Cream 1	0.02	0.001	N.a.	**PERFLUOROOCTYL TRIETHOXYSILANE (I)**
Foundation/BB Cream 2	0.18	0.002	N.a.	TRIFLUOROPROPYL DIMETHICONOL (Q)
Foundation/BB Cream 3*	1.41	0.042	N.a.	**C9-15 FLUOROALCOHOL PHOSPHATE (Y)**
Foundation/BB Cream 4*	3.31	1.310	N.a.	**AMMONIUM C6-16 PERFLUOROALKYLETHYL PHOSPHATE (T)**
Lip liner, pen 1*	0.52	0.010	N.a.	**PERFLUORONONYL DIMETHICONE (G)**
Lip liner, pen 2	0.94	0.004	N.a.	**POLYETHYLENE PERFLUORONONYL DIMETHICONE (V)**
Loose powder	6.01	0.028	N.a.	POLYPERFLUOROMETHYLISOPROPYL ETHER (B)
Mascara	3.54	0.063	N.a.	**PTFE*3**
Pressed Powder 1	0.23	0.012	0.13	POLYPERFLUOROMETHYLISOPROPYL ETHER (B)
Pressed Powder 2*	0.02	0.007	N.a.	POLYPERFLUOROETHOXYMETHOXY DIFLUOROETHYL PEG PHOSPHATE (Z)
Hair spray 1	0.01	0.000 3	N.a.	OCTAFLUOROPENTYL METHACRYLATE (OFPMA) (F)
Hair spray 2	<LOD	0.001	N.a.	HYDROFLUOROCARBON 152a (S)
Shampoo*	0.50	0.231	N.a.	OCTAFLUOROPENTYL METHACRYLATE (OFPMA) (F)

Styling cream*	0.20	0.011	N.a.	**C4-18 PERFLUOROALKYLETHYL THIOHYDROXYPROPYLTRIMONIUM CHLORIDE (R)**
Hair care, Treatment 1	0.03	0.012	N.a.	OCTAFLUOROPENTYL METHACRYLATE (OFPMA) (F)
After shave*	3.67	0.007	N.a.	POLYPERFLUOROMETHYLISOPROPYL ETHER (B)
Anti-age cream 1	0.08	0.019	0.02	ACETYL TRIFLUOROMETHYLPHENYL VALYLGLYCINE (D)
Anti-age cream 2*	0.18	0.014	N.a.	PERFLUOROHEXANE (C), PERFLUOROPERHYDROPHENANTHRENE (L), PERFLUORODECALIN (E)
Anti-age cream 3	3.80	0.023	N.a.	POLYPERFLUOROMETHYLISOPROPYL ETHER (B)
Exfoliator*	13.8	0.715	2.66	PERFLUOROHEXANE (C), PERFLUORODECALIN (E), PERFLUOROMETHYLCYCLOPENTANE (M)
Eye moisturiser 1	4.24	0.022	0.19	**PTFE*[3]**
Eye moisturiser 2	0.01	0.002	N.a.	TRIFLUOROACETYL TRIPEPTIDE-2 (H)
Facial moisturiser	2.58	0.006	N.a.	POLYPERFLUOROMETHYLISOPROPYL ETHER (B)
Mask 1*	<LOD	0.035	N.a.	ETHYL PERFLUOROBUTYL ETHER (J), ETHYL PERFLUOROISOBUTYL ETHER (N)
Mask 2*	10.6	0.042	0.90	METHYL PERFLUOROBUTYL ETHER (O), METHYL PERFLUOROISOBUTYL ETHER (K), PERFLUOROHEXANE (C), PERFLUOROPERHYDROPHENANTHRENE (L), PERFLUORODECALIN (E), PERFLUORODIMETHYLCYCLOHEXANE (P),
Mask 3	0.60	0.038	N/A	METHYL PERFLUOROISOBUTYL ETHER (K)
Moisturiser/Face cream 1	0.05	0.034	N.a.	ACETYL TRIFLUOROMETHYLPHENYL VALYLGLYCINE (D)
Moisturiser/Face cream 2	3.47	0.074	0.26	POLYPERFLUOROMETHYLISOPROPYL ETHER (B)
Serum and treatment 1	0.07	0.001	0.03	TRIFLUOROACETYL TRIPEPTIDE-2 (H)
Serum and treatment 2	0.10	0.013	N.a.	ACETYL TRIFLUOROMETHYLPHENYL VALYLGLYCINE (D)
Eye liner, pen 1 (Blank samples*[2])	0.02	0.007	0.02	N/A
Hair Care, Treatment 2 (Blank samples*[2])	<LOD	0.033	N.a.	N/A

*[1] *Samples chosen for further targeted PFAS analysis.*
*[2] *No PFAS listed as ingredient.*
**3 PTFE will be covered by the pending microplastics restriction if it is in both particulate and solid form (<5mm particle size). This includes if it is present as a coating around another 'inorganic material'. Liquid particles (colloids) would be excluded.*

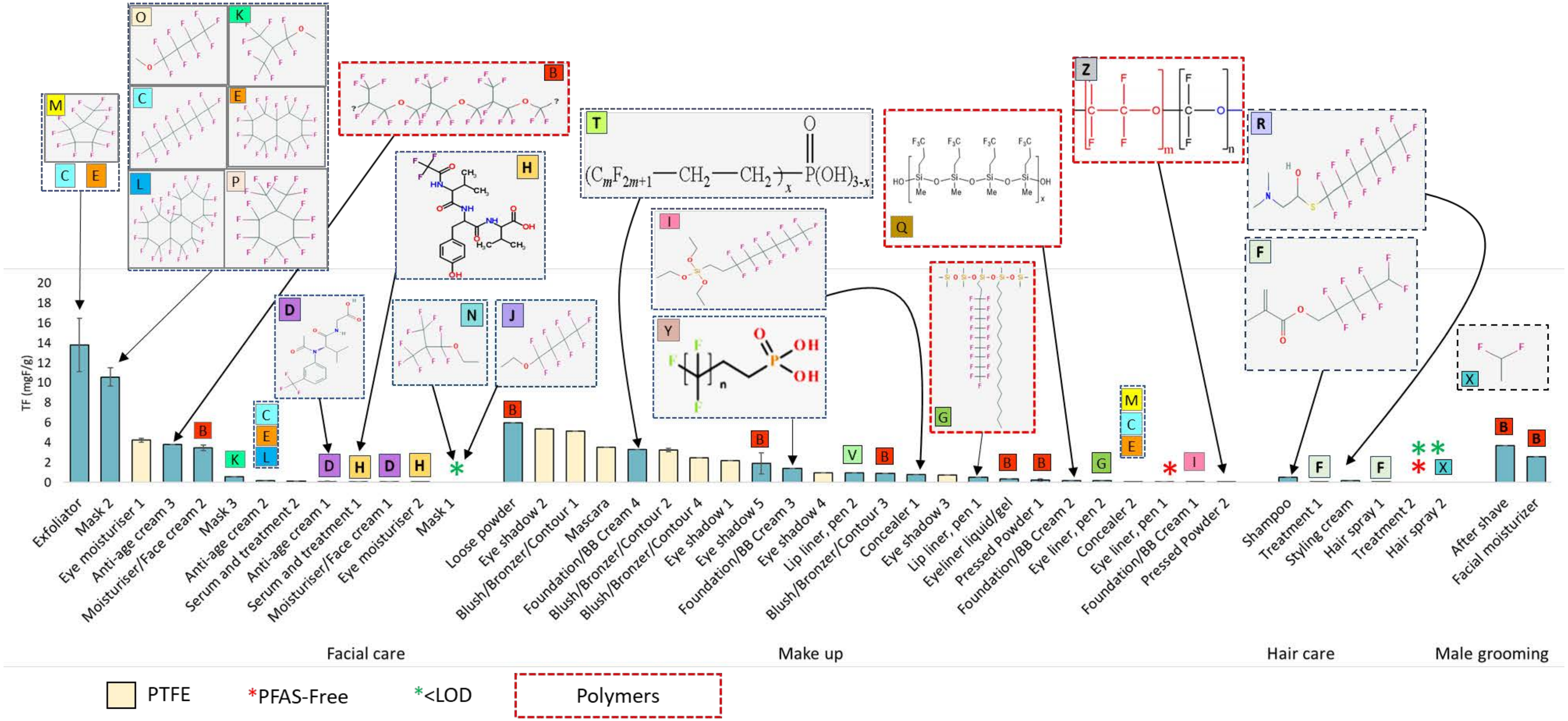

Figure 2: Analysis results of the total fluorine (TF) measurement (mg F/g product) for different cosmetic products and the chemical structures of the INCI names on the ingredient lists of the products; 2-D Structures of PFASs from PubChem; classification into product categories according to CosmEthics; for Cosmetics Europe classification: Facial care = Skin care; Make up = Decorative cosmetics; Hair care = Hair care; Male grooming= these product would also fall under Skin care; PFAS-Free products had no PFAS declared on their ingredient list; <LOD = TF below the limit of detection; Blue= any PFAS; Same letters indicate same PFASs/INCI names, for the corresponding PFAS/INCI names consult Table 19.

4.9.1 Extractable organic fluorine (EOF) in the cosmetic product samples

Extractable organic fluorine (EOF) concentrations ranged from <LOD (<162 ng F/g for Exfoliator, <325 ng F/g for Concealer 2 and Eyeshadow 5) up to 4.93 mg F/g for Foundation/BB Cream 4 (Table 20). The second highest concentration of EOF was detected in another Foundation/BB Cream (3) with 1.58 mg F/g. Both Foundation/BB Cream samples contained PAPs of different chain lengths on the ingredient lists that fall under current or pending restrictions (Table 20).

Table 20: Extractable organic fluorine (EOF) measurement results (ng F/g sample) of different products within the product categories Decorative Cosmetics, Hair Care and Skin Care and PFAS INCI names from the products' ingredient lists; Unique sample names given based on sub-category and identity (ID) number; PFAS INCI names in bold are under existing or pending PFAS restriction; LOD=limit of detection; Exfoliator (<LOD, therefore standard deviation, SD, could not be calculated) and Mask 2 (SD=12200 ng F/g); Values are rounded to three significant figures.

Sample name (Sub-category (ID))	Average EOF (ng F/g)	LOD (ng F/g)	INCI name/PFAS ingredient
Concealer 1	3910	325	**PERFLUOROOCTYL TRIETHOXYSILANE**
Concealer 2	<LOD	325	PERFLUORODECALIN, PERFLUOROHEXANE, PERFLUOROMETHYLCYCLOPENTANE
Eye liner, pen 2	11 400	325	**PERFLUORONONYL DIMETHICONE**
Eye shadow 5	<LOD	325	POLYPERFLUOROMETHYLISOPROPYL ETHER
Foundation/BB Cream 3	1 580 000	325	**C9-15 FLUOROALCOHOL PHOSPHATE**
Foundation/BB Cream 4	4 930 000	325	**AMMONIUM C6-16 PERFLUOROALKYLETHYL PHOSPHATE**
Lip liner, pen 1	9420	325	**PERFLUORONONYL DIMETHICONE**
Pressed Powder 2	18 900	325	POLYPERFLUOROETHOXYMETHOXY DIFLUOROETHYL PEG PHOSPHATE
Shampoo	14 700	325	OCTAFLUOROPENTYL METHACRYLATE (OFPMA)
Styling cream	190 000	325	**C4-18 PERFLUOROALKYLETHYL THIOHYDROXYPROPYLTRIMONIUM CHLORIDE**
After shave	374	325	POLYPERFLUOROMETHYLISOPROPYL ETHER
Anti-age cream 2	1260	325	PERFLUOROHEXANE, PERFLUOROPERHYDROPHENANTHRENE, PERFLUORODECALIN
Exfoliator	<LOD	162	PERFLUOROHEXANE, PERFLUORODECALIN, PERFLUOROMETHYLCYCLOPENTANE
Mask 1	2700	325	ETHYL PERFLUOROBUTYL ETHER, ETHYL PERFLUOROISOBUTYL ETHER
Mask 2	36 600	162	METHYL PERFLUOROBUTYL ETHER, METHYL PERFLUOROISOBUTYL ETHER, PERFLUOROHEXANE, PERFLUOROPERHYDROPHENANTHRENE, PERFLUORODECALIN, PERFLUORODIMETHYLCYCLOHEXANE

The EOF values vary within each product category and among the products within the same sub-category. The chosen Skin Care samples seemingly have lower EOF concentrations than Hair Care and Decorative Cosmetic products, which might not be true in general due to the small sample size (Table 20). In general, the measured EOF range of the cosmetic products compared well to a previous study on cosmetic products by Schultes et al. (2018) (EOF range <LOD up to 1.72 mg F/g); one products in the current study was above the previous range (4.93 mg F/g, Foundation/BB Cream 4).

4.9.2 PFASs in the cosmetic product samples

Out of the 15 analysed cosmetic products with PFAS listed as ingredients, only seven contained target PFASs from the targeted substance list above the LOD (Table 21). The detected compounds were all PFCAs and PAPs. None of the PFSAs from the target list were detected in concentrations above the LOD (Table 38), which is in accordance with previous studies (Danish EPA 2018, Schultes et al. 2018). The most frequent detected PFCA was PFBA (3 fully fluorinated carbons) in seven of the products, followed by PFHxA in three of the products and PFHpA in two of the products (Table 21 and Table 38). PFPeA, PFOA, PFNA, PFDA, PFDoDA and PFTeDA were each detected in one sample (PFPeA in Foundation/BB Cream 4, the other PFCAs in Foundation/BB Cream 3, Table 21). PFOA was measured in one sample and occurred at concentrations above the EU limit of 25 ng/g (112 ng/g in Foundation/BB Cream 3, Table 21) (ECHA 2017).

Sum PFCA (∑PFCAs) concentrations ranged from <LOD to 9560 ng/g (Mask 2, Table 21, Figure 3). The second highest ∑PFCA concentration (425 ng/g) was observed in another mask (Mask 1, Table 21). In both samples, the ∑PFCA concentration was attributable to exclusively PFBA (Figure 3, Table 21, Table 38). The three samples with contribution from several PFCAs had ∑PFCAs concentrations between 77.4 and 341 ng/g (Concealer 1 and Foundation/BB Cream 3, Table 21, Figure 3).

The two products containing PAPs as listed ingredients (Foundation/BB Cream 3 and 4) were the only products where PAPs were detectable by targeted analysis, with maximum concentrations up to 2.3 mg/g for 6:2/6:2 diPAP, 0.67 mg/g 8:2/8:2 diPAP and 0.15 mg/g 6:2/8:2 diPAP (Table 21). Both products therefore exceeded the limit of 1000 ng/g for PFOA-related substances (i.e. 6:2/8:2 and 8:2/8:2 PAP, Table 21) (ECHA 2017). These PAP concentrations exceeded any other PFAS concentration by several orders of magnitude in some cases. This demonstrates that when the listed ingredients are included in PFAS target lists, far higher ∑PFAS concentrations are obtained, compared to only including impurities (e.g. PFCAs). This underlines the need for more analytical standards in order to quantify a greater number of PFASs which are intentionally added to products.

