**Report on**

**the assessment of alternatives to**

**perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride**

**Second draft**

**(6 June 2014)**

1. Disclaimer
2. This report provides hazard-based information on the alternatives with respect to the POP criteria in Annex D of the Stockholm Convention and other relevant hazard criteria. It is important to note that the assessment should not be seen as a comprehensive and in depth assessment of all available information as only a limited number of databases and a limited amount of primary sources have been consulted. Many more alternative substances might be commercially available but detailed information on them was not provided from primary sources.
3. The fact sheets (compiled in the background document), on which this report is based, provide an analysis on a screening level as to whether or not the identified alternatives to PFOS meets the numerical thresholds in Annex D, but does not analyze monitoring data or other evidence as provided for in Annex D. So failure to meet the thresholds should be considered as a likelihood rather than as evidence that the alternative to PFOS is not a POP.
4. Parties may use this report when choosing alternatives to PFOS as a primary source of information. It is strongly recommended that further assessment is carried out within their national framework of authorization. In addition, substances which have been identified here as not likely to be a POP, may still exhibit hazardous characteristics that should be assessed by Parties before considering such substances as a suitable alternative.
5. Background
6. Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOSF) are listed in Annex B of the Stockholm Convention.
7. Paragraph 5 of part III of Annex B to the Stockholm Convention provides that the Conference of the Parties shall evaluate the continued need for PFOS, its salts and PFOSF for the various acceptable purposes and specific exemptions listed in Annex B on the basis of available scientific, technical, environmental and economic information. As stated in paragraph 6 of part III of Annex B to the Convention, the evaluation shall take place no later than in 2015 and every four years thereafter, in conjunction with a regular meeting of the Conference of the Parties.
8. By decision SC-6/4, the Conference of the Parties adopted a process to enable it to undertake the evaluation of PFOS, its salts and PFOSF in accordance with paragraphs 5 and 6 of part III of Annex B to the Convention. In this decision, the Conference of the Parties requested the Persistent Organic Pollutants Review Committee, with the support of the Secretariat, to prepare a report on the assessment of alternatives to PFOS, its salts and PFOSF to assist it in undertaking the evaluation. The report is to be developed on the basis of information on the availability, suitability and implementation of such alternatives and any other relevant information.
9. By decision POPRC-9/5, the Committee adopted terms of reference[[1]](#footnote-1) for the assessment of alternatives to PFOS, its salts and PFOSF and the preparation of a report for the evaluation of information on PFOS, its salts and PFOSF. A working group was established by the Committee to undertake the activities assigned to it in the terms of the reference. The current report was prepared by the working group, with the support of the Secretariat, for consideration by the Committee at its tenth meeting.
10. In accordance with the terms of reference, the assessment of alternatives to PFOS, its salts and PFOSF has been undertaken by applying the methodology used by the Committee in the assessment of alternatives to endosulfan.[[2]](#footnote-2) This methodology consists of a two-step screening process. In the first step, the alternatives to PFOS were subject to prioritization to screen for those alternatives that had a potential to be POPs and to identify those that were unlikely to be POP substances. To prioritize the alternatives, bioaccumulation (B) and persistence (P) (i.e., criteria (c) and (b) of Annex D to the Stockholm Convention on Persistent Organic Pollutants) were used. The second step consisted of a more detailed assessment of the POPs characteristics of alternatives that had been identified as having a potential to be POPs. Substances that had been identified as unlikely to be POP substances were not further analysed in the second step. In the assessment step, alternatives to PFOS were classified according to their likelihood to meet all the criteria of Annex D. The methodology used for the current report is summarised in graphical form in the figure below.

Assessment

(2nd screening)

Class 1

Class 2

Class 3

Class 4

Category I

Category II

Category III

Category IV

Identify alternatives to PFOS

Prioritization

(1st screening)

1. In accordance with the terms of reference, the assessment of alternatives to PFOS, its salts and PFOSF was based on information on alternatives to PFOS, its salts, PFOSF and their related chemicals[[3]](#footnote-3); These alternatives are referred to in this report and hereinafter as alternatives to PFOS.
2. Identification of alternatives
   1. Sources of information
3. Information on the identity of alternatives to PFOS was compiled from the Guidance on alternatives to PFOS, its salts and PFOSF and their related chemicals[[4]](#footnote-4) and the technical paper on the identification and assessment of alternatives to the use of PFOS, its salts and PFOSF and their related chemicals in open applications[[5]](#footnote-5). Information was also obtained from recent publications on this topic[[6]](#footnote-6).
4. In addition, in accordance with decision POPRC-9/5, information on alternatives to PFOS was collected from parties and observers using a format developed by the Committee[[7]](#footnote-7). The information submitted by parties (11) and others (3) is available on the website of the Stockholm Convention[[8]](#footnote-8).
5. In identifying alternatives to POPs, the list of alternatives should include not only alternative chemicals that can be used without major changes in products or processes in which they are used, but also innovative changes in the design of products, industrial processes and other practices that do not require the use of POPS[[9]](#footnote-9). While such changes and practices to substitute for the use of PFOS have been identified for a number applications, as described in the Guidance on alternatives to PFOS, its salts and PFOSF and their related chemicals, only chemical alternatives to PFOS are considered in this report since the methodology used for the assessment is applicable to chemical substances only.
   1. Description of alternatives to PFOS
6. In total 59 alternatives were identified (see Annex I). The alternatives to PFOS can be classified according to their occurrence as components of commercial products that are used in the applications listed as specific exemptions and acceptable purposes in Annex B of the Stockholm Convention (48 alternatives, thereinafter referred to as commercial products), manufacturing intermediates (10 alternatives), or transformation products (4 alternatives). For the purposes of this report, manufacturing intermediates are defined as chemicals used in the manufacture and/or synthesis of other alternatives to PFOS. Transformation products are substances that are formed as a result of abiotic or biotic transformation of another substance.
7. As described in the table in Annex I, the alternatives are used in wide range of applications that are listed as specific exemptions and acceptable purposes in Annex B of the Stockholm Convention. Given the range of applications, the alternatives have diverse functions and can have quite different properties. The alternatives include both fluorinated (23 alternatives) and non-fluorinated (36 alternatives) substances.
8. CAS numbers could not be obtained for a number of alternatives listed in the table in Annex I. This was an impediment for obtaining information about these alternatives as CAS numbers are essential for retrieving substance-specific information from the majority of databases. 12 of the alternatives are commercialised under brand names by various companies. While some are described as polymers by the companies that sell them, information about the exact composition of these products is not publicly available.
9. Prioritization of chemical alternatives to PFOS with respect to the persistent organic pollutant (POP) characteristics
   1. Introduction
10. This chapter addresses the prioritization of alternatives to PFOS to identify those that should be further assessed with respect to their POPs characteristics as defined by the criteria in Annex D of the Stockholm Convention. The methodology used for the prioritization is adapted from the report on the assessment of chemical alternatives to endosulfan[[10]](#footnote-10).
11. Of the 59 alternatives to PFOS described in Annex I, the 55 substances were classified as commercial products or manufacturing intermediates and were included in the prioritization analysis. Components of commercial products that are used in the applications listed as specific exemptions and acceptable purposes in Annex B of the Stockholm Convention are considered to be functional alternatives to PFOS, its salts, PFOSF and their related chemicals. Furthermore, as set out in Part I of Annex B of the Convention, the production and use of PFOS, its salts and PFOSF are allowed for the production of or as an intermediate in the production of other chemicals to be used in the applications listed as acceptable purposes and specific exemptions. Accordingly, alternatives to PFOS classified as manufacturing intermediates (see Annex I) were also included in the prioritization analysis.
12. The following 4 transformation products were not considered in the prioritization step or further analyzed in this report: perfluorohexanoic acid, perfluorohexanoic acid sodium salt, perfluorobutanoic acid, perfluoroheptanoic acid. Although consideration of transformation products may be relevant for the assessment of some alternatives to PFOS, their inclusion is outside of the mandate and scope of the current assessment which is intended to be a rapid screening of alternatives and not an extensive analysis of all possible degradation products of those alternatives.
13. Among the commercial products, the following 8 pesticides were previously included in the assessment of alternatives to endosulfan: abamectine, cypermethrin, chlorpyrifos, deltamethrin, fenitrothion, fipronil, imidacloprid, pyriproxyfen. Data for bioaccumulation, persistence and other hazard endpoints for these substances were obtained from the report on the assessment of alternatives to endosulfan. However, PB-scores (see section 4.3.2) were generated for these substances as part of the current assessment, as a new version of EPISUITE had become available since the endosulfan report was developed, thus leading to slightly different model outcomes.
    1. Endpoint and data selection for prioritisation
14. To obtain a reliable database for prioritization, experimental as well as QSARs/modeled data were collected for each chemical to address bioaccumulation (B) and persistence (P) (i.e., criteria (b) and (c) of Annex D of the Stockholm Convention). The two criteria were used in combination to reduce the uncertainty in selecting for substances that have a potential to be POPs. The information collected is presented in the table in annex II of the report.
    1. Sources of information
       1. Experimental information
15. Experimental data on persistence (P) (degradation half life in soil, water and sediment) and bioaccumulation (B) (aquatic BCF and log Kow) were compiled where available from publicly available databases and sources provided by parties and observers. The main databases consulted were eChemPortal[[11]](#footnote-11), Pesticide Properties DataBase (PPDB) and ChemSpider[[12]](#footnote-12).
16. eChemPortal provides free public access to information on chemical properties and direct links to collections of information prepared for government chemical review programmes at national, regional, and international levels. Access to information on existing chemicals, new industrial chemicals, pesticides and biocides is provided. eChemPortal also makes available national/regional classification results according to national / regional hazard classification schemes or according to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS)[[13]](#footnote-13). In addition, eChemPortal provides also exposure and use information on chemicals.
17. The PPDB (Pesticide Properties Data Base) is a comprehensive relational database of pesticide physicochemical, toxicological, ecotoxicological and other related data. Reliable sources of information for pesticide properties are monographs produced as part of the EU review process and published by EFSA (European Food Safety Agency). These documents have been used in priority for putting together the data in the PPDB. Where EFSA documents are not available, alternative sources are used (e.g. data published by national government departments, peer-reviewed scientific publications, other databases). PPDB was consulted for data on hydramethylnon as this database was also used for the assessment of alternatives to endosulfan. Given that the majority of PFOS alternatives are not pesticides, the PPDB was relevant for hydramethylnon only.
18. ChemSpider is a free chemical database, owned by the Royal Society of Chemistry. This database is a useful instrument to find physical and chemical properties of substances and to find the valid SMILES for further calculating parameters by EPIWEB 4.1.
    * 1. Modelling information
19. In cases where experimental data were not available modeled data for persistence and bioaccumulation were based on QSAR estimates. Such data were generated using EPIWEB 4.1[[14]](#footnote-14) and the PB-score tool[[15]](#footnote-15).
20. EPIWB 4.1 with the Estimation Programs Interface Suite (EPI SuiteTM) software is developed by US EPA and publicity available on the internet. This modelling programme is used to estimate properties related to a chemical’s environmental transport and fate. This information is used to support regulatory decisions in the new chemicals program and in other existing chemical assessment activities. Governmental and private organizations within the United States and elsewhere make extensive use of this software in supporting decisions regarding new and existing chemicals. The widespread use of this software for a number of different purposes stems, in part, from its utilization and integration of available science in combination with its ease of operation, transparency, and cost-effectiveness. There are other modelling programmes available, but EpiSuite is publicly accessible and a widely referenced modelling programme.
21. The PB-score tool, developed at RIVM, uses QSAR estimations for screening on persistence and bioaccumulation and generates a score, which reflects the chance that a certain substance is persistent in the environment, and bioaccumulating. It is developed as a first tier in the evaluation of PBT and POP substances. It should be noted that the bioaccumulation potential of fluorinated chemicals might not be estimated correctly by the tool as it mainly focuses on passive bioaccumulation in fatty tissues, relevant for hydrophobic substances. However, the underlying US-EPA models have been updated for the fluorinated substances recently[[16]](#footnote-16). Furthermore, the PB-score screening is conservative, as it is considered better to end up with false positives than with false negatives. Those false positives should be screened out as a result of more in depth assessment based on experimental data whenever available.
22. The overall PB-score varies between 0 and 2. Cut-off values complying with the formal screening criteria in Annex D are ≥0.5 for the P-score as well as the B-score. Thus substances with a PB score of ≥1.5 will have individual P or B-scores of 0.5 or higher and comply with both criteria, whereas substances with a PB-score between 1 and 1.5 might fulfil both criteria or not.
    * 1. Data quality and uncertainties
23. The main source of information on the name and identity of alternatives to PFOS was the reports by parties and observers about the use of alternatives in their countries. The accuracy and comprehensiveness of the information presented in annex I therefore depend on the ability of parties and observers to make such information available. Alternatives to PFOS were not reported for a number of applications listed in part I of Annex B to the Stockholm Convention such as chemically driven oil production, photo-imaging, etching agent for compound semiconductors and ceramic filters, photo masks in the semiconductor and liquid crystal display industries, electric and electronic parts for some printers and colour copy machines and certain medical devices. In some cases, only the brand names, and not the chemical identity, of the alternatives to PFOS were reported, making it difficult to further obtain data on the properties of these alternatives.
24. When available, experimental data were used in the analysis for the prioritization of alternatives to PFOS. However, one major limitation of this exercise was the scarcity of data in public databases about many of the alternatives. For chemicals for which experimental data for persistence and bioaccumulation were not available, modeled data were considered in the prioritization.
25. Available modelling tools are not ideal for generating estimated data on persistence and bioaccumulation for all PFOS alternatives. A number of estimation programs are available in EPI SuiteTM. These programs use the so-called fragment method and for organic substances, generate estimates of physical/chemical property and environmental fate based on the contribution of the hydrocarbon chains (–CH2-or -CH3 fragments). These programs are thus most suitable for estimating data for PFOS alternatives that are pure hydrocarbons such as the aromatic substances. The United States Environmental Protection Agency has recently updated EPI Suite to improve the prediction of persistence and bioaccumulation of fluorinated substances[[17]](#footnote-17). However, these programs are still less accurate for generating modeled data for fluorinated organic alternatives than for the non-fluorinated organic alternatives.
26. For perfluorinated substances, Kow values cannot be empirically determined due to the surface active nature of these chemicals. Thus only modeled values for Kow are available for these chemicals. Furthermore, log Kow values are usually not reliable predictors of bioaccumulation for highly fluorinated substances because these tend to bind to proteins rather than lipids. Since the fluorinated alternatives to PFOS identified in this report are highly fluorinated, logKow (experimental or modeled) was excluded as a criterion for bioaccumulation for such alternatives in the prioritization analysis.
    * 1. Data analysis
27. In the next step, the collected numerical data were compared to benchmarks/cut off values in order to classify the substances within four categories (see below). Cut off values were selected for the four categories to allow a ranking from a higher likelihood to be a POP (category I) to a lower likelihood to be a POP (category IV).
28. The methodology for data analysis used in this report is based on the one used in the assessment of alternatives to endosulfan. Some modifications were made to the endosulfan methodology to account for the diverse range of properties of alternatives to PFOS and the low availability of relevant data about these alternatives contained in databases. For the assessment of alternatives to endosulfan, the main criterion considered for bioaccumulation was experimental bioconcentration factor (BCF) and in its absence, log Kow values. For the current analysis, due to the scarcity of experimental BCF data, it was necessary to also include experimental logKow as a main criterion for bioaccumulation when assessing non-fluorinated alternatives to PFOS. However, for fluorinated substances logKow (experimental or modeled) is not considered as a reliable indicator of bioaccumulation (see section 4.4.3) and was not included as a criterion; only experimental BCF was used in the prioritization for those substances.

