REPORT

Production, use and trade of POPs newly listed in the Stockholm Convention 2009 to 2022

UNEP, 2024

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ACKNOWLEDGEMENT

This report, authored by Dr. Roland Weber in 2024 for Knowledge and Risk Unit at United Nations Environment Programme's Chemicals and Health Branch – Industry and Economy Division, under the project ID 9884 entitled "Integrated SC Toolkit to Improve the Transmission of Information under Articles 07 and 15" and ID 10785 "Global Development, Review and Update of National Implementation Plans (NIPs) under the Stockholm Convention (SC) on Persistent Organic Pollutants (POPs)" funded by Global Environment Facility (GEF) and implemented by United Nations Environment Programme.

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Recommended citation: *UNEP (2024), Production, use and trade of POPs newly listed in the Stockholm Convention 2009 to 2022.* This citation ensures proper acknowledgment and attribution in accordance with applicable standards.

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Abbreviations and Acronyms

BRS	Basel, Rotterdam and Stockholm conventions
CAS	Chemical Abstracts Service
c-DecaBDE	Commercial Decabromodiphenyl ether
c-OctaBDE	Commercial Octabromodiphenyl ether
c-PentaBDE	Commercial Pentabromodiphenyl ether
COP	Conference of Parties
CPs	Chlorinated paraffins
DDT	Dichlorodiphenyltrichloroethane
decaBDE; BDE-209	Decabromodiphenyl ether
EEE	Electrical and electronic equipment
EPS	Expanded polystyrene
EU	European Union
GEF	Global Environment Facility
HBB	Hexabromobiphenyl
HBCD(D)	Hexabromocyclododecane
HCBD	Hexachlorobutadiene
HCH	Hexachlorocyclohexane
heptaBDE	Heptabromodiphenyl ether
hexaBDE	Hexabromodiphenyl ether
HIPS	High impact polystyrene
HS Code	Harmonized System Codes
kt	Kilotonne; 1000 tonnes
LCCPs	Long-chain chlorinated paraffins
MCCPs	Medium-chain chlorinated paraffins
MFA/SFA	Material and substance flow analysis
NIP	National Implementation Plan
OFN	Octafluoronaphthalene

PBBs	Polybrominated biphenyls
PCA	Pentachloroanisole
PCBs	Polychlorinated biphenyls
PCNs	Polychlorinated naphthalenes
PCP	Pentachlorophenol and its salts and esters
PCP-Na	Sodium pentachlorophenolate
PeCB	Pentachlorobenzene
PFASs	Per- and polyfluorinated alkylated substances
PFHxS	Perfluorohexane sulfonic acid
PFNs	Polyfluorinated naphthalenes
PFOA	Perfluorooctanoic acid; Perfluorooctanoate
PFOI	Perfluorooctyl iodide
PFOS	Perfluorooctane sulfonic acid; Perfluorooctane sulfonate
PFOSF	Perfluorooctane sulfonyl fluoride
POPs	Persistent organic pollutants
POPRC	Persistent Organic Pollutants Review Committee
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
RME	Risk management evaluation
SCCPs	Short-chain chlorinated paraffins
t	Tonnes; metric tons
tetraBDE	Tetrabromodiphenyl ether
TOP-assay	Total Oxidisable Precursor assay
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environmental Programme
WEEE	Waste electrical and electronic equipment
XPS	Extruded polystyrene

1 Introduction and Background

1.1 Introduction and objective

This report compiles information on newly listed persistent organic pollutants (POPs) in the Stockholm Convention from 2009 to 2022[1]. It focuses on current and historical production, major uses, and information on current trade. Where particularly relevant, some information on waste and recycling products containing these POPs is also provided.

For the inventory, management, control and reduction of POPs, it is necessary to know if a POP is currently produced and traded and its current uses. Industrial POPs used in the past may still be present in products such as electrical and electronic equipment (EEE), in the transport sector (e.g., automobiles and airplanes), or in construction materials, like insulation foam, flooring, or sealants. For the inventory and management of remaining POPs containing products, it is important to know the former production, historical use and related service life of these products.

This report gives an overview of how to access information on the production, trade and use of listed POPs.

Newly listed POPs and entry into force of amendments

The Stockholm Convention on Persistent Organic Pollutants was adopted at a Conference of Plenipotentiaries on 22 May 2001 in Stockholm, Sweden. The Convention entered into force on 17 May 2004, ninety days after submission of the fiftieth instrument of ratification, acceptance, approval, or accession with respect to the Convention with 12 initially listed POPs.

The Convention has a mechanism for listing of new POPs. Any Party may submit a proposal for listing a new chemical in Annexes A, B, or C of the Convention. The POPs Review Committee evaluates the proposals and makes recommendations to the Conference of the Parties on such listing in accordance with Article 8 of the Convention. Since 2009, 20 POPs or POPs groups were newly listed in the Convention (Table 1).[2] Amendments to Annexes A, B or C to the Convention to list new persistent organic pollutants (POPs) therein enter into force one year from the date of communication of their adoption by the depositary, except for those Parties that submit either: a notification of non-acceptance in accordance with the provisions of paragraph 3 (b) of Article 22; or a declaration in accordance with paragraph 4 of Article 22 and paragraph 4 of Article 25 of the Convention. Table 1 gives an overview of newly listed POPs in the Convention and summarizes the dates of entry into force of the amendments to Annexes A, B and C for most Parties.

Table 1. Dates of entry into force of the amendments to list new POPs in Annexes A, B and C to the Stockholm Convention for most Parties, as of March 2021

Decision	Chemical	Annex	Date of entry into force for most Parties
SC-4/10	Alpha hexachlorocyclohexane (alphaHCH)	A	26 August 2010
SC-4/11	Beta hexachlorocyclohexane (betaHCH)	A	26 August 2010
SC-4/12	Chlordecone	A	26 August 2010
SC-4/13	Hexabromobiphenyl (HBB)	A	26 August 2010
SC-4/14	Hexabromodiphenyl ether and heptabromodiphenyl ether (hexaBDE and heptaBDE)	A	26 August 2010

1 Also, the management of the initially listed 12 POPs is relevant. However, the production of all pesticides stopped long ago (Figure 1) with the exemption of DDT. For DDT, particular activities like UNEP's DDT Expert Group address the reduction of production and use by promoting alternatives. For PCB, dedicated activities like the PCB Elimination Network and the intersessional working group are compiling up-to-date information.

2 http://chm.pops.int/TheConvention/ThePOPs/TheNewPOPs/tabid/2511/Default.aspx

Decision	Chemical	Annex	Date of entry into force for most Parties
SC-4/15	Lindane	A	26 August 2010
SC-4/16	Pentachlorobenzene (PeCB)	A and C	26 August 2010
SC-4/17	Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOSF)	B	26 August 2010
SC-4/18	Tetrabromodiphenyl ether and pentabromodiphenyl ether (tetraBDE and pentaBDE)	A	26 August 2010
SC-5/3	Endosulfan	A	27 October 2012
SC-6/13	Hexabromocyclododecane (HBCD)	A	26 November 2014
SC-7/12	Hexachlorobutadiene (HCBD)	A	15 December 2016
SC-7/13	Pentachlorophenol (PCP) and its salts and esters	A	15 December 2016
SC-7/14	Polychlorinated naphthalenes (PCN)	A and C	15 December 2016
SC-8/10	Decabromodiphenyl ether (decaBDE)	A	18 December 2018
SC-8/11	Short-chain chlorinated paraffins (SCCPs)	A	18 December 2018
SC-8/12	Hexachlorobutadiene	C	18 December 2018
SC-9/4	Perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride	B	3 December 2020
SC-9/11	Dicofol	A	3 December 2020
SC-9/12	Perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds	A	3 December 2020
SC-10/13	Perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS-related compounds	A	28 August 2023

1.2 Exemptions for continued production and use of POPs

It is important to understand the exemptions for the production and use of the respective POPs since they define the frame for continued production and use. Parties need to register for exemption for continued production and are encouraged to inform on production volume.

To enable Parties to the Convention to take measures to reduce or eliminate releases of POPs from intentional production and use, for which alternatives do not exist yet or are not readily available, the Convention allows Parties to register for specific exemptions for a specific time period.[3] Annexes A and B to the Convention describe specific exemptions, as well as acceptable purposes, which are available with respect to the relevant POPs. Parties that want to use certain exempted POPs need to register for specific exemptions listed in Annex A or B pursuant to Paragraph 3 of Article 4.[3] Specific exemptions have a limited timeframe and shall expire five (5) years after the date of entry into force of the Convention with respect to that particular chemical (Paragraph 4 of Article 4), unless an earlier date is indicated in the Register by the Party or an extension is granted by the Conference of the Parties under Paragraph 7 of Article 4.[3] Similarly, few acceptable purposes are relevant for the production, trade and use of POPs. Acceptable purposes have no limited timeframe unless specified otherwise by the Conference of the Parties.

Therefore, for the individual POPs in this document, a brief overview of the registration of exemptions for production and use is provided in the respective sections of POPs listed with exemptions.

[3] http://chm.pops.int/Implementation/Exemptions/Overview/tabid/789/Default.aspx

It needs to be highlighted that registration might not reflect the current situation of production and use of these POPs since:

- Parties might not be aware that they are using some of the currently produced POPs even in large amounts. This is, for example, the case for short-chain chlorinated paraffins (SCCPs), which are currently not traded as SCCPs, but rather contained in unspecified chlorinated paraffin (CP) mixtures (see Section 5.2), and for the more than 100 PFOA-related compounds which can degrade to PFOA (Section 3.2).
- Parties are also not aware that many products on the market contain listed POPs as additives or unintentional trace contaminants. This is in particular the case for PFOA and related compounds in products such as concentrates for firefighting foam or textile finishing agents. PFOA and related compounds might be present but are not labelled and therefore might be marketed and used without the awareness of a Party (Sections 3.23.3 and 3.3). This is also true for plasticized products made with unspecified CP mixtures that are likely to contain SCCPs (5.3 and 5.25.5).
- POP-containing products are also imported into countries without labelling and enter the consumer market or major use sectors like construction materials.
- In many cases, companies that put these products on the market are not aware that their products contain listed POPs (in particular SCCPs and PFOA-related substances).

There are a range of Parties to the Convention that ratified the Convention in accordance with Paragraph 4 of Article 25 of the Convention, in which case these Parties have not ratified major newly listed POPs,[4] which are still produced in the respective country. This includes potential producers of POPs like Bangladesh, China, or India known to have, for example, large productions of chlorinated paraffins which might contain SCCPs (see Section 5.2).

Therefore, while the listing in the register of exemptions gives some information on the production and use of several POPs, for some Parties there are information gaps on production and use. These gaps could be partly filled in this report by compilation of information from peer-reviewed science publications and other reports.

1.3 Overview of total historical production of POPs

For the inventory and management of individual POPs, it is important to understand what their total production amount and the major time period of production have been. Figure 1 gives an overview of the total production amount of all intentionally produced POPs in the past as well as the production history. The major industrial POPs with total production amount above 500 kilotonnes (kt) are SCCPs (8,795 kt), decaBDE (1,650 kt), PCB (1,326 kt) and HBCD (703 kt). Pesticides lindane (1,794 kt) and related waste isomers α-HCH (6,567 kt)/β-HCH (535 kt), DDT (4,500 kt), PCP (2,103 kt), toxaphene (1,352 kt) and endosulfan (622 kt) have a total production amount above 500 kt (Figure 1; Li et al. 2023[5]). Therefore, these high-volume POPs, in particular industrial POPs, including the products containing these POPs, are of particular relevance for POP inventory and management.

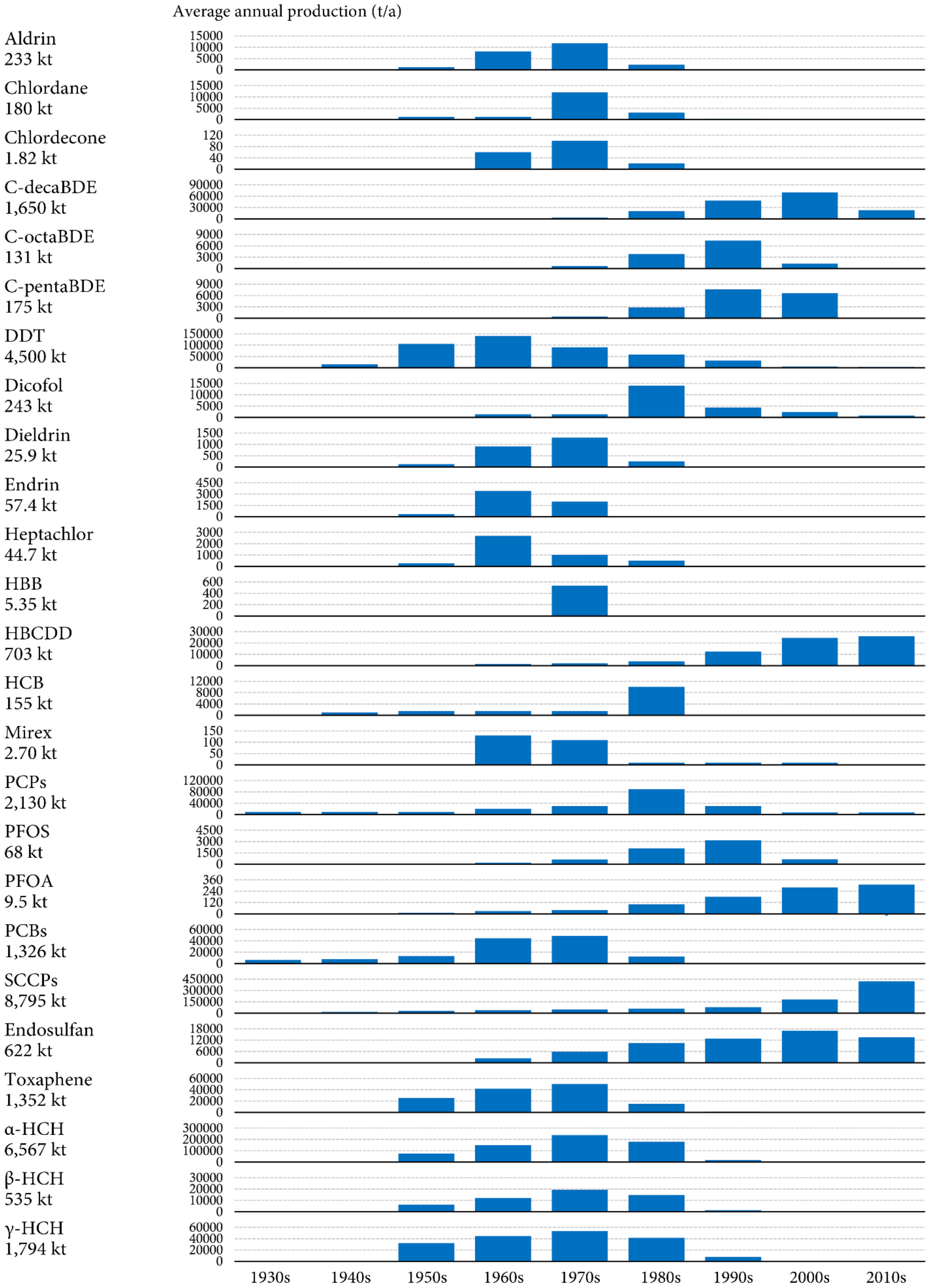
It needs to be stressed that while the total production of PFOS (68-96 kt) and PFOA (9.6 kt) is considerably lower, they are also highly relevant due to their high persistence, mobility and low tolerable daily intake exceeded for many people.[6]

Figure 1. Average annual global productions of the 25 intentionally produced POPs from the 1930s to the 2010s. Numbers under the chemical names on the left indicate the central-tendency estimate of the global cumulative production in kilotonnes (kt) (Li et al. 2023)[5]

4 Weber R (2021) Assessment of newly listed POPs for countries that need to ratify the amendments or to update NIPs. Secretariat of the Basel, Rotterdam and Stockholm Conventions, United Nations Environment Programme, Geneva.

5 Li L, Chen C, Li D, Breivik K, Abbasi G, Li YF (2023). What do we know about the production and release of persistent organic pollutants in the global environment? *Environmental Science: Advances*. 2, 55-68, DOI: 10.1039/d2va00145d.

6 EFSA (2020) Risk to human health related to the presence of perfluoroalkyl substances in food. *EFSA Journal* 2020;18(9):6223, https://doi.org/10.2903/j.efsa.2020.6223.


Average annual production (t/a)
Aldrin
233 kt
Chlordane
180 kt
Chlordecone
1.82 kt
C-decaBDE
1,650 kt
C-octaBDE
131 kt
C-pentaBDE
175 kt
DDT
4,500 kt
Dicofol
243 kt
Dieldrin
25.9 kt
Endrin
57.4 kt
Heptachlor
44.7 kt
HBB
5.35 kt
HBCDD
703 kt
HCB
155 kt
Mirex
2.70 kt
PCPs
2,130 kt
PFOS
68 kt
PFOA
9.5 kt
PCBs
1,326 kt
SCCPs
8,795 kt
Endosulfan
622 kt
Toxaphene
1,352 kt
α-HCH
6,567 kt
β-HCH
535 kt
γ-HCH
1,794 kt
1930s
1940s
1950s
1960s
1970s
1980s
1990s
2000s
2010s

2 Perfluorooctane Sulfonic Acid, Its Salts and Perfluorooctane Sulfonyl Fluoride

2.1 Chemical identity, POPs properties and listing under the Convention

Perfluorooctane sulfonate (PFOS) is a fully fluorinated anion that is used as such or as salt in some applications. PFOS and its related compounds, referred to as "PFOS precursors," which can transform or degrade into PFOS, are members of the large family of perfluoroalkyl substances (PFASs).

Perfluorooctane sulfonyl fluoride (PFOSF) was/is used to produce a wide range of PFOS-related compounds, including side-chain fluorinated polymers, which are used in polymer dispersion on textiles, paper and carpets for fat- and water-repellent properties. These PFOS-related compounds are precursors of PFOS and likely contain PFOS as a process impurity.

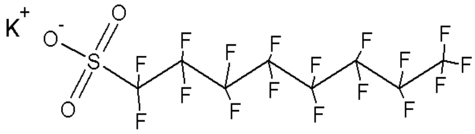
PFOS is extremely persistent and has substantial bioaccumulating and biomagnifying properties.[7,8] PFOS does not follow the classic pattern of other POPs by partitioning into fatty tissues, but instead is water soluble and binds to proteins in the blood, liver and other protein-rich organs.[9]

PFOS has the capacity to undergo long-range transport and also fulfils the toxicity criteria of the Stockholm Convention. Due to the chemical stability and the bond strength of the carbon-fluorine bond these substances are extremely persistent and make them suitable for high-temperature applications and applications in contact with strong acids or bases. The estimated half-life for PFOS in a hydrolysis test in water is reported as >41 years, but may be significantly longer than 41 years since no degradation was detected for "eternal chemicals."[10] Biodegradation of PFOS has also been evaluated under aerobic and anaerobic conditions, but no apparent degradation occurred.[9] Detailed information for listing has been compiled in the risk profile7 and the risk management evaluation (RME).[8]

Table 2. Chemical identification and structure of PFOS and some related compounds[7,8]

Chemical name:	Perfluorooctane Sulfonate (PFOS); Octanesulfonate, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-
Synonyms/abbreviations:	1-Octanesulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro; 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-1-octanesulfonic acid; 1-Octanesulfonic acid, heptadecafluoro-; 1-Perfluorooctanesulfonic acid; Heptadecafluoro-1-octanesulfonic acid; Perfluoro-n-octanesulfonicacid; Perfluoroctanesulfonicacid; Perfluoroctylsulfonicacid
Trade names:	Various
CAS Registry Number:	Sulfonic acid (CAS No. 1763-23-1), perfluorooctane sulfonyl fluoride (CAS No. 307-35-7) and its salts - some examples of commercially important salts are: Potassium salt (CAS No. 2795-39-3); Diethanolamine salt (CAS No. 70225-14-8); Ammonium salt (CAS No. 29081-56-9) Lithium salt (CAS No. 29457-72-5) Tetraethylammonium perfluorooctane sulfonate (CAS No. 56773-42-3) Didecyldimenthylammonium perfluorooctane sulfonate (CAS No. 251099-16-8)

7 Risk profile on perfluorooctane sulfonate. UNEP/POPS/POPRC.2/17/Add.5 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.2-17-Add.5.English.pdf
8 Risk management evaluation on perfluorooctane sulfonate. UNEP/POPS/POPRC.3/20/Add.5 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.3-20-Add.5.English.PDF
9 OECD (Organisation for Economic Co-operation and Development) (2002). Co-operation on Existing Chemicals - Hazard Assessment of Perfluorooctane Sulfonate and its Salts, Environment Directorate Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology, Paris, November 2002.
10 Hekster FM, de Voogt P, Pijnenburg AM Laane RW (2002) Perfluoroalkylated substances. Aquatic environmental assessment Report RIKZ/2002.043. 1 July 2002.