For completeness, ∑PAP and ∑PFAS concentrations are provided in Table 21 as well (see even Figure 5 for ∑PFASs). However, these sums should not be considered much further and should be treated very cautiously. The ∑PFCA concentrations reflect unintended ingredients/impurities (i.e. not on the ingredient list), whereas the ∑PAP concentrations reflect intentionally added ingredients. The ∑PAP concentrations reported here are based on three PAPs (6:2/6:2-, 6:2/8:2-, 8:2/8:2 diPAP) and are therefore likely to underestimate the true ∑PAP concentrations in these products, since a much wider range of PAP chain lengths are indicated on the ingredients lists for these products (i.e. C9-15 fluoroalcohol phosphate for Foundation/BB Cream 3 and Ammonium C6-16 Perfluoroalkylethyl phosphate for Foundation/BB Cream 4). Considering the uncertainties associated with ∑PAP concentrations, and the fact that no other listed PFAS ingredients were included in our targeted analysis, target PFAS concentrations were not considered for emission estimates.

Table 21: Targeted PFAS measurement results (ng PFAS/g sample) of different products within the product categories Decorative Cosmetics, Hair Care and Skin Care; sums of different PFAS groups are given (i.e. (∑PFCAs, (∑PAPs, ∑PFASs,. Unique sample names given based on Sub-category and identity (ID) number; conc=concentration, SD=Standard deviation, LOD=limit of detection, N.a.=not analysed, i.e. sample measured once and not in triplicates. Values are reported partly un-rounded (for the purposes of auditing), but only 3 values should be considered significant.

Substance	Product category	Decorative Cosmetics					Skin Care	
	Sample	Concealer 1	Eye shadow 5	Foundation/BB Cream 3	Foundation/BB Cream 4	Lip liner, pen 1	Mask 1	Mask 2
∑PFASs	conc (ng/g)	**77,4**	**10,2**	**908154**	**2273290**	**5,93**	**425**	**9559**
∑PFCAs	conc (ng/g)	**77,4**	**10,2**	**341**	**163**	**5,93**	**425**	**9559**
PFBA	conc (ng/g)	**38,2**	**10,2**	**6,05**	**15,4**	**5,93**	**425**	**9559**
	SD (ng/g)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2010,2
	LOD (ng/g)	2,66	2,66	2,66	2,66	2,66	2,66	2,66
PFPeA	conc (ng/g)	<LOD	<LOD	<LOD	**29,3**	<LOD	<LOD	<LOD
	LOD (ng/g)	17,4	17,4	17,4	17,4	17,4	17,4	17,4
PFHxA	conc (ng/g)	**39,2**	<LOD	**86,0**	**96,8**	<LOD	<LOD	<LOD
	LOD (ng/g)	14,6	14,6	14,6	14,6	14,6	14,6	14,6
PFHpA	conc (ng/g)	<LOD	<LOD	**24,2**	**21,6**	<LOD	<LOD	<LOD
	LOD (ng/g)	14,6	14,6	14,6	14,6	14,6	14,6	14,6
PFOA	conc (ng/g)	<LOD	<LOD	**112**	<LOD	<LOD	<LOD	<LOD
	LOD (ng/g)	12,6	12,6	12,6	12,6	12,6	12,6	12,6
PFNA	conc (ng/g)	<LOD	<LOD	**21,5**	<LOD	<LOD	<LOD	<LOD
	LOD (ng/g)	13,0	13,0	13,0	13,0	13,0	13,0	13,0
PFDA	conc (ng/g)	<LOD	<LOD	**63,9**	<LOD	<LOD	<LOD	<LOD
	LOD (ng/g)	13,1	13,1	13,1	13,1	13,1	13,1	13,1
PFDoDA	conc (ng/g)	<LOD	<LOD	**22,4**	<LOD	<LOD	<LOD	<LOD
	LOD (ng/g)	16,7	16,7	16,7	16,7	16,7	16,7	16,7
PFTeDA	conc (ng/g)	<LOD	<LOD	**4,75**	<LOD	<LOD	<LOD	<LOD
	LOD (ng/g)	1,06	1,06	1,06	1,06	1,06	1,06	1,06

∑PAPs	**conc (ng/g)**	<LOD	<LOD	**907813**	**2273127**	<LOD	<LOD	<LOD
6:2/6:2 diPAP	**conc (ng/g)**	<LOD	<LOD	**86019**	**2269310**	<LOD	<LOD	<LOD
	LOD (ng/g)	15,4	15,4	15,4	15,4	15,4	15,4	15,4
6:2/8:2 diPAP	**conc (ng/g)**	<LOD	<LOD	<LOD	**151790**	<LOD	<LOD	<LOD
	LOD (ng/g)	9,54	9,54	9,54	9,54	9,54	9,54	9,54
8:2/8:2 diPAP	**conc (ng/g)**	<LOD	<LOD	**670005**	**3817**	<LOD	<LOD	<LOD
	LOD (ng/g)	29,3	29,3	29,3	29,3	29,3	29,3	29,3

For more information on detection limits of the other analysed, but non-detected PFASs (i.e. concentrations <LOD), see Table 38.

Two other studies by Fujii et al. (2013) and Schultes et al. (2018) investigated PFASs in cosmetic products before and can be compared to the current data. In Fujii et al. (2013), thirteen out of 15 cosmetic products listing PFAS(s) as ingredients contained PFCAs with an equal to or longer chain length than PFOA (samples purchased between 2009 and 2011 originating from Japan, France, Korea and the United States). All eleven samples listing PAPs as ingredients contained long chain PFCAs from PFOA on upwards to PFTeDA (Fujii et al. 2013). A few years later, Schultes et al. (2018) investigated 24 cosmetic products listing PFASs as ingredients (bought 2016 and 2017 on the Swedish market) and found 7 products to contain (at least one) PFCA longer than PFOA. The current study only showed one out of 15 products to contain long-chain PFCAs (Table 21). Further, in Schultes et al. (2018) three products (all foundations) listed long-chain PAPs as ingredients, out of which one product contained all PFCAs from PFBA up to PFTrDA, one product PFCAs between PFBA and PFOA as well as PFDA and PFUnDA, the last product only PFCAs from PFBA on to PFHpA. The current study's PAP-containing products (Foundation/BB Cream 3 and 4) contained in one case no long chain PFCAs and in the other case PFCAs with a chain length up to PFTeDA (Table 21). Concentrations of the long chain PFCAs in PAPs containing products were much lower in this study than measured in Schultes et al. (2018). The comparison of the three studies likely shows the shift from long chain PFCAs to short chain PFCAs over the years. However, differences can also occur due to the choice of products and their origin.

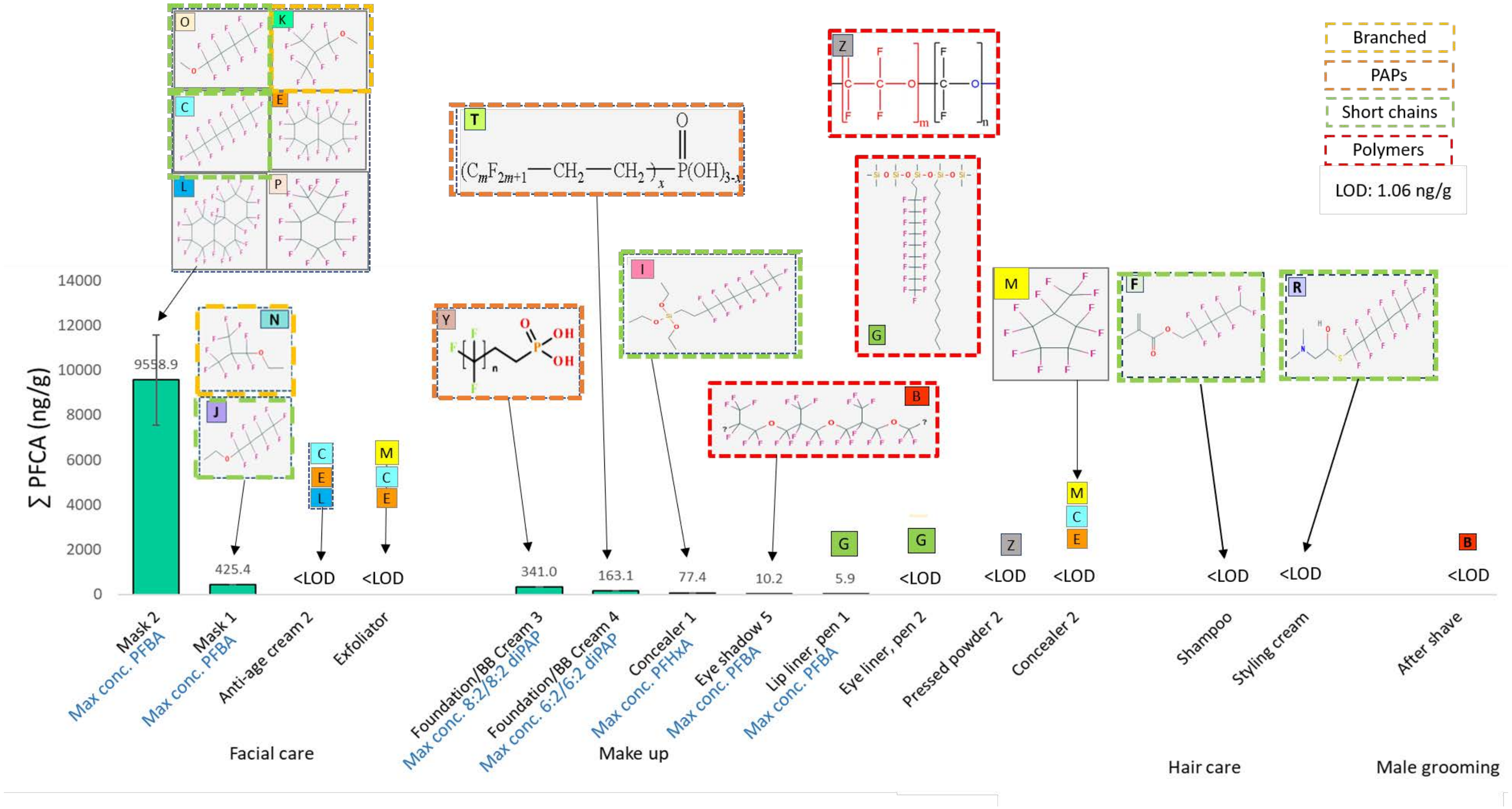

Figure 3: Analysis results of the targeted PFAS measurement, results given as ∑PFCAs (ng/g product) for different cosmetic products and the chemical structures of the INCI names on the ingredient lists of the products; 2-D Structures of PFASs from PubChem; classification into product categories according to CosmEthics; for Cosmetics Europe classification: Facial care=Skin care; Make up=Decorative cosmetics; Hair care=Hair care; Male grooming=this product would also fall under Skin care; concentrations of single PFCAs below the limit of detection (<LOD) treated as equal to zero; <LOD=all analysed PFASs <LOD; LOD given equal to 1.06 ng/g corresponds to lowest LOD (PFTeDA); Max conc.=PFAS with the maximum concentration in the sample; Blue frame=any PFAS; Same letters indicate same PFAS/INCI names, for the corresponding PFAS/INCI names consult Table 19; Values are reported partly un-rounded (for the purposes of auditing), but only 3 values should be considered significant.

4.9.3 Mass balance PFAS, EOF and TF

The ∑PFAS concentrations were translated into fluorine concentrations for the means of comparison to EOF and TF fluorine concentrations. The EOF were lower than the TF concentrations (except for in three cases), which was expected, as the EOF concentrations do reflect fewer PFASs than the TF concentrations reflecting the entire sample without any pre-treatment (Figure 4). Given values are rounded to two significant figures.

The EOF concentrations accounted for 0.01-150 % of the TF concentrations and the ∑PFAS for 0.01-43 % of the TF concentrations (not considering samples <LOD, Figure 4, Table 39). The few instances of EOF exceeding TF concentrations are attributable to the variability in TF and EOF analysis, and have been documented previously (Spaan et al. 2020). In these few cases the EOF and TF are considered equivalent. For samples containing detectable PFAS and EOF concentrations, ∑PFAS concentrations accounted for 0.04-37 % of the EOF concentrations (Figure 4, Table 39). Especially the Foundation/BB Cream 3 and 4, as well as Pressed powder 2 and Styling cream show a good agreement between EOF and TF concentrations (110, 150 as well as 120 and 94 %, respectively, Figure 4, Table 39). Therefore, the (listed) PFAS ingredients in these products are likely well exactable in methanol and detectable with EOF. In case of Pressed powder 2, this seems surprising, considering that the listed ingredient is a polymer (polyperfluoroethoxymethoxy difluoroethyl PEG phosphate, structure Z in Figure 4). Further, other polymer containing products such as Eyeshadow 5 and Lip liner, pen 1, Eye liner, pen 2 and After shave do not show a good agreement between EFO and TF (range 0.01-6.8 %, Figure 4, Table 39). It is therefore likely, that the polymer in Pressed powder 2 is much smaller and more methanol soluble than the two other polymers in the previously mentioned products.

Four of the analysed products contain mica, i.e. potentially inorganic fluorine. For two of those, the contribution of inorganic fluorine to the TF concentrations was negligible, due to equally high EOF concentrations (Styling cream and Pressed Powder 2, Figure 4). In Eye liner pen 2, the difference in TF and EOF concentrations is at least to some extent likely caused by the listed polymer ingredient, whereas for Mask 2, the difference could be caused by any PFAS not soluble in methanol from the ingredient list and/or mica (Figure 4). Considering that the Mask 2 ingredients also appear in other products (Anti age cream 2, Exfoliator, Concealer 2) with extremely low EOF concentrations, it is still very likely that the TF concentrations are caused by PFASs (Figure 4).

Some of the products with smaller PFAS molecules, such as Exfoliator have comparably high TF concentrations, but very low EOF concentrations (even below the LOD in this case, Figure 4). These PFASs do not seem to solve (well) in methanol, i.e. are hydrophobic and therefore not detectable with EOF. This indicates that the variety of PFAS characteristics and the potential for underestimating the PFAS amounts if considering EOF concentrations only and underlines the importance of considering both, TF and EOF. The importance of these two methods becomes even more clear, considering their relation to the ∑PFAS concentrations (Figure 4). Only Foundation/BB Cream 3 and Foundation/BB Cream 4 had ∑PFAS concentrations explaining between 29 and 37 % of the EOF and 42 and 43 % of the TF concentrations, whereas all other cosmetic products had well below 10 % (with the exception of Mask 2, 16 % of EOF, Figure 4, Table 39). Even the major fluorine amount in Foundation/BB Cream 3 and Foundation/BB Cream 4 (approx. >60 %) remains therefore unexplained, although at least some of the targeted compounds were matching the listed PFASs in these two samples. The remaining PFASs in the Foundation/BB Creams were likely PAPs of different chain length.