Category I: High potential to be POPs substances (subject to further assessment)

**Cut-offs**: Bioaccumulation: experimental BCF > 5000 and/or experimental log Kow > 5 (for non-fluorinated substances). Persistence: half-life (experimental) in water greater than two months (60 days), in soil greater than six months (180 days) or sediment greater than six months (180 days).

Category II: Candidates that could be POPs substances (subject to further assessment)

**Cut-offs**: bioaccumulation: experimental BCF >1000 and/or experimental logKow > 4 (for non-fluorinated substances).

Persistence: A PB-score >1 (P-score >0.5) and/or half life (experimental and/or estimated) in water greater than two months (60 days), in soil greater than six months (180 days) or in sediment greater than six months (180 days). The reason for the selection of a BCF>1000 is that the Annex D criteria for bioaccumulation includes the consideration of other reasons for concern.

Category III: Candidates that are difficult for prioritization (subject to further assessment)

**Cut-offs**: bioaccumulation: No experimental data for BCF and logKow for non-fluorinated substances. No experimental data for BCF for fluorinated substances.

Category IV: Unlikely to be POP substances based on persistence and bioaccumulation characteristics

**Cut-offs**: bioaccumulation: experimental BCF< 1000 and/or experimental log Kow < 4.0) and/or persistence: half life (experimental) in water less than 2 month ( 60 days), in soil less than six months (180 days) and sediment less than six months (180 days).

However these substances, which are not likely to be a POP, may exhibit hazardous characteristics (e.g. mutagenicity, carcinogenicity, reproductive and developmental toxicity, endocrine disruption, immune suppression or neurotoxicity) that should be assessed by Parties before considering such substances as a suitable alternative.

* + 1. Results

1. Of the 59 alternatives to PFOS, 55 substances were subject to prioritization. No substance were selected as having a high potential to be POPs (category I), 12 substances could be POPs (category II), 33 substances were difficult for prioritization (category III) and 10 substances were selected as unlikely to be a POP (category IV).
2. Substances in categories I, II and III were subject to further assessment as described in section 5.1. Substances in category IV were not further analyzed.
3. The results of the prioritization are provided below. The complete list of alternatives to PFOS with data for each endpoint is reported in the table in Annex II.
4. Category I : High potential to be POPs substances: 0 substances
5. Category II: Candidates that could be POPs substances: 12 substances

| **CAS No** | **Substance name** |
| --- | --- |
| **Non-fluorinated alternatives** | |
| 541-02-6 | Decamethyl cyclopentasiloxane (D5) |
| 540-97-6 | Dodecamethyl cyclohexasiloxane (D6) |
| 556-67-2 | Octamethyl cyclotetrasiloxane (D4) |
| 107-51-7 | Octamethyl trisiloxane (MDM) |
| 141-62-8 | Decamethyl tetrasiloxane (MD2M) |
| 38640-62-9 | Diisoproplynaftalene |
| 35860-37-8 | Triisopropylnaftalene |
| 25640-78-2 | 1-Isopropyl-2-phenyl-benzene |
| 69009-90-1 | Diisopropyl-1,1'-biphenyl |
| **Pesticides** | |
| 2921-88-2 | Chlorpyrifos\* |
| 52315-07-8 | Cypermethrin\* |
| 52918-63-5 | Deltamethrin\* |

1. Category III: Candidates that are difficult for prioritization: 33 substances

| **CAS No** | **Substance name** |
| --- | --- |
| **Fluorinated alternatives** | |
| 355-86-2 | Tris(octafluoropentyl) phosphate |
| 563-09-7 | Tris(heptafluorobutyl) phosphate |
| 40143-77-9 | Sodium bis(perfluorohexyl) phosphinate |
| 34455-29-3 | Carboxymethyldimethyl-3-[[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)sulfonyl]amino]propylammonium hydroxide |
| 358-63-4 | Tris(trifluoroethyl) phosphate |
| [163702-07-6](http://www.chemicalbook.com/CASEN_163702-07-6.htm) | Methyl nonafluorobutyl ether |
| 163702-08-7 | Methyl nonafluoro isobutyl ether |
| 59587-38-1 | 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooctane-1-sulphonate potassium salt |
| 2043-47-2 | 1*H*,1*H*,2*H*,2*H*-Perfluorohexanol or 3,3,4,4,5,5,6,6,6-nonafluorobutyl ethanol |
|  | 2-(6-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetrafluoroethane sulfonate |
|  | 1,1,2,2,-tetrafluoro-2-(perfluorohexyloxy)-ethane sulfonate |
|  |  |
|  | perfluorohexane ethyl sulfonyl betaine |
| 756-13-8 | Dodecafluoro-2-methylpentan-3-one |
| 2144-53-8 | 2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl ester |
| 40143-76-8 | Perfluorohexyl phosphonic acid |
|  | 1-chloro-perfluorohexyl phosphonic acid |
| 67674-67-3 | (Hydroxyl) Terminated polydimethylsiloxane |
| **Non-fluorinated alternatives** | |
| 577-11-7 | Di-2-ethylhexyl sulfosuccinate, sodium salt |
| 4261-72-7 | Stearamidomethyl pyridine chloride |
| 141-63-9 | Dodecamethyl pentasiloxane (MD3M) |
| 107-46-0 | Hexamethyl disiloxane (MM or HMDS) |
| **Commercial brands** |  |
|  | Polyfox® |
|  | Emulphor® FAS |
|  | Enthone® |
|  | Zonyl® |
|  | Polyfox® |
|  | Capstone® |
|  | Nuva® |
|  | Unidyne® |
|  | Rucoguard® |
|  | Oleophobol® |
|  | Asahiguard® |
|  | Solvera® |