Structure:		Molecular weight: 506.1 (potassium salt) Molecular formula: $C_8F_{17}SO_3K$

PFOS has been listed in 2009 under Annex B with a range of acceptable purposes[11] and specific exemptions (Decision SC-4/17)[12]. This has been amended in 2019 by Decision SC-9/4[13] (entry into force on 3 December 2020) with only one remaining acceptable purpose, which is the use as insect baits with sulfluramid (CAS No. 4151-50-2) as an active ingredient for the control of leaf-cutting ants for agricultural use only (Table 3).

With the adoption of Decision SC-9/4, only two specific exemptions remain, namely the hard-metal plating only in closed-loop systems and firefighting foams for specific uses (Table 4).

The specific exemptions are time-limited for a period of five years. Every four years, each Party that uses and/or produces PFOS must report to the Conference of the Parties on progress made to eliminate it. The Conference of the Parties will evaluate the continued need for these specific exemptions and acceptable purposes.

Table 3. Amended list of acceptable purposes for PFOS by Decision SC-9/4[13] eliminating most of the former acceptable purposes[12]

Chemical	**Activity**	**Acceptable purpose**
Perfluorooctane sulfonic acid (CAS No: 1763-23-1), its salts and perfluorooctane sulfonyl fluoride (CAS No: 307-35-7)	Production	In accordance with Part III of Annex B, production of other chemicals to be used solely for the uses below. Production for uses is listed below
	Use	**As adopted by Decision SC-9/4[13] (entry into force on 3 December 2020):** In accordance with Part III of Annex B for the following acceptable purposes, or as an intermediate in the production of chemicals with the following acceptable purpose: • Insect baits with sulfluramid (CAS No. 4151-50-2) as an active ingredient for control of leaf-cutting ants from Atta spp. and Acromyrmex spp. for agricultural use only

Table 4. Updated listing of specific exemptions for PFOS (Decision SC-9/4)[13]

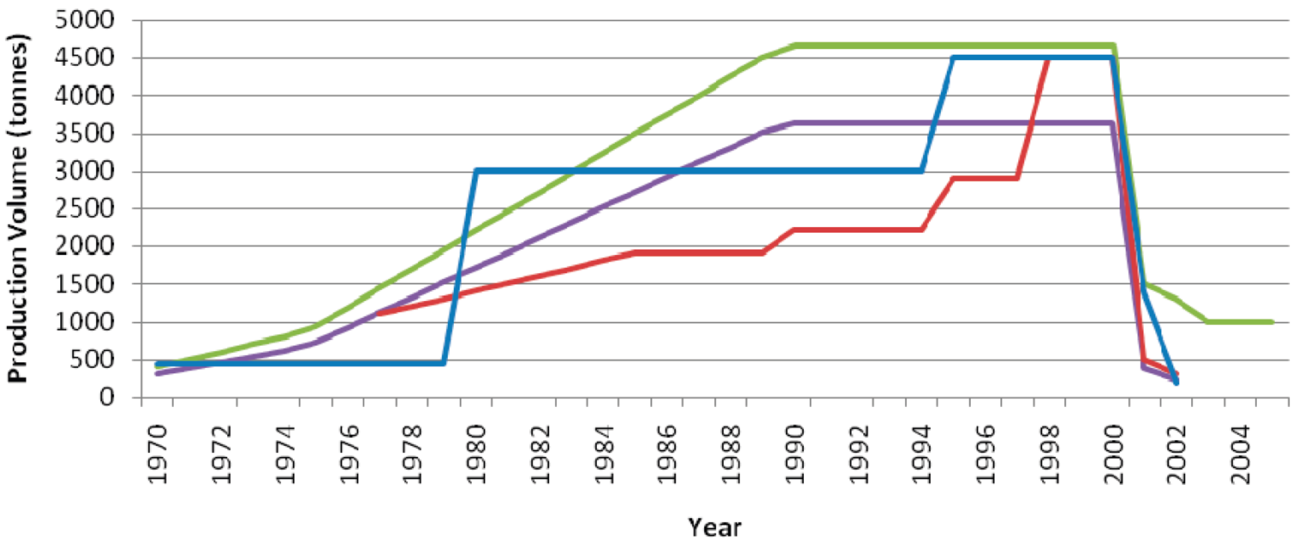
Chemical	Activity	Specific exemptions
Perfluorooctane sulfonic acid (CAS No: 1763-23-1), its salts and perfluorooctane sulfonyl fluoride (CAS No: 307-35-7)[14]	Production	None
	Use	• Metal plating (hard-metal plating) only in closed-loop systems • Firefighting foam for liquid fuel vapour suppression and liquid fuel fires (Class B fires) in installed systems, including both mobile and fixed systems, in accordance with paragraph 10 of part III of Annex B

11 http://chm.pops.int/Implementation/Exemptions/AcceptablePurposesPFOSandPFOSF/tabid/794/Default.aspx
12 Decision SC-4/17: http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.4-SC-4-17.English.pdf
13 Decision SC-9/4 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.9-SC-9-4.English.pdf
14http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/ChemicalslistedinAnnexBRoSE/PFOSRoSE/tabid/4644/Default.aspx

2.2 Production

Reviews on global production estimate that in total 68,000[5] to 96,000[15] tonnes of PFOS/PFOSF have been produced in history with an increase of production in the 1970s and major production in the 1980s and 1990s (Figure 1 and Figure 2). 3M was the major global producer of PFOS and PFOS-related substances prior to 2000 and with a final production amount of 3700 to 4500 t of PFOS and PFOS-related substances in 2000 (Figure 2). The stop of production by 3M in 2000 (with sales until 2002)[15] resulted in a major decrease in global production **(**Figure 2), which is particularly relevant to understanding the age of remaining stocks and waste (see Section 2.5). China increased production to 100 tonnes in 2003/2004 and then to 200 tonnes/year.[16] Minor productions continued also in Germany and Italy for some years.[17] In the past 10 years, China was the last producer of PFOS with a production capacity of 100 to 200 t/y[18,19] and had a production and use notification for some acceptable purposes activities with a term until 3 December 2020.[11] According to China's 5th Article 15 national report submitted in 2022, PFOS/PFOSF production stopped in China in 2021[20] and there is no known other production of PFOS or PFOSF.

Figure 2. Estimated total global PFOSF production volumes (1970-2002). This work's estimates of total global (green line) and 3M's production (purple line) are compared to estimates from Smithwick et al. 2006[21] (red line) and Prevedouros et al. 2006[22] (blue line) (Paul et al. 2009)[15]



2.3 Use

The historical use of by far the largest amount of PFOS and PFOS-related substances was in the surface treatment of textiles/carpet, leather and paper (Table 5). These uses were largely phased out when 3M ceased sales of PFOS in 2002 and were stopped by 2012.

For the past 10 years, PFOS and related substances have been mainly used in firefighting foam, plating industry, insect baits and oil production.

15 Paul AG, Jones KC, Sweetman AJ (2009) A first global production, emission, and environmental inventory for perfluorooctane sulfonate. Environ Sci Technol. 43, 386-392.

16 Lim TC, Wang B, Huang J, Deng S, Yu G (2011) Emission Inventory for PFOS in China: Review of Past Methodologies and Suggestions. The Scientific World Journal 11, 1963–1980

17 Oliaei F, Kriens D, Weber R, Watson A. (2013) PFOS and PFC releases and associated pollution from a PFC production plant in Minnesota (USA). Environ Sci Pollut Res Int. 20, 1977-1992.

18 Zhang Lai et. al. (2012), The inventory of sources, environmental releases and risk assessment for perfluorooctane sulfonate in China, Environmental Pollution 165 (2012) 193 – 198.

19 Lim, Wang B, Huang J, Deng S, Yu G (2011) Emission Inventory for PFOS in China: Review of Past Methodologies and Suggestions, TheScientificWorldJOURNAL11, 1963–1980.

20 Chinese Ministry of Ecology and Environment (2022) Article 15 Report. Submission date: 31/08/2022

21 Smithwick M, Norstrom, R J, Mabury S A; et al. (2006) Temporal Trends of Perfluoroalkyl Contaminants in Polar Bears Ursus maritimus from Two Locations in the North American Arctic, 1972-2002. Environ. Sci. Technol. 40, 1139–1143.

22 Prevedouros, K.; Cousins, I. T.; Buck, R. C.; Korzeniowski, S. H. (2006) Sources, Fate and Transport of Perfluorocarboxylates. Environ. Sci. Technol. 2006, 40, 32–44.

Currently, the use of PFOS or related substances is only allowed for the acceptable purpose of insect baits for control of leaf-cutting ants with Brazil and Viet Nam as registered Parties.[23] For the only remaining specific exemption of metal plating in closed-loop systems Norway, Switzerland and Viet Nam are registered.

With the stop of PFOS production, it is expected that these uses will stop after potentially remaining stocks have been used up such as the import of 4200 t PFOSF to Brazil in June 2022 (see Section 2.4).

2.4 Trade

With the cessation of the last production of PFOS, the trade has largely stopped. However, still some stocks might exist, including expired foams. PFOS and related substances have specific HS Codes since 2017 (Section 18.1). This allows the tracking of imports and exports if respective countries are appropriately reporting.

The assessment of the major HS Codes for PFOS (HS 2904.31), ammonium perfluorooctane sulfonate (HS 2904.32) potassium perfluorooctane sulfonate (HS 2904.34) and PFOSF (HS 2904.36) revealed that trade is considerably decreasing in recent years and has stopped for many countries. For example, for the major known trade of PFOSF from China to Brazil (HS 2904.36; Mercosur specific NCM Code 29043600) the decline was as follows: from 2017 to December 2019 Brazil imported 93.7 t of PFOSF from China, equivalent to over 31 t per year.[24] These imports were the same in 2020 (31 t), increased in 2021 (35 t) and sharply decreased in 2022 (9.2 t) with the last import in June 2022. No import was recorded for 2023 and the first half of 2024 indicating that the PFOS/PFOSF stocks in China are exhausted.

Other remarkable imports are recorded for PFOS (HS 2904.31) in recent years to the Netherlands with a total import of 2,521 t from 2017 to 2021 with a peak import of 777 t in 2020 and 644 t in 2021. This amount of PFOS is several times larger than the global production of 100 to 200 t for these years. Since the Netherlands has a large waste destruction capacity and imports large amounts of waste, it is likely that these reported imports do not correspond to the chemical, but are rather PFOS waste, like firefighting foams, imported for destruction.

Another interesting observation of the specific PFOS data is that global exports and imports for an HS Code do not correspond. For example, the total global imports for PFOS (HS 2904.31) from 2017-2022 was 3348 t while the total exports were only 604 t, which means that many countries have not reported their exports of PFOS (or PFOS waste?) to the UN Comtrade database, which is voluntary.

It is recommended for each Party assess the imports and exports of PFOS and related substances by assessing the specific HS Codes (Table 32; Section 18.2) with possible further assessment if imports are for use or destruction and possibly include this information in their National Implementation Plan (NIP).

2.5 Major former uses of PFOS in products and related waste

2.5.1 Products in use and wastes

The more than 50 years of production and use of PFOS and related compounds resulted in stockpiles and waste. Most of the products treated with PFOS in the 1970s to 2000, like paper, carpets, furniture, or textiles, have been disposed largely to landfills with current and future risks of release (See Section 2.5.2). Some of the products with long service life like synthetic carpets or textiles in vehicles/furniture are still in use to some extent. Also, firefighting foams have a long service life, as ideally, they are never used, and have been produced until recently. Therefore, stocks of PFOS-

23 http://chm.pops.int/Implementation/Exemptions/AcceptablePurposes/AcceptablePurposesPFOSandPFOSF/tabid/794/Default.aspx
24 Torres FBM, Guida Y, Weber R, Torres JPM (2022) Brazilian overview of per-and polyfluoroalkyl substances listed as persistent organic pollutants in the Stockholm convention. Chemosphere 291, 132674.

containing foams still exist, in particular in stationary installations and major use sectors like refineries, oil production and storage sites, airports, power plants, or military installations.[25]

Table 5. Global usage amounts of PFOS-related substances per use area in 2000[16, 26]

Main category	Applications	Global usage (in 2000)
Surface treatment	Apparel and leather, upholstery, carpet, automobile	2,160 tonnes
Paper	Food contact applications (plates, food containers, bags, and wraps), non-food contact applications (folding cartons, containers, carbonless forms, masking papers)	1,490 tonnes
Performance chemical	Firefighting foam	151 tonnes
Performance chemicals	Mining and oil well surfactants, metal plating, electronic etching baths, photolithography, electronic chemicals, hydraulic fluid additives, cleaners, floor polishes, photographic film, denture cleaners, shampoos, chemical intermediates, coating additives, insecticide	680 tonnes

2.5.2 Waste disposed to landfills and threat of future release

During the past 60 years, tens of thousands of tonnes of PFOS and related compounds have been disposed of in products (e.g. carpets, textiles, paper and furniture) to landfills. PFOS does not degrade in landfills even after the product's core materials like side-chain fluorinated polymers on carpets, textiles, or paper break down which might take decades to centuries.[27,28,29,30] The compounds will eventually migrate into liquids in the landfill, then into leachate collection systems or directly into the natural environment and are a current and future risk.[27,31] PFOS (and other PFASs) then can contaminate drinking water supplies, be taken up by edible plants and bioaccumulate in the food chain. Therefore, landfilling of PFOS and related compounds containing waste is not a viable solution. Environmentally sound management of firefighting foam stockpiles and wastes that contain or may contain PFOS (and other PFASs) is a challenge, in particular for countries without or with limited destruction capacity. [27,31]

3 PFOA and PFOA-related Compounds

3.1 Chemical identity, POPs properties and listing under the Convention

PFOA, its salts and PFOA-related compounds are members of the large family of PFASs. Perfluorinated acids, like PFOA, are not degradable under normal environmental conditions in soils

25 See e.g. the detailed PFOS inventory in Japan; Government of Japan (2020) The National Implementation Plan of Japan under the Stockholm Convention on Persistent Organic Pollutants.
26 3M Company (2000) Sulfonated perfluorochemicals in the environment: sources, dispersion, fate and effects, Tech. Rep. AR226-0620,
27 Nordic Council of Ministers (2019) The Cost of Inaction - A socioeconomic analysis of environmental and health impacts linked to exposure to PFAS. TemaNord 2019:516.
28 Washington, J.W., Jenkins, T.M., Rankin, K. and Naile, J.E., (2015). Decades-scale degradation of commercial, side-chain, fluorotelomer-based polymers in soils and water. Environmental science & technology, 49(2), 915-923.
29 Washington JW, Ellington J.J, Jenkins TM, Evans JJ, Yoo H, Hafner, SC (2009). Degradability of an acrylate-linked, fluorotelomer polymer in soil. Environmental science & technology, 43(17), 6617-6623.
30 Li L, Liu J, Hu J, Wania F (2017). Degradation of fluorotelomer-based polymers contributes to the global occurrence of fluorotelomer alcohol and perfluoroalkyl carboxylates: a combined dynamic substance flow and environmental fate modeling analysis. Environmental Science & Technology, 51(8), 4461-4470.
31 Weber R, Watson A, Forter M, Oliaei F. (2010). Persistent organic pollutants and landfills – a review of past experiences and future challenges. Waste Management and Research. 107-121.

and water. Those PFASs, which can be degraded to PFOA in the environment or organisms are referred to as PFOA-related compounds.[32] An indicative list of substances covered by the listing of perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds has been developed by POPRC including more than 100 substances.[32]

PFOA is very persistent, bioaccumulative and toxic for humans and other biota. Detailed information for listing has been compiled in the risk profile[33] and the RME[34] of PFOA.

PFOA has been listed in 2019 under Annex A with specific exemptions for the production and use (Table 7) and a new part X in Annex A.[35] None of the specific exemptions have yet expired.

Table 6. Chemical identification and properties of PFOA, its salts and PFOA-related compounds[33,34]

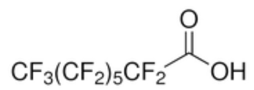
Chemical name:	Octanoicacid, 2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-pentadecafluoro-	
Synonyms/abbreviations	Perfluorooctanoic acid; PFOA; pentadecafluoro-1-octanoic acid; perfluorocaprylicacid; perfluoro-n-octanoicacid; pentadecafluoro-n-octanoicacid; pentadecafluorooctanoicacid; n-perfluorooctanoic acid; 1-octanoic acid, 2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-pentadecafluoro	
CAS Registry Number:	335-67-1 (PFOA)	
Trade names:	None	
Structure:		Molecular weight: 414.07 g/mol Molecular formula: $C_8HF_{15}O_2$

Table 7. Listing of specific exemptions for PFOA (Decision SC-9/12)

Chemical	Activity	Specific exemptions
Perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds mean the following: (i) Perfluorooctanoic acid (PFOA; CAS No. 335-67-1), including any of its branched isomers; (ii)Its salts; (iii) PFOA-related compounds which, for the purposes of the Convention, are any substances that degrade to PFOA, including any substances (including salts and polymers) having a linear or branched perfluoroheptyl group with the moiety $(C_7F_{15})C$ as one of the structural elements	Production	• Firefighting foam: None • For other production, as allowed for the Parties listed in the Register in accordance with provisions of part X of Annex A
	Use	• Photolithography or etch processes in semiconductor manufacturing • Photographic coatings applied to films • Textiles for oil and water repellency for the protection of workers from dangerous liquids that pose risks to their health and safety • Invasive and implantable medical devices • Firefighting foam for liquid fuel vapour suppression and liquid fuel fires (Class B fires) in installed systems, including both mobile and fixed systems, in accordance with paragraph 2 of part X of Annex A • Use of perfluorooctyl iodide for the production of perfluorooctyl bromide for the purpose of producing pharmaceutical products, in accordance with the provisions of paragraph 3 of part X of Annex A

32 Indicative list of substances covered by the listing of perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds. UNEP/POPS/POPRC.19/INF/16.
33 Risk Profile on pentadecafluorooctanoic acid (PFOA, perfluorooctanoic acid), its salts and PFOA-related compounds. Persistent Organic Pollutants Review Committee. 2016; UNEP/POPS/POPRC. 12/11/Add.2.
34 Risk management evaluation on pentadecafluorooctanoic acid (PFOA, perfluorooctanoic acid), its salts and PFOA-related compounds. Persistent Organic Pollutants Review Committee. 2017; UNEP/POPS/POPRC.13/7/Add.2.
35 Decision SC-9/12: Listing of perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds.