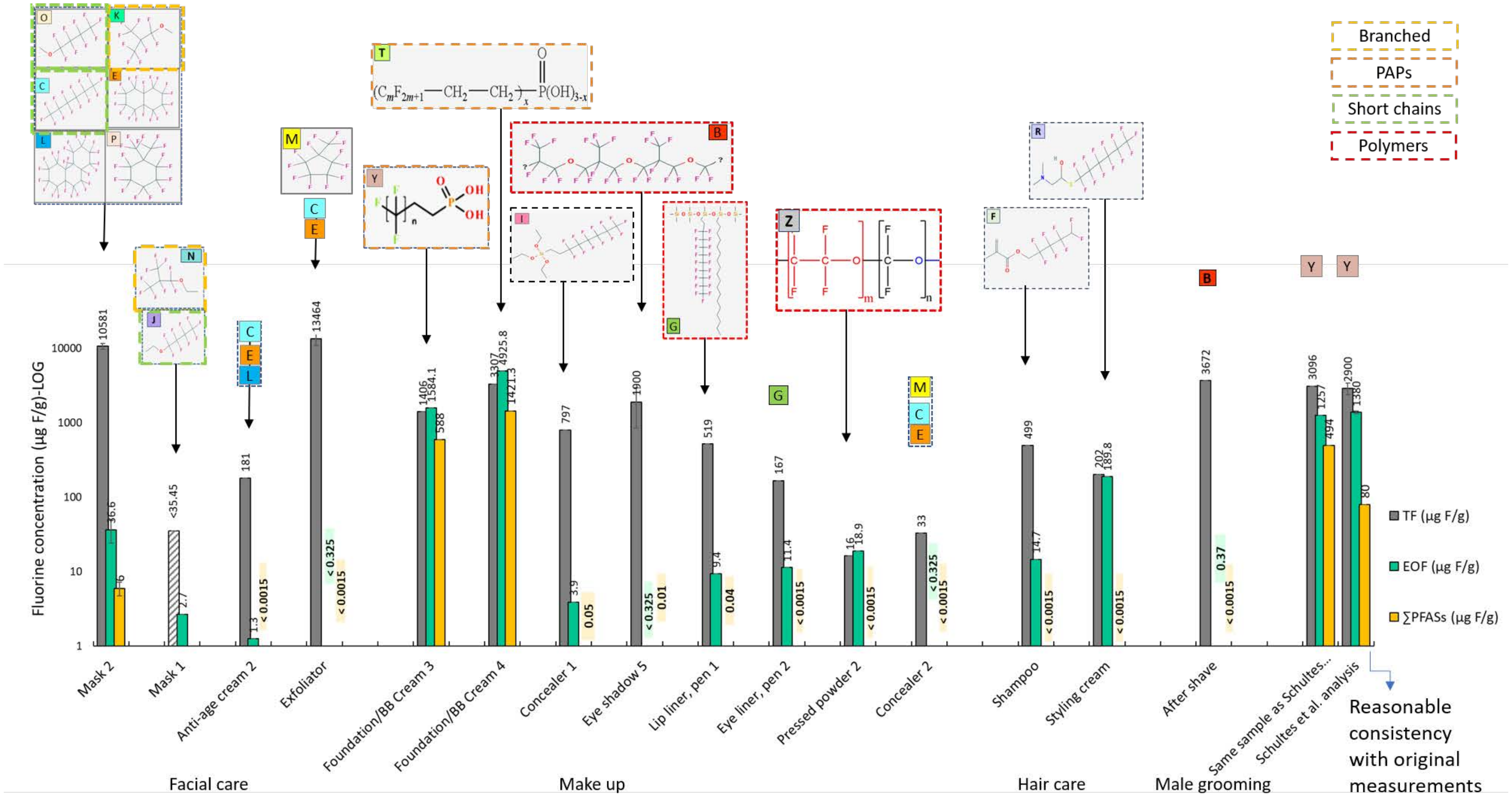

Figure 4: Fluorine mass balance between TF, EOF and ∑PFAS, results given as fluorine concentrations (µg F/g product) for different cosmetic products and the chemical structures of the INCI names on the ingredient lists of the products; 2-D Structures of PFASs from PubChem; classification into product categories according to CosmEthics; for Cosmetics Europe classification: Facial care=Skin care; Make up=Decorative cosmetics; Hair care=Hair care; Male grooming=this product would also fall under Skin care; <LOD=below limit of detection for all analysed PFASs; LOD value given for lowest substance LOD; Blue frame=any PFAS; Same letters indicate same PFAS/INCI names, for the corresponding PFAS/INCI names consult Table 20; Values are reported un-rounded (for the purposes of auditing), but only 3 values should be considered significant.

4.10 Emissions estimates of PFASs from cosmetic products

All emission estimates are annual values for the EEA (not including Lichtenstein and Iceland), or correspondingly the EU27 and Norway. The total emissions are assumed to occur after product use only and to exclusively occur to the wastewater or to solid waste. No other emissions were considered (see chapter 3.6.4). The emissions to solid waste in all worst-case scenarios are equal to zero, as the entire emissions are assumed to go into wastewater, i.e. the total emissions in the worst-case scenario are equal to the emissions into wastewater. The emissions calculations for Toiletries are based on the measured concentrations in Hair Care products (see chapter 3.6.1) and are thus uncertain. Further, only one out of 3637 products (CosmEthics database) within Perfumes and Fragrances listed a PFAS as an intended ingredient, and as a result, this category's product concentration was assumed to be equal to zero (for TF, EOF as well as ∑PFCAs, chapter 3.6.1). Therefore, the emissions for Perfumes and Fragrances are zero in all scenarios and for all emissions (i.e. total, wastewater and solid waste). For more details on the parameters and assumptions that were made for the emission calculations see chapter 3.6. All values are rounded to two significant figures.

The **emissions based on TF** represents any kind of PFAS (low and high molecular weight PFASs, including polymers, non-polar and polar, as well as ionisable and non-ionisable PFASs), but can also represent inorganic fluorine if present in the product (see chapter 3.5 and Table 2 for more details). The total emission estimates based on the TF measurement for all cosmetic products were 17 kg F/year in the best-case, 11000 kg F/year in the average-case and 38000 kg F/year (Table 22). In the average-case scenario, 8300 kg F/year were estimated to go into wastewater, whereas 2700 kg F/year were estimated to end up in solid waste. In the average-case scenario based on the TF measurements, Decorative Cosmetics seem of similar importance to Hair Care (1200 vs. 1000Table 22).

Table 22: Estimates for total emissions, emissions to wastewater and solid waste, each in a best-, average- and worst-case scenario for the different cosmetic product categories based on the total fluorine (TF) measurements. Annual emission estimates (kg F/year) for the EEA without Lichtenstein and Iceland, or correspondingly the EU27 and Norway. Numbers in bold present cosmetic product category contributing most to the total, wastewater or solid waste emission, respectively and in each certain scenario; All values are rounded to two significant figures. Quantities F/year can be converted to PFAS/year by using a factor of 1.4-2.0.

Product category	Best-case TF emissions (kg F/year) TOTAL	Best-case TF emissions (kg F/year) Waste-water	Best-case TF emissions (kg F/year) Solid waste	Average-case TF emissions (kg F/year) TOTAL	Average-case TF emissions (kg F/year) Waste-water	Average-case TF emissions (kg F/year) Solid waste	Worst-case TF emissions (kg F/year) TOTAL	Worst-case TF emissions (kg F/year) Waste-water	Worst-case TF emissions (kg F/year) Solid waste
Skin Care	**8.0**	**5.3**	2.7	**8200**	**6200**	**2000**	**29 000**	**29 000**	0
Toiletries	1.0	0.82	0.21	560	500	58	1500	1500	0
Hair Care	1.9	1.5	0.35	1000	930	86	2700	2700	0
Perfumes and Fragrances	0	0	0	0	0	0	0	0	0
Decorative Cosmetics	5.6	1.0	**4.6**	1200	650	570	4100	4100	0
Total	17	8.6	7.9	11 000	8300	2700	38 000	38 000	0

The EOF-based emission calculations are the best estimate for non-polymeric and polar (i.e. soluble in methanol) PFASs that are present in the cosmetic products (see chapter 3.5 and Table 2 for more details). The total emission estimates based on the EOF measurements were 37, 1300, and 5100 kg F/year for the best-, average- and worst-case, respectively, for the sum of all cosmetic products (Table 23). In the best-case scenario Hair Care was the product category with the largest contribution to the total, wastewater and solid waste emissions (24, 20 and 4.4 kg F/year, respectively, Table 23). Hair Care was also the main contributing product category to the total and wastewater emissions in the best-case scenario for EOF. However, Decorative Cosmetics dominated emissions in the average scenario to solid waste (180 kg F/year), as well as the total and wastewater EOF emissions in the worst-case scenario (3400 kg F/year each, Table 23).

Table 23: Estimates for total emissions, emissions to wastewater and solid waste, each in a best-, average- and worst-case scenario for the different cosmetic product categories based on the extractable organic fluorine (EOF) measurements. Annual emission estimates (kg F/year) for the EEA without Lichtenstein and Iceland, or correspondingly the EU27 and Norway. Numbers in bold present cosmetic product category contributing most to the total, wastewater or solid waste emission, respectively and in each certain scenario; all values are rounded to two significant figures. Quantities F/year can be converted to PFAS/year by using a factor of 1.4-2.0.

Product category	**Best-case EOF emissions (kg F/year) TOTAL**	**Best-case EOF emissions (kg F/year) Wastewater**	**Best-case EOF emissions (kg F/year) Solid waste**	**Average-case EOF emissions (kg F/year) TOTAL**	**Average-case EOF emissions (kg F/year) Wastewater**	**Average-case EOF emissions (kg F/year) Solid waste**	**Worst-case EOF emissions (kg F/year) TOTAL**	**Worst-case EOF emissions (kg F/year) Wastewater**	**Worst-case EOF emissions (kg F/year) Solid waste**
Skin Care	0.17	0.11	0.059	11	8.7	2.8	78	78	0
Toiletries	13	10	2.7	310	270	32	570	570	0
Hair Care	**24**	**20**	**4.4**	**560**	**510**	47	1000	1000	0
Perfumes and Fragrances	0	0	0	0	0	0	0	0	0
Decorative Cosmetics	0.11	0.020	0.092	380	200	**180**	**3400**	**3400**	0
Total	37	30	7.3	1300	1000	260	5100	5100	0

The total **emission estimates based on ∑PFCAs** measured as impurities in the products (see chapter 3.5 and Table 2 for more details) resulted in a total average emission of 2.7 kg ∑PFCAs/year for Skin Care and 0.035 kg ∑PFCAs/year for Decorative Cosmetics and in a total worst-case emission of 20 for Skin Care and 0.24 kg/year for Decorative Cosmetics. These emissions were orders of magnitude lower than TF and EOF emissions, as only a minor fraction of unintended and non-listed ingredients is reflected by the ∑PFCAs. Both measured Hair Care products contained no detectable PFCAs (concentrations <LOD treated as equal to zero for the PFCAs to prevent any overestimation), because of which emission estimates of PFCAs for both Hair Care and Skin Care are equal to zero. Especially for these two categories - although generally true for all categories and measurement types - measuring more products of the same category will be beneficial to confirm or revise these estimates.

Putting these emissions into a broader context, a substantial share, i.e. about 1/5 to 1/3 of the PFAS-containing products in the three different Cosmetic databases listed PFASs as ingredients that are restricted or for which restrictions are pending (chapter 4.3). These PFASs will likely make a substantial contribution to the presented emissions (i.e. TF and EOF emissions). After products containing restricted PFASs are removed from the market, the emission estimates will likely decrease (assuming that no new PFAS-containing products are introduced to the market). These restricted PFASs are PFCA precursors that may transform to persistent PFCAs in the environment. At the same time, a large fraction of the emission estimates is likely due to polymers. PTFE, for example, accounts for >30 % of PFAS-containing products in the cosmetic databases (chapter 4.3). Fluoropolymers contain a high fluorine content compared to other PFASs and are expected to contribute greatly to the emission estimates on a fluorine equivalent basis; however, their contribution towards environmental PFCA levels remains unclear at this time. On the other hand, the discrepancy between TF and EOF emissions cannot be considered as coming from the polymers only, but rather from PFASs which are non-extractable in methanol (e.g. polymers and non-polar PFASs) and to a (probably negligible) fraction from potential inorganic fluorine. The contribution of low-molecular weight, non-polar PFASs (e.g. perfluorodecalin) to environmental PFCA levels is also uncertain at this time.

Table 24: Estimates for total emissions, emissions to wastewater and solid waste, each in a best-, average- and worst-case scenario for the different cosmetic product categories based on the on the targeted PFAS measurements. Annual emission estimates as ∑PFCA (kg ∑PFCAs/year) for the EEA without Lichtenstein and Iceland, or correspondingly the EU27 and Norway. Numbers in bold present cosmetic product category contributing most to the total, wastewater or solid waste emission, respectively and in each certain scenario; All values are rounded to two significant figures.

Product category	Best-case ∑PFCA emissions (kg ∑PFCAs /year) TOTAL	Best-case ∑PFCA emissions (kg ∑PFCAs /year) Wastewater	Best-case ∑PFCA emissions (kg ∑PFCAs /year) Solid waste	Average-case ∑PFCA emissions (kg ∑PFCAs /year) TOTAL	Average-case ∑PFCA emissions (kg ∑PFCAs /year) Wastewater	Average-case ∑PFCA emissions (kg ∑PFCAs /year) Solid waste	Worst-case ∑PFCA emissions (kg ∑PFCAs /year) TOTAL	Worst-case ∑PFCA emissions (kg ∑PFCAs /year) Wastewater	Worst-case ∑PFCA emissions (kg ∑PFCAs /year) Solid waste
Skin Care	0	0	0	**2.7**	**2.0**	**0.64**	**20**	**20**	0
Toiletries	0	0	0	0	0	0	0	0	0
Hair Care	0	0	0	0	0	0	0	0	0
Perfumes and Fragrances	0	0	0	0	0	0	0	0	0
Decorative Cosmetics	0	0	0	0.035	0.019	0.016	0.24	0.24	0
Total	0	0	0	2.7	2.0	0.66	21	21	0

In a previous report, total fluorine emission estimates made for Sweden based on average concentrations in cosmetic products resulted in 1300 kg F/year for Skin Care and 130 kg F/year for Decorative Cosmetics (vs. approx. 8200 kg F/year and 1200 kg F/year, respectively, in the current study's average scenario) (Hansson et al. 2020). Comparing these emission estimates, the current estimates for the EEA seem low related to the estimates for Sweden only. However, considering the following differences that likely contributed to comparably higher estimates for the Swedish emissions, the emission estimates in this report seem reasonable:

- The average TF concentrations going into the emission estimates for Sweden were higher than in the current study (3.6 mg F/g for Decorative Cosmetics and 5.5 mg F/g for Skin Care vs. 1.8 and 3.8 mg F/g, respectively) (Table 28, Table 29, Table 30 and chapter 3.6.1).
- The share of PFAS containing products was assumed to be 4.4 % (Hansson et al. 2020) for all product categories in the Swedish emission estimates (based on an overall inventory from Henricsson (2017)). In the current study, the share of PFAS containing products turned out to be lower than the estimates, especially for Skin care (0.8 %), but even for Decorative Cosmetics (3.7 %) (chapter 3.6.3, Table 8).
- The assumed average product size was bigger in the Swedish estimates (15 g Decorative Cosmetics and 100 g Skin Care vs. 10 and 75 g, respectively, in the current study) (chapter 3.6.2.3, Table 7).