1. Category IV: Unlikely to be POP substances based on persistence and bioaccumulation characteristics: 10 substances

| **CAS No** | **Substance name** |
| --- | --- |
| **Fluorinated alternatives** | |
| [29420-49-3](http://www.chemicalbook.com/CASEN_29420-49-3.htm) | Perfluorobutane sulfonate potassium salt |
| 3871-99-6 | Perfluorohexanesulfonate potassium salt |
| 647-42-7 | 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluoro-1-octanol |
| 27619-97-2 | 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooctane-1-sulphonate |
| **Pesticides** | |
| 95737-68-1 | Pyriproxyfen\* |
| 138261-41-3, 105827-78-9 | Imidacloprid\* |
| 120068-37-3 | Fipronil\* |
| 122-14-5 | Fenitrothion\* |
| 71751-41-2 | Abamectine\* |
| 67485-29-4 | Hydramethylnon |

\*Categorization of these pesticides are based on the results of the assessment of alternatives to endosulfan.

* + 1. Comments on selected alternative substances

1. 12 of the alternatives to PFOS are commercialized under brand names and described as polymers by the companies that market them (see table in Annex I).Due to their large molecular weight[[18]](#footnote-18)  and low mobility in the environment, polymers are thought not to bioaccumulate. It should be noted also that polymers are generally not subject to in-depth exposure and risk assessment. Generally a registration is not required for polymers in many jurisdictions and that, if registration is judged appropriate, the test information burdens are reduced[[19]](#footnote-19). Information about the exact composition of the brand name products listed in Annex I and the molecular weight of the substances they may contain is however not publicly available. These products were therefore placed in category III and were not further analysed.
2. **Methodology for the assessment of persistent organic pollutant characteristics and identification of other hazard indicators for the assessment of alternatives to PFOS**
   1. Introduction
3. Depending on the category in which they had been placed in the prioritization step, the alternatives to PFOS were further assessed and consequently assigned to one of the four classes based on their likelihood to meet all the criteria in annex D of the convention. The four classes are as follows:

Class 1: Substances that are likely to meet all Annex D criteria (b), (c), (d) and (e).

Class 2: Substances that may meet all of the Annex D (b), (c), (d) and (e) criteria but have equivocal or insufficient data.

Class 3: Substances that are difficult for classification due to insufficient data.

Class 4: Substances that are not likely to meet all Annex D criteria (b), (c), (d) and (e).

1. The following approach was used for the assessment of substances in each category:
   * 1. Category I and II: an assessment of POPs characteristics and other hazard indicators (toxicity and ecotoxicity). For each substance, compile a detailed fact sheet on the properties selected for assessment.
     2. Category III: a more exhaustive search for experimental data on bioaccumulation. If such data is obtained, determine if the substance is meets the Annex D (c) (i) criterion. If that criterion is met and the substance is considered likely to be bioaccumulative, proceed as described in (a). If no data was obtained, no factsheet is compiled and the substance is assigned to class 3.
     3. Category IV: no further action, substances are assigned to class 4.
   1. Properties to be considered
2. **Substance identity**: CAS no, IUPAC name, molecular weight, chemical structure, chemical group.
3. **Physical-chemical properties**: vapour pressure, water solubility, Partition coefficient

n-octanol/water (log value), Partition coefficient air/water (log value), Partition coefficient

air/octanol (log value), Henry’s Law Constant.

1. **Bioaccumulation**: experimental BCF and log Kow data (Annex D (c) (i) criterion). The evidence for assessment was considered reliable when at least two data points were available.
2. **Persistence**: experimental data when available; modelling data on half-life in water, soil and sediment (Annex D (b) (i) criterion). The evidence for assessment was considered reliable when at least two data points were available.
3. **Long-range transport**: Gather information on experimental and/or estimated half-life data in air (EpiSuite) (Annex D (d) (ii) criterion).
4. **Ecotoxicity** (Annex D (e) criterion): GHS (global harmonization system) classification (only harmonized classifications were considered) on aquatic toxicity, rated as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Classification** | **Hazard statement** | **Ecotoxicity level** | **Acute effect conc. [mg/L]** | **Chronic effect conc. [mg/L]** |
| Aquatic chronic 1 | H410 | Severe | 1 | 0,1 |
| Aquatic chronic 2 | H411 | High | >1-10 | > 0,1 - 1 |
| Aquatic chronic 3 | H412 | Moderate | >10-100 | >1-10 |
| Aquatic chronic 4  Aquatic acute 1 | H413 | Low | >100 | >10 |

1. **Toxicity** (Annex D (e) criterion): GHS classification (only harmonized classifications were considered) on toxicity on humans, rated as follows:

|  |  |  |
| --- | --- | --- |
| **Classification** | **Hazard statement** | **Toxicity level** |
| Muta 1A/1B  Carc. 1A/1B  Repro. 1A/1B  Carc 2+STOT RE  Skin corr | H340  H350  H360 | Severe |
| Muta 2.  Carc 2.  Repro 2.  Skin irrit.  Resp. sens. STOT RE1 | H341  H351  H361 | High |
| STOT RE 2  Acute tox 1  Acute tox 2 |  | Moderate |
| Acute tox 3  Acute tox 4 |  | Low |

Additionally, the following hazards were considered:

1. Acute toxicity
2. Mutagenicity
3. Carcinogenity
4. Toxicity for reproduction
5. Neurotoxicity
6. Immunotoxicity
7. Endocrine disruption
8. Mode of action
9. Acceptable exposure levels
   1. Information sources
10. In order to assess selected alternative substances for PFOS and related substances within the given time frame and resources, preference was given to governmental reports, relevant databases and evaluated peer review data. When information was not available from such sources, a search in the primary literature was carried out, where recent sources were consulted.
    * 1. Databases consulted as references:
11. ESIS: http://esis.jrc.ec.europa.eu/index.php?PGM=cla

C&L (Classification and Labelling, Annex VI to EU CLP Regulation 1272/2008)

Risk Assessment Reports (RAR)

1. CLP inventory (for endpoints not covered by ESIS):

http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database

1. EFSA: http://www.efsa.europa.eu/en/search.htm
2. EU Endocrine Disruption Database:

http://ec.europa.eu/environment/chemicals/international\_conventions/index\_en.htm

1. WHO/EPS: http://www.who.int/publications/en/
2. EPI SUITE: http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm
3. IARC: http://monographs.iarc.fr/ENG/Monographs/PDFs/index.php
4. International limit values (working place): http://limitvalue.ifa.dguv.de/Webform\_gw.aspx
5. ECETOC: http://www.ecetoc.org/index.phpECOTOX
6. TOXNET: <http://toxnet.nlm.nih.gov/index.html>
7. ECHA information on chemicals: http://echa.europa.eu/nl/information-on-chemicals
   * 1. Database for peer-reviewed literature:

Scopus: http://www.scopus.com/

1. Results of the assessment of the persistent organic pollutant characteristics and other hazard indicators of the alternatives to PFOS
2. For each of the 9 alternatives to PFOS in category II, a summary factsheet was compiled (see document UNEP/POPS/POPRC10/INF/xx). The summary factsheets provide an indication as to whether or not the alternative substance meets the numerical thresholds in annex D in the Stockholm Convention, but do not analyze monitoring data or other evidence in depth so failure to meet the thresholds should not be taken as a determination that the alternative substance is not a POP. Furthermore, not all criteria of Annex D were considered for the assessment such that the conclusions regarding certain alternatives may change in light of information for other Annex D criteria. As an overview, a table summarizing the data contained in the factsheets for the endpoints considered in the assessment is set out in Annex III.
3. For substances in category III, a more exhaustive search was performed for experimental data on bioaccumulation. The results are presented in table 1 below. For 5 substances of the 36 substances in category III, data were available in the ECHA’s database on information on chemicals. Reliable experimental data on bioaccumulation could be obtained for four of the substances. The substances for which the annex D (c) (i) criterion was not met were assigned to class 4.

Table 1: Results of the assessment of substances in category III for which bioaccumulation data was available.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Substance name** | **Cas. No.** | **Bioaccumulation**  **Experimental BCF** | **Reference** | **Class assigned** |
| 2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl ester | 2144-53-8 | 268 | http://echa.europa.eu/information-on-chemicals | 4 |
| Perfluoro-2-methylpentan-3-one | 756-13-8 | < 1 | http://echa.europa.eu/information-on-chemicals | 4 |
| Di-2-ethylhexyl sulfosuccinate, sodium salt | 577-11-7 | No data available | http://echa.europa.eu/information-on-chemicals | 3 |
| Hexamethyl disiloxane (MM or HMDS) | 107-46-0 | 776, 1290, 1660 and 2410 | http://echa.europa.eu/information-on-chemicals | 4 |
| Dodecamethyl pentasiloxane (MD3M) | 141-63-9 | 1240 and 1430 | http://echa.europa.eu/information-on-chemicals | 4 |

* 1. Data availability and uncertainties

1. Consistent with the methodology used for the assessment of alternatives to endosulfan, the assessment of the 9 substances in category II was based on data available from databases and governmental reports and additional information from parties and observers. However, the availability of such data for alternatives to PFOS, which are in majority industrial chemicals, is relatively low and comparatively much lower than for pesticides. The number of peer-reviewed studies from primary literature that was available as second-line references was also limited for the assessed alternatives to PFOS. The conclusions on some of the alternatives may thus change when more data become available.
2. The scarcity of data on alternatives to PFOS has been one of the major limitations for their assessment as undertaken in this report. A large number of substances were assigned to category III at the prioritization step and could not be further analysed due to lack of data.
3. For bioaccumulation, persistence and long-range transport, the factsheets compiled for the substances in category II provide an analysis of whether the substances meet the numerical thresholds in Annex D but not of other evidence as provided for in Annex D such as monitoring data (see section 5.2). Therefore consideration of data on other Annex D criteria might change the conclusions on some substances. Moreover, failure to meet the thresholds should be considered as a likelihood rather than as evidence that the substance is not a POP.
4. Conclusions of the screening assessment on POPs characteristics of alternatives to PFOS
5. Based on the results of the screening assessment the conclusions below are suggested. However, the assessment provides only an indication as to whether or not the alternative substances meet the numerical threshold in annex D of the Stockholm Convention, and does not analyse monitoring data or other evidence as provided for in annex D, so failure to meet the thresholds should not be taken as a determination that the alternative substance is not a POP. Furthermore this work is only a first screening indicating the likelihood and not a definite classification of the substances concerning their POP characteristics.