Chemical	Activity	Specific exemptions

		• Manufacture of polytetrafluoroethylene (PTFE) and polyvinylidene fluoride (PVDF) for the production of:
		  • High-performance, corrosion-resistant gas filter membranes, water filter membranes and membranes for medical textiles
		  • Industrial waste heat exchanger equipment
		  • Industrial sealants capable of preventing leakage of volatile organic compounds and PM2.5 particulates
		• Manufacture of polyfluoroethylene propylene (FEP) for the production of high-voltage electrical wire and cables for power transmission
		• Manufacture of fluoroelastomers for the production of O-rings, v-belts and plastic accessories for car interiors

3.2 Production

According to the Risk Profile[33], 3,600-5,700 tonnes of PFOA and APFO (ammonium perfluorooctanoic acid) were produced worldwide from 1951 to 2004. The total production from 1951 to 2020 is estimated to be 9,500 t.[5]

Perfluoroalkyl iodides (PFAIs) are a PFOA-related compound when they contain seven or more perfluorinated carbons. They have been used since 1961 to produce so-called fluorotelomer-based products, such as fluorotelomer phosphate diesters (diPAPs), fluorotelomer sulfonic acids (FTSAs) and fluorotelomer ethoxylates (FTEOs), which are widely used as surface treatment agents and fluorinated surfactants.[36] The production of PFAIs was estimated to be as high as 171,000 t between 1961 and 2015[36].

PFOA has been manufactured by two synthesis routes, namely electrochemical fluorination (ECF) of octanoic acid fluoride (OCF, $C_7H_{15}COF$), and oxidation of perfluorooctyl iodide (PFOI).[36] PFOA production has decreased in the US, EU and Japanese companies due to voluntary phase-out. However, the production has increased in China from 30 t in 2004 to about 90 t in 2012[37] with unknown current production amount.

PFOA is also produced unintentionally during thermal decomposition of fluoropolymers such as polytetrafluoroethylene (PTFE; Teflon) from municipal solid (pyrolysis) waste incineration with inappropriate incineration or open burning facilities at moderate temperatures.33

3.3 Use

Due to their physicochemical properties, PFOA, its salts and PFOA-related compounds are used in a wide range of applications in industry and consumer products in different sectors. A list of current uses is compiled as exemptions in the Stockholm Convention (Table 7). In the past, the largest amounts were used in the production of fluoroelastomers and fluoropolymers, with associated release and contamination of drinking water in the surrounding of such production sites.[38,39] This includes, for example, the production of fluoropolymers PTFE and PVDF, related membranes and non-stick kitchenware. PFOA-related compounds were also found in side-chain fluorinated polymers

36 UNEP (2023) Guidance on preparing inventories of PFOS, PFOA and PFHxS. Secretariat of the Basel, Rotterdam and Stockholm Conventions.

37 Li L, Zhai Z, Liu J, Hu J (2015) Estimating industrial and domestic environmental releases of perfluorooctanoic acid and its salts in China from 2004 to 2012, Chemosphere, 129: 100–109.

38 Hu X C, Andrews DQ, Lindstrom A et al. (2016) Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants. Environ. Sci. Technol. Lett. 3, 344-350.

39 Qu Y, Huang J, Willand W, Weber R (2020) Occurrence, removal and emission of per- and polyfluorinated alkyl substances (PFASs) from chrome plating industry: A case study in Southeast China. Emerging Contaminants 6, 2020, 376-384. https://doi.org/10.1016/j.emcon.2020.10.001.

(SCFPs) widely used for surface treatment of textiles, carpets and paper.[40] Additionally, PFOA-related compounds are used as surfactants and surface treatment agents in paints, inks and firefighting foams.[33,34]

The current use of PFOA is indicated by the list of exemptions (Table 7) and the list of registered specific exemptions (Table 8). Since the assessment of the use of PFOA by Parties is still underway and most countries have not yet developed inventories, the list of requests for exemptions is likely to increase. Since several countries, including China and India, have not yet ratified the listing of PFOA, there is further uncertainty in its production and use.

A major complexity is the determination of PFOA-related compounds in products or mixtures that would define if a chemical, mixture, or product contains one or more PFOA-related compounds. Complex PFAS mixtures are included in product mixtures such as in textile finishing agents[41] or firefighting foam and related fluorocarbon surfactants[42]. In these mixtures, PFOA and PFOA-related substances are present in a wide concentration range (e.g. the PFOA-related compound 8:2 FTOH was detected up to 1.85 g/L in fluorocarbon surfactants for firefighting foam).[42] PFOA is sometimes only recognized after the oxidative degradation of product mixtures or materials with Total Oxidisable Precursor (TOP) assay.[41,42,43]

Table 8. Register of specific exemptions of PFOA, its salts and PFOA-related compounds

Specific exemption	Parties	Expiry date	Quantity of production/use
Production*			
For production other than firefighting foam, as allowed for the Parties listed in the Register in accordance with provisions of Annex A part X	EU and Switzerland	EU (03/12/2025) Switzerland (not provided)	Not provided
Use			
Photolithography or etch processes in semiconductor manufacturing	EU, Norway, Switzerland	EU/Norway (04/7/2025) Switzerland (not provided)	Not provided
Photographic coatings applied to films	EU, New Zealand, Norway, Switzerland	EU and Norway (04/07/2025) New Zealand and Switzerland (not given)	Not provided
Textiles for oil and water repellency for the protection of workers from dangerous liquids that pose risks to their health and safety	EU, Norway, Switzerland	EU and Norway (04/07/2023) Switzerland (not given)	Not provided
Invasive and implantable medical devices	EU, Norway, Switzerland	EU, Norway (04/07/2025) Switzerland (not given)	Not provided
Firefighting foam for liquid fuel vapour suppression and liquid fuel fires (Class B fires) in installed systems (mobile and fixed systems)	EU, New Zealand, Norway	EU, Norway (04/07/2025) New Zealand (not given)	Not provided
Use of perfluorooctyl iodide for the production of perfluorooctyl bromide for	EU, Norway, Switzerland	EU (Review and assessment by	Not provided

40 OECD (2022) Synthesis Report on Understanding Side-Chain Fluorinated Polymers and Their Life Cycle, OECD Series on Risk Management, No. 73. Environment, Health and Safety, Environment Directorate, OECD.
41 Mumtaz M, Bao Y, Li W, Kong L, Huang J, Yu G (2019). Screening of textile finishing agents available on the Chinese market: An important source of per-and polyfluoroalkyl substances to the environment. Frontiers of Environmental Science & Engineering, 13(5), 1-10.
42 Liu, L., Lu, M., Cheng, X., Yu, G. and Huang, J., (2022). Suspect screening and nontargeted analysis of per-and polyfluoroalkyl substances in representative fluorocarbon surfactants, aqueous film-forming foams, and impacted water in China. Environment International, 167, 107398.
43 UNEP (2021). Draft guidance on sampling, screening and analysis of persistent organic pollutants in products and recycling. Secretariat of the Basel, Rotterdam and Stockholm conventions, Geneva.

the purpose of producing pharmaceutical products		31/12/2026, every four years thereafter and by 31/12/2036; Norway and Switzerland (not provided)	
Manufacture of polytetrafluoroethylene (PTFE) and polyvinylidene fluoride (PVDF) for the production of high-performance, corrosion-resistant gas filter membranes, water filter membranes and membranes for medical textiles	EU, Norway, Switzerland	EU, Norway (04/07/2023)	Not provided

**This refers to the use of PFOA or related substances in production, not the production of PFOA itself.*

3.4 Trade

PFOA and related compounds are likely traded as chemicals, in mixtures (e.g. textile finishings[41] or fluorocarbon surfactants for firefighting foams[42]) and in products (e.g. firefighting foam[42] or textiles). However, there is no specific HS Code for PFOA and PFOA-related compounds yet. Therefore, the trade of PFOA and related compounds cannot be traced by HS Codes.

For import to the European Union, it is estimated that PFOA and related compounds are mainly imported in products such as outdoor clothing, workers' protection clothing, membranes for apparel, treated home textile and upholstery, treated non-woven medical garments, leather finishing, carpets, impregnating sprays/waterproofing agents, firefighting foams, treated paper, paints and inks, cleaning agents, floor waxes/wood sealants, lubricants and sealant tapes.[33] The largest volume of imported PFOA, its salts and PFOA-related compounds to the EU comes from textiles (mainly outdoor jackets) with 1,000-10,000 tonnes until 2015. The annual imported quantity of PFOA in products declined after 2015 due to the availability of alternatives.[33] Therefore, trade and imports of PFOA and related compounds in products are likely the most relevant for most countries.

3.5 Products in use/stocks and waste containing PFOA and related compounds

3.5.1 Products in use and wastes

A major use of PFOA and related compounds was in side-chain fluorinated polymers such as fluorinated (meth)acylate polymers, fluorinated urethane polymers, or fluorinated oxetane polymers.[44] These polymers are used for surface treatment on plastic fiber on carpets, furniture (textiles), and other textiles to repel water, oil and dirt. Major products in use and related wastes containing PFOA and related compounds are treated outdoor clothing, workers' protection clothing, fluoropolymer membranes for apparel, treated home textile and upholstery, treated non-woven medical garments, carpets, treated paper, leather finishing, impregnating sprays/waterproofing agents, firefighting foams, paints and inks, floor waxes/wood sealants, and fluoropolymer sealant tapes.[33] Stockpiles of firefighting foams containing PFAS including PFOA are likely to be present at military bases, airports, oil production facilities and rigs, and other facilities.

PFOA has been produced and used since the 1960s (Figure 1) and therefore a share of these products has entered waste treatment and landfills (below Section 3.5.2). Since the major production and use of PFOA occurred in the last 30 years (Figure 1) a large share of products is still in use.

3.5.2 Waste disposed to landfills as source and threat of future release

In the past 60 years, thousands of tonnes of PFOA and related compounds have been disposed of in landfills in textiles, carpets, paper, or fluoropolymers. As has already been described for PFOS (Section 2.5.2), PFOA also does not degrade in landfills even after the product's core materials like

[44] Buck RC, Franklin J, Berger U, et al. (2011). Perfluoroalkyl and polyfluoroalkyl substances in the environment: Terminology, classification, and origins. Integrated Environmental Assessment and Management, 7(4), 513–541.

side-chain fluoropolymers break down, which might take decades to centuries.[28,29,31] The compounds will eventually migrate into liquids in the landfill, then into leachate collection systems, or directly into the environment.[27,45] They may then contaminate drinking water supplies, be taken up by edible plants and bioaccumulate in the food chain. Therefore, landfilling of waste containing PFOA and related compounds is not a viable solution. Environmentally sound management is a challenge, in particular for countries without or with limited destruction capacity. [27,31]

4 Perfluorohexane Sulfonic Acid (PFHxS) and Related Compounds

4.1 Chemical identity, POPs properties and listing under the Convention

Perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS-related compounds are members of the large family of PFASs. PFHxS is extremely persistent in the environment. In 2022, the Conference of the Parties listed PFHxS, its salts and PFHxS-related compounds in Annex A to the Convention without specific exemptions (Decision SC-10/13[46]). The group of PFHxS, its salts and PFHxS-related compounds includes linear and branched isomers, including the following substances:[46]

(i) Perfluorohexane sulfonic acid (CAS No: 355-46-4, PFHxS)

(ii) Its salts

(iii) Any substance that contains the chemical moiety $C_6F_{13}SO_2$ as one of its structural elements and that potentially degrades to PFHxS

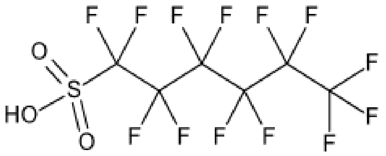
More than 75 PFHxS-related compounds have been identified.[47] PFHxS and related compounds have unique properties similar to PFOS with high resistance to friction, heat, chemical agents and low surface energy, and used as water, grease, oil and soil repellent.[48] PFHxS is a strong acid with six fully fluorinated carbons, having both hydrophobic- and hydrophilic properties. PFHxS is very resistant to chemical, thermal and biological degradation due to its strong carbon-fluorine bonds. and this resistance to degradation makes it persist in the environment. PFHxS concentrations are found in biota and humans alike and its elimination takes approximately eight years. PFHxS was found to reduce neuronal activity involved in learning and memory in adult rats. In humans, PFHxS has adverse effects on the nervous system, immune system, brain development and endocrine system, such as thyroid hormones.

Detailed information has been compiled in the risk profile[49] and the RME.[50]

Table 9. Chemical identification and properties of PFHxS, its salts and PFHxS-related compounds49,50

Chemical name:	Perfluorohexane-1-sulfonic acid (PFHxS)
Synonyms/ abbreviations:	PFHxS; PFHS, Tridecafluorohexane-1-sulfonic acid, Tridecafluorohexane-1-sulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-Tridecafluorohexane-1-sulfonic acid, 1,1,2,2,3,3,4,4,5,5,6,6,6-Tridecafluoro-1-hexanesulfonic acid
Trade names:	RM70 (CAS No: 423-50-7), RM75 (CAS No: 3871-99-6), and RM570 (CAS No: 41997-13-1) (PFHxS-related substances produced by Miteni SpA, Italy). FC-95 Fluorad brand fluorochemical surfactant (CAS No: 3871-99-6). Contains PFHxS-K produced by 3M

45 Weber R, Watson A, Forter M, Oliaei F. (2010). Persistent organic pollutants and landfills – a review of past experiences and future challenges. Waste Management and Research. 107-121.
46 UNEP (2022) SC-10/13: Listing of perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS-related compounds.
47 UNEP (2019) Initial indicative list of perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS-related compounds. UNEP/POPS/POPRC.15/INF/9
48 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-PUB-factsheet-PFHxS-2020.English.pdf
49 UNEP (2018) Risk profile on perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS-related compounds Persistent. Organic Pollutants Review Committee. UNEP/POPS/POPRC.14/6/Add.1,
50 UNEP (2019) Risk management evaluation on perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS-related compounds. UNEP/POPS/POPRC.15/7/Add.1

CAS Registry Number:	355-46-4	
Structure:		Molecular weight: 400.11 Molecular formula: $C_6F_{13}SO_3H$

4.2 Production

4.2.1 Intentional production

Historical production was mainly carried out by 3M (approx. 227 tonnes in 1997 and therefore approx. 10% of PFOS), which phased out its production of C6, C8 and C10 perfluoroalkyl sulfonic acids (PFSAs) in 2002.[49] Further, former and/or current manufacturers or suppliers of PFHxS, its salts and PFHxS-related compounds include one manufacturer from Italy (Miteni) and some from China. Approx. 6 tonnes of PFHxS were produced in 2003 in Italy, which stopped production in 2013.[51] For a major PFAS producer in China (Hengxin Chemical Plant) annual production of PFHxS in 2011 was 30 tonnes with a production stop in 2012.[49]

The most recent data for PFHxS production[52] was about 700-750 kg in 2012 and decreased to less than 700 kg in 2016 from Chinese producers.[51,53] China has banned the production, export and use of PFHxS in 2023.[54]

4.2.2 Unintentional production

PFHxSF has been unintentionally produced as a by-product of the electrochemical fluorination (ECF) of octanesulfonyl fluoride or chloride, the process to produce PFOSF.[55.] PFHxS concentrations detected in commercial PFOS products were 3.5%-9.8% in 3M's FC-9556 (3M, 2015) and 11.2%-14.2% in three products from China.[55] Assuming approx. 10% of by-product in the total production of PFOS (68,000 t[5] to 96,000 t[15]; Section 2.2), a total of 7,000-10,000 t of PFHxS might have been produced within the PFOS production.

4.3 Use of PFHxS

PFHxS has been used in the same application as PFOS (and PFOA) and partly substituted PFOS. PFHxS and related substances have been intentionally used at least in the following applications: aqueous film-forming foams (AFFFs) for firefighting; metal plating; textiles, leather and upholstery; (4) polishing agents and cleaning/washing agents; coatings, impregnation/proofing (for protection from damp, fungus, etc.); and within the manufacturing of electronics and semiconductors. In addition, other potential use categories may include pesticides, flame retardants, paper and packaging, and the oil industry.

The most recent information on the use distribution of PFHxS stems from 2016 (time of last confirmed production) and it is estimated that around ~66% of PFHxS was used in firefighting foams, ~22% in textile finishing and 12% in other applications (not further specified).[53]

51 ECHA (2019) Annex XV Restriction Report Proposal for a Restriction - Substance Name(S): Perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS-related substances.
52 While there is an estimate from a market report by an extrapolation from former uses that PFOSF might have a production of more than 80 t in 2020.[53] However this estimate should be treated with caution since there is no information to corroborate the extrapolation[51] and there is no confirmed producer.
53 Norwegian Environment Agency (2017). Monitoring of environmental contaminants in air and precipitation. Report M-757/2017. http://www.miljodirektoratet.no/no/Publikasjoner/2017/September-2017/Monitoring-of-environmental-contaminants-in-air-and-precipitation.
54 Ministry of Ecology and Environment of China. (2023). List of New Pollutants for Priority Control (Final Version 2023)
55 Jiang W, Zhang Y, Yang L, Chu X, Zhu L (2015). Perfluoroalkyl acids (PFAAs) with isomer analysis in the commercial PFOS and PFOA products in China. Chemosphere, 127, 180–187.
56 3M (3M Canada Company) (2015). Material Safety Data Sheet – FC-95 Fluorad Brand fluorochemical surfactant.

4.4 Trade of PFHxS

PFHxS, its salts and PFHxS-related compounds have been listed on national chemical inventories (e.g., EU ECHA inventory notification system, Australia, New Zealand, Canada, China, Japan and the US) indicating historical import and/or uses of products containing these substances. However, neither PFHxS nor any of the compounds considered to be PFHxS-related substances like PFHxSF are registered under the EU regulation REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals).

Since no current production is known and also the annual production in the past five years was likely below 1 t/year (Section 4.2), the trade is likely small or does not exist.

As for PFOS and PFOA, technical PFAS mixtures might contain PFHxS as an impurity[42] and might be traded in products.

PFHxS and related compounds do not have specific HS Codes yet. Therefore, a trade of PFHxS and related compounds is not tracked by the UN Comtrade database (unlike PFOS with specific HS Codes; Section 2.4).

4.5 Products in use/stocks and waste containing PFHxS and related compounds

4.5.1 Products in use and wastes

Since the largest amount of PFHxS was produced by 3M before 2002, major products like firefighting foam, textiles, leather, or upholstery have been disposed of largely in landfills with risk of release (See Section 2.5.2). Some products with long service life, like synthetic carpets, are still in use to some extent. Firefighting foams also have a long service life and have been produced until at least 2017. PFHxS in firefighting foam might be still in stock, particularly in stationary installations and major use sectors like refineries, oil production and storage sites, airports, power plants, or military installations.[57] Carpets, leather and textiles treated with PFAS can also contain PFHxS. Due to the considerably lower production/use of PFHxS compared to PFOS, the products in stock and waste are smaller.