In the current study, the fluorine emissions based on TF and EOF were also recalculated into the theoretical corresponding amount of specific PFCAs. In the average case-scenario, the fluorine amount of the total emission from all cosmetic product categories based on the TF measurement (i.e. 11000 kg F/year) would translate into 18000 kg PFBA/year, or 16000 kg PFHxA/year, or 16000 kg PFOA/year, whereas the fluorine amount based on the EOF measurements (i.e. 1300 kg F/year) would translate into a total of 2000 kg PFBA/year, or 1900 kg PFHxA/year, or 1800 kg PFOA/year. In the worst-case scenario, the EOF fluorine amount would translate into a total of 8200 kg PFBA/year, 7600 kg PFHxA/year and 7400 kg PFOA/year. These recalculations are a vast overestimation of the actual PFCA amount in the products; This is especially true for the amounts based on TF, where the signal even comprises polymers and potentially inorganic fluorine, but even for the amounts based on EOF, as the entire fluorine amount is assumed to be caused by one PFCA as impurity only and neglects the contribution of intentional added PFASs (i.e. PFASs on the ingredient list). The intentional ingredients will contribute mostly to the fluorine signal, whereas the PFCAs will make only a minor contribution. The recalculation was purely done in order to give an estimate of theoretical corresponding PFCA amount for the measured fluorine amount, which otherwise might be hard to comprehend and classify. These recalculations into PFCAs are not presented further in a table in this report to prevent overinterpretation of the data.

5 Conclusions

A total of 169 unique INCI names were identified as PFAS according to the definition provided by the OECD/UNEP Global PFC Group (i.e. a chemical structure having at least one $-CF_2$ element (chapter 4.3). 42 INCI names that are PFAS(s) were found in products listed in the cosmetic databases consulted for this report (chapter 4.3).

The market share of PFAS-containing cosmetic products ranged from 1.1 to 1.4 % (using the most reliable cosmetic databases, Kemiluppen and CosmEthics). An even more similar range was obtained after removing discontinued products from Kemiluppen (1.3 compared to 1.4 % chapter 4.1). The PFAS-containing product share was updated from prior estimates (Henricsson 2017), specified by product categories was found to be highest for Decorative cosmetics (3.7 %), followed by Skin care, Hair care and Toiletries (0.78, 0.65 and 0.27 %, respectively). A negligible fraction of Perfumes and Fragrances contained PFAS among their ingredients (0.03 %, data based on CosmEthics, chapter 4.2). One fifth to one third (depending on the database) of the PFAS-containing products list PFAS ingredients that are under current or pending restriction, when considering the top 10 ranked PFASs/INCI names each (chapter 4.3). This indicates a high frequency of restricted PFASs in cosmetic products, while at the same time many of the PFASs are still unregulated. The most frequent PFAS in products is the polymer PTFE, followed by the INCI name C9-15 fluoroalcohol chapter 4.3). The latter belongs to the C9-C14 PFCA precursors, i.e. is under pending restriction. The ongoing detection of PFASs (including restricted substances) in cosmetic products highlights the need for further regulation. Additionally, a stricter regulation for cosmetic product labelling might be useful for products both in physical and online-shops, considering the challenges associated with sampling in the present work (chapter 4.8).

The major functions of PFASs in cosmetics are conditioning, film forming, solvents and surfactants (chapter 4.4). Although public information on non-fluorinated alternatives is scarce, given the number of PFAS phase-out statements of cosmetic brands, it is assumed that some producers have either introduced new, non-fluorinated ingredients, are reverting to existing non-fluorinated ingredients which serve a similar purpose, or have abandoned or are about to abandon products with PFASs as ingredients (chapter 4.7). However, the extent to which PFAS-containing cosmetics product have been phased-out from the entire market remains unclear. Considering the Kemiluppen database, removing the discontinued products from the total database, the share of PFAS-containing products seems even to increase (chapter 4.1). There are far more non-fluorinated cosmetic products within the same product categories than PFAS containing products, which suggests that PFASs can be replaced by other ingredients and do not have unique functions, which also was supported by one interviewed cosmetic producer.

Current TF and EOF concentrations were in the same range as previously reported for cosmetic products sampled in 2016/2017 (Schultes et al. 2018). Products among the Skin Care category had the highest fluorine content (TF: 13.8 and 10.6 mg F/g, exfoliator and mask, respectively; EOF: 4.93 and 1.58 mg F/g both foundation/BB creams, chapter 4.9). Among the analysed PFASs, PFCAs from PFBA (most frequent, in 7 out of 15 samples) up to PFTeDA were detected as impurities with a maximum ∑PFCA concentration of 9.56 µg/g in one mask and PFOA concentrations exceeding the EU limit of 25 ng/g more than four-fold (ECHA 2017) (chapter 4.9.3). PAPs were exclusively detected in products that listed these substances as ingredients at concentrations exceeding EU limit values (ECHA 2017) (chapter 4.9.3). ∑PAP concentrations are nevertheless underestimated, since targeted analysis only included three di-PAPs, compared to the wide range of chain-lengths listed among the ingredients. In these cases, the detected ∑PFAS concentrations accounted for only up to 37 % of the EOF concentrations (chapter 4.9.4). Still, this was the highest share of PFASs explaining EOF concentrations, because other products listed PFAS ingredients which were not measured as part of the targeted analysis. This shows the need for the inclusion of a wider range of PFAS in order to avoid underestimating sum PFAS concentrations. Such efforts will ultimately require further development of analytical standards for quantification. Alternatively, TF, and EOF measurements can be used as a substitute for targeted analyses. While these approaches can capture all fluorinated substances regardless of their structure or standard availability, TF measurements may also capture inorganic fluorine (if present), while EOF measurements are driven largely by the extraction procedure. Clearly a combined approach of TF, EOF, and target PFAS analysis is necessary to obtain a full picture of the PFAS occurrence in any kind of products or other samples.

While all three approaches have advantages and limitations, EEA emission estimates from cosmetic products based on TF and EOF concentrations were deemed most realistic of emissions from listed ingredients, whereas the ∑PFCA concentrations reflect impurities which are present at much lower (i.e. orders of magnitude) concentrations. The estimated total emissions to wastewater and solid waste from cosmetics of all product categories were in the average case scenario 11000, 1300 kg F/year (TF, EOF, respectively) and 2.7 kg PFCAs/year (∑PFCAs) and in the worst-case scenario 38000, 5100 kg F/year (TF, EOF, respectively) and 21 kg PFCAs/year (∑PFCAs) (chapter 4.10). Based on both TF and ∑PFCAs measurements, Skin Care represented the product category with the highest contribution to emissions. In comparison, using EOF, Hair Care (best- and average-case scenario) and Decorative Cosmetics (worst-case scenario) made the greatest contribution to emissions. Wastewater received a higher share of the total PFAS from cosmetic products compared to solid waste in nearly all scenarios and product categories. Assumptions and uncertainties connected to these emission estimates are presented and discussed extensively and should be considered interpreting the data and improving future emission scenarios (chapter 3.6, 4.10 and 6). The previously identified data gap on PFASs in Hair Care products (Hansson et al. 2020), was addressed through total fluorine measurements of five different Hair Care products listing PFAS(s) as ingredients (chapter 4.9.1). Measured product data are still needed for Toiletries, especially considering the high market share of this category (25 %; second highest of all cosmetic product categories, chapter 3.6.2.1). Even if only 0.27 % of the Toiletries products seem to contain PFAS (chapter 3.6.3), the estimated annual product volume (tonnes) was highest for this product category (chapter 3.6.2). Therefore, Toiletries probably will still contribute greatly to total PFAS emissions of cosmetic products and new estimates based on measured concentrations in Toiletries would be a valuable update of the current emission estimates based on assumptions (assuming Hair Care product concentrations to be equal to Toiletries').

Sales data indicate increased purchasing of cosmetic products specifically in Eastern European countries (Cosmetics Europe), which may expose the environment and humans in these regions to higher PFAS loads than previously (chapter 4.5). Changes in cosmetic manufacturing appear to be driven by both consumers and initiatives within the cosmetics industry. Strong indications for this are a) the full PFAS phase-out statements of in total 57 different brands (at least for all new products, see chapter 4.7); b) that a few PFAS-containing products according to the cosmetic databases did not list any PFAS on the ingredients list when sampling; c) that the targeted analysis indicates a shift from long-chain to short-chain PFCA impurities when comparing the current data to previous studies (Fujii et al. (2013), Schultes et al. (2018), chapter 4.9.3. At the same time, many of the supposedly still commercially available technical products intended for cosmetics contain PFASs (chapter

4.6.2); also, EOF and TF concentrations were in the same range as a few years ago (Schultes et al. 2018). Further, the cosmetic database information is striking considering the share of products containing restricted PFASs (chapter 4.3), which were found to exceed EU limits in two of the measured products (chapter 4.9.3). A restriction of PFASs in cosmetics is expected to accelerate the phase-out of PFAS from cosmetic products and ultimately reduce potential risks for humans during cosmetic use as well as emissions into the environment, especially via wastewater.

6 Limitations and uncertainties of the study

The total number of PFASs occurring in cosmetic products and/or existing as INCI names identified in this report is likely an underestimate for the following reasons:

- One INCI name can include several different PFASs;
- It is unlikely that all PFAS INCI names in CosIng were covered during the database searches. As an example, another PFAS INCI name (polyvinylidene difluoride) was randomly found when checking CosIng for the functions in cosmetics of another INCI name (vinylidene difluoride);
- Some ingredient names on the labels of cosmetic products are not part of the CosIng database, i.e. CosIng does not reflect all ingredient names and is therefore not a complete list;
- The PFAS searches within the cosmetic database (CosmEthics, Kemiluppen, ToxFox) considered the exact PFAS/INCI name from the list, on which the received database extracts in this report are based on. However, typing errors of the ingredient names can occur both on the package labels, or when transferring the ingredient names into the database (the latter especially when done by the app-users themselves, as in ToxFox). Some examples of altered/missing parts of the INCI name on the packaging labels, that were discovered by a database administrator:
  - INCI “C9-15 fluoroalcohol phosphate” found in the plural wordform, i.e. “C9-15 fluoroalcohol phosphates” on the label;
  - INCI “Hydrofluorocarbon 152A” found without the “A”, i.e. “Hydrofluorocarbon 152” on the label.

All of the aforementioned factors have the potential to contribute to an underestimation of the total number of PFAS in cosmetic products. 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 PFAS analysis.

At the same time, the products listed in the cosmetic databases reflect the product information as entered into the system, meaning that there could be even an overestimation of PFASs. The below uncertainties could lead to both an, over- and underestimation of PFASs in cosmetic products:

- Outdated products, both taken from the market or with meanwhile changed ingredients might still be part of the databases, even though some databases are actively updating this information (chapter 3.2). The targeted sampling showed that some products previously listing PFASs as ingredients did not contain the according INCI anymore.
- At the same time, the latest products might still be missing in the current database extracts due to missing or too few scans.
- Generally, it is unlikely that all products available at the EEA market are in the databases (reflected by the different number of registered products in the databases).
- Especially for ToxFox, there is the risk of missing or faulty classification, i.e. both missing products that are cosmetic products and including products falsely as cosmetic products that are e.g. hygiene products instead (chapter 3.2.3).

For more information on the differences among the databases see chapter 3.2. The information of the consulted database for technical products (SpecialChem) is afflicted by the same uncertainties and limitations as mentioned for the cosmetic databases.

Products in the cosmetic databases were assumed to be representative of the entire EEA market. However, this is only true in cases where the products are sold in all EEA countries and where product scans/registrations are not conducted by app users located outside EEA countries. Producers may have different products in different countries, depending on consumer preferences (e.g. Nordic countries prefer less perfume than other European countries). When it comes to cosmetic legislation, there are very few country-specific laws for chemical ingredients (among the exemptions is Denmark’s restriction on parabens), which might influence the ingredient lists. The previous information was received by the Swedish Medical Products Agency (MPA, personal communication with Josefin Backman, August 2020) and is consistent with information obtained from inquiries to several cosmetic producers (July 2020).

6.1 Uncertainties related to the emission estimates

There are several uncertainties and limitations connected to the emissions estimates. These are listed and sorted below according to the four major parameters driving the emission calculations (see chapter 3.6 for more information). Within each parameter, the influence of the uncertainty on the emission estimates was sorted according to perceived relative importance.

6.1.1 The total amount of cosmetic products sold per year

Ideally the amount or volume of cosmetic products sold per year would exist as a recorded tonnage value. As this information is not available, several assumptions on different parameters leading to this parameter had to be made that partly have a big influence on the emission estimates. Therefore, this parameter is considered the most uncertain among the four overarching one’s going into the emission calculations.

The two parameters with the biggest influence on the cosmetic product amount sold per year are likely the price per product and the size of a product. A 10 % change (e.g. increase) of the two parameters would each result in a change of 10 % in the total emission estimates (i.e. in case of the price a decrease and in case of the size an increase). In detail the uncertainties that have to be considered in connection with the total amount of cosmetic products sold per year are:

1. Assumption on an average price per product category (based on estimates and price screening) might be flawed due to a great price span among and within different product sub-categories, which also might be of different importance for the overall product categories;
2. An average price assumption cannot reflect country specific prices, which might vary greatly and might have a huge influence on the average price, or the related tonnages sold per country;
3. Assumption on an average size of a product (mL or g) might be flawed due to a great span among and within different product sub-categories,
4. Products bought outside the EEA and are directly imported by the customers are not captured by the sales data;
5. Retail Sales Price statistics were missing for Lichtenstein and Iceland, thus the EEA emission estimates are just an approximation and are likely a slight underestimation;
6. It is assumed that all products sold per year are used during a year;
7. Retail Sales Price data do not necessarily reflect the product volume (tonnages), especially over time, i.e. an increase in Retail Sales Price could also show an increase in value of the products.