***Class 1: Substances that are likely to meet all Annex D criteria (b), (c), (d) and (e)***

Octamethyl cyclotetrasiloxane (D4)

***Class 2: Substances that may meet all of the Annex D (b),(c), (d) and (e) criteria but have equivocal or insufficient data***

Chloropyrifos

***Class 3: Substances that are difficult for classification due to insufficient data***

Tris(octafluoropentyl) phosphate

Tris(heptafluorobutyl) phosphate

Sodium bis(perfluorohexyl) phosphinate

Carboxymethyldimethyl-3-[[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)sulfonyl]amino]propylammonium hydroxide

Tris(trifluoroethyl) phosphate

Methyl nonafluorobutyl ether

3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooctane-1-sulphonate potassium salt

1*H*,1*H*,2*H*,2*H*-Perfluorohexanol or 3,3,4,4,5,5,6,6,6-nonafluorobutyl ethanol

2-(6-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetrafluoroethane sulfonate

1,1,2,2,-tetrafluoro-2-(perfluorohexyloxy)-ethane sulfonate

Perfluorohexane ethyl sulfonyl betaine

Dodecafluoro-2-methylpentan-3-one

Perfluorohexyl phosphonic acid

1-chloro-perfluorohexyl phosphonic acid

Di-2-ethylhexyl sulfosuccinate, sodium salt

Stearamidomethyl pyridine chloride

(Hydroxyl) Terminated polydimethylsiloxane

Polyfox®

Emulphor® FAS

Enthone®

Zonyl®

Polyfox®

Capstone®

Nuva®

Unidyne®

Rucoguard®

Oleophobol®

Asahiguard®

Solvera®

***Class 4: Substances that are not likely to meet all Annex D criteria (b), (c), (d) and (e)***

Perfluoro-2-methylpentan-3-one

2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl ester

Decamethyl cyclopentasiloxane (D5)

Dodecamethyl cyclohexasiloxane (D6)

Hexamethyl disiloxane (MM or HMDS)

Octamethyl trisiloxane (MDM)

Decamethyl tetrasiloxane (MD2M)

Dodecamethyl pentasiloxane (MD3M)

1-Isopropyl-2-phenyl-benzene

Diisoproplynaftalene (DIPN)

Triisopropylnaftalene

Diisopropyl-1,1'-biphenyl

Cypermethrin

Deltamethrin

In addition, the following 10 substances in category IV of the results of the prioritization step (see section III) are not likely to meet the Annex D criteria (b), (c), (d) and (e):

Perfluorobutane sulfonate potassium salt

Perfluorohexanesulfonate potassium salt

3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluoro-1-octanol

3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooctane-1-sulphonate

Pyriproxyfen

Imidacloprid

Fipronil

Fenitrothion

Abamectine

Hydramethylnon

1. In summary, 55 chemical alternatives to PFOS were analysed following a methodology previously used for the assessment of alternatives to endosulfan. 1 substance ((octamethyl cyclotetrasiloxane (D4)) was identified as being likely to meet all the annex D criteria. Chloropyrifos was identified as a substance that may meet all of the Annex D criteria but have equivocal data. A further 24 substances were classified as unlikely to be POPs. 29 of the alternatives to PFOS could not be classified since data on their potential to bioaccumulate was not available.
2. Information gaps
3. The methodology used for the assessment of alternatives to endosulfan, which was adapted for use in the current assessment, had been developed for a group of chemicals that are all pesticides. Because pesticides are subject to a process of registration and risk assessment in many countries, reliable information about their properties is readily available in a number of public databases. In contrast, the alternatives to PFOS are in majority industrial chemicals on which much less information is made publicly available. The low availability of data presented one of the main difficulties in undertaking the assessment of alternatives to PFOS, as evidenced by the large number of chemicals that could not be classified due to insufficient data.
4. The scarcity of experimental data about alternatives to PFOS also made it necessary to rely more heavily on modeled data for their assessment than in the case of alternatives to endosulfan. Existing modelling tools provide estimates of bioaccumulation based on log Kow values. Such values were not considered as reliable predictors of bioaccumulation for highly fluorinated alternatives to PFOS because these tend to bind to proteins rather than lipids. Although modelling tools have in recent years shown some improvement in accurately predicting the properties of fluorinated substances, further development of tools more suited for estimating bioaccumulation and biomagnifications values for this group of chemicals should facilitate their assessment.
5. According to the Guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals[[20]](#footnote-20) , in identifying and evaluating alternatives to POPs, it is important to describe the specific use and functionality of POPs as specifically as possible. In the case of PFOS, the various specific exemptions and acceptable purposes listed in Annex B of the Convention describe broad use categories (e.g. fire fighting foams) , articles (e.g. electric and electronic parts for some colour printers and colour copy machines ) and processes (e.g. chemically driven oil production) for which PFOS can have a variety of uses. The lack of information about the precise use and function of PFOS in these applications makes it difficult to identify corresponding alternatives with a high degree of certainty. Where possible, the functionality and application of alternative substances have been indicated in the table in annex I.
6. Alternatives to PFOS that are not likely to meet all Annex D criteria were identified for several of the applications listed as specific exemptions and acceptable purposes in part I of Annex B of the Stockholm Convention. The information provided by parties and others on the technical feasibility, cost-effectiveness, efficacy, availability and accessibility of the alternatives to PFOS (see paragraph 11 and the Technical paper on the identification and assessment on alternatives to the use of perfluorooctane sulfonic acid in open applications) did not however include enough data to enable a comprehensive assessment related to the availability, suitability and implementation of such alternatives. Moreover, alternatives to PFOS were not reported for a number of applications listed in part I of Annex B to the Stockholm Convention.
7. As highlighted in the preceeding paragraphs, obtaining precise and detailed information about altenatives to the use of PFOS and their properties is necessary for the assessment of these alternatives by the Committee. It is recommended that the format for collecting information from parties and others be revised to facilitate the provision of such information by, e.g., specifying the functionality of PFOS under the use categories listed as specific exemptions and acceptable purposes. Parties and others should also be encouraged to provide information to support the assessment of alternatives to PFOS.