4.5.2 Waste disposed to landfills and threat for future release

PFHxS does not degrade in landfills similar to PFOS and PFOA. PFHxS in landfills will eventually migrate into liquids in the landfill, then into leachate collection systems, or directly into the natural environment,[27,58] and can then contaminate drinking water supplies, be taken up by edible plants and bioaccumulate in the food chain. In landfill leachates, PFHxS concentrations were at a similar level as for PFOS.[59,60] Therefore, landfilling of PFHxS and related compounds containing waste is not a viable solution; environmentally sound management of PFHxS waste is a challenge, particularly for countries without or with limited destruction capacity.[27,31]

5 Short-Chain Chlorinated Paraffins (SCCPs)

5.1 Chemical identity, POPs properties and listing under the Convention

Chlorinated paraffins (CPs) are semi-volatile organochlorine compounds produced in high production volumes (around 1 million t/year).[5,61,62] Chemically, they are polychlorinated unbranched

57 See e.g. the PFOS inventory in Japan; Government of Japan (2020) The National Implementation Plan of Japan under the Stockholm Convention on Persistent Organic Pollutants.
58 Weber R, Watson A, Forter M, Oliaei F. (2010). Persistent organic pollutants and landfills – a review of past experiences and future challenges. Waste Management and Research. 107-121.
59 Busch J, Ahrens L, Sturm R, Ebinghaus R (2010). Polyfluoroalkyl compounds in landfill leachates. Environmental Pollution, 158(5), 1467-1471.
60 Kim JW, Tue NM, Isobe T, Misaki K, Takahashi S, Viet PH, Tanabe S. (2013). Contamination by perfluorinated compounds in water near waste recycling and disposal sites in Vietnam. Environmental monitoring and assessment, 185, 2909-2919.
61 UNEP (2019) Detailed guidance on preparing inventories of short-chain chlorinated paraffins. Draft. UNEP/POPS/COP.9/INF/19
62 Chen C, Chen A, Zhan F, Wania F, Zhang S, Li L, Liu J (2022) Global historical production, use, in-use stocks, and emissions of short-, medium-, and long-chain chlorinated paraffins, Environ. Sci. Technol. 56, 7895–7904. + Supporting Information.

hydrocarbons with different chlorine contents and chain lengths. CPs are classified according to their chain length into short-chain CPs (SCCPs; C_{10} to C_{13}) (Table 10), medium-chain CPs (MCCPs; C_{14} to C_{17}) and long-chain CPs (LCCPs; C≥18).

SCCPs are substances that are hazardous to the environment and human health. Available data indicate that SCCPs are persistent, bioaccumulative and toxic, especially to aquatic organisms. SCCPs are sufficiently persistent in the air for long-range transport. Many SCCPs accumulate in biota; the average SCCP concentration in human milk is the second highest POP concentration globally, only exceeded by DDT.[63] Detailed information is provided in the risk profile[64] and the risk management evaluation.[65] Information on chemical identity and structures is compiled in Table 10.

SCCPs with a chlorine content of more than 48% by mass were listed in the Stockholm Convention in 2019 under Annex A with a wide range of specific exemptions covering most of the major application areas.[66] (Table 11). MCCPs, LCCPs, or other CP mixtures containing more than 1% of SCCPs are also POPs.[61] MCCPs have been recommended by the POPRC as POP for listing at COP12 in 2025.[67]

To date, there is one registered exemption pursuant to paragraph 3 of Article 4 from Viet Nam for 15,000 t/year, highlighting that this is a POP with the highest use amount ever recorded in the country.[68] Since global production of SCCPs is still high (Section 5.2) and since they are often not marketed as SCCP, many countries are currently using CP mixtures containing SCCP and are not aware of it (Section 18.3).

Table 10. Chemical identification and properties of SCCPs[64,65]

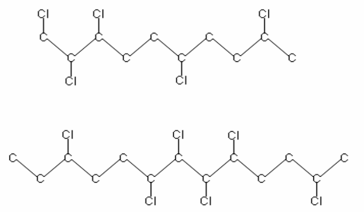
Chemical name:	Short-chain chlorinated paraffins (SCCP)		
Synonyms/abbreviations:	Alkanes, chlorinated; alkanes (C10-13), chloro-(50%-70%); alkanes (C10-13), chloro-(60%); chlorinated alkanes, chlorinated paraffins; chloroalkanes; chlorocarbons; polychlorinated alkanes; paraffins chlorinated.		
CAS Registry Number:	CAS No. 85535-84-8; CAS No. 68920-70-7; CAS No. 71011-12-6; CAS No. 85536-22-7; CAS No. 85681-73-8; CAS No. 108171-26-2		
Structure of two SCCP compounds ($C_{10}H_{17}Cl_5$ and $C_{13}H_{22}Cl_6$):		Molecular formula:	CxH(2x-y+2)Cly, where x=10-13 and y=1-13

Table 11. Specific exemptions for the production and use of SCCPs,[66] which expired 12/2023[69]

Chemical	Activity	Specific exemptions
Short-chain chlorinated paraffins (Alkanes, C_{10-13}, chloro)$^{+}$: straight-chain chlorinated hydrocarbons with chain lengths ranging from C_{10}	Production	As allowed for the Parties listed in the Register
	Use	• Additives in the production of transmission belts in the natural and synthetic rubber industry • Spare parts of rubber conveyor belts in the mining and forestry industries

63 Krätschmer K, Malisch R, Schächtele A, Vetter W (2019) POPs in human milk of 65 countries sampled 2000 to 2012. WHO & EU POPs Reference Laboratory.
64 UNEP/POPS/POPRC.11/10/Add.2 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.11-10-Add.2.English.pdf
65 UNEP/POPS/POPRC.12/11/Add.3 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.12-11-Add.3.English.pdf
66 Decision SC-8/11; http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.8-SC-8-11.English.pdf
67 UNEP (2023) Report of the Persistent Organic Pollutants Review Committee on the work of its nineteenth meeting. UNEP/POPS/POPRC.19/9.
68 http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/ShortchainchlorinatedparaffinsRoSE/tabid/7595/Default.aspx
69 Decision SC11/1 Exemptions.

to C_{13} and content of chlorine greater than 48% by weight. For example, the substances with the following CAS numbers may contain SCCPs: CAS No. 85535-84-8; CAS No. 68920-70-7; CAS No. 71011-12-6; CAS No. 85536-22-7; CAS No. 85681-73-8; CAS No. 108171-26-2.		• Leather industry, in particular, fatliquoring in leather • Lubricant additives, in particular for engines of automobiles, electric generators and wind power facilities, and for drilling in oil and gas exploration, petroleum refineries to produce diesel oil • Tubes for outdoor decoration bulbs • Waterproofing and fire-retardant paints • Adhesives • Metal processing • Secondary plasticizers in flexible polyvinyl chloride, except in toys and children's products

5.2 Production of SCCPs and CPs potentially containing SCCPs

Chlorinated paraffins, including SCCPs, have been produced commercially since the 1930s. The total historical production of SCCPs is estimated at 8,795 kt,[5] 18,525 kt for MCCPs and 32,500 kt for all CPs.[62] In India and China (and in several other countries), produced CP technical mixtures are not categorized according to chain length, but to chlorine content (30 to 70%) and often contain mixtures of SCCPs and MCCPs[62,70,71]. The production of CPs worldwide has increased in the last 15 years to more than 1,300 kt per year.[5] Major production is in China, which reached 1,100 kt in 2014 with possibly some decrease in recent years.[62] The second largest production is in India with 226.4 kt in 2010 and an estimated increase to more than 350 kt in 2020.[62] Productions in all other countries are considerably lower, with reported annual CP amount for the most recent reported years at 45 kt in EU (2010), 40 kt in the US (2011), 27 kt in Russia (2011), 20 kt in Egypt (2008), 12 kt in Jordan (2015) and 10 kt in South Africa.[62]

Based on measured data of CP mixtures and products containing CP mixtures and related SCCP content, it is estimated that a maximum 440 kt/year of SCCPs were produced in 2014, which slightly declined but with still more than 400 kt/year in 2020.[62] The total production of MCCPs is estimated at approximately 750 kt/year in recent years.[62] Since a large share of these technical CPs are mixtures of SCCPs and MCCPs, up to 900,000 t of CP mixtures/year might have SCCP contents of more than 1% (average more than 30%) and therefore be classified as POPs.

On the other hand, industrial countries normally categorize CP production according to the chain length. SCCP production stopped in Japan in 2006, Canada in 2008 and the EU and US in 2012. The production and export of SCCPs are prohibited in China since 31 December 2023.[54]

5.3 Use of SCCPs and CPs potentially containing SCCPs

The bulk of historically produced CPs is estimated to be used as additives in PVC products, accounting for 50-66% during 2000-2020.[71] Metal-working fluids/lubricants are considered the second-largest use accounting for 12-29% during 1990-2020. Lower amounts were used in rubber and other plastics (10-14%), adhesives and sealants (5-6%), and paints and varnishes (3-10%).[71]

To understand the major current use of SCCPs (and MCCPs), it is necessary to examine the current use of CP mixtures produced by China and India, which account for more than 90% of SCCP and MCCP production.

A monitoring study evaluated the SCCPs (and MCCPs) use in major products manufactured in China.[71] It is estimated that 88% of the Chinese annual SCCP production and 74% of the MCCPs are used in plasticized PVC.[71] Other major CP additive use in China were rubber (5% of SCCPs and 18% of MCCPs) and PUR foam adhesives (5% of SCCPs and 6% of MCCPs).[71] Minor shares were

70 Chen C, Chen A, Li L, Peng W, Weber R, Liu J (2021) Chlorinated Paraffins in Chinese Products through Detection-based Mass Balancing. Environ Sci Techn. 55, 7335–7343. https://doi.org/10.1021/acs.est.0c07058.
71 Xia D, Vaye O, Lu R, Sun Y (2021) Resolving mass fractions and congener group patterns of C8 - C17 chlorinated paraffins in commercial products: associations with source characterization, Sci. Total Environ. 769, 144701.

used in metalworking fluids and leather (~2% SCCPs and MCCPs). A similar study does not exist for India, but Indian CP producers note the same use categories as PVC, plastics, rubber, lubricants, paints and sealants.[72]

A recent study assessed the imports and use of CPs in Brazil. The study concluded that between 2014 and 2019 approximately 58% of the imported technical CP mixtures were sold to the polymer industry (mainly PVC and other plastic manufacturers) and 22% to lubricant producers.[73] Other uses in Brazil were rubber, polyurethane, sealants, paints, resin, lubricants for metal and adhesives.[73]

The use pattern of regions and countries can significantly differ depending on the industries present.[71,74] For countries without CP production, a major driver of the SCCPs (and MCCPs) in use is the import of SCCP/MCCP-containing products and materials like plasticized PVC, rubber products (e.g. conveyor belt or transmission belts), PUR spray foam, lubricants and paints. The initial SCCP and MCCP inventory in Nigeria estimated that more than 37,400 t of SCCP were present in PVC, rubber and PUR spray foam imported 1996 to 2018.[75]

Many applications of SCCPs have a long service life, particularly in the construction sector (e.g., various PVC uses, PUR spray foam, sealants, paints and adhesives).

5.4 Trade of SCCPs

SCCPs (and MCCPs) do not have specific HS Codes[75,76] and therefore an assessment of global trade based on the UN Comtrade database is not possible. It is estimated that China exports only approximately 4% of CPs,[62] which is 16 kt SCCP and 22.5 kt MCCP. India exported 42.3 kt and 41.2 kt in 2015 and 2016, respectively, accounting for 15% of production volumes in India.[62] Export data or estimates for other countries are not available and are of lower interest due to much lower production capacity.

Since the largest share (95%) of SCCPs and MCCPs in China are used in products that are partly exported, the major trade of SCCPs and MCCPs is primarily in these products, particularly in PVC, PUR spray foam, rubber products and lubricants, with minor relevance in paints and leather.[62,71] These products are not labelled and can enter countries by imports not covered by the Rotterdam Prior Informed Consent (PIC) procedure (See Section 18.4).

Initial Nigerian CP inventory estimates for SCCP and MCCP imports of products from China (with impact factors measured/published for China[71]) indicate a total amount of SCCP imported in plasticized PVC products from 1996 to 2018 of 33,712 t, with lower imports in PUR spray foam (2,331 t) and rubber products (1,386 t). The amount of imported MCCPs from China to Nigeria in products was estimated to mainly enter rubber products (32,317 t) and plasticized PVC products (25,599 t) and lower MCCP imports in PUR foam were estimated at 2,020 tonnes.[75] This indicates that in addition to the trade of CP mixtures containing SCCPs products also containing SCCPs need to be considered and controlled.

Given the enormous former and current production and trade of SCCPs, MCCPs and other CPs containing SCCPs,[62] they are likely relevant for all countries, particularly low- and middle income countries, where the highest human milk levels have also been detected.[63]

The reason why most countries are not aware that they are importing SCCPs and other CPs containing SCCPs is likely that commercial CP mixtures are not traded as SCCP, but as CP mixtures with certain chlorine content (e.g., CP52), and that in most countries, SCCP are imported in products/materials like PVC, rubber, or PUR spray foam. Only one country (Viet Nam) registered for

72 e.g. https://www.pciplindia.com/product-detail/Chlorinated-Paraffin-#; https://www.omal.in/chlorinated-paraffin.php; http://www.flowtechgroup.in/products-chlorinated-paraffin.php; and https://thesuntek.com/Chlorinated-paraffins.php

73 Guida Y, Capella R, Kajiwara N, Babayemi OJ, Torres JPM, Weber R (2022) Inventory approach for short-chain chlorinated paraffins for the Stockholm Convention implementation in Brazil. Chemosphere 287, 132344.

74 Glüge, J., Wang, Z., Bogdal, C., Scheringer, M., Hungerbühler, K., (2016). Global production, use, and emission volumes of short-chain chlorinated paraffins – a minimum scenario. Sci. Total Environ. 573, 1132–1146.

75 Babayemi JO, Nnorom IC, Weber R (2022) Initial assessment of imports of chlorinated paraffins into Nigeria and the need for improvement of the Stockholm and Rotterdam Convention. Emerg. Contam. 8, 360-370 https://doi.org/10.1016/j.emcon.2022.07.004

76 UNEP (2019) Guidance on preparing inventories of short-chain chlorinated paraffins (SCCPs). Detailed guidance.

all listed exemptions after assessing that approximately 15,000 t/year of SCCPs are used in the country.

5.5 Major use/stock of SCCPs in products, waste and recycling

5.5.1 Major use/stock of SCCPs in products

By the end of 2020, there were more than 13,000 kt, or ∼40% of historically produced, in-use stocks of CPs, including 2,860 kt SCCPs (22%) and 8,450 kt MCCPs (65%).[62] The majority are additives in PVC products (78%), followed by rubber and other plastics (11%) and adhesives and sealants (8%).[62] Assuming an average CP content of 10%, this can be estimated to be 130,000 kt of CP-containing products/materials with SCCP content in most of these products in use above the provisional Basel Convention low POP content limits.[77]

5.5.2 SCCP in waste, recycling and landfills

Approximately 20,000 kt of CPs have already entered their end-of-life[62] and have been largely disposed to landfills including approximately 6,000 kt of SCCPs.

A part of this waste enters recycling and a recent study in Thailand measured that SCCPs are present in a wide range of PVC products together with several other plasticizers from PVC recycling.[78]

77 UNEP (2024) General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants. UNEP/CHW/OEWG.14/INF/5.
78 Ramungul N, Boontongkong Y, Pavares V (2023). Circular economy without chemical controls? Evidence of recirculated toxic plasticizers in flexible PVC products. J Environ Expo Assess; 2:2. DOI: 10.20517/jeea.2022.081601.

6 Decabromodiphenyl Ether (decaBDE; BDE-209)

Polybrominated diphenyl ethers (PBDEs) are major brominated flame retardants that were frequently used in plastics in EEE, the transport sector, the construction sector and textiles (PBDE inventory guidance79). PBDEs are produced and used as technical mixtures of different congeners. Three commercial mixtures have been produced, each named after the main homologue group:

- Commercial DecaBDE (c-DecaBDE) with ~98% decabromodiphenyl ether (decaBDE)
- Commercial PentaBDE (c-PentaBDE) with main components tetrabromodiphenyl ether (tetraBDE) and pentabromodiphenyl ether (pentaBDE), (see Chapter 7)
- Commercial OctaBDE (c-OctaBDE) with main components hexabromodiphenyl ether (hexaBDE) and heptabromodiphenyl ether (heptaBDE), (see Chapter 7)

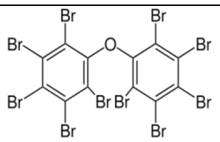
6.1 Chemical identity, POPs properties and listing under the Convention

Commercial DecaBDE typically contain 90-99% decaBDE (BDE-209), and up to 10% mainly nonaBDE and lower levels of octaBDE.[79,80]

C-DecaBDE is a general-purpose additive flame retardant that is physically mixed with the material in which it is used to reduce the flammability and the rate at which flames spread. It is compatible with a wide variety of polymers and materials.

DecaBDE is persistent, has a potential for bioaccumulation and food-web biomagnification and undergoes long-range transport. Adverse effects are reported for soil organisms, birds, fish, frogs, rats, mice and humans. Detailed information is provided in the risk profile[81] and the RME82. Information on chemical identity and structures is compiled in (Table 12).

Table 12. Chemical identification and structures of decaBDE[81,82]

<table>
<tr><td>Chemical name:</td><td colspan="3">Decabromodiphenyl ether (commercial mixture, c-DecaBDE)</td></tr>
<tr><td>Synonyms/abbreviations:</td><td colspan="3">decabromodiphenyl ether, decabromodiphenyl oxide, bis(pentabromophenyl) oxide, decabromobiphenyloxide, decabromophenoxybenzene, benzene 1,1’ oxybis-, decabromo derivative, decaBDE, DBDPE2, DBBE, DBBO, DBDPO</td></tr>
<tr><td>CAS Registry Number:</td><td colspan="3">1163-19-5</td></tr>
<tr><td>Trade name</td><td colspan="3">DE-83R, DE-83, Bromkal 82-ODE, Bromkal 70-5, Saytex 102 E, FR1210,
Flamecut 110R</td></tr>
<tr><td rowspan="2">Structure:</td><td rowspan="2"></td><td>Molecular weight:</td><td>959,17 g/mol</td></tr>
<tr><td>Molecular formula:</td><td>$C_{12}Br_{10}O$</td></tr>
</table>

In May 2017, the Conference of the Parties amended Annex A through its decision SC-8/1083 to list decabromodiphenyl ether (decaBDE; BDE-209) present in commercial Decabromodiphenyl ether (c-DecaBDE), with specific exemptions for the production and use (see Table 13 and Table 14). Due to the wide variety of applications many exemptions have been approved in the listing of DecaBDE, including housings for electrical appliances, PUR insulation, textiles, and parts for automobiles and

79 UNEP (2021) Draft guidance on preparing inventories of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants. BRS Secretariat.
80 La Guardia MJ, Hale RC, Harvey E. (2006) Detailed Polybrominated Diphenyl Ether (PBDE) congener composition of the widely used Penta-, Octa- and Deca- PBDE technical flame retardant mixtures. Environmental Science and Technology, 40, 6247-6254.
81 UNEP/POPS/POPRC.10/10/Add.2 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.10-10-Add.2.English.pdf
82 UNEP/POPS/POPRC.11/10/Add.1 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.11-10-Add.1.English.pdf
83 Decision SC-8/10. Listing of decabromodiphenyl ether. http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.8-SC-8-10.English.pdf

aircraft (Table 13 and Table 14).[83] The exemptions for textiles and insulation foam expired in December 2023.[69]

While the PBDEs listed in 2009 were listed with an exemption for recycling, there is no exemption for the recycling of decaBDE-containing products. Specific exemptions for parts for use in vehicles may be available for the production and use of c-DecaBDE (Table 14). Several countries registered for exemptions for production and use.[84]

Table 13. Specific exemptions for decabromodiphenyl ether[83]

Chemical	**Activity**	**Specific exemption**
DecaBDE (BDE-209) present in commercial decabromodiphenyl ether (CAS No: 1163-19-5)	Production	As allowed for the Parties listed in the Register
	Use	In accordance with Part IX of Annex A: • Parts for use in vehicles specified in paragraph 2 of Part IX of Annex A • Aircraft for which type approval has been applied for before December 2018 and has been received before December 2022 and spare parts for those aircraft* • Additives in plastic housings and parts used for heating home appliances, irons, fans, immersion heaters that contain or are in direct contact with electrical parts or are required to comply with fire retardancy standards, at conc. <10% by weight of the part **Expired exemptions 12/2023:** • Textile products that require anti-flammable characteristics, excluding clothing and toys • Polyurethane foam for building insulation

**Specific exemptions for spare parts for aircraft for which type approval has been applied before 12/2018 and has been received before 12/2022 shall expire at the end of the service life of those aircraft.*

Table 14. Specific exemptions for decaBDE for parts for use in vehicles[81]

Specific exemption	**Application** (Part IX of Annex A)	**Expire date**
(a) Parts for use in legacy vehicles, defined as vehicles that have ceased mass production, and with such parts falling into one or more of the following categories:	(i) Powertrain and under-hood applications such as battery mass wires, battery interconnection wires, mobile air-conditioning pipes, powertrains, exhaust manifold bushings, under-hood insulation, wiring and harness under the hood (e.g., engine wiring), speed sensors, hoses, fan modules & knock sensors; (ii) Fuel system applications such as fuel hoses, fuel tanks and fuel tanks underbody; (iii) Pyrotechnical devices and applications affected by pyrotechnical devices such as airbag ignition cables, seat covers/fabrics (only if airbag relevant) and airbags; (iv) Suspension and interior applications such as trim components, acoustic material and seat belts.	At the end of the service life of legacy vehicles or in 2036, whichever comes earlier
(b) Parts in vehicles specified in paragraphs (a) (i)–(iv) above and those falling into one or more of the following categories:	(i) Reinforced plastics (instrument panels and interior trim); (ii) Under the hood or dash (terminal/fuse blocks, higher-amperage wires and cable jacketing (spark plug wires)); (iii) Electric and electronic equipment (battery cases and battery trays, engine control electrical connectors, components of radio disks, navigation satellite systems, global positioning systems and computer systems); (iv) Fabric such as rear decks, upholstery, headliners, automobile seats, headrests, sun visors, trim panels, carpets.	at the end of the service life of vehicles or in 2036, whichever comes earlier

84 http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/DecabromodiphenyletherRoSE/tabid/7593/Default.aspx

6.2 Production

Some 2 million tonnes of technical PBDE mixtures were produced in the past (Table 15). C-DecaBDE has been produced since 1970s and is still produced. It is by far the most relevant technical mixture with a total historical production of 1,650,000 t and therefore more than 85% of all PBDEs produced (Table 15).