6.1.2 The PFAS concentrations (EOF/TF) in cosmetic products

The major concern for the product concentration is how representative the analysed samples are for all cosmetic products that contain PFASs. Further sources for uncertainties are (in order of decreasing importance):

1. The low number of samples compared to the vast number of cosmetic products, even though this is one of the largest analytical studies on PFASs in cosmetic products;
2. Missing measurements within the product category Toiletries - for which the same concentrations as in Hair Care were assumed in the different scenarios - might result in a greater uncertainty of emissions from all cosmetic products;
3. Products were not measured from all sub-categories within the different product categories and important sub-categories might be missed out;
4. The assumption that all products within the sub-category contain an equal concentration of PFASs as the average/min/max of the measured products may be an oversimplification;
5. Emissions estimates based on ∑PFAS or ∑PFCA concentrations are likely to be underestimated, because target PFAS analysis only covers a fraction of PFAS which may be present in a product (and in most cases none of the listed PFAS ingredients);
6. Emission estimates derived from EOF measurements may be underestimated in products containing polymers and other highly non-polar PFAS, which are not extractable with methanol;
7. Inorganic fluorine is expected to occur at low or negligible concentrations relative to organic fluorine (in PFAS-containing products), but it cannot be ruled out that TF emission estimates may be overestimated in cases where large quantities of inorganic fluorine are present;
8. A potential underestimation of PFASs as impurities in the share of products not listing PFASs as ingredients, which could increase the share of products containing PFAS (one of the two blank samples not listing any PFAS contained TF); measurement of a wider range of supposedly PFAS-free product could be helpful here;
9. A potential underestimation of Perfumes and Fragrances (assumed concentration 0, as so few products contained PFAS(s) as ingredients), if of relevance, likely only for PFASs as impurities;
10. Analytical uncertainties, which in comparison to the above mentioned are quantifiable and appear within an acceptable range (chapter 3.5.4).

6.1.3 The fraction of PFASs released from cosmetic products contains uncertainties as well:

1. All total emissions are likely underestimated, as emissions during production are not considered;
2. Emissions to wastewater and solid waste might be flawed, as a reduction of emission due to PFAS release to other compartments (such as air, while product application) or skin-uptake and ingestion by consumers (the latter especially in the case of lip-products) was considered zero;
3. Total emissions of PFASs were split between solid waste and wastewater and were based partly on assumptions, so the emissions might be shifted towards either;
4. Statistics for consumer habits on cosmetics’ removal were not available for all product categories, for which assumptions had to be made;

5. Statistics for consumer habits on cosmetics' removal were paired with assumptions to obtain one value per cosmetic product category only and also for the different emission scenarios;
6. Data on product disposal before they are completely used up and on the fraction of the cosmetic product which remains inside the package when used up could improve the emission estimates to wastewater and solid waste; i.e. likely lower the emissions to wastewater and increase the emissions to solid waste (only in the best-case scenario, there was the attempt to account for these additional disposal fractions: by lowering the wastewater fraction by 10 % compared to the average-case scenario and considering this to go into solid waste instead);
7. Emissions to wastewater and solid waste might be flawed, as the consumer habits on cosmetics' removal date a few years back. There is an upcoming trend towards multiple-use and washable pads/whips for make-up removal instead of single-use cotton/pads/whips. The multiple-use products are promoted as more environmentally friendly compared to single-use products in terms of saving water/resources during cotton production. However, this ensures that the products are released into the wastewater when washing the reusable pads. In future, consumer habit studies on cosmetic removal should include the use of multiple-use/washable removal products as an additional answer option in questionnaires.

6.1.4 The share of products containing PFASs

The share of products containing PFASs is considered the most certain compared to the other major parameters. Besides the above-mentioned database uncertainties, the following is true for PFAS-containing product share:

1. Potential slight over- or underestimation of to the share of products containing PFASs (missing PFASs or including replaced products), although it is the best estimate possible based on the biggest cosmetic database and the different databases seem to match (at least for the product share over all products);
2. Potentially uncertain, when taking the same current product share in future due to changes in production/products placed of the market (new database information should be considered in a few years for emission calculations);
3. Potential underestimation of the product share containing PFASs and the emissions due to a share of products that contain PFASs as impurities, but that are not listing PFASs as ingredients;
4. Potential for slight deviation of the product share in the different categories due to rearrangement of sub-categories from CosmEthics' into Cosmetics Europe's classification (unlikely to have a big influence at all; also probably a very minor source of failure, especially as a terminology and classification list provided by Cosmetics Europe was used for this)

Appendix

Table 25: Overview cosmetic product samples purchased (September 2020 in different stores in Stockholm, Sweden) for the analyses of TF, EOF and targeted PFASs; Triggering ingredient on the ingredient list, country barcode = barcode starting sequence (i.e. GS1 country prefix within the EAN-13) stands for the country where the manufacturer is registered, if no EAN-13 code, unknown; Country (made in) and (DIST. IMP.) = further information on the packaging.

Sample name (Sub-category (ID))	Triggering Ingredient	Country barcode (manufacturer registered in)	Country (made in)	Country (DIST. IMP.)
Decorative Cosmetics	N/A	N/A	N/A	N/A
Blush/Bronzer/Contour 1	PTFE	Unknown	USA	Ireland
Blush/Bronzer/Contour 2	PTFE	Unknown	USA	USA
Blush/Bronzer/Contour 3	POLYPERFLUOROMETHYLISOPROPYL ETHER	Poland	Sweden	Sweden
Blush/Bronzer/Contour 4	PTFE	France and Monaco	England	USA
Concealer 1	PERFLUOROOCTYL TRIETHOXYSILANE	France and Monaco	France	France
Concealer 2	PERFLUORODECALIN, PERFLUOROHEXANE, PERFLUOROMETHYLCYCLOPENTANE	France and Monaco	Corea	USA, France
Eye liner, pen 2	PERFLUORONONYL DIMETHICONE	France and Monaco	Germany	Canada, USA
Eye shadow 1	PTFE	France and Monaco	USA	France
Eye shadow 2	PTFE	Sweden	Sweden	Sweden
Eye shadow 3	PTFE	Unknown	USA	Ireland
Eye shadow 4	PTFE	France and Monaco	ITALY	USA
Eye shadow 5	POLYPERFLUOROMETHYLISOPROPYL ETHER	Poland	Sweden	Sweden
Eyeliner liquid/gel	POLYPERFLUOROMETHYLISOPROPYL ETHER	Poland	Sweden	Sweden
Foundation/BB Cream 1	PERFLUOROOCTYL TRIETHOXYSILANE	France and Monaco	France	France
Foundation/BB Cream 2	TRIFLUOROPROPYL DIMETHICONOL	Japan	Japan	France
Foundation/BB Cream 3	C9-15 FLUOROALCOHOL PHOSPHATE	Unknown	Belgium	UK, USA
Foundation/BB Cream 4	AMMONIUM C6-16 PERFLUOROALKYLETHYL PHOSPHATE	United Kingdom	UK	UK
Lip liner, pen 1	PERFLUORONONYL DIMETHICONE	France and Monaco	Germany	France
Lip liner, pen 2	POLYETHYLENE PERFLUORONONYL DIMETHICONE	Sweden	Germany	Sweden
Loose powder	POLYPERFLUOROMETHYLISOPROPYL ETHER	Poland	Sweden	Sweden
Mascara	PTFE	Unknown	Canada	UK, USA
Pressed Powder 1	POLYPERFLUOROMETHYLISOPROPYL ETHER	Poland	Sweden	Sweden

Pressed Powder 2	POLYPERFLUOROETHOXYMETHOXY DIFLUOROETHYL PEG PHOSPHATE	Sweden	USA	UK
Hair Care	N/A	N/A	N/A	N/A
Hair spray 1	OCTAFLUOROPENTYL METHACRYLATE (OFPMA)	Italy, San Marino and Vatican City	USA	UK
Hair spray 2	HYDROFLUOROCARBON 152a	Italy, San Marino and Vatican City	USA	UK
Shampoo	OCTAFLUOROPENTYL METHACRYLATE (OFPMA)	Unknown	USA	UK
Styling cream	C4-18 PERFLUOROALKYLETHYL THIOHYDROXYPROPYLTRIMONIUM CHLORIDE	Italy, San Marino and Vatican City	USA	UK, USA
Treatment 1	OCTAFLUOROPENTYL METHACRYLATE (OFPMA)	Czech Republic	USA	UK
Skin Care	N/A	N/A	N/A	N/A
After shave	POLYPERFLUOROMETHYLISOPROPYL ETHER	France and Monaco	France	Canada
Anti-age cream 1	ACETYL TRIFLUOROMETHYLPHENYL VALYLGLYCINE	France and Monaco	France	France
Anti-age cream 2	PERFLUOROHEXANE, PERFLUOROPERHYDROPHENANTHRENE, PERFLUORODECALIN	United Kingdom	UK	UK
Anti-age cream 3	POLYPERFLUOROMETHYLISOPROPYL ETHER	France and Monaco	France	Canada
Exfoliator	PERFLUOROHEXANE, PERFLUORODECALIN, PERFLUOROMETHYLCYCLOPENTANE	France and Monaco	France	France
Eye moisturiser 1	PTFE	France and Monaco	France	Canada
Eye moisturiser 2	TRIFLUOROACETYL TRIPEPTIDE-2	Unknown	Belgium	UK, France
Facial moisturiser	POLYPERFLUOROMETHYLISOPROPYL ETHER	France and Monaco	USA	Canada
Mask 1	ETHYL PERFLUOROBUTYL ETHER, ETHYL PERFLUOROISOBUTYL ETHER	Unknown	USA	UK
Mask 2	METHYL PERFLUOROBUTYL ETHER, METHYL PERFLUOROISOBUTYL ETHER, PERFLUOROHEXANE, PERFLUOROPERHYDROPHENANTHRENE, PERFLUORODECALIN, PERFLUORODIMETHYLCYCLOHEXANE,	Unknown	USA	UK, Belgium
Mask 3	METHYL PERFLUOROISOBUTYL ETHER	Unknown	Corea	UK
Moisturiser/Face cream 1	ACETYL TRIFLUOROMETHYLPHENYL VALYLGLYCINE	France and Monaco	France	France
Moisturiser/Face cream 2	POLYPERFLUOROMETHYLISOPROPYL ETHER	France and Monaco	USA	Canada
Serum and treatment 1	TRIFLUOROACETYL TRIPEPTIDE-2	Finland	Finland	Finland

Serum and treatment 2	ACETYL TRIFLUOROMETHYLPHENYL VALYLGLYCINE	France and Monaco	France	Canada
Blank samples (no PFAS on the ingredient list)	N/A	N/A	N/A	N/A
Eye liner, pen 1	N/A	UPC-A compatible - United States and Canada	China	USA, Sweden
Treatment 2	N/A	Italy, San Marino and Vatican City	USA	UK

Table 26: PFAS (native and internal standards (IS)) included in this study and mass spectrometer (MS) detection/quantification parameters.

Target Analyte	**Precursor Ion**	**Quantitative Product ion**	**Qualitative product ion**	**Internal standard**	**Internal standard transition channels**	**Native PFAS used for quantification**
PFBA	213	169	149	$^{13}C_4$ -PFBA	217>172	PFBA
PFPeA	263	219	169	$^{13}C_5$-PFPeA	266>223	PFPeA
PFHxA	313	269	119	$^{13}C_2$-PFHxA	315>270	PFHxA
PFHpA	363	319	169	$^{13}C_4$-PFHpA	367>322	PFHpA
PFOA	413	169	369	$^{13}C_4$-PFOA	417>372	PFOA
PFNA	463	419	219	$^{13}C_5$-PFNA	468>423	PFNA
PFDA	513	469	269	$^{13}C_2$-PFDA	515>470	PFDA
PFUnDA	563	519	269	$^{13}C_2$-PFUnDA	565>520	PFUnDA
PFDoDA	613	569	169	$^{13}C_2$-PFDoDA	615>570	PFDoDA
PFTriDA	663	619	169	$^{13}C_2$-PFDoDA	615>570	PFDoDA
PFTeDA	712.9	669	169	$^{13}C_2$-PFDoA	615>570	PFTeDA
PFHxDA	813	769	169	$^{13}C_2$-PFDoDA	615> 570	PFHxDA
PFOcDA	913	869	169	$^{13}C_2$-PFDoDA	615> 570	PFOcDA
PFBS	299	80	99	$^{18}O_2$-PFHxS	403>84	PFBS
PFHxS	399	80	99	$^{18}O_2$-PFHxS	403>84	PFHxS
PFOS	498.9	80	99	$^{13}C_4$-PFOS	503>80	PFOS
PFDS	598.9	80	99	$^{13}C_4$-PFOS	503>80	PFDS
FOSA	497.9	78	169	$^{13}C_8$-FOSA	506>78	FOSA
6:2/6:2 diPAP	789	443	97	$^{13}C_4$-6:2/6:2	793>445	6:2/6:2 diPAP
6:2/8:2 diPAP	889	443	543	$^{13}C_4$-6:2/6:2	793>445	6:2/8:2 diPAP
8:2/8:2 diPAP	989	543	97	$^{13}C_4$-8:2/8:2	993>545	8:2/8:2 diPAP

Table 27: Mobile phase gradient profile for PFASs measured by LC-MS/MS.

Time (min)	LC Gradient Program Mobile phase A (%)*1	LC Gradient Program Mobile phase B (%)*2	LC Flow Rate (ml/min)
0.0	90	10	0.4
0.5	90	10	0.4
5	20	80	0.4
5.1	0	100	0.4
6.6	0	100	0.4
8	0	100	0.55
10	90	10	0.4

*1 *Mobile phase A: 90 % water and 10 % acetonitrile containing 2 mM ammonium acetate.*
*2 *Mobile phase B: 100 % acetonitrile containing 2 mM ammonium acetate.*

Table 28: Overall average, minimum and maximum of the TF concentration (ng F/g) per product category (Decorative Cosmetics, Hair Care and Skin Care) that went into the emission calculations (in bold); and average, minimum and maximum concentration per sub-category (sub-categories separated by thin horizontal lines) based on average measured concentrations per sample (i.e. Sub Category (ID));.LOD=limit of detection. Note: "Facial moisturizer" (name of a male product sub-category) falling under the "Male grooming" product category in CosmEthics has been pooled with the female according products (Moisturiser/Face cream, falling under "Facial Care" as a product category in CosmEthics), as these both would fall under Skin Care in Cosmetics Europe.