**Annex I: Alternatives to PFOS, their occurrence and functions**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Compound** | | | **Functionality** | **Occurrence** | **Applications[[21]](#footnote-21)** | **Class**  **(results of the assessment)** |
| **CAS no** | **Name** | **Abbr.** |
| [29420-49-3](http://www.chemicalbook.com/CASEN_29420-49-3.htm) | Perfluorobutane sulfonate potassium salt | PFBS K | Fluorosurfactant[[22]](#footnote-22) | commercial product | Coating and coating agents, carpets, leather and apparel, textiles and upholstery, paper and packaging, rubber and plastics. A,B | 4 |
| 3871-99-6 | Perfluorohexanesulfonate potassium salt | PFHxS K | Fluorosurfactant[[23]](#footnote-23) | commercial product | Carpets, leather and apparel, textiles and upholstery B, | 4 |
| 307-24-4 | Perfluorohexanoic acid | PFHxA |  | transformation product | Not applicable |  |
| 2923-26-4 | Perfluorohexanoic acid sodium salt | PFHxA Na |  | transformation product | Not applicable |  |
| 375-22-4 | Perfluorobutanoic acid | PFBA |  | transformation product | Not applicable |  |
| 375-85-9 | Perfluoroheptanoic acid | PFHpA |  | transformation product | Not applicable |  |
| 2043-47-2 | 1*H*,1*H*,2*H*,2*H*-Perfluorohexanol or 3,3,4,4,5,5,6,6,6-nonafluorobutyl ethanol | 4:2 FTOH | Raw material for surfactant and surface protection products[[24]](#footnote-24) | manufacturing intermediate | Carpets, leather and apparel, textiles and upholstery A, | 4 |
| 647-42-7 | 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluoro-1-octanol | 6:2 FTOH | Raw material for surfactant and surface protection products[[25]](#footnote-25) | manufacturing intermediate | Carpets, leather and apparel, textiles and upholstery A,B | 4 |
| 2144-53-8 | 2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl ester | 6:2 FMA | Raw material for surfactant and surface protection products[[26]](#footnote-26) | manufacturing intermediate | Carpets, leather and apparel, textiles and upholstery A | 4 |
| 756-13-8 | Dodecafluoro-2-methylpentan-3-one |  | Fluorosurfactant | commercial product | Fire fighting foams A,B | 4 |
|  | Perfluorohexane ethyl sulfonyl betaine |  | Fluorosurfactant | commercial product | Fire fighting foams A,B | 3 |
| 34455-29-3 | Carboxymethyldimethyl-3-[[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)sulfonyl]amino]propylammonium hydroxide |  | Fluorosurfactant | commercial product | Fire fighting foams A,B | 3 |
| [163702-07-6](http://www.chemicalbook.com/CASEN_163702-07-6.htm) | Methyl nonafluorobutyl ether |  | Fluorosurfactant | commercial product | Coating and coating additives A,B | 3 |
| 163702-08-7 | Methyl nonafluoro isobutyl ether |  | Fluorosurfactant | commercial product | Coating and coating additives A,B | 3 |
| 27619-97-2 | 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooctane-1-sulphonate | 6:2 FTS | Fluorosurfactant | commercial product | Metal plating A,B. | 3 |
| 59587-38-1 | 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooctane-1-sulphonate potassium salt | 6:2 FTS K | Fluorosurfactant | commercial product | Metal plating A,B. | 3 |
|  | 1,1,2,2,-tetrafluoro-2-(perfluorohexyloxy)-ethane sulfonate | F-53 | Fluorosurfactant | commercial product | Metal plating A,B | 3 |
|  | 2-(6-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetrafluoroethane sulfonate | F-53B | Fluorosurfactant | commercial product | Metal plating A,B | 3 |
| 355-86-2 | Tris(octafluoropentyl) phosphate | POFPP  (PAPs) | Fluorosurfactant | commercial product | Paper and packaging A,B | 3 |
| 563-09-7 | Tris(heptafluorobutyl) phosphate | PHFBP  (PAPs) | Fluorosurfactant | commercial product | Paper and packaging A,B | 3 |
| 358-63-4 | Tris(trifluoroethyl) phosphate | PTEHP  (PAPs) | Fluorosurfactant | commercial product | Paper and packaging A,B | 3 |
| 40143-76-8 | Perfluorohexyl phosphonic acid | PFHxPA  (PAPs) | Fluorosurfactant | commercial product | Paper and packaging A,B, | 3 |
|  | 1-chloro-perfluorohexyl phosphonic acid | Cl-PFHxPA (PAPs) | Fluorosurfactant | commercial product | Paper and packaging A,B | 3 |
| 40143-77-9 | Sodium bis(perfluorohexyl) phosphinate | 6:6 PFPi  (PAPs) | Fluorosurfactant | commercial product | Paper and packaging A,B, | 3 |
|  |  |  |  |  |  |  |
| 577-11-7 | Di-2-ethylhexyl sulfosuccinate, sodium salt |  | Waxes and resins | commercial product | Carpets, leather and appareltextiles and upholstery B, | 3 |
| 4261-72-7 | Stearamidomethyl pyridine chloride |  | Waxes and resins | commercial product | Carpets, leather and apparel, textiles and upholstery A,B, | 3 |
| 556-67-2 | Octamethyl cyclotetrasiloxane | D4 | Manufacturing intermediate for the production of silicone polymers[[27]](#footnote-27) | manufacturing intermediate | Carpets, leather and apparel, textiles and upholstery, coating and coating additives A,B. | 1 |
| 541-02-6 | Decamethyl cyclopentasiloxane | D5 | Manufacturing intermediate for the production of silicone polymers[[28]](#footnote-28) | manufacturing intermediate | Carpets, leather and apparel, textiles and upholstery, coating and coating additives A,B. | 4 |
| 540-97-6 | Dodecamethyl cyclohexasiloxane | D6 | Manufacturing intermediate for the production of silicone polymers[[29]](#footnote-29) | manufacturing intermediate | Carpets, leather and apparel, textiles and upholstery, coating and coating additives A,B. | 4 |
| 107-46-0 | Hexamethyl disiloxane | MM (or HMDS) | Manufacturing  intermediate for the production of silicone polymers[[30]](#footnote-30) | manufacturing intermediate | Carpets, leather and apparel, textiles and upholstery, coating and coating additives A,B. | 4 |
| 107-51-7 | Octamethyl trisiloxane | MDM | Manufacturing  intermediate for the production of silicone polymers. | manufacturing intermediate | Carpets, leather and apparel, textiles and upholstery, coating and coating additives A,B. | 4 |
| 141-62-8 | Decamethyl tetrasiloxane | MD2M | Manufacturing  intermediate for the production of silicone polymers.[[31]](#footnote-31) | manufacturing intermediate | Carpets, leather and apparel, textiles and upholstery, coating and coating additives A,B. | 4 |
| 141-63-9 | Dodecamethyl pentasiloxane | MD3M | Manufacturing  intermediate for the production of silicone polymers.[[32]](#footnote-32) | manufacturing intermediate | Carpets, leather and apparel, textiles and upholstery, coating and coating additives A,B. | 4 |
| 38640-62-9 | Diisoproplynaftalene |  | Waxes and resins | commercial product | Coating and coating additives A,B. | 4 |
| 35860-37-8 | Triisopropylnaftalene |  | Waxes and resins | commercial product | Coating and coating additives A,B | 4 |
| 69009-90-1 | Diisopropyl-1,1'-biphenyl |  | Waxes and resins | commercial product | Coating and coating additives A,B | 4 |
| 25640-78-2 | 1-Isopropyl-2-phenyl-benzene |  | Waxes and resins | commercial product | Coating and coating additives A,B | 4 |
| 67674-67-3 | (Hydroxyl) Terminated polydimethylsiloxane |  | Non ionic surfactant[[33]](#footnote-33) | commercial product | Coating and coating additives A,B | 3 |
| **Pesticides** |  |  |  |  |  |  |
| 120068-37-3 | Fipronil |  | Pesticides | commercial product | Insecticides for control of red imported fire ants and termites.  Insect bait for control of leaf-cutting ants from *Atta spp*.and *Acromyrmex spp* B | 4 |
| 71751-41-2 | Abamectine |  | Pesticides | commercial product | Insecticides for control of red imported fire ants and termites | 4 |
| 95737-68-1 | Pyriproxyfen |  | Pesticides | commercial product | Insecticides for control of red imported fire ants and termites B | 4 |
| 122-14-5 | Fenitrothion |  | Pesticides | commercial product | Insecticides for control of red imported fire ants and termites.  Insect bait for control of leaf-cutting ants from *Atta spp*. And*Acromyrmex spp* B | 4 |
| 138261-41-3, 105827-78-9 | Imidacloprid |  | Pesticides | commercial product | Insecticides for control of red imported fire ants and termites B | 4 |
| 52315-07-8 | Cypermethrin |  | Pesticides | commercial product | Insecticides for control of red imported fire ants and termitesA | 4 |
| 52918-63-5 | Deltamethrin |  | Pesticides | commercial product | Insecticides for control of red imported fire ants and termites.  Insect bait for control of leaf-cutting ants from *Atta spp*. And *Acromyrmex spp* B | 4 |
| 2921-88-2 | Chlorpyrifos |  | Pesticides | commercial product | Insecticides for control of red imported fire ants and termites B | 2 |
| 67485-29-4 | Hydramethylnon |  | Pesticides | commercial product | Insecticides for control of red imported fire ants and termites. Insect bait for control of leaf-cutting ants from *Atta spp*. And *Acromyrmex spp* A[[34]](#footnote-34) | 4 |
| **Commercial brands** | |  |  |  |  |  |
|  | Polyfox® |  | Polymer coating | commercial product | Coating and coating additives A,B | 3 |
|  | Emulphor® FAS |  | Polymer coating | commercial product | Coating and coating additives A,B  Metal plating A,B | 3 |
|  | Enthone® |  | Polymer coating | commercial product | Coating and coating additives A,B  Metal plating A,B | 3 |
|  | Zonyl® |  | Polymer coating | commercial product | Carpets, leather and apparel, textiles and upholstery A,B | 3 |
|  | Polyfox® |  | Polymer coating | commercial product | Coating and coating additives A,B | 3 |
|  | Capstone® |  | Polymer coating | commercial product | Coating and coating additives, carpets, leather and apparel, textiles and upholstery, and metal plating A,B | 3 |
|  | Nuva® |  | Polymer coating | commercial product | Carpets, leather and apparel, textiles and upholstery A,B | 3 |
|  | Unidyne® |  | Polymer coating | commercial product | Carpets, leather and apparel, textiles and upholstery A,B | 3 |
|  | Rucoguard® |  | Polymer coating | commercial product | Carpets, leather and apparel, textiles and upholstery A,B | 3 |
|  | Oleophobol® |  | Polymer coating | commercial product | Carpets, leather and apparel, textiles and upholstery A,B, | 3 |
|  | Asahiguard® |  | Polymer coating | commercial product | Carpets, leather and apparel, textiles and upholstery A,B | 3 |
|  | Solvera® |  | Polymer coating | commercial product | Paper and packaging A,B | 3 |