The production of c-DecaBDE stopped in the EU, Japan, the US and recently in China. Currently, India is the only known producer of c-DecaBDE, but with an unknown production amount.

Table 15. Estimated total production of commercial PBDE mixtures[5,85]

Commercial mixture	Time of production	Tonnes
Commercial PentaBDE	1970s to 2004	175,000
Commercial OctaBDE	1970s to 2004	131,000
Commercial DecaBDE	1970s to today (ongoing)	1,650,000

6.3 Trade

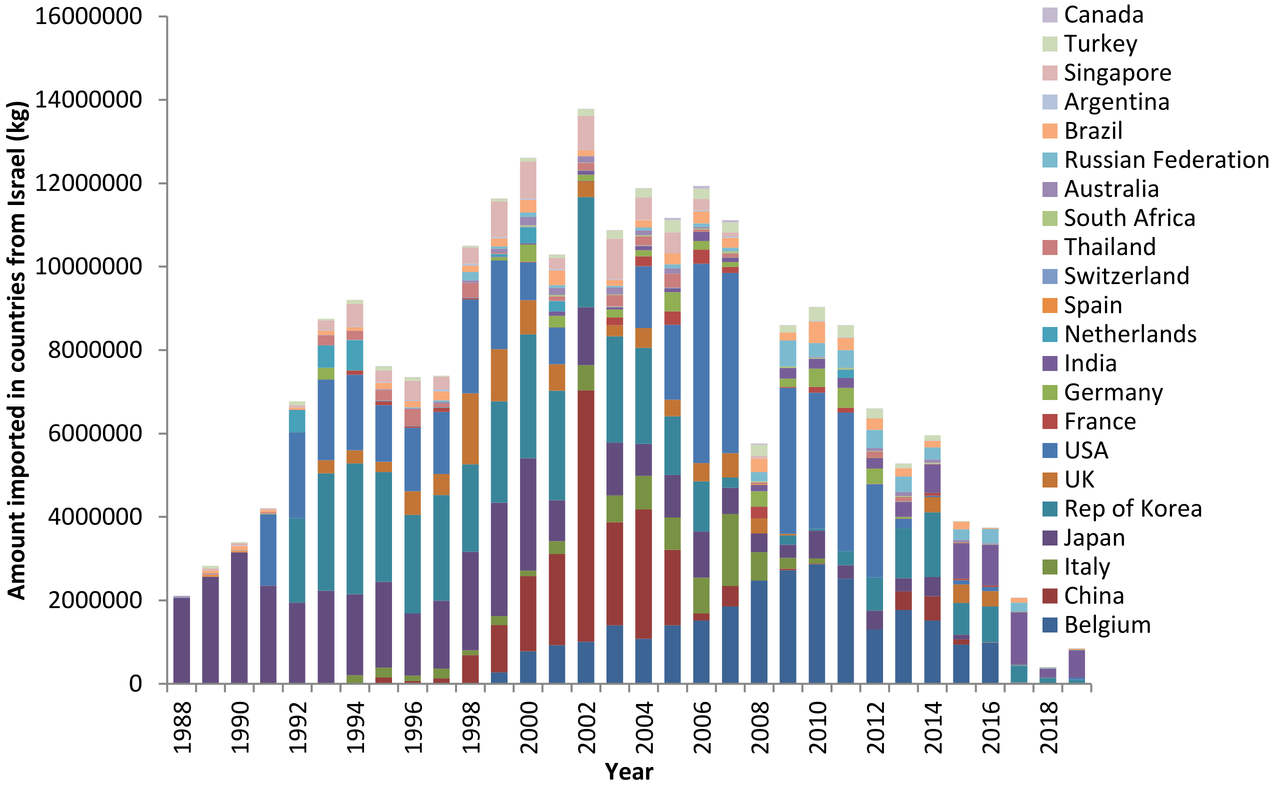
There is currently no robust trade data for PBDEs because the HS Code under for their trade, HS 290930 ("Aromatic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives") is not specific to PBDEs. This code also covers other chemicals, making it difficult to isolate data specifically for PBDEs. However, the assessment of exports under HS Code 290930 from Israel,[86] where one of the (former) major producers of brominated flame retardants was manufacturing PBDEs, gives reasonable results of PBDE exports (Figure 3). The time trend of exports of chemicals under this HS Code reflects the overall global production trend of PBDEs (Figure 1)[5] and indicates that reported imports from Israel to other countries were largely (legal) PBDE exports, with a strong decrease after 2010 (Figure 3).

For China, which produced c-DecaBDE until 2023, exports under HS Code 290930 amounted to approximately 26,000 tonnes of chemicals in both 2020 and 2021. This figure is comparable to the last reported production of c-DecaBDE in China (21,000 t). However, it likely represents an upper estimate, as other aromatic ethers and their halogenated, sulphonated, nitrated, or nitrosated derivatives are exported from China under this HS Code. Similarly, India's exports under HS Code 290930 are significant, with 43,600 tonnes in 2022 and 9,600 tonnes in 2023, totalling 866,000 tonnes over the past 20 years. This suggests a range of other aromatic ethers are exported under this code. India, along with several other countries,[87] has not ratified the decaBDE listing, resulting in a lack of information on production and use for these countries.

It is recommended that countries assess the imports of chemicals under HS Code 290930, track their use and assess their Chemical Abstracts Service (CAS) Registry Number as a unique identifier to clarify if these imports are decaBDE (UNEP 2021).[79] DecaBDE used in products like EEE, or polymers used in construction, are not labelled and related products can enter countries by imports not covered by the Rotterdam Prior Informed Consent (PIC) procedure (See Section 18.4).

85 Abbasi G, Li L, Breivik K (2019). Global historical stocks and emissions of PBDEs. Environ Sci & Technol, 53, 6330-6340.
86 The data were compiled from countries importing chemicals from Israel. UNEP (2021) PBDE inventory guidance.[79]
87 Weber R (2021) Assessment of newly listed POPs for countries that need to ratify the amendments or to update NIPs. Secretariat of the Basel, Rotterdam and Stockholm Conventions, UNEP, Geneva.

Figure 3. Time trend of export of chemicals (kg) under HS 290930 (aromatic ethers and their halogenated, sulphonated, nitrated, or nitrosated derivatives) from Israel to countries (1988–2019) (UNEP 2021)[86]



6.4 Use

Applications include plastics/polymers/composites, textiles, adhesives, sealants, coatings and inks. The major use sectors of c-DecaBDE were plastics and other polymers in EEE, transport, construction and textiles (see Section 6.5).

To date, several registered exemptions for the use in production are listed, including for the production of parts in vehicles (EU, Republic of Korea, Switzerland), for aircraft parts (EU, Republic of Korea, UK, Switzerland) and for production of plastic housings and parts of EEE (Republic of Korea, UK). As mentioned above, India – as the last producer and likely major user of decaBDE in production – has not registered for an exemption for production and use. This is because India has not yet ratified the decaBDE ban;[87] a range of countries have registered for continued use of products. For details of exemptions, see registration on the BRS website.[88]

6.5 Major use/stock of PBDEs in products, waste and recycling

6.5.1 Major use/stock of PBDEs in products and waste

The 1.65 million tonnes of decaBDE have been used in approximately 16 to 33 million tonnes of plastic and other polymers, including textiles.[89] The major former uses are considered for electronics (30%), foam in furniture/carpets (25%), plastic/polymers in construction (20%), transport (15%) and textiles (15%) (Table 16).[85]

88 http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/DecabromodiphenyletherRoSE/tabid/7593/Default.aspx
89 Considering an average 5% to 10% use (for amount of decaBDE in products see PBDE inventory guidance[79]).

While a large share of treated textiles and electronics has entered end-of-life and has been disposed of, the largest share of decaBDE used in polymers in construction is likely still in use. Based on the estimated share of decaBDE use in construction (Table 16), 3 to 6 million tonnes of plastic/polymers containing 330,000 tonnes of decaBDE (e.g., PUR foams, PE and PP foil and coatings) were installed in buildings. These materials have a long service life and are likely today the largest use of decaBDE-containing plastic.

An estimated 250,000 tonnes of decaBDE have been used in the transport sector. DecaBDE was the main PBDE used in vehicles with major use from the 1970s to 2016. DecaBDE is still in use in vehicles in textile back coating and other parts, as compiled in the listed exemptions (Table 14). Currently, a large share of these vehicles produced in this time period is present in developing countries, receiving second-hand vehicles with a long service life of ~35 years (see case study POPs in the transport sector in Nigeria in the UNEP sectoral POP inventory guidance (UNEP 2024[90])).

Table 16. Percentage of commercial PBDEs in major uses and average lifespan of product type[85]

Use area	c-PentaBDE	c-OctaBDE	c-DecaBDE	Lifespan*
Electronics	10%	40%	30%	7 – 20*
Foam & carpet	50%	15%	25%	10
Construction	20%	25%	20%	30 – 50
Transportation	15%	15%	15%	15 – 35*
Textile	5%	5%	15%	10

**The longer lifespan for vehicles or electronics is prevalent in low- and middle-income countries.*

6.5.2 PBDE in waste and reuse and recycling

Plastic from waste electrical and electronic equipment (WEEE) contains PBDEs since the 1980s and some WEEE plastic fractions are above the provisional low POP content of 1,000 mg/kg PBDE, while nearly all WEEE fractions are above the provisional low POP content of 50 mg/kg with major contribution from decaBDE (Table 17). These concentrations are expected to decrease over time as more EEE produced in the last 10 years, which contains little to no decaBDE, becomes waste. However, in low- and middle-income countries, older EEE is still in use and waste containing higher levels of PBDEs.[91] The recycling of a share of decaBDE-containing plastic has impacted a multitude of plastic and polymer products, including toys,[92] food contact materials[93] and a wide range of other products.[94] Such plastic contains brominated dioxins at levels of concern.

Table 17. Listed PBDE content (hexa/heptaBDE and decaBDE) in total (mixed) polymer fractions of different WEEE in Europe (UNEP 2021[79])

Category/article		∑hexa/heptaBDE in plastic fractions [kg/tonne]* ($C_{hexa/heptaBDE;Polymer}$)			decaBDE in plastic fractions [kg/ tonne] ($C_{decaBDE;Polymer}$)		
		Minimum	Maximum	**Mean**	Minimum	Maximum	**Mean**
1	Cooling/freezing appliances; washing machines	-	-	**<0.05**	-	-	**<0.05**
1	Heating appliances	-	-	**<0.05**	-	-	**0.8**

90 Sectoral guidance for inventories of POPs and other chemicals of concern in buildings/construction, electrical and electronic equipment, and vehicles

91 Sindiku O, Babayemi J, Osibanjo O, Schlummer M, Schluep M, Watson A, Weber R (2015) Polybrominated diphenyl ethers listed as Stockholm Convention POPs, other brominated flame retardants and heavy metals in E-waste polymers in Nigeria. Environ Sci Pollut Res Int. 22, 14489-14501.

92 Chen S-J, Ma Y-J, et al. (2009) Brominated Flame Retardants in Children's Toys: Concentration, Composition, and Children's Exposure & Risk Assessment. Environ SciTechnol 43, 4200- 4206.

93 Kuang J, Abdallah MA-E, Harrad S (2018) Brominated flame retardants in black plastic kitchen utensils: Concentrations and human exposure implications. Science of The Total Environment 610–611, 1138-1146.

94 Gallen C, Banks A, Brandsma S, et al. (2014) Towards development of a rapid and effective non-destructive testing strategy to identify brominated flame retardants in the plastics of consumer products. Sci Total Environ. 491-492:255-265.

2	Small household appliances	-	-	-	<0.1	0.5	**0.17**
3	ICT equipment. w/o monitors	0.027	0.22	**0.12**	0.5	1.4	**0.8**
3	CRT monitor casings	0.08	5.7	**1.37**	0.5	7.8	**3.2**
4	Consumer equipment w/o monitors (composite sample)	-	-	**0.08**	0.7	0.9	**0.8**
4	TV CRT monitor casings	0.03	1.9	**0.47**	0.8	7.8	**4.4**
4	Flat screens TVs (LCD)	0.008	0.010	**0.009**	1.2	4.3	**2.75**

**RoHS limit for PBDEs is 1000 mg/kg or 1 kg/t. The Basel provisional low POPs limit for PBDEs is currently 1000 mg/kg (1kg/t) or 500 mg/kg (500 g/t) or 50 mg/kg (50 g/t).*

Classic cars in high income countries as well as vehicles in low income countries have long service lives. Additionally plastic and polymers from end-of-life vehicles are reused for repairing other vehicles which is exempted by the Convention (Table 14).

When buildings constructed from the 1970s on are demolished, plastic and other polymers containing PBDEs enter construction and demolition waste. Initial projects to assess the recycling of plastic in buildings have started[95] and should consider POP contamination and establish separation of PBDEs and other POPs containing plastic.

7 Polybrominated Diphenyl Ethers (PBDEs) Listed in 2009

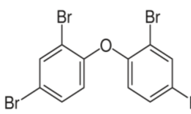
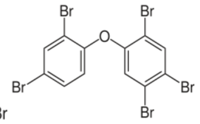
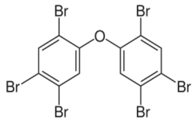
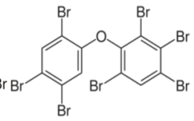
7.1 Chemical identity, POPs properties and listing under the Convention

In 2009, tetraBDE and pentaBDE (in commercial PentaBDE) as well hexaBDE and heptaBDE (contained in c-OctaBDE) were listed in Annex A to the Convention with specific exemptions for continued use of articles and recycling, but no specific exemptions for production.[96] The listed PBDEs are highly persistent in the environment, are bioaccumulative and have potential for long-range transport. These chemicals have been detected in humans in all regions with congeners of c-PentaBDE as major contaminants. These PBDEs are likely, as a result of long-range environmental transport, to lead to significant adverse effects on human health and/or the environment. Detailed information for listing has been compiled in the risk profile[97] and the risk management evaluation.[98] Information on chemical identity is compiled in Table 18.

Table 18. Chemical identification and structures of PBDEs

Chemical name:	Tetrabromodiphenyl ether and pentabromodiphenyl ether	Hexabromodiphenyl ether and heptabromodiphenyl ether
Synonyms/ abbreviations:	Commercial pentabromodiphenyl ether; c-PentaBDE	Commercial octabromodiphenyl ether; c-OctaBDE
CAS registry number:	5436-43-1; 60348-60-9	68631-49-2; 207122-15-4 446255-22-7; 207122-16-5
Trade name	DE-71 Bromkal 70DE;	DE-79; Bromkal 79-8DE

95 German Environment Agency (2021) Promoting the high-quality recycling of plastics from demolition waste and enhancing the use of recycled materials in construction products in accordance with the European Plastics Strategy. Texte 152/2021.
96 Decision SC-4/14. http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.4-SC-4-14.English.pdf and Decision SC-4/18. http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.4-SC-4-18.English.pdf.
97 Risk profile on commercial pentabromodiphenyl ether. Persistent Organic Pollutants Review Committee 2006; UNEP/POPS/POPRC.2/17/Add.1 and Risk profile on commercial octabromodiphenyl ether. Persistent Organic Pollutants Review Committee 2007; UNEP/POPS/POPRC.3/20/Add.6.
98 Risk management evaluation for commercial pentabromodiphenyl ether. Persistent Organic Pollutants Review Committee 2007; UNEP/POPS/POPRC.3/20/Add. and Risk management evaluation for commercial octabromodiphenyl ether. Persistent Organic Pollutants Review Committee 2008; UNEP/POPS/POPRC.4/15/Add.1.

Structure (example):	tetraBDE  pentaBDE 	hexaBDE  heptaBDE 
Molecular weight:	485.7 g/mol564.7 g/mol	643.5 g/mol 722.5 g/mol
Molecular formula:	C12H6Br4O C12H5Br5O	C12H4Br6O C12H3Br7O

7.2 Production

An estimated 175,000 t of c-PentaBDE (listed tetraBDE/pentaBDE) has historically been produced since the 1970s with production stopped in 2004; 131,000 tonnes of c-OctaBDE (containing hexaBDE/heptaBDE) has historically been produced since the 1970s with production stopped in 2004.

7.3 Use

C-PentaBDE (listed tetraBDE/pentaBDE) was primarily (90%) used in rigid and flexible polyurethane (PUR) foams and PUR elastomers. The major use sectors were in foam in upholstered furniture/carpets (50%), plastic/polymers in construction (20%), transport (15%), electronics (10%), and textiles (5%) with more than 90% use in the US (Table 16).[85]

C-OctaBDE (containing hexaBDE/heptaBDE) was mainly used in acrylonitrile-butadiene-styrene copolymers (ABS) with lower use in high-impact polystyrene (HIPS) and polybutylene terephthalate (PBT). The major use sectors were plastic in electronics, especially in the manufacture of computer and television housings (40%) and plastic, adhesives and coatings in construction (25%). Lower-use sectors were plastic/polymers in transport (15%), furniture/carpets (15%), and textiles (5%) (Table 16).

Currently, there are some Parties registered for continued use of products for tetraBDE/pentaBDE[99] and Parties with different uses for hexaBDE/heptaBDE[100] without any data on the quantity of use.

7.4 Trade

Since the production of c-PentaBDE (tetraBDE and pentaBDE) and c-OctaBDE (hexaBDE and heptaBDE) stopped in 2004 there has been no trade of chemicals or new uses of these PBDEs. However, products like cars produced before 2005 might be exported and traded. Also, used electronics and e-waste containing PBDEs might be exported and traded.

7.5 PBDE listed 2009 in products, waste and recycling

The levels of PBDEs listed in 2009 in waste and recycling are considerably lower compared to decaBDE (Table 17). The reason is their considerably lower total production/use (Table 15) and that their main use was in the 1980s and 1990s and therefore most EEE-containing PBDEs listed in 2009 has already been disposed of.