Product category	Sub Category (ID)	Average measured TF (mg F/g)	Average TF (mg F/g)	min TF (mg F/g)	max TF (mg F/g)	LOD (mg F/g)
Decorative Cosmetics (total)	N/A	N/A	**1.77**	**0.016**	**6.01**	N/A
Decorative Cosmetics	Blush/Bronzer/Contour 1	5.14	2.95	0.90	5.14	0.022
Decorative Cosmetics	Blush/Bronzer/Contour 2	3.26	2.95	0.90	5.14	0.012
Decorative Cosmetics	Blush/Bronzer/Contour 3	0.90	2.95	0.90	5.14	0.310
Decorative Cosmetics	Blush/Bronzer/Contour 4	2.49	2.95	0.90	5.14	0.014
Decorative Cosmetics	Concealer 1	0.80	0.41	0.03	0.80	0.002
Decorative Cosmetics	Concealer 2	0.03	0.41	0.03	0.80	0.016
Decorative Cosmetics	Eye liner, pen 2	0.17	0.17	0.17	0.17	0.004
Decorative Cosmetics	Eye shadow 1	2.21	2.23	0.72	5.35	0.021
Decorative Cosmetics	Eye shadow 2	5.35	2.23	0.72	5.35	0.028
Decorative Cosmetics	Eye shadow 3	0.72	2.23	0.72	5.35	0.020
Decorative Cosmetics	Eye shadow 4	0.99	2.23	0.72	5.35	0.011
Decorative Cosmetics	Eye shadow 5	1.90	2.23	0.72	5.35	0.015
Decorative Cosmetics	Eyeliner liquid/gel	0.35	0.35	0.35	0.35	0.028
Decorative Cosmetics	Foundation/BB Cream 1	0.02	1.23	0.02	3.31	0.001
Decorative Cosmetics	Foundation/BB Cream 2	0.18	1.23	0.02	3.31	0.002
Decorative Cosmetics	Foundation/BB Cream 3	1.41	1.23	0.02	3.31	0.042
Decorative Cosmetics	Foundation/BB Cream 4	3.31	1.23	0.02	3.31	1.310
Decorative Cosmetics	Lip liner, pen 1	0.52	0.73	0.52	0.94	0.010
Decorative Cosmetics	Lip liner, pen 2	0.94	0.73	0.52	0.94	0.004
Decorative Cosmetics	Loose powder	6.01	6.01	6.01	6.01	0.028
Decorative Cosmetics	Mascara	3.54	3.54	3.54	3.54	0.063
Decorative Cosmetics	Pressed Powder 1	0.23	0.13	0.02	0.23	0.012
Decorative Cosmetics	Pressed Powder 2	0.02	0.13	0.02	0.23	0.007
Hair Care (total)	N/A	N/A	**0.19**	***0.0012***	**0.50**	N/A
Hair Care	Hair spray 1	0.01	0.008	*0.0012*	0.01	0.0003
Hair Care	Hair spray 2	<LOD	0.008	*0.0012*	0.01	0.001
Hair Care	Shampoo	0.50	0.50	0.50	0.50	0.231
Hair Care	Styling cream	0.20	0.20	0.20	0.20	0.011
Hair Care	Treatment 1	0.03	0.03	0.03	0.03	0.012
Skin Care (total)	N/A	N/A	**3.83**	**0.0075**	**13.79**	N/A
Skin Care	After shave	3.67	3.67	3.67	3.67	0.007
Skin Care	Anti-age cream 1	0.08	1.35	0.08	3.80	0.019
Skin Care	Anti-age cream 2	0.18	1.35	0.08	3.80	0.014
Skin Care	Anti-age cream 3	3.80	1.35	0.08	3.80	0.023
Skin Care	Exfoliator	13.79	13.79	13.79	13.79	0.715

Skin Care	Eye moisturiser 1	4.24	2.12	0.01	4.24	0.022
Skin Care	Eye moisturiser 2	0.01	2.12	0.01	4.24	0.002
Skin Care	Mask 1	<LOD	3.74	<LOD	10.58	0.035
Skin Care	Mask 2	10.58	3.74	<LOD	10.58	0.042
Skin Care	Mask 3	0.60	3.74	<LOD	10.58	0.038
Skin Care	Facial moisturizer	2.58	2.03	0.05	3.47	0.006
Skin Care	Moisturiser/Face cream 1	0.05	2.03	0.05	3.47	0.034
Skin Care	Moisturiser/Face cream 2	3.47	2.03	0.05	3.47	0.074
Skin Care	Serum and treatment 1	0.07	0.08	0.07	0.10	0.001
Skin Care	Serum and treatment 2	0.10	0.08	0.07	0.10	0.013

Table 29: Overall average, minimum and maximum of the EOF concentration (ng F/g) per product category (Decorative Cosmetics, Hair Care and Skin Care) that went into the emission calculations (in bold); and average, minimum and maximum concentration per sub-category (sub-categories separated by thin horizontal lines) based on average measured concentrations per sample (i.e. Sub Category (ID));.LOD=limit of detection. Values are reported un-rounded (for the purposes of auditing), but only 3 values should be considered significant.

Product category	Sub Category (ID)	Average measured EOF (ng F/g)	Average EOF (ng F/g)	min EOF (ng F/g)	max EOF (ng F/g)	LOD (ng F/g)
Decorative Cosmetics (total)	N/A	N/A	**549516**	***325***	**4925752**	N/A
Decorative Cosmetics	Concealer 1	3912	2118	*325*	3912	325
Decorative Cosmetics	Concealer 2	<MDL	2118	*325*	3912	325
Decorative Cosmetics	Eye liner, pen 2	11423	11423	11423	11423	325
Decorative Cosmetics	Eye shadow 5	<MDL	*325*	*325*	*325*	325
Decorative Cosmetics	Foundation/BB Cream 3	1584131	3254941	1584131	4925752	325
Decorative Cosmetics	Foundation/BB Cream 4	4925752	3254941	1584131	4925752	325
Decorative Cosmetics	Lip liner, pen 1	9417	9417	9417	9417	325
Decorative Cosmetics	Pressed Powder 2	18870	18870	18870	18870	325
Hair Care (total)	N/A	N/A	**102228**	**14654**	**189803**	N/A
Hair Care	Shampoo	14654	14654	14654	14654	325
Hair Care	Styling cream	189803	189803	189803	189803	325
Skin Care (total)	N/A	N/A	**5358**	***162***	**36583**	N/A
Skin Care	After shave	374	374	374	374	325
Skin Care	Anti-age cream 2	1258	1258	1258	1258	325
Skin Care	Exfoliator	<MDL	*162*	*162*	*162*	162
Skin Care	Mask 1	2695	19639	2695	36583	325
Skin Care	Mask 2	36583	19639	2695	36583	162

Table 30: Overall average, minimum and maximum of the ∑PFCA concentration (ng ∑PFCA/g) per product category (Decorative Cosmetics, Hair Care and Skin Care) that went into the emission calculations (in bold); and average, minimum and maximum concentration per sub-category (sub-categories separated by thin horizontal lines) based on average measured concentrations per sample (i.e. Sub Category (ID)); Note: average concentrations equal to zero, if all PFCA concentrations of the ∑PFCA were below the limit of detection (<LOD). Values are partly reported un-rounded (for the purposes of auditing), but only 3 values should be considered significant.

Product category	Sub Category (ID)	Average ∑PFCAs (ng/g)	Average ∑PFCAs (ng/g)	min ∑PFCAs (ng/g)	max ∑PFCAs (ng/g)
Decorative Cosmetics (total)	N/A	N/A	**51.2**	**0.00**	**341**
Decorative Cosmetics	Concealer 1	**77.4**	38.7	0.00	77.4
Decorative Cosmetics	Concealer 2	0.00	38.7	0.00	77.4
Decorative Cosmetics	Eye liner, pen 2	0.00	0.00	0.00	0.00
Decorative Cosmetics	Eye shadow 5	**10.2**	10.2	10.2	10.2
Decorative Cosmetics	Foundation/BB Cream 3	**341**	252	163	341
Decorative Cosmetics	Foundation/BB Cream 4	**163**	252	163	341
Decorative Cosmetics	Lip liner, pen 1	**5.93**	5.93	5.93	5.93
Decorative Cosmetics	Pressed Powder 2	0.00	0.00	0.00	0.00
Hair Care (total)	N/A	N/A	**0.00**	**0.00**	**0.00**
Hair Care	Shampoo	0.00	0.00	0.00	0.00
Hair Care	Styling cream	0.00	0.00	0.00	0.00
Skin Care (total)	N/A	N/A	**1248**	**0.00**	**9559**
Skin Care	After shave	0.00	0.00	0.00	0.00
Skin Care	Anti-age cream 2	0.00	0.00	0.00	0.00
Skin Care	Exfoliator	0.00	0.00	0.00	0.00
Skin Care	Mask 1	**425**	4992	425	9559
Skin Care	Mask 2	**9559**	4992	425	9559

Table 31: PFAS containing products and product versions by product categories and sub-categories and share of PFAS containing products/versions in %; classification based on the CosmEthics database, entire database included (products and product versions, EU/EEA and non-EU/EEA).

Product category (CosmEthics) *[1]	Sub-category (CosmEthics) *[2]	Total number of products, including versions*[1]	Total number of PFAS containing products, including versions	% share PFAS containing products, including versions
Make up (total)	N/A	**26 899**	**1102**	**4.09**
Make up	Blush/Bronzer/Contour	1483	75	5.05
Make up	Concealer	1227	64	5.21
Make up	Eye shadow	3735	231	6.18
Make up	Eyebrow pen/gel/powder	944	48	5.08
Make up	Eyeliner liquid/gel	359	2	0.55
Make up	Eyeliner, pen	600	27	4.50
Make up	Foundation/BB Cream*[3]	5051	324	6.41
Make up	Highlighter	544	14	2.57
Make up	Lip gloss	1554	1	0.06
Make up	Lip liner, pen	809	36	4.44
Make up	Lipstick	4115	46	1.11
Make up	Loose powder	464	19	4.09
Make up	Make up remover	1423	2	0.14
Make up	Mascara	1142	43	3.76
Make up	Pressed powder	1497	113	7.54
Make up	Tinted lip balm	274	1	0.36
Make up	Other	1408	44	3.12
Facial care (total)	N/A	**23 059**	**285**	**1.23**
Facial care	Anti-age cream	1043	35	3.35
Facial care	Cleansers	4257	7	0.16
Facial care	Exfoliators	1015	3	0.29
Facial care	Eye gel	213	3	1.40
Facial care	Eye moisturiser	849	26	3.06
Facial care	Lip balm	1473	2	0.13
Facial care	Masks	3073	46	1.49
Facial care	Moisturisers/Face cream	5489	103	1.87
Facial care	Self tanner face	118	1	0.84
Facial care	Serums and treatments	2532	44	1.73
Facial care	Sunscreen	535	3	0.56
Facial care	Toners and mists	1501	2	0.13
Facial care	Other	881	9	1.02
Male grooming (total)	N/A	**4394**	**52**	**1.18**
Male grooming	After shave	400	5	1.25

Male grooming	Creams and lotions	99	2	2.02
Male grooming	Deodorant	1133	4	0.35
Male grooming	Eau de Toilette	317	1	0.31
Male grooming	Facial care	160	4	2.50
Male grooming	Facial moisturizers	215	6	2.79
Male grooming	Shaving foam	205	2	0.97
Male grooming	Shaving gel	302	27	8.94
Male grooming	Other	301	1	0.33
Hair care (total)	N/A	**22135**	**145**	**0.65**
Hair care	Conditioner	3917	16	0.40
Hair care	Dry shampoo	434	14	3.22
Hair care	Hair gel	478	1	0.20
Hair care	Hair spray	2172	67	3.08
Hair care	Holding or styling foam or mousse	733	6	0.81
Hair care	Masks	1111	4	0.36
Hair care	Serum/oil	617	4	0.64
Hair care	Shampoo	7587	13	0.17
Hair care	Styling cream	680	3	0.44
Hair care	Thickening product	128	4	3.12
Hair care	Treatments	1510	10	0.66
Hair care	Other	796	3	0.37
Hands and Nails (total)	N/A	**7869**	**26**	**0.33**
Hands and Nails	Creams and lotions	3063	5	0.16
Hands and Nails	Nail polish	2504	20	0.79
Hands and Nails	Other nail or cuticle products	270	1	0.37
Tanning (total)	N/A	**2717**	**7**	**0.25**
Tanning	After sun	384	1	0.26
Tanning	Self-tanner	590	3	0.50
Tanning	Sunscreen	1667	3	0.17
Bath and Body Products (total)	N/A	**25 089**	**38**	**0.15**
Bath and Body Products	Anti cellulite	152	1	0.65
Bath and Body Products	Body lotion/Balm/Cream/Gel	7467	11	0.14
Bath and Body Products	Body oil	1239	1	0.08
Bath and Body Products	Deodorant	3452	5	0.14
Bath and Body Products	Hair removal	246	2	0.81
Bath and Body Products	Shaving foam	64	6	9.37
Bath and Body Products	Soaps	2083	2	0.09
Bath and Body Products	Other	1846	10	0.54
Mouth (total)	N/A	**2081**	**2**	**0.09**
Mouth	Toothpaste	1494	1	0.06

Mouth	Other	116	1	0.86
Baby and Children's Products (total)	N/A	**2610**	**1**	**0.03**
Baby and Children's Products	Sunscreen	359	1	0.27
Fragrances (total)	N/A	**3455**	**0**	**0.00**
Foot care (total)	N/A	**931**	**0**	**0.00**

**[1]Product categories (total) data refers to total number of products and product versions, the total product number of products and product versions even includes the number of products/versions of the non-listed sub-categories, i.e. the ones without any PFAS containing product.*
**[2] Only sub-categories with at least one PFAS containing product are listed. Not shown within the different product categories are the following sub-categories: <u>Facial care:</u> After sun gel, After sun moisturiser; <u>Male grooming:</u> Body lotion, Cleansers/Scrubs, Eau de Parfum, Eye gel, Hair styling, Hands and Nails, Lip balm, Shower gel, Soap; <u>Hair care:</u> Hair colour, Hair wax, Scalp Care; <u>Hands and Nails:</u> Hand sanitizer, Hand wash, Nail polish remover, Other; <u>Tanning:</u> Other; <u>Bath and Body Products:</u> Antiseptic, Bath foam/oil/salt, Body butter, Body wash, Exfoliators/Body scrub, Intime care, Massage oil, Wipes; <u>Mouth:</u> Mouthwash; <u>Baby and Children's Products:</u> Baby Oil, Baby wash, Butter, Conditioner, Cream, Diaper Ointment, Lotion, Other baby products, Powder, Shampoo, Toothpaste, Wipes, Other; <u>Fragrances:</u> Eau de Toilette, Perfume/Parfum/Eau de Parfum, Other; <u>Foot care:</u> Foot cream, Foot lotion, Foot scrubs, Foot wash/bath, Other*
**[3] BB cream = synonymous use: Blemish Balm, Beauty Balm or Beauty Benefit (pigmented day cream/foundation/moisturizing/skin care product).*

Table 32: INCI name list of all INCI names (registered in CosIng) that were identified as PFAS or PFASs during the course of this report.