**Annex II: Results of the prioritization of alternatives to PFOS**

| **Substance** | |  |  | |  | |  | **POP indicators** | | |  | | | | |  | | |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  | |  | |  | **Bioaccumulation** | | | **Persistence[[35]](#footnote-35)** | | | | | **RIVM modeled** | | |  |
| **CAS no** | **Name** | | | **Abbr.** | **Molecular weight**  **[g/mol][[36]](#footnote-36)** | | **Functionality & occurrence** | **logKow (modeled)** | **log Kow (exp)** | **BCF (exp)** | **Half life**  **Water**  **(days)** | **Half life**  **Soil**  **(days)** | **Half life**  **Sediment**  **(days)** | | | **PB-score** | **P-score** | **B-score** | **Category**  **(result of prioritisation step)** |
| [29420-49-3](http://www.chemicalbook.com/CASEN_29420-49-3.htm) | Perfluorobutane sulfonate potassium salt | | | PFBS K | 338.19 | | Fluorosurfactant | EPI: -0.33 |  | 32 – 126[[37]](#footnote-37) | 180 | 360 | 1620 | | | 1.00 | 1.00 | 0.00 | IV |
| 3871-99-6 | Perfluorohexanesulfonate potassium salt | | | PFHxS K | 438 | | Fluorosurfactant | EPI: 1.01 |  | 68[[38]](#footnote-38),  100[[39]](#footnote-39) | 180 | 360 | 1620 | | | 1.01 | 1.00 | 0.01 | IV |
| 2043-47-2 | 1*H*,1*H*,2*H*,2*H*-Perfluorohexanol or 3,3,4,4,5,5,6,6,6-nonafluorobutyl ethanol | | | 4:2 FTOH | 264,02 | | Raw material for surfactant and surface protection products | Epi: 3.66 | 3.30[[40]](#footnote-40) |  | 180 | 360 | 1620 | | | 0,36 | 0,27 | 0,09 | III |
| 647-42-7 | 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluoro-1-octanol | | | 6:2 FTOH | 364,1 | | Raw material for surfactant and surface protection products | Epi: 4.41 | 4,54[[41]](#footnote-41) | 34-99[[42]](#footnote-42) |  | Exper: < 2[[43]](#footnote-43) | Exper: < 2 | | | 0,66 | 0,36 | 0,30 | IV |
| 2144-53-8 | 2-Propenoic acid, 2-methyl-, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl ester | | | 6:2 FMA | 432,18 | | Raw material for surfactant and surface protection products[[44]](#footnote-44) | Epi: 6.32 | 5,2[[45]](#footnote-45) |  | 180 | 360 | 1620 | | | 0.79 | 0,39 | 0,40 | III |
| 756-13-8 | Dodecafluoro-2-methylpentan-3-one | | |  | 316,04 | | Fluoro  surfactant | 2.79[[46]](#footnote-46)  EPI: 2.79 |  |  |  |  |  | | | 1.05 | 1.00 | 0.05 | III |
|  | Perfluorohexane ethyl sulfonyl betaine | | |  |  | | Fluoro  surfactant |  |  |  |  |  |  | | |  |  |  | III |
| 34455-29-3 | Carboxymethyldimethyl-3-[[(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)sulfonyl]amino]propylammonium hydroxide | | |  | 537,415 | | Fluoro  surfactant | EPI: 2.9 |  |  | 180 | 360 | 1620 | | | 1,06 | 0.99 | 0,07 | III |
| [163702-07-6](http://www.chemicalbook.com/CASEN_163702-07-6.htm) | Methyl nonafluorobutyl ether | | |  | 250,06 | | Fluoro  surfactant | EPI: 3,34 |  |  | 180 | 360 | 1620 | | | 1.14 | 0.93 | 0.11 | III |
| 163702-08-7 | Methyl nonafluoro isobutyl ether | | |  | 250,06 | | Fluoro  surfactant | EPI: 3,23 |  |  | 180 | 360 | 1620 | | | 1.13 | 0.93 | 0.10 | III |
| 27619-97-2 | 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooctane-1-sulphonate | | | 6:2 FTS |  | | Fluoro  surfactant | EPI: 2.66 |  | < 50[[47]](#footnote-47) |  |  |  | | | 0.47 | 0.43 | 0.04 | IV |
| 59587-38-1 | 3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooctane-1-sulphonate potassium salt | | | 6:2 FTS K |  | | Fluoro  surfactant | EPI: -0.11 |  |  |  |  |  | | | 0.42 | 0.42 | 0.003 | III |
|  | 1,1,2,2,-tetrafluoro-2-(perfluorohexyloxy)-ethane sulfonate | | | F-53 | 516,13 | | Fluoro  surfactant | EPI: 2.78 |  |  | 180 | 360 | 1620 | | | 1.06 | 1.00 | 0.06 | III |
|  | 2-(6-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetrafluoroethane sulfonate | | | F-53B | 532,58 | | Fluoro  surfactant | EPI: 3.1 |  |  | 180 | 360 | 1620 | | | 1.09 | 1.00 | 0.09 | III |
| 355-86-2 | Tris(octafluoropentyl) phosphate | | | POFPP | 702,07 | | Fluoro  surfactant | EPI: 7.21 |  |  | 180 | 360 | 1620 | | | 1.27 | 0.64 | 0.63 | III |
| 563-09-7 | Tris(heptafluorobutyl) phosphate | | | PHFBP | 644,12 | | Fluoro  surfactant | EPI:7,02 |  |  | 180 | 360 | 1620 | | | 1.30 | 0.59 | 0.71 | III |
| 358-63-4 | Tris(trifluoroethyl) phosphate | | | PTEHP | 344,07 | | Fluoro  surfactant | EPI:2,12 |  |  | 180 | 360 | 1620 | | | 0.42 | 0.40 | 0.02 | III |
| 40143-76-8 | Perfluorohexyl phosphonic acid | | | PFHxPA | 400 | | Fluoro  surfactant | EPI:3.06 | 3.55[[48]](#footnote-48) |  | 180 | 360 | 1620 | | | 1.28 | 0.99 | 0.29 | III |
|  | 1-chloro-perfluorohexyl phosphonic acid | | | Cl-PFHxPA | 416,49 | | Fluoro  surfactant | EPI:3.37 | 4.01[[49]](#footnote-49) |  | 180 | 360 | 1620 | | | 1.37 | 0.99 | 0.38 | III |
|  | Sodium bis(perfluorohexyl) phosphinate | | |  |  | |  |  |  |  | 180 | 360 | 1620 | | | 1.58 | 0.77 | 0.81 | III |
| Non fluorinated alternatives (13 substances) | | | | | | | | | | | | | | | | | | | |
| 577-11-7 | Di-2-ethylhexyl sulfosuccinate, sodium salt | | |  | 444,56 | Waxes and resins  Sulfosuccinate | | EPI:3,95 |  |  | 9 | 17 | 78 | | | 0,04 | 0,03 | 0,01 | III |
| 4261-72-7 | Stearamidomethyl pyridine chloride | | |  | 411,08 | Waxes and resins  Stearamide | | EPI: 5.16 |  |  | 38 | 75 | 338 | | | 0,49 | 0,25 | 0,24 | III |
| 556-67-2 | Octamethyl cyclotetrasiloxane | | | D4 | 296.2 | Siloxanes. intermediate for the production of silicone polymers | | EPI: 6.74 | 4.34 to 6,49[[50]](#footnote-50) |  | Exper.  < 6,5  Not persistent[[51]](#footnote-51) | Exper. < 5,2  Not persistent[[52]](#footnote-52) | Exper.  288-588  estimated. > 365  Persistent[[53]](#footnote-53) | | | 1.16 | 0.26 | 0.88 | II |
| 541-02-6 | Decamethyl cyclopentasiloxane | | | D5 | 370.8 | Siloxanes  intermediate for the production of silicone polymers | | EPI: 8.03 | 4,76 to 7,61[[54]](#footnote-54) |  | Estimated > 182  Persistent[[55]](#footnote-55) | Estimated  < 182  Not persistent[[56]](#footnote-56) | Estimated:> 365  Persistent[[57]](#footnote-57) | | | 1.30 | 0.40 | 0.89 | II |
| 540-97-6 | Dodecamethyl cyclohexasiloxane | | | D6 | 444,93 | Siloxanes intermediate for the production of silicone polymers | | EPI:9.06 | 5,86 to 9.06[[58]](#footnote-58)[[59]](#footnote-59) |  | Exper. >411  Persistent[[60]](#footnote-60) | Estimated  < 182  No exper. data | Estimated >365  Persistent[[61]](#footnote-61) | | | 1,26 | 0,55 | 0,71 | II |
| 107-46-0 | Hexamethyl disiloxane | | | MM (or HMDS) | 162,38 | Siloxanes  intermediate for the production of silicone polymers | | EPI:5,25 |  |  | 15 | 30 | 135 | | | 0,54 | 0,09 | 0,45 | III |
| 107-51-7 | Octamethyl trisiloxane | | | MDM | 236,54 | Siloxanes  intermediate for the production of silicone polymers. | | EPI:6.6 | 6.60[[62]](#footnote-62) | 3610 - 7730[[63]](#footnote-63) | 38  Estimated[[64]](#footnote-64)  >182 | 75  Estimated[[65]](#footnote-65) 120 | 338  Estimated[[66]](#footnote-66) 480  No experimental data available | | | 0,76 | 0,06 | 0,71 | II |
| 141-62-8 | Decamethyl tetrasiloxane | | | MD2M | 310,69 | Siloxanes  intermediate for the production of silicone polymers | | EPI:8.21 | 8.21[[67]](#footnote-67) |  | 38 | 75 | 338 | | | 0,91 | 0,20 | 0,71 | II |
| 141-63-9 | Dodecamethyl pentasiloxane | | | MD3M | 384,85 | Siloxanes  intermediate for the production of silicone polymers | | EPI:9,61  7,8[[68]](#footnote-68) |  |  | 38 | 75 | 338 | | | 1,01 | 0,14 | 0,87 | III |
| 38640-62-9 | Diisoproplynaftalene | | |  | 212,34 | Waxes and resins  Aromatics | | EPI:6,08 |  | 2630[[69]](#footnote-69) | 38 | 75 | 338 | | | 0.93 | 0,44 | 0,49 | II |
| 35860-37-8 | Triisopropylnaftalene | | |  | 254,42 | Waxes and resins  Aromatics | | EPI:7,54 |  | 138038[[70]](#footnote-70) | 38 | 75 | 338 | | | 1.08 | 0.27 | 0.81 | II |
| 69009-90-1 | Diisopropyl-1,1'-biphenyl | | |  | 238,38 | Waxes and resins  Aromatics | | EPI:6,67 |  | 104712[[71]](#footnote-71) | 38 | 75 | 338 | | | 1,20 | 0,39 | 0,81 | II |
| 25640-78-2 | 1-Isopropyl-2-phenyl-benzene | | |  | 196,29 | Waxes and resins  Aromatics | | 5,21[[72]](#footnote-72) | 5,21[[73]](#footnote-73) |  | 38 | 75 | 338 | | | 1,24 | 0,31 | 0,93 | II |
| 67674-67-3 | (Hydroxyl) Terminated polydimethylsiloxane | | |  | 550 - 650 | | Non ionic surfactant |  |  |  |  |  | | |  |  |  |  | III |
| **Pesticides (9 substances)[[74]](#footnote-74)** | | | | | | | | | | | | | | | | | | | |
| 120068-37-3 | Fipronil | | |  | 437,15 | Pesticides | |  | 3,75 | 321 | Exper: 68,0 | field. 65,0  Lab: 142,0 | | Exper: 68,0 | | 1.40 | 1.00 | 0.40 | IV |
| 71751-41-2 | Abamectine | | |  | 866,60 | Pesticides | |  | 4,40 | 69 | Exper. 89,0 | Field: 1,0  Lab:28,7 | | Exper: 89 | | 1.36 | 0.97 | 0.38 | IV |
| 95737-68-1 | Pyriproxyfen | | |  | 321,37 | Pesticides | |  | 5,37 | 1379 | Exper: 4,2 | Field . 6,5  Lab: 6,7 | | Exper: 4,2 | | 0.82 | 0.63 | 0.19 | IV |
| 122-14-5 | Fenitrothion | | |  | 277,23 | Pesticides | |  | 3,32 | 29 | Exper: 1,6 | Lab: 2,7 | | Exper: 1,6 | | 0.60 | 0.31 | 0.29 | IV |
| 138261-41-3, 105827-78-9 | Imidacloprid | | |  | 255,66 | Pesticides | |  | 0,57 | 1 | Exper: 129 | Field: 174  Lab: 187 | | Exper: 129 | | 0.33 | 0.33 | 0.00 | IV |
| 52315-07-8 | Cypermethrin | | |  | 416,31 | Pesticides | |  | 6,60 | 356 | Exper: 2 | Field: 10  Lab: 60 | | Exper: 2 | | 1.26 | 0.86 | 0.36 | II |
| 52918-63-5 | Deltamethrin | | |  | 505,20 | Pesticides | |  | 4,60 | 1400 | Exper: 65 | Field:21  Lab: 26 | | Exper: 65 | | 1.06 | 0.75 | 0.31 | II |
| 2921-88-2 | Chlorpyrifos | | |  | 350,89 | Pesticides | |  | 5,00 | 1374 | Exper: 36,5 | Field: 21  Lab: 76 | | Exper: 36,5 | | 1.41 | 0.85 | 0.56 | II |
| 67485-29-4 | Hydramethylnon | | |  | 494,5 | Pesticides | | 7.54[[75]](#footnote-75) | 2.31[[76]](#footnote-76)[[77]](#footnote-77) | 36[[78]](#footnote-78) | <0,04[[79]](#footnote-79) [[80]](#footnote-80) | 5[[81]](#footnote-81)  7-391[[82]](#footnote-82) | | 7-28[[83]](#footnote-83) (sandy loam) | | 1.67 | 0.95 | 0.72 | IV |
| **Commercial brands (12 brands)** | | | | | | | | | | | | | | | | | | | |
|  | Polyfox® | | |  | 1150-4480[[84]](#footnote-84) | | Polymers |  |  |  |  |  |  | | |  |  |  | III |
|  | Emulphor® FAS | | |  | High-molecular fatty alcohol polyglycol ether sulphate, sodium salt[[85]](#footnote-85) | | Polymers |  |  |  |  |  |  | | |  |  |  | III |
|  | Enthone® | | |  | nanofinish technology[[86]](#footnote-86) | | Polymers |  |  |  |  |  |  | | |  |  |  | III |
|  | Zonyl® | | |  | Fluoropolymers[[87]](#footnote-87) | | Polymers |  |  |  |  |  |  | | |  |  |  | III |
|  | Polyfox® | | |  | Reactive intermediates in the formulation of acrylic, ester and urethane polymers and copolymers[[88]](#footnote-88) | | Polymers when applied |  |  |  |  |  |  | | |  |  |  | III |
|  | Capstone® | | |  | > 40 000 (acrylate polymer)  3000-5000 (urethane polymer) | | Polymers |  |  |  |  |  |  | | |  |  |  | III |
|  | Nuva® | | |  | C6 side chain fluoropolymers[[89]](#footnote-89). | | Polymers when applied. |  |  |  |  |  |  | | |  |  |  | III |
|  | Unidyne® | | |  | Side chain fluoropolymers[[90]](#footnote-90) | | Polymers when applied |  |  |  |  |  |  | | |  |  |  | III |
|  | Rucoguard® | | |  | Aqueous C6-based Fluorocarbon Polymeric Dispersions[[91]](#footnote-91) | | Polymers |  |  |  |  |  |  | | |  |  |  | III |
|  | Oleophobol® | | |  | Dispersion of a polymer, perfluorinated compound[[92]](#footnote-92) | | Polymers |  |  |  |  |  |  | | |  |  |  | III |
|  | Asahiguard® | | |  | C6 fluorinated polymer technology[[93]](#footnote-93) | | Polymers when applied |  |  |  |  |  |  | | |  |  |  | III |
|  | Solvera® | | |  | Perfluoropolyether[[94]](#footnote-94) | | Polymers |  |  |  |  |  |  | | |  |  |  | III |