Classic cars in high income countries as well as vehicles in low income countries have long service lives. Additionally plastic and polymers from end-of-life vehicles are reused for repairing other vehicles which is exempted by the Convention (Table 14).

Construction materials have long service lives in buildings (30 to more than 50 years). Plastic and other polymers containing PBDEs enter construction and demolition waste when buildings constructed from the 1970s onwards are demolished. Initial projects to assess the recycling of plastic in buildings have started[95] and should consider POP contamination and establish separation of PBDEs and other POPs containing plastic.

99 http://www.pops.int/Implementation/Exemptions/SpecificExemptions/TetraBDEandPentaBDERoSE/tabid/5039/Default.aspx
100 http://www.pops.int/Implementation/Exemptions/SpecificExemptions/HexaBDEHeptaBDERoSE/tabid/5035/Default.aspx

8 Hexabromocyclododecane (HBCD)

8.1 Chemical identity, POPs properties and listing under the Convention

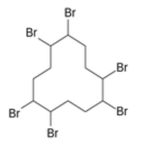
Hexabromocyclododecane (HBCD or HBCDD[101]) is an additive brominated flame retardant used since the 1960s. Information on chemical identity and structure is compiled in Table 19.

HBCD has the potential to bioaccumulate and biomagnify. It is persistent in the environment and monitoring data show its long-range environmental transport. It is very toxic to aquatic organisms. Though information on the human toxicity of HBCD is to a great extent lacking, vulnerable groups could be at risk, particularly due to the observed neuroendocrine and developmental toxicity of HBCD.[102]

Detailed information is provided in the Risk Profile[103] and the Risk Management Evaluation.[104]

HBCD was listed in Annex A in 2013 with specific exemptions for production and use in expanded polystyrene (EPS) and extruded polystyrene (XPS) insulation in buildings.[105] This exemption decision on HBCD allowed a time-limited exemption, but has stopped for all countries in 2021[105] and all registered exemptions are withdrawn or have expired.[106] New uses of HBCD are not exempted and allowed anymore. However, the existing HBCD-containing insulation materials in buildings may continue to be used. Due to the long service life of building insulation, EPS/XPS waste containing HBCD will be in use for decades and up to a century.[107]

Table 19. Chemical identification and properties of HBCD[103,104]

<table>
<tr><td>Chemical name:</td><td colspan="3">Hexabromocyclododecane</td></tr>
<tr><td>Synonyms/abbreviations:</td><td colspan="3">HBCD, HBCDD Various</td></tr>
<tr><td>CAS Registry Number:</td><td colspan="3">25637-99-4; 3194-55-6</td></tr>
<tr><td>Trade names</td><td colspan="3">Cyclododecane, hexabromo; HBCD; Bromkal 73-6CD; Nikkafainon CG 1;
Pyroguard F 800; Pyroguard SR 103; Pyroguard SR 103A; Pyrovatex 3887;
Great Lakes CD-75P™, CD-75, CD75XF and CD75PC (compacted); Dead Sea Bromine Group Ground FR 1206 I-LM, Standard FR 1206 I-LM and Compacted FR 1206 I-CM</td></tr>
<tr><td rowspan="2">Structure:</td><td rowspan="2"></td><td>Molecular weight:</td><td>641,73 g/mol</td></tr>
<tr><td>Molecular formula:</td><td>C12H18Br6</td></tr>
</table>

8.2 Production

The last production of HBCD stopped in November 2021 in China within a GEF HBCD phase-out project and the ending of exemption.[108] Remaining HBCD stockpiles in China will be destroyed within the GEF project.[108]

101 The abbreviation in the Convention is HBCD while in most scientific literature HBCDD is used as abbreviation.
102 Factsheet Hexabromocyclododecane. http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-NewPOPs-Factsheet-08-20200226.English.pdf
103 UNEP/POPS/POPRC.6/13/Add.2 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.6-13-Add.2.English.pdf
104 UNEP/POPS/POPRC.7/19/Add.1 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.7-19-Add.1.English.pdf and Addendum; UNEP/POPS/POPRC.8/16/Add.3 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.8-16-Add.3.English.pdf
105 Decision SC-6/13. http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.6-SC-6-13.English.pdf
106 http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/HexabromocyclododecaneRoSE/tabid/5034/Default.aspx
107 Li L, Weber R, Liu J, Hu J (2016) Long-term emissions of hexabromocyclododecane as a chemical of concern in products in China. Environ Int. 91, 291-300.
108 UNIDO (2022) https://www.unido.org/stories/unidos-help-china-stops-production-hazardous-chemical

HBCD has been produced and on the market since the late 1960s; a total of 703,000 tonnes has been produced[5] in more than 50 years (Figure 1). HBCD is the industrial POP with the fourth largest production in history (after SCCPs, decaBDE and PCB) (see Section 1.3).

8.3 Trade

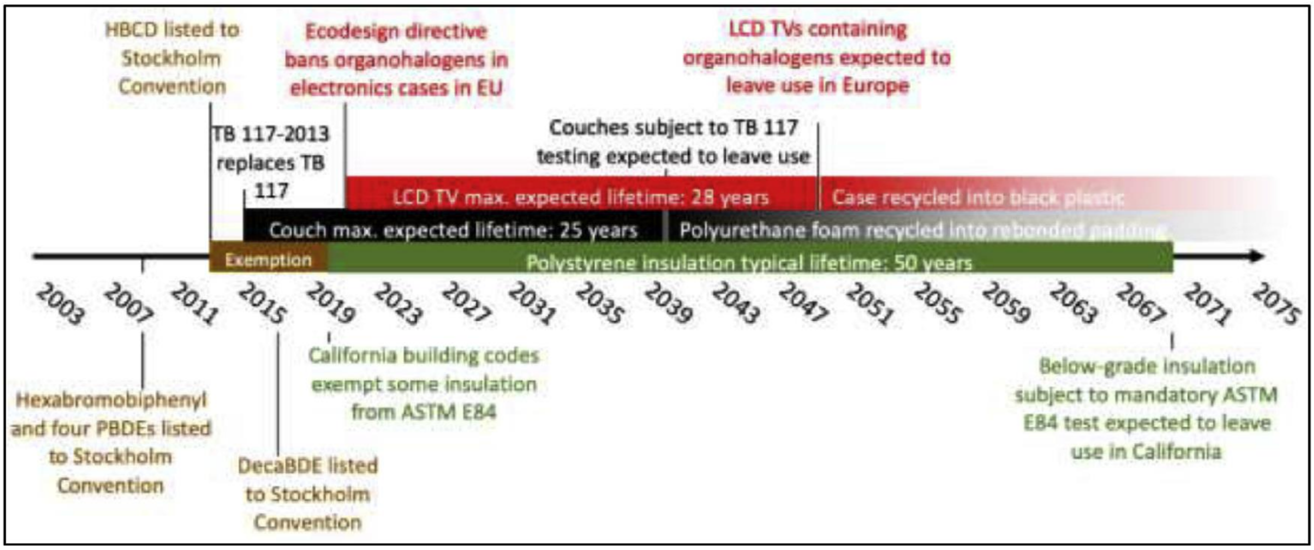
Since HBCD production ended in 2021, including the phase-out of HBCD use in China,[108] no trade of HBCD as a chemical or mixture or trade of new HBCD-containing products is expected. Waste EPS/XPS from refurbishment and demolition of buildings will be generated in the decades to come and might partly be exported and traded for environmentally sound disposal or illegally.

8.4 Use and stocks

The main application (about 90%; 633 kt) of HBCD was in EPS and XPS insulation in buildings and construction. HBCD was applied as a flame retardant in EPS at 0.5-1.0 % by weight and in XPS at 0.8-2.5 % by weight. Considering an average HBCD content of 1% a total of 63,300 kt of contaminated EPS/XPS has been produced. The HBCD-containing insulation materials already installed in buildings may continue to be used. Due to the long service life of building insulation of 25 to 100 years,[109] with an average lifespan of 50 years,[110] (Figure 4) almost all of this EPS/XPS is still in use and EPS/XPS containing HBCD will remain in use for the next decades and up to a century[107] and will then become waste when buildings are refurbished or demolished.

In the past (before 2013), HBCD was also used as a flame retardant in HIPS in EEE and in polymer dispersions for textiles and synthetic fabrics often in public spaces, such as for curtains, furniture, mattresses and home textiles. About 2% of the total amount of HBCD might have been used in HIPS (~14 kt) and less than 10% in textiles (<70 kt).

Figure 4. The impact of the enactment of flame-retardant restrictions by the Stockholm Convention and selected standards reforms on affected products (Charbonnet et al. 2020)[110]



109 UNEP (2021) Guidance on preparing inventories of hexabromocyclododecane (HBCD).
110 Charbonnet J, Weber R, Blum A (2020) Flammability standards for furniture, building insulation and electronics: Benefit and risk. Emerg. Contam 6, 432-441, https://doi.org/10.1016/j.emcon.2020.05.002.

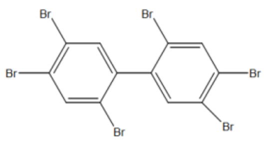
9 Hexabromobiphenyl (HBB)

9.1 Chemical identity, POPs properties and listing under the Convention

Hexabromobiphenyl (HBB) belongs to a wider group of polybrominated biphenyls (PBBs). The major congeners of commercial HBB (Trade Names: FireMaster(R) BP-6; FireMaster(R) FF-1) were largely 2,2',4,4',5,5'-hexabromobiphenyl (PBB 153), accounting for 50-60% of the total mass, followed by 2,2',3,4,4',5,5'-heptabromobiphenyl (PBB 180; 10-15%), and 2,2',3,4,4',5'-HBB (PBB 138; 5-10%).[111,112] The chemical is highly persistent in the environment, highly bioaccumulative and has the potential for long-range environmental transport.[111] HBB is classified as a possible human carcinogen and has chronic toxic effects.[111] Detailed information is provided in the risk profile[111] and the risk management evaluation (RME).[113] Information on chemical identity is compiled in Table 20.

Since 2009, HBB has been listed in Annex A to the Stockholm Convention without exemptions (SC-4/13).114

Table 20. Chemical identification and structure of HBB[111,113]

Chemical name:	Hexabromo-1,1´-biphenyl;		
Synonyms/abbreviations:	Hexabromobiphenyl (HBB), biphenyl, hexabromo; 1,1´-biphenyl, hexabromo		
Trade names	FireMaster BP-6 and FireMaster FF-1		
CAS Registry Number:	36355-01-8; 59536-65-1; 67774-32-7		
Structure:		Molecular weight:	627.58
		Molecular formula:	C12H4Br6

9.2 Production

HBB is an industrial chemical that was produced in the United States from 1970 to 1976 with a total production quantity of 5,400 tonnes;[111] no other country has recorded production of HBB. In the United States and Canada, hexabromobiphenyl (FireMaster (R)) was the principal PBB product; 98% was used as the trade name FireMaster BP-6 and the rest as FireMaster FF-1.[111]

9.3 Use

HBB has been used as an additive flame retardant in the 1970s in three main commercial uses:[111]

- ABS thermoplastics (plastic for constructing business machine housings and in industrial (e.g. motor housing) and electrical sectors (e. g. radio and TV parts)
- PUR foam for automotive upholstery
- Coatings and lacquers

Due to the low production amount and production stop in 1976, most EEE/WEEE or vehicles containing HBB were disposed of decades ago. As a result, there are no or very limited HBB-containing products in use.

9.4 Trade

Since production stopped in 1976, trade stopped more than 40 years ago.[111] Some classic cars produced from 1970 to 1976 might contain HBB as a flame retardant and might still be traded.

111 UNEP/POPS/POPRC.2/17/Add.3 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.2-17-Add.3.English.pdf
112 Pijnenburg AMCM, Everts JW, de Boer J, Boon JP. (1995) Polybrominated biphenyl and diphenylether flame retardants: analysis, toxicity and environmental occurrence. Rev Environ ContamToxicol 141, 1-26.
113 UNEP/POPS/POPRC.3/20/Add.3 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.3-20-Add.3.English.pdf
114 Decision SC-4/13: Listing of HBB: http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.4-SC-4-13.English.pdf

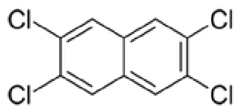
10 Polychlorinated Naphthalenes (PCNs)

10.1 Chemical identity, POPs properties and listing under the Convention

Polychlorinated naphthalenes (PCNs) are a group of compounds of naphthalenes in which one or more hydrogen atoms are replaced by chlorine. There are 75 PCN congeners, which are divided into eight homologous groups according to the number of chlorine atoms in the molecule. All PCNs are listed in the Convention in Annex A and C but not the monochlorinated naphthalenes (Table 22).

PCNs are persistent in the environment and can undergo long-range transport. Acute exposure caused chloracne and PCNs had greater acute toxicity and higher mortality rates than PCBs. Chronic exposure led to liver diseases including cancer.[115,116] Detailed information for listing is compiled in the risk profile[116] and the risk management evaluation.[117] Information on chemical identity and structures is compiled in Table 21.

Table 21. Chemical identification and structure of listed PCNs[116,117]

<table>
<tr><td>Chemical name:</td><td colspan="3">Polychlorinated naphthalenes</td></tr>
<tr><td>Synonyms/abbreviations:</td><td colspan="3">PCNs; CNs; naphthalene chloro-derivatives</td></tr>
<tr><td>Trade names:</td><td colspan="3">Various, but trade stopped more than 20 years ago</td></tr>
<tr><td>CAS Registry Number:</td><td colspan="3">70776-03-3 and others</td></tr>
<tr><td rowspan="2">Structure:</td><td rowspan="2"></td><td>Molecular weight:</td><td>197 - 335[118] g/mol</td></tr>
<tr><td>Molecular formula:</td><td>$C_{10}H_{8-n}Cl_n$ (n=2 to 8)</td></tr>
</table>

PCNs are listed in Annex A with specific exemption for the use as intermediates in the production of polyfluorinated naphthalenes (PFNs), including octafluoronaphthalene (OFN), and the use of those chemicals for the production of PFNs, including OFN119 (Table 22).[120]

Table 22. Listing of specific exemptions for PCNs (Decision SC-7/14)[120]

Chemical	**Activity**	**Specific exemptions**
Polychlorinated naphthalenes, *including* *dichlorinated naphthalenes, trichlorinated naphthalenes, tetrachlorinated naphthalenes, pentachlorinated naphthalenes, hexachlorinated naphthalenes, heptachlorinated naphthalenes, octachlorinated naphthalene*	Production	Intermediates in production of polyfluorinated naphthalenes (PFNs), including octafluoronaphthalene (OFN)
	Use	Production of polyfluorinated naphthalenes, including octafluoronaphthalene

10.2 Production

The production of PCNs stopped around 2000. Some 150,000 tonnes were produced from 1920 to 2000. Most of the industrially produced PCNs were mixtures of several congeners marketed as

115 Factsheet PCNs. http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-NewPOPs-Factsheet-15-20200226.English.pdf
116 UNEP/POPS/POPRC.8/16/Add.1 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.8-16-Add.1.English.pdf
117 UNEP/POPS/POPRC.9/13/Add.1 file:///C:/Users/roland/Downloads/UNEP-POPS-POPRC.9-13-Add.1.English.pdf
118 The range refers to the different degree of chlorination of the PCN congeners.
119 http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/PolychlorinatednaphthalenesRoSE/tabid/5483/Default.aspx
120 Decision SC-7/14. http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.7-SC-7-14.English.pdf

Halowax, Nibren and other commercial trade names. PCN production stopped in most countries more than 20 years ago and the production volume had decreased already by the 1970s.

Currently, Russia has registered for exemption for the production of 500 tonnes of PCNs per year.[121]

10.3 Use

PCNs have been used in the past in various applications, including the insulation of electrical wires, as an additive for waterproof metal paints (e.g. in the marine industry) and in rubber, as wood preservatives, as dielectrics for capacitors, as fog ammunition and ammunition ballast, as an additive in machine oils and as a lubricant in grinding or cutting.[116,122]

Due to the limited service life of, for example, cables, lubricants, ammunition, or rubber products, it can be assumed that the largest proportion of these products containing PCNs has already been disposed of.[122.] Some of the products used in construction like treated wood or sealants have long service life and therefore some PCNs might still be present in these uses.[122]

Currently, PCNs are used as intermediates for the production of PFNs, including OFN (Table 22).

10.4 Trade

Since the production of 500 tonnes of PCNs is only exempted for the use as intermediates in the production of PFNs, including OFN in Russia,[121] no trade of PCNs is expected.

11 Hexachlorobutadiene (HCBD)

11.1 Chemical identity, POPs properties and listing under the Convention

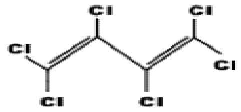
Hexachlorobutadiene (HCBD) is a chlorinated organic compound belonging to the group of aliphatic unsaturated perchlorinated alkenes (Table 23). HCBD has the potential for long-range transport, is persistent and highly toxic to aquatic organisms and birds. It can affect food chains due to its bioaccumulation and persistence. HCBD has been shown to cause irritation, nervous system depression and kidney damage when inhaled at higher levels. It is genotoxic and may have an adverse effect to fatty liver degeneration as well. The relatively volatile HCBD can be absorbed orally, by inhalation, and dermally. It is classified as a possible human carcinogen and is genotoxic.[123] Detailed information is provided in the risk profile[124] and the risk management evaluation.[125] Information on chemical identity and structures is compiled in Table 23.

In 2015, HCBD was listed in Annex A to the Convention without specific exemptions[126] and was listed in 2017 additionally in Annex C.[127] Parties must take measures to eliminate the production and use of HCBD and also take measures to minimize the unintentional releases of HCBD.

Table 23. Chemical identification and structure of hexachlorobutadiene[124,125]

Chemical name	Hexachlorobutadiene
Synonyms/abbreviations	HCBD; perchloro-1, 3-butadine; perchlorobutadiene; 1,3-hexachlorobutadine; 1,3-butadiene, 1,1,2,3,4,4-hexachloro-; 1,3-butadiene, hexachloro-; hexachlorobuta-1,3-diene

121 http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/PolychlorinatednaphthalenesRoSE/tabid/5483/Default.aspx
122 UNEP (2017) Draft guidance on preparing inventories of polychlorinated naphthalenes (PCNs). UNEP/POPS/COP.8/INF/19.
123 Brüschweiler BJ, Märki W, Wülser R (2010) In vitro genotoxicity of polychlorinated butadienes (Cl4-Cl6). Mutation Research - Genetic Toxicology and Environmental Mutagenesis 699, 47-54.
124 UNEP/POPS/POPRC.8/16/Add.2 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.8-16-Add.2.English.pdf
125 UNEP/POPS/POPRC.9/13/Add.2 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.9-13-Add.2.English.pdf
126 Decision SC-7/12: Listing of HCBD in Annex A: http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.7-SC-7-12.English.pdf
127 Decision SC-8/12: Listing of HCBD in Annex C: http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.8-SC-8-12.English.pdf

Trade Names	Dolen-pur, C-46, UN2279, GP-40-66:120[128]		
CAS Registry Number	87-68-3		
Structure		Molecular weight:	260.76 g/mol
		Molecular formula:	C_4Cl_6, $Cl_2C=CClClC=CCl_2$

11.2 Production

HCBD is primarily a by-product of the chlorolysis process in the production of carbon tetrachloride, tetrachloroethene and chloroform.[129] These chlorinated solvents are produced in many countries on a large scale and enough unintentional HCBD was/is formed that could be separated as a commercial HCBD product. HCB was unintentionally produced in the same processes and the resulting production waste containing mainly HCBD and HCB is called “HCB waste”. This production waste, however, also contains high levels of PCBs, PCNs, PeCB and a minor amount of PCDD/PCDFs.[130,131,132] HCBD was never produced intentionally.[129]

In terms of quantity, the unintentional production or manufacture of HCBD as a by-product of industrial processes was 10,000 tonnes per year in 1982.[133] Unintentional HCB/HCBD waste from individual large solvent producers has generated waste deposits in the scale of 10,000 t of “HCB waste” at respective sites with associated pollution.[129,131,132] Other thermal processes such as waste incineration are not considered as relevant source of HCBD.[129]

HCBD is still unintentionally produced in certain production processes of the organochlorine industry in particular in the production of chlorinated solvents. In industrial countries, the recycling of these HCBD has stopped. There is a lack of specific information on current production in emerging countries such as China and India, which have large production of chlorinated solvents and might separate HCBD[129] as indicated by sales platforms.[134] Only for one production of chloromethanes a detailed analysis of unintentional POPs in waste was conducted and published.[130]

11.3 Use

HCBD was used in several technical and agricultural applications and as an intermediate in the chemical industry or as a product.[129] It was applied as a solvent (for rubber and other polymers); as a “scrubber” to recover chlorine-containing gas or to remove volatile organic components from gas; as hydraulic, heat transfer or transformer fluid; in gyroscopes; or in the production of aluminium and graphite rods.[126, 129.]