INCI name list
ACETYL SH-DECAPEPTIDE-4 SP AMIDE TRIFLUOROACETATE
ACETYL TRIFLUOROMETHYLPHENYL VALYLGLYCINE
ACRYLATES/METHOXY PEG-23 METHACRYLATE/PERFLUOROOCTYL ETHYL ACRYLATE COPOLYMER
ACRYLATES/PERFLUOROHEXYLETHYL METHACRYLATE COPOLYMER
ACRYLATES/TRIFLUOROPROPYLMETHACRYLATE/POLYTRIMETHYL SILOXYMETHACRYLATE COPOLYMER
ACRYLIC ACID/PERFLUOROHEXYLETHYL ACRYLATE CROSSPOLYMER
ADAMANTANYLCARBOXAMIDO TRIFLUOROMETHYLBENZONITRILE
AMMONIUM C6-16 PERFLUOROALKYLETHYL PHOSPHATE
AMMONIUM C9-10 PERFLUOROALKYLSULFONATE
AMMONIUM PERFLUOROHEXYL ETHYLPHOSPHATES
AMP-C8-18 PERFLUOROALKYLETHYL PHOSPHATE
BEHENYL METHACRYLATE/PERFLUOROOCTYLETHYL METHACRYLATE COPOLYMER
BIOTINOYL HISTIDYL D-TRYPTOPHANYL DIPEPTIDE-29 D-PHENYLALANYL LYSINAMIDE TRIFLUOROACETATE
BUTYL ACRYLATE/C6-14 PERFLUOROALKYLETHYL ACRYLATE/MERCAPTOPROPYL DIMETHICONE COPOLYMER
C20-28 ALKYL PERFLUORODECYLETHOXY DIMETHICONE
C4-14 PERFLUOROALKYLETHOXY DIMETHICONE
C4-18 PERFLUOROALKYLETHYL THIOHYDROXYPROPYLTRIMONIUM CHLORIDE
C6-12 PERFLUOROALKYLETHANOL
C6-14 PERFLUOROALKYLETHYL ACRYLATE
C6-14 PERFLUOROALKYLETHYL ACRYLATE/HEMA COPOLYMER
C8-18 FLUOROALCOHOL PHOSPHATE
C9-13 FLUOROALCOHOL
C9-15 FLUOROALCOHOL PHOSPHATE
CALCIUM TRIFLUOROACETATE
CHLOROTRIFLUOROPROPENE
CLOFLUCARBAN
DEA-C8-18 PERFLUOROALKYLETHYL PHOSPHATE
DEA-PERFLUOROHEXYL ETHYLPHOSPHATES
DEA-POLYPERFLUOROETHOXYMETHOXY PEG-2 PHOSPHATE
DECAFLUOROPENTANE
DIETHYLAMINOETHYL METHACRYLATE/HEMA/PERFLUOROHEXYLETHYL METHACRYLATE CROSSPOLYMER
DIFLUOROCYCLOHEXYLOXYPHENOL
DIMETHICONOL FLUOROALCOHOL DILINOLEIC ACID
DIOCTYLDODECYL FLUOROHEPTYL CITRATE
ETHYL NITROTRIFLUOROMETHYLPHENYL CITRAMALAMIDE
ETHYL PERFLUOROBUTYL ETHER
ETHYL PERFLUOROISOBUTYL ETHER
ETHYL TAFLUPROSTAMIDE

ETHYL TRAVOPROSTAMIDE
EUROPIUM TRIS(TRIFLUOROTHIENYLBUTANEDIONE) BIS(TRIPHENYLPHOSPHINE OXIDE)
FLUORO C2-8 ALKYLDIMETHICONE
FLUOROSALAN
FLURIDIL
HC YELLOW NO. 13
HEXAFLUOROPROPYLENE/TETRAFLUOROETHYLENE COPOLYMER
HYDROCHLOROFLUOROCARBON 142B
HYDROCHLOROFLUOROCARBON 22
HYDROFLUOROCARBON 134A
HYDROFLUOROCARBON 152A
HYDROFLUOROCARBON 227EA
HYDROGEN TRIFLUOROPROPYL DIMETHICONE
ISOBUTYL METHACRYLATE/TRIFLUOROETHYLMETHACRYLATE/BIS-HYDROXYPROPYL DIMETHICONE ACRYLATE COPOLYMER
ISOBUTYLMETHACRYLATE/TRIFLUOROETHYLMETHACRYLATE/BIS-HYDROXYPROPYL DIMETHICONE ACRYLATE COPOLYMER
ISODODECYL/PERFLUORONONYLETHYL DIMER DILINOLEATE/CITRATE
ISOPROPYL TITANIUM TRIISOSTEARATE/PERFLUOROOCTYL TRIETHOXYSILANE CROSSPOLYMER
KETOTRAVOPROST
METHYL PERFLUORO BUTYL/ISOBUTYL ETHER
METHYL PERFLUOROBUTYL ETHER
METHYL PERFLUOROISOBUTYL ETHER
NORTAFLUPROST
OCTAFLUOROPENTYL METHACRYLATE
OCTAPEPTIDE-29 TRIFLUOROACETATE
OLIGOPEPTIDE-177 TRIFLUOROACETATE
PEG-10 ACRYLATE/PERFLUOROHEXYLETHYL ACRYLATE COPOLYMER
PEG-10 NONAFLUOROHEXYL DIMETHICONE COPOLYMER
PEG-10 TRIFLUOROPROPYL DIMETHICONE COPOLYMER
PEG-4 TRIFLUOROPROPYL DIMETHICONE COPOLYMER
PEG-8 TRIFLUOROPROPYL DIMETHICONE COPOLYMER
PENTAFLUOROPROPANE
PENTAPEPTIDE-34 TRIFLUOROACETATE
PENTAPEPTIDE-35
PERFLUORO DIMETHYLETHYLPENTANE
PERFLUORO T-BUTYLCYCLOHEXANE
PERFLUOROBUTOXYDIGLYCOL DIFLUOROETHOXY PROPYL TRIMETHOXYSILANE
PERFLUOROBUTYLCYCLOHEXANE
PERFLUOROBUTYLETHYL DIMETHICONE
PERFLUOROCAPRYLYL BROMIDE
PERFLUOROCAPRYLYL TRIETHOXYSILYLETHYL METHICONE
PERFLUOROCYCLOHEXYLMETHANOL
PERFLUORODECALIN
PERFLUORODIMETHYLCYCLOHEXANE

PERFLUOROHEPTANE
PERFLUOROHEXANE
PERFLUOROHEXYL ETHYLPHOSPHONIC ACID
PERFLUOROHEXYLETHYL DIMETHYLBUTYL ETHER
PERFLUOROISOHEXANE
PERFLUOROMETHYLCYCLOHEXANE
PERFLUOROMETHYLCYCLOPENTANE
PERFLUOROMETHYLDECALIN
PERFLUORONONYL DIMETHICONE
PERFLUORONONYL DIMETHICONE/METHICONE/AMODIMETHICONE CROSSPOLYMER
PERFLUORONONYL OCTYLDODECYL GLYCOL GRAPESEEDATE
PERFLUORONONYL OCTYLDODECYL GLYCOL MEADOWFOAMATE
PERFLUORONONYLETHYL CARBOXY PEG-7 DIMETHICONE PHOSPHATE
PERFLUORONONYLETHYL CARBOXYDECYL BEHENYL DIMETHICONE
PERFLUORONONYLETHYL CARBOXYDECYL HEXACOSYL DIMETHICONE
PERFLUORONONYLETHYL CARBOXYDECYL LAURYL DIMETHICONE
PERFLUORONONYLETHYL CARBOXYDECYL LAURYL/BEHENYL DIMETHICONE
PERFLUORONONYLETHYL CARBOXYDECYL PEG-10 DIMETHICONE
PERFLUORONONYLETHYL CARBOXYDECYL PEG-8 DIMETHICONE
PERFLUORONONYLETHYL DIMETHICONE/METHICONE COPOLYMER
PERFLUORONONYLETHYL PEG-8 DIMETHICONE
PERFLUORONONYLETHYL PEG-8 PHENYLISOPROPYL DIMETHCONE
PERFLUORONONYLETHYL STEARYL DIMETHICONE
PERFLUOROOCTYL TRIETHOXYSILANE
PERFLUOROOCTYLETHYL TRIETHOXYSILANE
PERFLUOROOCTYLETHYL TRIMETHOXYSILANE
PERFLUOROOCTYLETHYL TRISILOXANE
PERFLUOROOCTYLETHYL/DIPHENYL DIMETHICONE COPOLYMER
PERFLUOROPERHYDROBENZYL TETRALIN
PERFLUOROPERHYDROFLUORENE
PERFLUOROPERHYDROPHENANTHRENE
PERFLUOROPROPANE
PERFLUOROPROPYLENE
PERFLUOROPROPYLENE/VINYLIDENE DIFLUORIDE COPOLYMER
PERFLUOROTETRALIN
POLYACRYLATE-37
POLYACRYLATE-48
POLYCHLOROTRIFLUOROETHYLENE
POLYPERFLUOROETHOXYMETHOXY DIFLUOROETHYL PEG DIISOSTEARATE
POLYPERFLUOROETHOXYMETHOXY DIFLUOROETHYL PEG ETHER
POLYPERFLUOROETHOXYMETHOXY DIFLUOROETHYL PEG ETHER DIISOSTEARATE
POLYPERFLUOROETHOXYMETHOXY DIFLUOROETHYL PEG PHOSPHATE
POLYPERFLUOROETHOXYMETHOXY DIFLUOROHYDROXYETHYL ETHER
POLYPERFLUOROETHOXYMETHOXY DIFLUOROMETHYL DISTEARAMIDE
POLYPERFLUOROETHOXYMETHOXY DIFLUOROMETHYL ETHER

POLYPERFLUOROETHOXYMETHOXY PEG-2 PHOSPHATE
POLYPERFLUOROISOPROPYL ETHER
POLYPERFLUOROMETHYLISOPROPYL ETHER
POLYPERFLUOROPERHYDROPHENANTHRENE
POLYSILICONE-10
POLYSILICONE-7
POLYTETRAFLUOROETHYLENE ACETOXYPROPYL BETAINE
POLYURETHANE-26
POLYURETHANE-27
POLYVINYLIDENE DIFLUORIDE
POTASSIUM PERFLUOROHEXYL ETHYLPHOSPHATE
PTFE
S-ENTEROBACTERIA PHAGE T4 DECAPEPTIDE-1 SP TRIFLUOROACETATE
SH-HEPTAPEPTIDE-4 SP TRIFLUOROACETATE
SH-OLIGOPEPTIDE-73 AMIDE TRIFLUOROACETATE
SH-TETRAPEPTIDE-38 TRIFLUOROACETATE
SODIUM FORMYLHIPPURATE TRIFLUOROACETYLISOBUTYL DIPEPTIDE-42 AMIDE
SODIUM PERFLUOROHEXYL ETHYLPHOSPHONATE
STEARYL METHACRYLATE/PERFLUOROOCTYLETHYL METHACRYLATE COPOLYMER
TAFLUPROST
TEA-C8-18 PERFLUOROALKYLETHYL PHOSPHATE
TEA-PERFLUOROHEXYL ETHYLPHOSPHATES
TETRADECYL AMINOBUTYROYLVALYLAMINOBUTYRIC UREA TRIFLUOROACETATE
TETRAFLUOROPROPENE
TRIFLUOROACETYL TRIPEPTIDE-2
TRIFLUOROETHYL METHACRYLATE
TRIFLUOROMETHYL C1-4 ALKYL DIMETHICONE
TRIFLUOROMETHYL DEHYDROLATANOPROST
TRIFLUOROMETHYLBIPYRIDYL BROMOBENZIMIDAZOLE
TRIFLUOROMETHYLPHENETHYL MESALAZINE
TRIFLUOROPROPYL CYCLOPENTASILOXANE
TRIFLUOROPROPYL CYCLOTETRASILOXANE
TRIFLUOROPROPYL CYCLOTRISILOXANE
TRIFLUOROPROPYL DIMETHICONE
TRIFLUOROPROPYL DIMETHICONE/PEG-10 CROSSPOLYMER
TRIFLUOROPROPYL DIMETHICONE/TRIFLUOROPROPYL DIVINYLDIMETHICONE CROSSPOLYMER
TRIFLUOROPROPYL DIMETHICONE/VINYL TRIFLUOROPROPYL DIMETHICONE/SILSESQUIOXANE CROSSPOLYMER
TRIFLUOROPROPYL DIMETHICONOL
TRIFLUOROPROPYL METHICONE
TRIFLUOROPROPYLDIMETHYL/TRIMETHYLSILOXYSILICATE
TRIFLUOROPROPYLDIMETHYLSILOXY/TRIMETHYLSILOXY SILSESQUIOXANE
TRIMETHYL TRIFLUOROMETHYLINDOLINO PIPERIDINYLSPIRONAPHTHOOXAZINE
VINYLIDENE DIFLUORIDE

Table 33: INCI substance list of all INCI substances (registered in CosIng) that were identified as PFAS or PFASs during the course of this report.

INCI substance list
AMMONIUM HEPTADECAFLUOROOCTANESULFONATE
AMMONIUM NONADECAFLUORODECANOATE
AMMONIUM PERFLUOROOCTANE SULFONATE
DIETHANOLAMINE PERFLUOROOCTANE SULFONATE
HEPTADECAFLUOROOCTANE-1-SULFONIC ACID
LITHIUM HEPTADECAFLUOROOCTANESULFONATE
LITHIUM PERFLUOROOCTANE SULFONATE
NONADECAFLUORODECANOIC ACID
PERFLUOROOCTANE SULFONIC ACID
POTASSIUM HEPTADECAFLUOROOCTANE-1-SULFONATE
POTASSIUM PERFLUOROOCTANESULFONATE
SODIUM NONADECAFLUORODECANOATE

Table 34: PFAS INCI names and number of cosmetic products with according ingredient found in the ToxFox Database.

PFAS INCI name	Number of products with according ingredient found in the ToxFox Database
PTFE	321
Hydrofluorocarbon 152a	86
C9-15 fluoroalcohol phosphate	76
Perfluorodecalin	70
Perfluorononyl dimethicone	60
Polyperfluoromethylisopropyl ether	55
HC yellow no. 13	16
Trifluoromethyl C1-4 alkyl dimethicone	7
PEG-8 trifluoropropyl dimethicone copolymer	2
Polyperfluoroisopropyl ether	1
Polysilicone-10	1
Polysilicone-7	1

Table 35: PFASs and PFAS INCI names and number of cosmetic products with according ingredient found in the CosmEthics Database (entire database, 2014-2020); Note: Perfluoropolymethylisopropyl ether and Perfluoropolymethylisopropylether are no INCI names.