**Annex III: Results of the screening assessment for 9 alternatives to PFOS**

| **Substance** | **Persistence Annex D 1. (b)** | **Bioaccumulation Annex D 1 (c)** | **LRT**  **Annex D 1 (d)** | **Adverse effects: ecotoxicity**  **Annex D1 (e)** | **Adverse effects to human health**  **Annex D1 (e)** |
| --- | --- | --- | --- | --- | --- |
| Decamethyl cyclopentasiloxane (D5) | Yes | Yes | Yes | No | No |
| Decamethyl tetrasiloxane (MD2M) | Equivocal data | No | Yes | No | No |
| Diisoproplynaftalene (DIPN) | Yes | Yes | No | Yes | No |
| Diisopropyl-1,1'-biphenyl | Insufficient data | Insufficient data | No | Insufficient data | Insufficient data |
| 1-Isopropyl-2-phenyl-benzene | No | Yes | No | Yes | No |
| Octamethyl cyclotetrasiloxane (D4) | Yes | Yes | Yes | Yes | Yes |
| Octamethyl trisiloxane (MDM) | Equivocal data | Yes | Yes | No | No |
| Triisopropylnaftalene | Yes | Yes | No | Insufficient data | Insufficient data |

1. Annex to decision POPRC-9/5 [↑](#footnote-ref-1)
2. UNEP/POPS/POPRC.8/INF/28. [↑](#footnote-ref-2)
3. Related chemicals are chemicals that contain the structural element PFOS in their molecular structure and are or were produced with PFOSF as a starting or intermediate material. [↑](#footnote-ref-3)
4. UNEP/POPS/POPRC.9/INF/11/Rev.1 [↑](#footnote-ref-4)
5. UNEP/POPS/POPRC.8/INF/17/Rev.1 [↑](#footnote-ref-5)
6. ENVIRON, Assessment of POP Criteria for Specific Short-Chain Perfluorinated Alkyl Substances, project number: 0134304A, (2014) ; OECD, “Synthesis paper on per- and polyfluorinated chemicals (PFCs)”, (2013) ; Nordic Council of Ministers, Per- and polyfluorinated substances in the Nordic Countries,Use, occurence and toxicology”, TemaNord 2013:542, ISBN: 978-92-893-2562-2, (2013), http://dx.doi.org/10.6027/TN2013-542 [↑](#footnote-ref-6)
7. UNEP/POPS/POPRC.9/INF/10/Rev.1 [↑](#footnote-ref-7)
8. http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/tabid/3565/Default.aspx [↑](#footnote-ref-8)
9. Guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals indicates (UNEP/POPS/POPRC.5/10/Add.1) [↑](#footnote-ref-9)
10. UNEP/POPS/POPRC.8/INF/28 [↑](#footnote-ref-10)
11. OECD Global Portal to Information on Chemical Substances; http://www.echemportal.org/echemportal [↑](#footnote-ref-11)
12. Chem-phys data Chemspider; http://www.chemspider.com/ [↑](#footnote-ref-12)
13. http://www.unece.org/trans/danger/publi/ghs/ghs\_welcome\_e.html" \t "\_blank [↑](#footnote-ref-13)
14. EPIWB 4.1 (US EPA, 2011). Estimation Programs Interface Suite™ for Microsoft® Windows, v 4.10. United States Environmental Protection Agency, Washington, DC, USA. [↑](#footnote-ref-14)
15. http://www.rivm.nl/bibliotheek/rapporten/601356001.html. [↑](#footnote-ref-15)
16. http://www.epa.gov/oppt/exposure/pubs/updates\_episuite\_v4.11.revised.htm [↑](#footnote-ref-16)
17. http://www.epa.gov/oppt/exposure/pubs/updates\_episuite\_v4.11.revised.htm [↑](#footnote-ref-17)
18. A polymer has a number-average molecular weight (NAVG MW) in a range that is greater than or equal to 1,000 daltons and less than 10,000 daltons; http://www.epa.gov/oppt/newchems/pubs/polyguid.pdf [↑](#footnote-ref-18)
19. Risk and policy analysts limited. Review of REACH with regard to the Registration Requirements on Polymers. 2012. http://ec.europa.eu/enterprise/sectors/chemicals/files/reach/review2012/registr-req-final-report-part-a\_en.pdf [↑](#footnote-ref-19)
20. UNEP/POPS/POPRC.5/10/Add.1 [↑](#footnote-ref-20)
21. Applications listed in part I of Annex B of the Stockholm Convention for which the alternative is relevant.(A) Information from the Guidance on alternatives to PFOS, its salts and PFOSF and their related chemicals (UNEP/POPS/POPRC.9/INF/11/rev1); (B) Information from the technical paper on the identification and assessment of alternatives to the use of PFOS, its salts and PFOSF and their related chemicals in open applications UNEP/POPS/POPRC.8/INF/17. [↑](#footnote-ref-21)
22. Buck et al. “Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins”, Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011)

    Buck et al. “Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins”, Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011) [↑](#footnote-ref-22)
23. Buck et al. “Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins”, Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011) [↑](#footnote-ref-23)
24. Buck et al. “Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins”, Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011) [↑](#footnote-ref-24)
25. Buck et al. “Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins”, Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011) [↑](#footnote-ref-25)
26. Buck et al. “Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins”, Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011) [↑](#footnote-ref-26)
27. Wang, De-Gao, et al. "Review of recent advances in research on the toxicity, detection, occurrence and fate of cyclic volatile methyl siloxanes in the environment." *Chemosphere* Vol. 93, Issue 5, October 2013: 711–725  
    URL: <http://www.sciencedirect.com/science/article/pii/S0045653512012805> [↑](#footnote-ref-27)
28. Wang, De-Gao, et al. "Review of recent advances in research on the toxicity, detection, occurrence and fate of cyclic volatile methyl siloxanes in the environment." *Chemosphere* Vol. 93, Issue 5, October 2013: 711–725  
    URL: <http://www.sciencedirect.com/science/article/pii/S0045653512012805> [↑](#footnote-ref-28)
29. Wang, De-Gao, et al. "Review of recent advances in research on the toxicity, detection, occurrence and fate of cyclic volatile methyl siloxanes in the environment." *Chemosphere* Vol. 93, Issue 5, October 2013: 711–725  
    URL: <http://www.sciencedirect.com/science/article/pii/S0045653512012805> [↑](#footnote-ref-29)
30. <http://echa.europa.eu/documents/10162/c98c53e1-7228-4985-8f87-6e202788106f> [↑](#footnote-ref-30)
31. <http://echa.europa.eu/documents/10162/c98c53e1-7228-4985-8f87-6e202788106f> [↑](#footnote-ref-31)
32. <https://echa.europa.eu/documents/10162/13632/intentions_2013_en.pdf> [↑](#footnote-ref-32)
33. <http://www.cdms.net/ldat/mp9fi001.pdf>,