11.4 Trade

Today, some companies still offer HCBD as a product in tonnes scale on internet platforms indicating that HCBD is still separated to some extent at some production sites for sales and commercial use.

The trade of HCBD is not regulated under the Rotterdam Convention, so HCBD is not subject to the Prior Inform Consent (PIC) procedure and does not have a specific HS Code. Thus, no data on the international trade of HCBD could be retrieved.

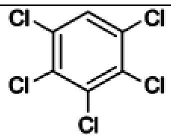
128 van der Honing M. (2007) Exploration of management options for Hexachlorobutadien (HCBD), Paper for the 6th meeting of the UNECE CLRTAP Task Force on Persistent Organic Pollutants, Vienna, 4-6 June 2007.
129 UNEP (2017) Draft guidance on preparing inventories of hexachlorobutadiene (HCBD).UNEP/POPS/COP.8/INF/18
130 Zhang L, Yang W, Zhang L, Lib X (2015) Highly chlorinated unintentionally produced persistent organic pollutants generated during the methanol-based production of chlorinated methanes: a case study in China. Chemosphere 133, 1–5.
131 Weber R, Watson A, Malkov M, Costner P, Vijgen J (2011) Unintentionally produced hexachlorobenzene and pentachlorobenzene POPs waste from solvent production – the need to establish emission factors and inventories. Organohalogen Compounds 73, 2205-2208. http://dioxin20xx.org/wp-content/uploads/pdfs/2011/5002.pdf
132 Weber R, Watson A, Forter M, Oliaei F (2011) Persistent Organic Pollutants and Landfills - A Review of Past Experiences and Future Challenges. Waste Management & Research 29 (1) 107-121.
133 International Programme on Chemical Safety, Environmental Health Criteria 156, Hexachlorobutadiene, WHO. http://www.inchem.org/documents/ehc/ehc/ehc156.htm, 2012-02-01
134 https://www.globalchemmall.com/hexachlorobutadiene; https://www.nacchemical.com/hexachlorobutadiene-solution-3744326.html

12 Pentachlorobenzene (PeCB)

12.1 Chemical identity, POPs properties and listing under the Convention

Pentachlorobenzene (PeCB) belongs to a group of chlorobenzenes that are characterized by a benzene ring in which the hydrogen atoms are substituted by five chlorines (Table 24). PeCB is persistent in the environment and is bioaccumulative. PeCB has a very long atmospheric residence time and is transported over long distances. Detailed information for listing is provided in the risk profile[135] and the risk management evaluation.[136] Information on chemical identity is compiled in Table 24. Since 2009, PeCB has been listed in Annex A without specific exemptions and in Annex C to the Stockholm Convention.[137]

Table 24. Chemical identification and structure of PeCB[135, 136]

Chemical name:	Pentachlorobenzene		
Synonyms/abbreviations:	1,2,3,4,5-pentachlorobenzene; pentachlorobenzene; PeCB; QCB; quintochlorobenzene		
Trade names:	None		
CAS registry number:	608-93-5		
Structure:		Molecular weight:	250.32 g/mol
		Molecular formula:	C6HCl5

12.2 Production

There is no known intentional production of industrial PeCB. However, one company offers PeCB and related derivatives on a commercial platform.[138] PeCB is produced and used in relatively small amounts as analytical grade PeCB by laboratories for the preparation of standard solutions used for analytical purposes.136

12.3 Use

PeCB was used in mixtures with PCBs in equipment such as transformers, in dyestuff carriers, as a fungicide, as flame retardant and as a chemical intermediate, e.g. previously for the production of the fungicide quintozene. The degradation of quintozene partly produces PeCB, which was once the most important source of PeCB.[135] Production of quintozene in the US was estimated to be 1,300 tonnes in 1972.[135] Major US and European manufacturers of quintozene have changed their manufacturing process to eliminate this use of PeCB. The use of quintozene has also been stopped in most UNECE countries due to its persistence and due to contamination with PCDD/PCDFs and related releases.[139,140] The situation outside the UNECE region on production and use at this stage is unknown.

12.4 Trade

Since there is no intentional production of industrial PeCB, there is also no trade of PeCB with the exemption of analytical standards.

135 UNEP/POPS/POPRC.3/20/Add.7 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.3-20-Add.7.English.pdf
136 UNEP/POPS/POPRC.4/15/Add.2 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.4-15-Add.2.English.pdf
137 Decision SC-4/16: Listing of Pentachlorobenzene http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.4-SC-4-16.English.pdf
138 https://www.echemi.com/shop-us20220607140012825/products.html?keywords=pentachlorobenzene
139 Holt E, Weber R, Stevenson G, Gaus C (2010) Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans (PCDD/Fs) Impurities in Pesticides: A Neglected Source of Contemporary Relevance. Environ. Sci. Technol 44, 5409–5415.
140 Huang J, Gao J, Yu G, Yamazaki N, Deng S, Wang B, Weber R (2015) Unintentional formed PCDDs, PCDFs, and DL-PCBs as impurities in Chinese pentachloronitrobenzene products. Environ Sci Pollut Res Int. 22, 14462-14470.

13 Lindane (Gamma-HCH) and Alpha- and Beta-HCH

13.1 Chemical identity, POPs properties and listing under the Convention

Three major isomers of hexachlorocyclohexane (HCH), have been listed in 2009 in the Convention:

- alpha-hexachlorocyclohexane (alpha-HCH)
- beta-hexachlorocyclohexane (beta-HCH)
- gamma- hexachlorocyclohexane (lindane; gamma-HCH)

Only lindane has insecticidal activity. However, lindane could not be produced isomer-specifically, but was produced as an HCH mixture during the chlorination of benzene and then was separated from the HCH mixture. The HCH waste isomers from lindane production have resulted in large waste and contaminated site legacies at the production sites.[141,142]

Lindane is persistent, bioaccumulates easily in the food chain and bioconcentrates. There is evidence for long-range transport and toxic effects in laboratory animals and aquatic organisms. In 2018, the International Agency for Research on Cancer (IARC) classified lindane as a group 1 carcinogen (carcinogenic to humans).

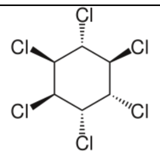
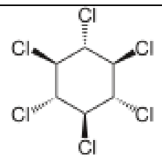
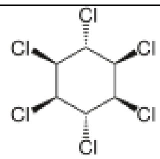
Alpha- and beta-HCH are subject to long-range transport. They are highly persistent in water in colder regions and may bioaccumulate and biomagnify in biota and arctic food webs. They are classified as possibly carcinogenic to humans and adversely affect wildlife and human health in contaminated regions.[142] Detailed information is provided in the respective risk profiles and risk management evaluations of alpha-/beta-HCH[143] and lindane.[144,145] Chemical identity and structures are compiled in Table 25.

These three HCH isomers were included in Annex A of the Stockholm Convention in May 2009. Lindane was listed with specific exemptions for the use as a human health pharmaceutical for the control of head lice and scabies as second line treatment[146] but production of lindane was not exempted.

Table 25. Chemical identification and structure of HCHs isomers listed in the convention[143,144,145]

Chemical name:	Alpha-HCH	Beta-HCH	Gamma-HCH (lindane)
Synonyms/ abbreviations:	Alpha-1,2,3,4,5,6-hexachlorocyclohexane, alpha isomer, alpha-HCH; alpha-BHC,	beta-1,2,3,4,5,6-Hexachlorocyclohexane; beta-HCH; beta-BHC,	1,2,3,4,5,6-hexachlorocyclohexane (HCH)
Trade names			Lindane, BHC
CAS registry number:	319-84-6	319-85-7	58-89-9
Commercial use	By-product of lindane and in technical HCH	By-product of lindane and in technical HCH	Insecticide

141 Vijgen J, Abhilash PC, Li Y-F, et. al (2011) HCH as new Stockholm Convention POPs – a global perspective on the management of Lindane and its waste isomers. EnvSciPollut Res. 18, 152-162.
142 Vijgen J, Fokke B, van de Coterlet G, Amstaetter K, Sancho J, Bensaïah C, Weber R (2022) European cooperation to tackle the legacies of hexachlorocyclohexane (HCH) and lindane. Emerg. Contam. 8, 97-112 https://doi.org/10.1016/j.emcon.2022.01.003
143 UNEP/POPS/POPRC.3/20/Add.8; UNEP/POPS/POPRC.3/20/Add.9; UNEP/POPS/POPRC.4/15/Add.3; UNEP/POPS/POPRC.4/15/Add.4
144 UNEP/POPS/POPRC.2/17/Add.4 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.2-17-Add.4.English.pdf
145 UNEP/POPS/POPRC.3/20/Add.4 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.3-20-Add.4.English.pdf
146 Decision SC-4/15: Listing of lindane. http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.4-SC-4-15.English.pdf

Structure:			
Molecular weight:	290.83 g/mol	Molecular formula:	C6H6Cl6

13.2 Historic production

Lindane (gamma-HCH) and technical HCH were among the most widely produced pesticides in the world. It is estimated that global lindane usage from 1950 to 2000 for agricultural, livestock, forestry, human health and other purposes amounted to around 600 kt. The total gamma-HCH production was estimated to 1,794 kt[5] (Figure 1). With each tonne of lindane produced, around 6-10 tonnes of the other isomers including alpha-and beta-HCH were created. The total 600,000 tonnes of lindane produced from 1950 to 2000 generated between 5 and 7.4 million tonnes of HCH waste isomers[5,147] (Figure 1).

13.3 Use

Lindane has been used as a broad-spectrum insecticide for seed and soil treatment, foliar applications, tree and wood treatment, and against ectoparasites in both veterinary and human applications. Lindane production has declined in recent decades, and the last lindane production was stopped in India several years ago.[148]

Since 2019, no Parties have registered for specific exemptions for lindane use as a human-health pharmaceutical for the control of head lice and scabies as a second-line treatment. Therefore, the exemption ended in 2019 and no new registrations may be made.[149] Alpha-and beta-HCH are listed in Annex A without specific exemptions.[150,151]

13.4 Trade

Some trade of lindane continued for the exempted use of lindane for pharmaceutical use from the stocks of lindane until recently at low volume[163] but the exemption stopped in 2019. Therefore, there is likely no trade and use of lindane in recent years.

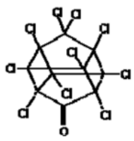
147 Vijgen J, Abhilash PC, Li Y-F, et al. (2011) HCH as new Stockholm Convention POPs – a global perspective on the management of Lindane and its waste isomers. Env Sci Pollut Res. 18, 152-162
148 Jit S, Dadhwal M, Kumari H, et al. (2010) Evaluation of hexachlorocyclohexane contamination from the last Lindane production plant operating in India. EnvSciPollut Res 18(4), 586-597
149 UNEP (2019) SC-9/1: Exemptions. UNEP/POPS/COP.9/SC9-1
150 Decision SC-4/10: Listing of alpha-HCH. http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.4-SC-4-10.English.pdf
151 Decision SC-4/11: Listing of beta-HCH. http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.4-SC-4-11.English.pdf

14 Chlordecone

14.1 Chemical identity, POPs properties and listing under the Convention

Chlordecone is a synthetic organochlorine pesticide, which has mainly been used as an agricultural insecticide, miticide and fungicide. Chlordecone is chemically closely related to mirex. Chlordecone is highly persistent in the environment, has a high potential for bioaccumulation and biomagnification, and based on physico-chemical properties and modelling data, chlordecone can be transported for long distances. It is classified as a possible human carcinogen and is very toxic to aquatic organisms. Detailed information for listing is provided in the risk profile[152] and the risk management evaluation.[153.] Chemical identity and structures are compiled in Table 26. Since 2009, Chlordecone has been listed in Annex A of the Stockholm Convention without exemptions.[154.]

Table 26. Chemical identification and structure of chlordecone

Chemical name:	1,1a,3,3a,4,5,5,5a,5b,6-decachloro-octahydro-1,3,4-metheno-2H-cyclobuta-[cd]-pentalen-2one		
Synonyms/abbreviations:	Decachloropentacyclo(5.2.1.0'2,6.0'3,9.0'5,8)decan-4-one; decachlorooctahydro-1,3,4-metheno-2H,5H-cyclobuta-[cd]-pentalen-2-one; decachloroketone		
Trade names	GC 1189, Kepone, Merex, ENT 16391, Curlone		
CAS registry number:	143-50-0		
Structure:		Molecular weight:	490.6 g/mol
		Molecular formula:	$C_{10}Cl_{10}O$

14.2 Production

Chlordecone was mainly produced in the United States (trade names GC 1189; Kepone) until 1976 when it was banned. Between 1951 and 1975, approximately 1600 tonnes of chlordecone were produced in the United States with major exports to Europe, Asia, Latin America and Africa. In France, chlordecone was produced until the 1990s. An estimated total of 1,820 tonnes[5] of chlordecone has been produced in the past (Figure 1).

14.3 Use

Chlordecone has been used as an agricultural insecticide, miticide and fungicide in various parts of the world for the control of a wide range of pests, in particular the control of banana root borer. It has been used as a fly larvicide, a fungicide against apple scab and powdery mildew to control the Colorado potato beetle, the rust mite on non-bearing citrus, and the potato and tobacco wireworm on gladioli and other plants. Chlordecone has also been used in ant and roach traps in households.[155] The chlordecone produced in France was used primarily in banana plantations in, for example, Martinique and Guadeloupe until 1993 and until the remaining stocks were destroyed in 2002.[156]

14.4 Trade

Since the production and use of chlordecone has been phased out 30 years ago with stockpiles destroyed, no trade of chlordecone has taken place in the past 20 years.

152 UNEP/POPS/POPRC.3/20/Add.10 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.3-20-Add.10.English.pdf
153 UNEP/POPS/POPRC.3/20/Add.2 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.3-20-Add.2.English.pdf
154 Decision SC-4/12: http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.4-SC-4-12.English.pdf
155 Factsheet chlordecone: http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-NewPOPs-Factsheet-04-20200226.English.pdf
156 https://web.archive.org/web/20100710190934/http://www.pan-germany.org/deu/~news-691.html

15 Endosulfan

15.1 Chemical identity, POPs properties and listing under the Convention

Endosulfan is a synthetic organochlorine pesticide. Technical grade endosulfan is a mixture of two isomers (α- and β-) in approximately 2:1 to 7:3 ratio, along with impurities and degradation products.

Endosulfan is persistent in the atmosphere, sediments and water. It bioaccumulates and has the potential for long-range transport. Endosulfan is toxic to humans and has been shown to have adverse effects on a wide range of aquatic and terrestrial organisms. Exposure to endosulfan has been linked to congenital physical disorders, mental retardations and deaths in farm workers and villagers in low-/middle-income countries in Africa, Asia and Latin America. Endosulfan sulfate shows toxicity similar to that of endosulfan. Detailed information for listing is provided in the risk profile[157] and the risk management evaluation.[158] Information on chemical identity is compiled in Table 27.

Since 2011, endosulfan is listed in Annex A to the Stockholm Convention with specific exemptions for production and use on crop-pest complexes listed in Part VI of Annex A (Table 28).[159] According to the Convention website, there are no more registered exemptions for the production and use.[160]

Table 27. Chemical identification and structure of technical endosulfan[157,158]

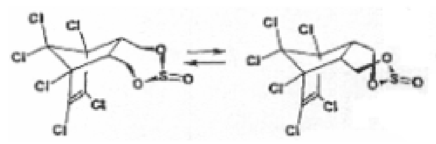
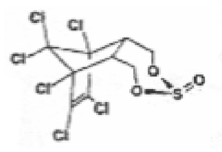
<table>
<tr><td>Chemical name:</td><td colspan="2">alpha (α) endosulfan</td><td>beta (β) endosulfan</td></tr>
<tr><td>Synonyms/ abbreviations:</td><td colspan="3">6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide 6,9-methano-2,4,3-benzodioxathiepin-6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9-hexahydro-3-oxide</td></tr>
<tr><td>CAS registry number:</td><td colspan="2">959-98-8</td><td>33213-65-9</td></tr>
<tr><td>Structure:</td><td colspan="2"></td><td></td></tr>
<tr><td>Molecular weight:</td><td>406.96 g/mol</td><td>Molecular formula:</td><td>C9H6Cl6O3S</td></tr>
</table>

Table 28. Listing of specific exemptions for endosulfan (Decision SC-5/3)[161]

Chemical	Activity	Specific exemptions
Technical endosulfan and its related isomers	Production	As allowed for the parties listed in the Register of specific exemptions
	Use	Crop-pest complexes as listed in accordance with the provisions of part VI of Annex A. For example, apple, mango, eggplant, okra.

15.2 Production

Around 2009, Brazil, China, India, Israel and South Korea produced combined between 18 and 20 kt of endosulfan annually. In total 622 kt have been produced in the past. Currently there is no known production.

15.3 Use

Endosulfan is an insecticide, which has been used for over 50 years to control pests, such as chewing, sucking and boring insects, including aphids, thrips, beetles, foliar-feeding caterpillars,

157 UNEP/POPS/POPRC.5/10/Add.2 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.5-10-Add.2.English.pdf
158 UNEP/POPS/POPRC.6/13/Add.1 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.6-13-Add.1.English.pdf
159 Decision SC-5/3. Listing of Endosulfan. http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.5-SC-5-3.English.pdf
160http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/TechnicalendosulfanRoSE/tabid/5037/Default.aspx
161 Decision SC-5/3. Listing of Endosulfan. http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.5-SC-5-3.English.pdf

mites, borers, cutworms, bollworms, bugs, white flies, leafhoppers, snails in rice paddies, and tsetse flies. Endosulfan was used on a range of crops. Major crops to which it is applied include soy, cotton, rice and tea. Other crops include vegetables, fruits, nuts, berries, grapes, cereals, pulses, corn, oilseeds, potatoes, coffee, mushrooms, olives, hops, sorghum, tobacco and cacao. It has also been used on ornamentals and forest trees, and as an industrial and domestic wood preservative.[162]

There is no known current use of endosulfan, but stocks might be present in some countries.

15.4 Trade

The endosulfan trade drastically decreased from 500 tonnes in 2017 to around 100 tonnes in 2018 and less than 10 tonnes in 2019.[163] Today, there is no known endosulfan trade. Since endosulfan was produced and used until recently, there might be remaining stockpiles that might be traded.