PFAS	Number of products with the according PFAS found in the CosmEthics Database (entire database, 2014-2020)
PTFE	541
Perfluorooctyl triethoxysilane	232
C9-15 fluoroalcohol phosphate	208
Perfluorononyl dimethicone	111
Hydrofluorocarbon 152a	103
Perfluorodecalin	64
Acetyl trifluoromethylphenyl valylglycine	63
Polyperfluoromethylisopropyl ether	55
Polyperfluoroethoxymethoxy difluoroethyl PEG phosphate	47
Trifluoropropyldimethyl/trimethylsiloxysilicate	42
Methyl perfluorobutyl ether	34
Octafluoropentyl methacrylate	31
Trifluoropropyl Dimethiconol	26
Ammonium C6-16 perfluoroalkylethyl phosphate	25
Trifluoroacetyl tripeptide-2	24
Methyl perfluoroisobutyl ether	23
Tetradecyl aminobutyroylvalylaminobutyric urea trifluoroacetate	21
Perfluorohexane	17
Pentafluoropropane	11

PEG-10 nonafluorohexyl dimethicone copolymer	7
Perfluoroperhydrophenanthrene	7
Polyperfluoroisopropyl ether	7
C8-18 fluoroalcohol phosphate	7
Perfluoropolymethylisopropyl ether (*no INCI name)	6
Trifluoromethyl C1-4 alkyl dimethicone	6
Perfluorodimethylcyclohexane	6
Dioctyldodecyl fluoroheptyl citrate	5
Trifluoropropyl dimethicone	5
Perfluorooctylethyl triethoxysilane	4
PEG-8 trifluoropropyl dimethicone copolymer	3
Polyperfluoroethoxymethoxy difluoroethyl PEG diisostearate	2
Perfluorononylethyl carboxydecyl lauryl dimethicone	2
Ethyl perfluorobutyl ether	2
Perfluoromethylcyclopentane	1
Perfluorononylethyl carboxydecyl PEG-10 dimethicone	1
Tetrafluoropropene	1
Perfluoropolymethylisopropylether (*no INCI name)	1
Pentapeptide-34 trifluoroacetate	1
Ethyl perfluoroisobutyl ether	1
Perfluorononyl dimethicone/methicone/amodimethicone crosspolymer	1

*Table 36: PFASs and PFAS INCI names and number of cosmetic products with according ingredient found in the Kemiluppen database; Note: *Trifluoromethyl dechloro ethylprostenolamide is no INCI name.*

PFAS	Number of products with the according PFAS found in the Kemiluppen Database
PTFE	64
Octafluoropentyl methacrylate	31
C9-15 fluoroalcohol phosphate	27
Perfluorooctyl triethoxysilane	14
Perfluorodecalin	13
Acetyl trifluoromethylphenyl valylglycine	9
Methyl perfluorobutyl ether	9
Polyperfluoromethylisopropyl ether	9
Methyl perfluoroisobutyl ether	7
Ammonium C6-16 perfluoroalkylethyl phosphate	6
Polyperfluoroethoxymethoxy difluoroethyl peg phosphate	5
Perfluorononyl dimethicone	5
Perfluorohexane	4
Polyperfluoroethoxymethoxy difluoromethyl distearamide	4
Tetradecyl aminobutyroylvalylaminobutyric urea trifluoroacetate	4
Trifluoroacetyl tripeptide-2	3
Hydrofluorocarbon 152a	3
Perfluoroperhydrophenanthrene	2
Polyperfluoroisopropyl ether	2
Trifluoromethyl dechloro ethylprostenolamide (*no INCI name)	2
Pentafluoropropane	1
Pentapeptide-34 trifluoroacetate	1
Perfluorodimethylcyclohexane	1
Perfluoromethylcyclopentane	1
Perfluorononylethyl carboxydecyl peg-10 dimethicone	1
Trifluoropropyldimethyl/trimethylsiloxysilicate	1

Table 37: PFASs and PFAS INCI names and ranks based on to the number of cosmetic products (in parentheses) with according ingredient found in the CosmEthics Database for the entire database and EU/EEA barcode products only (both 2014-2020); Note: Perfluoropolymethylisopropyl ether and Perfluoropolymethylisopropylether are no INCI names.

PFAS	Rank PFAS/INCI entire database (number of products)	Rank PFAS/INCI EU/EEA barcode products (number of products)
PTFE	1 (541)	1 (249)
Perfluorooctyl triethoxysilane	2 (232)	2 (184)
C9-15 fluoroalcohol phosphate	3 (208)	3 (107)
Perfluorononyl dimethicone	4 (111)	6 (43)
Hydrofluorocarbon 152a	5 (103)	17.5 (3)
Perfluorodecalin	6 (64)	7.5 (31)
Acetyl trifluoromethylphenyl valylglycine	7 (63)	4 (59)
Polyperfluoromethylisopropyl ether	8 (55)	5 (50)
Polyperfluoroethoxymethoxy difluoroethyl PEG phosphate	9 (47)	7.5 (31)
Trifluoropropyldimethyl/trimethylsiloxysilicate	10 (42)	9 (28)
Methyl perfluorobutyl ether	11 (34)	10 (16)
Octafluoropentyl methacrylate	12 (31)	N/A
Trifluoropropyl Dimethiconol	13 (26)	N/A
Ammonium C6-16 perfluoroalkylethyl phosphate	14 (25)	24 (1)
Trifluoroacetyl tripeptide-2	15 (24)	11 (15)
Methyl perfluoroisobutyl ether	16 (23)	13 (9)
Tetradecyl aminobutyroylvalylaminobutyric urea trifluoroacetate	17 (21)	12 (14)
Perfluorohexane	18 (17)	14 (7)
Pentafluoropropane	19 (11)	15.5 (6)
Polyperfluoroisopropyl ether	21.5 (7)	15.5 (6)
Perfluoroperhydrophenanthrene	21.5 (7)	20 (2)
PEG-10 Nonafluorohexyl dimethicone copolymer	21.5 (7)	N/A
C8-18 fluoroalcohol phosphate	21.5 (7)	N/A
Perfluoropolymethylisopropyl ether (*no INCI name)	25 (6)	20 (2)
Perfluorodimethylcyclohexane	25 (6)	24 (1)
Trifluoromethyl C1-4 alkyl dimethicone	25 (6)	N/A
Dioctyldodecyl fluoroheptyl citrate	27.5 (5)	N/A
Trifluoropropyl dimethicone	27.5 (5)	N/A
Perfluorooctylethyl triethoxysilane	29 (4)	17.5 (3)
PEG-8 trifluoropropyl dimethicone copolymer	30 (3)	N/A

Polyperfluoroethoxymethoxy difluoroethyl PEG diisostearate	32 (2)	20 (2)
Perfluorononylethyl carboxydecyl lauryl dimethicone	32 (2)	N/A
Ethyl perfluorobutyl ether	32 (2)	24 (1)
Pentapeptide-34 trifluoroacetate	37 (1)	24 (1)
Perfluorononyl dimethicone/methicone/amodimethicone crosspolymer	37 (1)	24 (1)
Perfluoromethylcyclopentane	37 (1)	N/A
Perfluorononylethyl carboxydecyl PEG-10 dimethicone	37 (1)	N/A
Tetrafluoropropene	37 (1)	N/A
Perfluoropolymethylisopropylether (*no INCI name)	37 (1)	N/A
Ethyl perfluoroisobutyl ether	37 (1)	N/A

Table 38: Limit of detections (LODs) for the targeted PFAS analysis (LC-MS/MS) and number and kind of samples with detects above the LOD; Conc = if empty cell, varying concentration dependent on the sample if <LOD, all samples below LOD.

Substance	LOD (ng/g)	Conc (ng/g)	number of samples >LOD	Detected in Sample(s)
PFBA	2.66	N/A	7	Foundation/BB Cream 3, Foundation/BB Cream 4, Concealer 1, Mask 1, Mask 2, Eye shadow 5, Lip liner, pen 1;
PFPeA	17.4	N/A	1	Foundation/BB Cream 4
PFHxA	14.6	N/A	3	Foundation/BB Cream 3, Foundation/BB Cream 4, Concealer 1
PFHpA	14.6	N/A	2	Foundation/BB Cream 3, Foundation/BB Cream 4
PFOA	12.6	N/A	1	Foundation/BB Cream 3
PFNA	13.0	N/A	1	Foundation/BB Cream 3
PFDA	13.1	N/A	1	Foundation/BB Cream 3
PFUnDA	13.0	<LOD	0	N/A
PFDoDA	16.7	N/A	1	Foundation/BB Cream 3
PFTrDA	18.2	<LOD	0	N/A
PFTeDA	1.06	N/A	1	Foundation/BB Cream 3
PFHxDA	16.2	<LOD	0	N/A
PFOcDA	13.6	<LOD	0	N/A
PFBS	10.9	<LOD	0	N/A
PFHxS	12.9	<LOD	0	N/A
PFOS	1.46	<LOD	0	N/A
PFDS	14.8	<LOD	0	N/A
PFOSA	14.8	<LOD	0	N/A
6:2/6:2 diPAP	15.4	N/A	2	Foundation/BB Cream 3, Foundation/BB Cream 4
6:2/8:2 diPAP	9.54	N/A	1	Foundation/BB Cream 3
8:2/8:2 diPAP	29.3	N/A	2	Foundation/BB Cream 3, Foundation/BB Cream 4

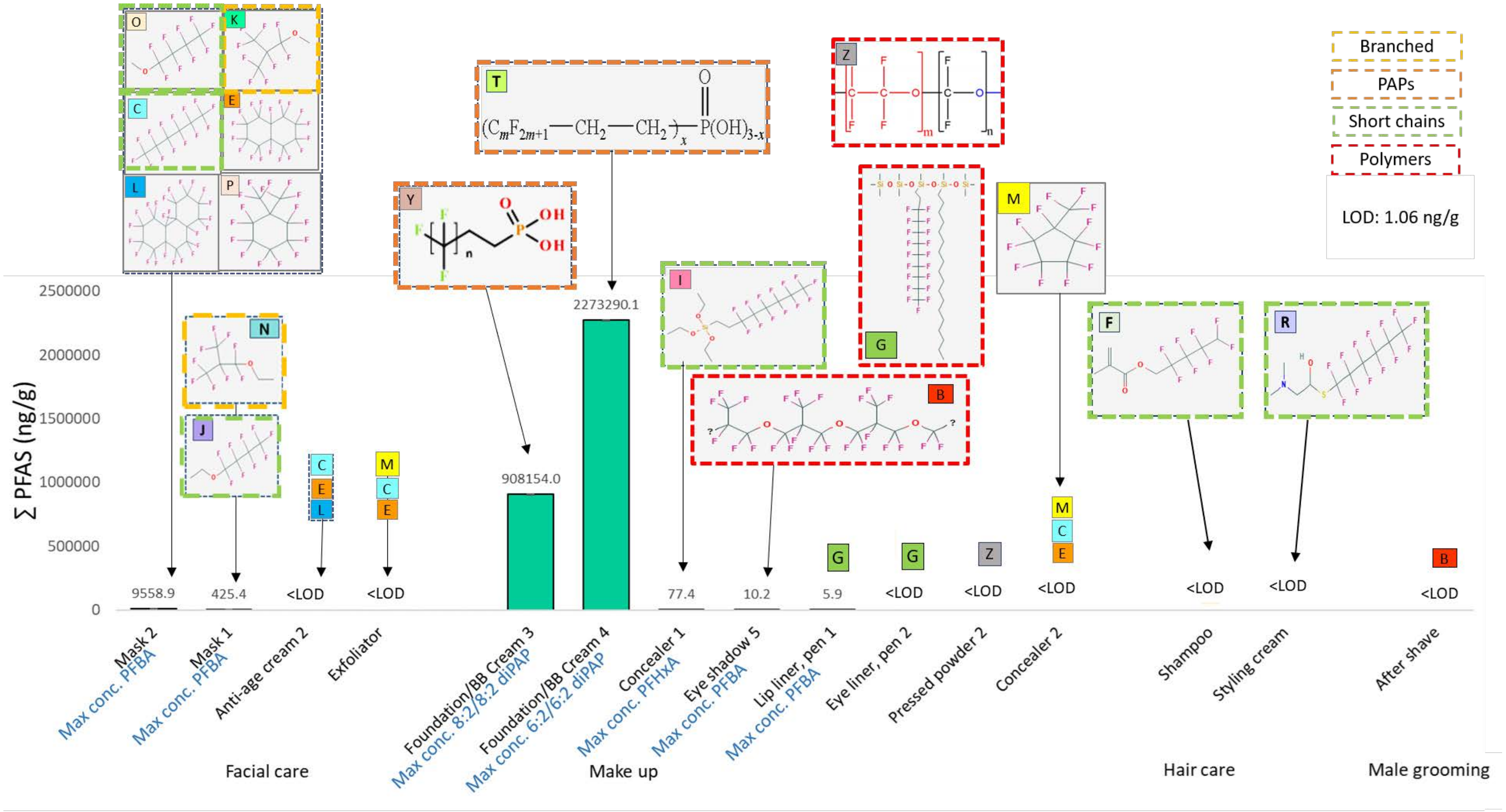

Figure 5: Analysis results of the targeted PFAS measurement, results given as ∑PFAS (ng ∑PFAS/g product) for different cosmetic products and the chemical structures of the INCI names on the ingredient lists of the products; 2-D Structures of PFASs from PubChem; classification into product categories according to CosmEthics; for Cosmetics Europe classification: Facial care = Skin care; Make up = Decorative cosmetics; Hair care = Hair care; Male grooming= this product would also fall under Skin care; concentrations of single PFCAs below the limit of detection (<LOD) treated as equal to zero; <LOD = all analysed PFASs <LOD; LOD given equal to 1.06 ng/g corresponds to lowest LOD (PFTeDA); Max conc. = PFAS with the maximum concentration in the sample; Blue frame= any PFAS; Same letters indicate same PFAS/INCI names. Values are reported un-rounded (for the purposes of auditing), but only 3 values should be considered significant.

Table 39: Fluorine mass balance between TF, EOF and ∑PFAS, results given in % based on fluorine concentrations (µg F/g product) for the cosmetic product samples; "-" indicates that at least one of the measurements resulted in concentrations below the limit of detection (<LOD);classification into product categories according to CosmEthics; for Cosmetics Europe classification: Facial care=Skin care; Make up=Decorative cosmetics; Hair care=Hair care; Male grooming=this product would also fall under Skin care; Values rounded to two significant figures.

Category (CosmEthics)	Sample name (Sub Category (ID))	EOF accounting for TF (%)	∑PFAS accounting for TF (%)	∑PFAS accounting for EOF (%)
Facial care	Mask 2	0.35	0.06	16
Facial care	Mask 1	N/A	N/A	9.9
Facial care	Anti-age cream 2	0.69	N/A	N/A
Facial care	Exfoliator	N/A	N/A	N/A
Make up	Foundation/BB Cream 3	110	42	37
Make up	Foundation/BB Cream 4	150	43	29
Make up	Concealer 1	0.49	0.01	1.3
Make up	Eye shadow 5	N/A	0.0003	N/A
Make up	Lip liner, pen 1	1.8	0.0007	0.04
Make up	Eye liner, pen 2	6.8	N/A	N/A
Make up	Pressed powder 2	120	N/A	N/A
Make up	Concealer 2	N/A	N/A	N/A
Hair care	Shampoo	2.9	N/A	N/A
Hair care	Styling cream	94	N/A	N/A
Male grooming	After shave	0.01	N/A	N/A

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