    <http://www.siltech.com/msds/P2002.2.pdf>,

    http://www.hitochem.com/uploadfile/20120411191716530.pdf, [↑](#footnote-ref-33)
34. Submission by Ecuador, http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/tabid/2266/Default.aspx [↑](#footnote-ref-34)
35. Epi Suite, level III fugacity model if nothing else is stated [↑](#footnote-ref-35)
36. If molecular weight is not available a short description from the producer is described. [↑](#footnote-ref-36)
37. <http://www.usask.ca/toxicology/jgiesy/pdf/publications/JA-689.pdf> [↑](#footnote-ref-37)
38. <http://www.chemspider.com/Chemical-Structure.10654380.html> [↑](#footnote-ref-38)
39. <http://webnet.oecd.org/CCRWEB/ChemicalDetails.aspx?ChemicalID=69fd4915-cbb4-4c6e-bb35-ee20e61ec8fc> [↑](#footnote-ref-39)
40. [↑](#footnote-ref-40)
41. ENVIRON ”Assessment of POP Criteria for Specific Short-Chain Perfluorinated Alkyl Substances”, project number; 0134304A, (2014) [↑](#footnote-ref-41)
42. ENVIRON ”Assessment of POP Criteria for Specific Short-Chain Perfluorinated Alkyl Substances”, project number; 0134304A, (2014) [↑](#footnote-ref-42)
43. ENVIRON ”Assessment of POP Criteria for Specific Short-Chain Perfluorinated Alkyl Substances”, project number; 0134304A, (2014) [↑](#footnote-ref-43)
44. Buck et al. “Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins”, Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011) [↑](#footnote-ref-44)
45. ENVIRON ”Assessment of POP Criteria for Specific Short-Chain Perfluorinated Alkyl Substances”, project number; 0134304A, (2014) [↑](#footnote-ref-45)
46. <http://www.chemspider.com/Chemical-Structure.2062563.html> [↑](#footnote-ref-46)
47. Dr. Stephen Korzeniowski,“Fluortelomer products in the Environment – an update“, oral presentation DuPont (2008). <http://www2.dupont.com/Forafac/en_US/assets/downloads/fluorotelomer_in_environment_nfpa2008_02june_shk.pdf> [↑](#footnote-ref-47)
48. [↑](#footnote-ref-48)
49. Quinete, N., et al., Degradation studies of new substitutes for perfluorinated surfactants. Arch. Environ. Contam. Toxicol., 2010. 59: p. 20-30 Quinete, N., et al., Degradation studies of new substitutes for perfluorinated surfactants. Arch. Environ. Contam. Toxicol., 2010. 59: p. 20-30 [↑](#footnote-ref-49)
50. Wang, De-Gao, et al. "Review of recent advances in research on the toxicity, detection, occurrence and fate of cyclic volatile methyl siloxanes in the environment."Chemosphere Vol. 93, Issue 5, October 2013: 711–725; URL: http://www.sciencedirect.com/science/article/pii/S0045653512012805 [↑](#footnote-ref-50)
51. <https://www.ec.gc.ca/ese-ees/2481B508-1760-4878-9B8A-270EEE8B7DA4/batch2_556-67-2_en.pdf> [↑](#footnote-ref-51)
52. <https://www.ec.gc.ca/ese-ees/2481B508-1760-4878-9B8A-270EEE8B7DA4/batch2_556-67-2_en.pdf> [↑](#footnote-ref-52)
53. <https://www.ec.gc.ca/ese-ees/2481B508-1760-4878-9B8A-270EEE8B7DA4/batch2_556-67-2_en.pdf> [↑](#footnote-ref-53)
54. Wang, De-Gao, et al. "Review of recent advances in research on the toxicity, detection, occurrence and fate of cyclic volatile methyl siloxanes in the environment." Chemosphere Vol. 93, Issue 5, October 2013: 711–725 [↑](#footnote-ref-54)
55. <http://www.ec.gc.ca/ese-ees/13CC261E-5FB0-4D33-8000-EA6C6440758A/batch2_541-02-6_en.pdf> [↑](#footnote-ref-55)
56. <http://www.ec.gc.ca/ese-ees/13CC261E-5FB0-4D33-8000-EA6C6440758A/batch2_541-02-6_en.pdf> [↑](#footnote-ref-56)
57. <http://www.ec.gc.ca/ese-ees/13CC261E-5FB0-4D33-8000-EA6C6440758A/batch2_541-02-6_en.pdf> [↑](#footnote-ref-57)
58. Wang, De-Gao, et al. "Review of recent advances in research on the toxicity, detection, occurrence and fate of cyclic volatile methyl siloxanes in the environment." *Chemosphere* Vol. 93, Issue 5, October 2013: 711–725 [↑](#footnote-ref-58)
59. <http://www.ec.gc.ca/ese-ees/FC0D11E7-DB34-41AA-B1B3-E66EFD8813F1/batch2_540-97-6_en.pdf> [↑](#footnote-ref-59)
60. <http://www.ec.gc.ca/ese-ees/FC0D11E7-DB34-41AA-B1B3-E66EFD8813F1/batch2_540-97-6_en.pdf> [↑](#footnote-ref-60)
61. <http://www.ec.gc.ca/ese-ees/FC0D11E7-DB34-41AA-B1B3-E66EFD8813F1/batch2_540-97-6_en.pdf> [↑](#footnote-ref-61)
62. <https://www.ec.gc.ca/ese-ees/19584F14-D972-46A1-B71C-FA9A36FFB0FE/batch12_107-51-7_en.pdf> [↑](#footnote-ref-62)
63. https://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=19584F14-1#toc30 [↑](#footnote-ref-63)
64. <https://www.ec.gc.ca/ese-ees/19584F14-D972-46A1-B71C-FA9A36FFB0FE/batch12_107-51-7_en.pdf> [↑](#footnote-ref-64)
65. <https://www.ec.gc.ca/ese-ees/19584F14-D972-46A1-B71C-FA9A36FFB0FE/batch12_107-51-7_en.pdf> [↑](#footnote-ref-65)
66. <https://www.ec.gc.ca/ese-ees/19584F14-D972-46A1-B71C-FA9A36FFB0FE/batch12_107-51-7_en.pdf> [↑](#footnote-ref-66)
67. VU University Amsterdam, J Weiss 2012

    <https://www.ec.gc.ca/ese-ees/19584F14-D972-46A1-B71C-FA9A36FFB0FE/batch12_107-51-7_en.pdf> [↑](#footnote-ref-67)
68. <http://webnet.oecd.org/hpv/UI/handler.axd?id=1A45D30D-D373-4696-8753-2FDF04A4B536> [↑](#footnote-ref-68)
69. <http://webnet.oecd.org/CCRWEB/ChemicalDetails.aspx?ChemicalID=5bbb30fa-beb8-4c8a-941c-1e8f8bb1c8c3> [↑](#footnote-ref-69)
70. <http://www.chemspider.com/Chemical-Structure.106232.html> [↑](#footnote-ref-70)
71. [http://www.chemspider.com/Chemical-Structure.157882.htm](http://www.chemspider.com/Chemical-Structure.157882.html)l [↑](#footnote-ref-71)
72. <http://www.chemspider.com/Chemical-Structure.21974.html> [↑](#footnote-ref-72)
73. VU University Amsterdam, J Weiss 2012 [↑](#footnote-ref-73)
74. All P and B data for the pesticides, except for hydramethylnon, are taken from document UNEP/POPS/POPRC.8/INF/28. For these 8 pesticides data of DT50water/sediment for the whole water/sediment system [days] is listed [↑](#footnote-ref-74)
75. <http://www.chemspider.com/Chemical-Structure.4445168.html>, Since Hydramethylnon is a fluorinated substance, log Kow may not reflect the bioaccumulation potential. [↑](#footnote-ref-75)
76. <http://www.cdpr.ca.gov/docs/emon/pubs/fatememo/hydmthn.pdf> [↑](#footnote-ref-76)
77. <http://www.fluoridealert.org/wp-content/pesticides/hydramethylnon.toxnet.hsdb.htm> [↑](#footnote-ref-77)
78. http://www.fluoridealert.org/wp-content/pesticides/hydramethylnon.toxnet.hsdb.htm [↑](#footnote-ref-78)
79. <http://www.cdpr.ca.gov/docs/emon/pubs/fatememo/hydmthn.pdf> [↑](#footnote-ref-79)
80. <http://npic.orst.edu/factsheets/hydragen.pdf> [↑](#footnote-ref-80)
81. <http://www.cdpr.ca.gov/docs/emon/pubs/fatememo/hydmthn.pdf> [↑](#footnote-ref-81)
82. <http://npic.orst.edu/factsheets/hydragen.pdf> [↑](#footnote-ref-82)
83. <http://www.fluoridealert.org/wp-content/pesticides/hydramethylnon.toxnet.hsdb.htm> [↑](#footnote-ref-83)
84. <http://www.omnova.com/products/chemicals/documents/PolyFoxReactivePolymerIntermediates09March30.pdf> [↑](#footnote-ref-84)
85. <http://www.formulation-technologies.basf.com/productdetails?prd=30061192> [↑](#footnote-ref-85)
86. <http://www.enthone.com/New_Technology_Development/ORMECON_Acquisition.aspx> [↑](#footnote-ref-86)
87. <http://www2.dupont.com/Teflon_Industrial/en_US/products/product_by_type/additives/index.html> [↑](#footnote-ref-87)
88. <http://www.omnova.com/products/chemicals/PolyFox.aspx> [↑](#footnote-ref-88)
89. <http://newsroom.clariant.com/clariant-expands-as-its-c6-chemistry-nuva%C2%AE-n-increasingly-gets-the-textile-industry%E2%80%99s-approval/> [↑](#footnote-ref-89)
90. <http://daikin-america.com/unidyne-repellants-and-surfactants/> [↑](#footnote-ref-90)
91. <http://www.rudolf.de/en/products/co-producer-b2b/10-water-oil-and-soil-repellent-agents/11-c6-based-fluorocarbon-polymers.html> [↑](#footnote-ref-91)
92. <http://www.relish.co.in/oleophobolzsr.pdf> [↑](#footnote-ref-92)
93. <http://www.textileworld.com/Articles/2013/June/Textile_News/AGC_Chemicals_Americas_Releases_PFOA-Free_AsahiGuard_AG-E550D_Water-Oil_Repellent> [↑](#footnote-ref-93)
94. TDS\_Solvera\_PT\_5045\_PG.pdf

    ´´ [↑](#footnote-ref-94)