16 Pentachlorophenol (PCP) and its Salts and Esters

16.1 Chemical identity, POPs properties and listing under the Convention

Pentachlorophenol (PCP) can be found in two forms: PCP itself or as the sodium salt of PCP, which dissolves easily in water. PCP is a chlorinated aromatic hydrocarbon, solid at ambient temperature, highly soluble in grease and non-flammable.[164]

PCP has been produced as PCP and as the sodium salt of PCP. PCP and its salts and esters include different substances: PCP (see Table 29. ; CAS-No: 87-86-5), sodium pentachlorophenolate (CAS-No: 131-52-2), as monohydrate (CAS-No: 27735-64-4), pentachlorophenyl laurate (CAS-No: 3772-94-9) and pentachloroanisole (CAS-No: 1825-21-4).

While the PCP molecule itself does not meet all the screening criteria specified in Annex D, PCP and its salts and esters meet the screening criteria of persistence, long-range transport and toxicity specified in Annex D, taking into account its transformation product pentachloroanisole (PCA). Considering the complex degradation and metabolic pathways of PCP and PCA, both in the environment and in the biota, they were considered together in the risk profile.

Detailed information for listing is provided in the risk profile[165] and the risk management evaluation.[166] Information on chemical identity and structures is compiled in Table 29.

In 2015, PCP and its salts and esters were included in Annex A of the Convention. PCP was listed in Annex A with specific exemptions for production and use for wooden utility poles and cross-arms (Table 30).[167]

Table 29. Chemical identification and structure of PCP[165,166]

Chemical name:	Pentachlorophenol
Synonyms/abbreviations:	Various (see Risk Profile PCP)[165]
Trade names:	KMG Penta Blocks; Dura-Treat 40 Wood Preserver; and others[165]
CAS registry number:	87-86-5

162 Factsheet Endosulfan: http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-NewPOPs-Factsheet-17-20200226.English.pdf

163 Zou H, Wang T, Wang ZL, Wang Z. (2023) Continuing large-scale global trade and illegal trade of highly hazardous chemicals. Nature Sustainability. 6(11), 1394-1405.

164 UNEP (2017) Draft guidance on preparing inventories of pentachlorophenol and its salts and esters and on identifying alternatives for the phase-out of those chemicals. UNEP/POPS/COP.8/INF/20.

165 UNEP/POPS/POPRC.9/13/Add.3 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.9-13-Add.3.English.pdf

166 UNEP/POPS/POPRC.10/10/Add.1 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.10-10-Add.1.English.pdf

167 Decision SC-7/13. Listing of pentachlorophenol and its salts and esters. http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.7-SC-7-13.English.pdf

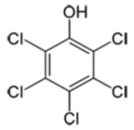
Structure:		Molecular weight:	266.34 g/mol
		Molecular formula:	C_6HCl_5O and C_6Cl_5OH

Table 30. Listing of specific exemptions for pentachlorophenol and its salts and esters

Chemical	Activity	Specific exemptions
Pentachlorophenol and its salts and esters	Production	As allowed for the Parties listed in the register of specific exemptions in accordance with the provisions of Part VIII of Annex A
	Use	Pentachlorophenol for utility poles and cross-arms in accordance with the provisions of Part VIII of Annex A

16.2 Production

PCP was first produced in the 1930s for use as a wood preservative marketed under many trade names. Historically, PCP has been produced at least in Brazil, China, Germany, Mexico, India, former Czechoslovakia, Denmark, France, Poland, Spain, Switzerland, the former USSR and the United Kingdom. In 1981, at the height of its production, the global output of PCP was around 90,000 tonnes per year[165] and in 2011 about 10,000 tonnes,[168] and still produced mainly in the United States, Mexico and India. In total, 2,130 kt of PCP has been produced in the 1940s[5] (Figure 1).

Mexico had registered for the PCP production of 6,800 tonnes/year. However, the expiry date of the specific exemption ended 15 December 2021.[169] Mexico also announced that the company producing the POP has stopped operation.

There is uncertainty if PCP production might start in the US after Mexico stopped. PCP is likely still produced in India which, as an Article 25(4) country, has not ratified the PCP amendment yet.

16.3 Use

PCP has been used as an herbicide, insecticide, fungicide, algaecide and disinfectant, and as an ingredient in antifouling paint.

The major uses of PCP-based products that have resulted in major stockpiles are:

(a) Treated wood (e.g. timber in constructions, utility poles, railway sleepers)

(b) Treated leather (e.g. shoes, clothes, furniture)

(c) Treated textiles

PCP has also been used in joint sealants, fillers and potting compounds, adhesives, varnishes and paints.

In recent years, the 6,800 tonnes of PCP produced in Mexico were largely (99.98%) exported to the US for the use on utility poles and cross arms.[169]

In the USA the USEPA has set an effective cancellation date for PCP of 29 February 2024 which will be followed by a 3 year period in which USEPA would allow for the use of existing stocks.[170]

168 Proposal to list pentachlorophenol and its salts and esters in Annexes A, B and/or C to the Stockholm Convention on Persistent Organic Pollutants. UNEP/POPS/POPRC.7/4.
169 http://www.pops.int/Implementation/Exemptions/SpecificExemptions/PCPRoSE/tabid/5481/Default.aspx
170 USEPA (2021) Pentachlorophenol Final Registration Review Decision Case Nr 2505; EPA-HQ-OPP-2014-0653.

Railway sleepers and other PCP-treated wood frequently get secondary use in private gardens and even in playgrounds. The use of PCP-treated wood has resulted in PCDD/PCDF-contaminated feed and food.[171] Therefore, the management and reuse of treated wood need particular care.

16.4 Trade[172]

It is estimated that 99.98% of the PCP produced in Mexico until recently was exported to the US while 0.02% was used in Mexico.[169] Since PCP is still likely produced in India, and the US continues to treat wood with PCP, PCP and PCP-treated wood might still be traded to some extent.

16.5 Former use of PCP and products in use and waste

Treated wood, leather and textiles might be still in use. Considering that the major production and use of PCP has been until the 1990s with major production and use in the 1980s and earlier, most PCP-treated textiles and a considerable share of treated leather have likely entered waste streams in the past 30 years. However, a large share of wood has a very long service life with treated timber wood used indoors of up to 100 years (see case study POPs in construction in the Sectoral POP inventory guidance[173]). Also, some treated utility poles and railway sleepers might still be in use and secondary use. In particular, the secondary use of PCP-treated wood in playgrounds or private gardens can considerably prolong the service life and result in human exposure.

17 Dicofol

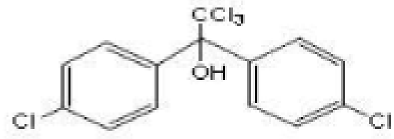
17.1 Chemical identity, POPs properties and listing under the Convention

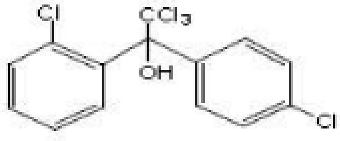
Dicofol is an insecticide produced from DDT, consisting of two isomers: p,p′-dicofol and o,p′-dicofol. The technical product (about 95% pure) is a brown viscous oil and consists of 80-85% p,p′-dicofol and 15-20% o,p'-dicofol with up to 18 impurities. In the past, some dicofol contained more than 10% DDT.[174]

Dicofol has a high bioconcentration potential as demonstrated by experimentally derived bioconcentration factor values in fish. Model results showed that dicofol and its metabolites can be transported to remote regions. Similar to DDT, dicofol is a toxic pesticide that is persistent in the environment and bioaccumulates in wildlife, livestock and humans. Prolonged or repeated exposure to dicofol can cause skin irritation, and hyperstimulation of nerve transmissions along nerve axons. Dicofol is highly toxic to fish, aquatic invertebrates, algae and birds. It is linked to eggshell thinning and reduced fertility. Detailed information for listing is provided in the risk profile[175] and the risk management evaluation.[176] Information on chemical identity is compiled in Table 31. Dicofol has been listed in 2019 under Annex A with no specific exemptions.[177]

171 Weber R, Herold C, Hollert H, et al. (2018) Reviewing the relevance of dioxin and PCB sources for food from animal origin and the need for their inventory, control and management. Environ Sci Eur. 30:42. https://rdcu.be/bax79.
172 Please note that the high trade volumes assigned to PCP in the review of Zou et al. (2023)[163] results from HS Code 290819 (Derivatives containing only halogen substituents and their salts, of phenols or phenol-alcohols (excl. PCP)) in their assessment. HS290819 covers, however, also brominated phenolic aromatic compounds including TBBPA with large productions in Israel, Jordan and USA which explains the high trade data of HS290819 from these countries but is not related to PCP.
173 UNEP (2022) Sectoral guidance for inventories of POPs and other chemicals of concern in buildings/construction, electrical and electronic equipment, and vehicles.
174 Qiu X, Zhu T, Yao B, Hu J, Hu S.(2005) Contribution of dicofol to the current DDT pollution in China. Environ Sci Technol. 39(12), 4385–4390. doi:10.1021/es050342a.
175 UNEP/POPS/POPRC.12/11/Add.1; http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.12-11-Add.1.English.pdf
176 UNEP/POPS/POPRC.13/7/Add.1 http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-POPRC.13-7-Add-1.English.pdf
177 Decision SC-9/11: Listing of dicofol. http://www.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.9-SC-9-11.English.pdf

Table 31. Chemical identification and structure of dicofol[179,180]

<table>
<tr><td>Chemical name:</td><td colspan="3">Dicofol</td></tr>
<tr><td>Synonyms/abbreviations:</td><td colspan="3">1,1-bis(4-chlorophenyl)-2,2,2-trichloroethanol and 1-(2-chlorophenyl)-1-(4-chlorophenyl)-2,2,2-trichloroethanol(p,p'-and o,p'-isomer)</td></tr>
<tr><td>Trade names</td><td colspan="3">1,1-bis(chlorophenyl)-2,2,2-trichloroethanol; 4-chloro-α-(4-chlorophenyl)-α-(trichloromethyl)-; Acarin; Benzenemethanol; Carbax; Cekudifol; CPCA; Decofol; Dicaron; Dichlorokelthane; Dicomite; Difol; DTMC; ENT 23648; FW293; Hilfol;Hilfol 18.5 EC; Kelthane; Kelthanethanol; Kelthane A; Kelthane (DOT); Kelthane Dust Base; Kelthane 35; Milbol; Mitigan; p,p’-dicofol; NA2761 (DOT); NCI-C00486</td></tr>
<tr><td>CAS registry number:</td><td colspan="3">115-32-2 (dicofol; p,p’-dicofol); 10606-46-9 (o,p'-dicofol)</td></tr>
<tr><td>Structure:</td><td colspan="3">

p,p'-dicofol


o,p-'dicofol</td></tr>
<tr><td>Molecular weight:</td><td>370.49 g/mol</td><td>Molecular formula:</td><td>$C_{14}H_9Cl_5O$</td></tr>
</table>

17.2 Production

Dicofol has been manufactured from technical DDT by hydroxylation of DDT. Dicofol was introduced commercially in 1955.[178] Between 2000 and 2007, global production of dicofol was estimated to have been 2,700-5,500 tonnes per year, but production has declined sharply since then as several countries have phased out production and usage.[176] In total, 244 kt Dicofol has been produced in the past[5] (Figure 1).

Dicofol was produced in India, China, Spain and Brazil. China used approximately 97,000 tonnes of DDT to produce 40,000 tonnes of dicofol between 1988 and 2002. In 2013-2014, the last remaining technical dicofol producer in China ceased production of technical dicofol[176] and the production in Brazil ceased in 2014-2015. India, where the last producer of dicofol operated, announced at COP9 that it would stop dicofol production in 2019.

17.3 Use

Dicofol is an organochlorine miticidal pesticide and has been used primarily in East and Southeast Asia, the Mediterranean coast, as well as in Northern and Central America. Dicofol has a diverse set of potential applications to control mites on a wide range of field crops, fruits, vegetables, orchids, ornamentals, Christmas tree plantations, cotton and tea as well as in non-agricultural outdoor buildings and structures. Since production stopped in 2019, only some remaining stocks might be in use but the use is not exempted (see Section 17.1).

17.4 Trade

Since the last dicofol production stopped in 2019 in India there is likely no expected trade. But as production was only recently stopped, some remaining stocks might be traded.

178 International Programme on Chemical Safety, Dicofol, WHO/FAO Data Sheets on Pesticides No. 81 World Health Organization. Geneva, July 1996 (http://www.inchem.org/documents/pds/pds/pest81_e.htm, 2015-01-15).

18 How to Access Relevant International Databases and Statistics on POPs Production and Use

For this report, the state of knowledge on production, trade and use of POPs has been compiled from various data sources. Several of the evaluated materials used contain more detailed information that could not be integrated into the report but has been referenced and can be found in these reports and scientific publications.

Some of the data sources considered and referenced are continuously updated, like the registration of specific exemptions[179] and acceptable purposes[180] (see also Section 18.3) or import and export data compiled in the UN Comtrade database (Section 18.2). In addition to their continuous update, these data sources also have shortcomings and flaws that need to be considered when they are used as information source (see Section 18.2 and 18.3).

18.1 Scientific reviews and compilations of production, use and trade of POPs

Several peer-reviewed scientific studies have compiled information on the production, use and trade of individual POPs. These studies were also utilized for the compilation of data for this report and have been introduced in respective chapters. A comprehensive review of total intentional POPs production has been compiled recently by Li et al. 2023[181] (see also Figure 1).

Several review articles have compiled information on the production and use of specific POPs such as PBDEs,[182] SCCPs/MCCPs,[183] or PFOS.[184] Another type of useful scientific study for understanding the use, stocks and waste of POPs in products is material and substance flow analysis (MFA/SFA). In particular, dynamic material and substance flow analysis of POPs in products. Since such material and substance flow analysis are scarce in low- and middle-income countries,[185] inventory case studies for major use sectors have been compiled for the sectoral guidance document (UNEP 2023).[186]

There are also review reports compiling the information on POPs in products (e.g. for PFHxS[187] or SCCPs/MCCPs[188]) which are helpful to understand the major use of POPs in products that for the industrial POPs are most critical for inventory and management.

Another comprehensive study investigated the global trade of highly hazardous chemicals listed in the Rotterdam Convention including POPs in the last 20 years based on information in the UN Comtrade Database (see below).[189]

It can be expected that further useful reviews on POP/POP-candidate data or MFA/SFAs of flows of POP/POP candidates will be published in the future.

179 http://chm.pops.int/Implementation/Exemptions/RegisterofSpecificExemptions/tabid/1133/Default.aspx
180 http://www.pops.int/Implementation/Exemptions/AcceptablePurposes/tabid/793/Default.aspx
181 Li L, Chen C, Li D, Breivik K, Abbasi G, Li YF (2023). What do we know about the production and release of persistent organic pollutants in the global environment?. Environmental Science: Advances. 2(1), 55-68.
182 Abbasi, G., Li, L. Breivik, K., (2019). Global historical stocks and emissions of PBDEs. Environ Sci & Technol, 53, 6330-6340.
183 Chen C, Chen A, Zhan F, Wania F, Zhang S, Li L, Liu J (2022) Global historical production, use, in-use stocks, and emissions of short-, medium-, and long-chain chlorinated paraffins, Environ. Sci. Technol. 56, 7895–7904. +SI
184 Paul AG, Jones KC, Sweetman AJ (2009). A first global production, emission, and environmental inventory for perfluorooctane sulfonate. Environmental Science & Technology, 43(2), 386-392.
185 Babayemi J, Sindiku O, Osibanjo O, Weber R (2015) Substance flow analysis of polybrominated diphenyl ethers in plastic from EEE/WEEE in Nigeria in the frame of Stockholm Convention as a basis for policy advice. Environ Sci Pollut Res. 22, 14502-14514.
186 Annexes of UNEP (2023) Sectoral guidance for inventories of POPs and other chemicals of concern in buildings/construction, electrical and electronic equipment, and vehicles.
187 UNEP (2018) Additional information on perfluorohexane sulfonic acid (CAS No: 355-46-4, PFHxS), its salts and PFHxS-related compounds. UNEP/POPS/POPRC.14/INF/4
188 Chen C, Chen A, Li L, Peng W, Weber R, Liu J. (2021) Distribution and Emission Estimation of Short- and Medium-Chain Chlorinated Paraffins in Chinese Products through Detection-Based Mass Balancing. Environ. Sci. Technol. 55, 7335–7343.
189 Zou H, Wang T, Wang ZL, Wang Z. (2023) Continuing large-scale global trade and illegal trade of highly hazardous chemicals. Nature Sustainability. 6(11), 1394-1405.

18.2 HS Codes to assess global trade and imports and exports – option and limitation

18.2.1 Introduction to HS Codes and the UN Comtrade database

The Harmonized System (HS) was developed by the World Customs Organization for product classification, which describes all goods that may be traded internationally. For goods to successfully cross international borders, the correct HS Code must be declared. This code determines the rate of duty and tax to be paid on the item. As an importer or exporter, it is the legal responsibility to correctly classify the goods shipped, but the compilation of overall country reporting is voluntary.

The HS Code system uses a six-digit code as the basis with the first two digits as chapter, the second two digits as heading and the third two digits as subheading. Further regional/national classification with an extended coding system is possible and used. There are regional or national coding systems that use an eight-or-more digit code, but consider the basic six-digit code (see example in Box 1). For example, the European Union uses its eight-digit CN (Combined Nomenclature) and 10-digit TARIC codes. India has an ITC-HS Code (ITC standing for Indian Trade Clarification), the US uses a 10-digit HTS code and China has a 13-digit HS Code.

The Harmonized System includes 5,300 item or product descriptions displayed as "headings" and "subheadings". In theory, all 180 WTO countries using the HS Agreement (7th version from 2022) should classify a given product with the same HS section, chapter, heading and subheading. Unfortunately, not all countries apply the same HS versions or the rules in an identical manner. This uncertainty, along with the increasing complexity of products, historical decisions, and lack of expertise in the technical aspects of a particular product, combine to create complex, inconsistent classification rules that can be difficult to navigate.

The United Nations Comtrade database aggregates detailed global annual and monthly trade statistics by product and trading partner for use by governments, academia, research institutes and enterprises. Data compiled by the United Nations Statistics Division covers approximately 200 countries and represents more than 99% of the world's merchandise trade with a recent update.[190]

A recent study assessed and compiled the trade data for 46 listed chemicals of the Rotterdam Convention traded 2004-2019, indicating high illegal trade.[163] The compilation also covered a range of POPs listed in the Rotterdam Convention, but some of the assignments likely covered other chemicals, e.g. for PCP.[172]

Box 1. Case study of specific import codes in Brazil

In some regions, more specific tracking codes have been established covering POPs, but later they were adapted to more generic HS Codes. The case of Brazil illustrates this challenge as follows: From 1989 to 1996, the foreign trade of decaBDE was registered under a specific tracking code in Brazil (Brazilian Merchandise Nomenclature: 2909301700 – decabromodiphenyl ether). However, in 1997 Brazil adopted the MERCOSUR Common Nomenclature (NCM). While HS Codes are based on six digits; being the first two digits: chapter; second two digits: heading; and the third two digits: subheading; NCM codes are two digits longer than HS Codes, and initial HS classifications are further subdivided using the item (seventh digit) and sub-item (eighth digit) classifications in the MERCOSUR economic bloc. Nevertheless, NCM codes are also not detailed enough to track some POPs, as highlighted by Guida et al., 2021191, because the MERCOSUR is following the HS Code classification for POPs, and thus, among industrial POPs, only those that also have a specific HS Code have been specified in the NCM192. Due to that, decaBDE foreign trade data were only accurately recorded until 1996 and from 1997 on it could be traded under

190 https://comtrade.un.org/
191 Guida Y, Capella R, Kajiwara N, Babayemi JO, Torres JPM, Weber R (2022). Inventory approach for short-chain chlorinated paraffins for the Stockholm Convention implementation in Brazil. Chemosphere 287, 132344.
192 Torres F, Guida Y, Weber R, Torres J, (2021). Brazilian overview of per- and polyfluoroalkyl substances listed by the Stockholm convention as persistent organic pollutants. Chemosphere 291, 132674. https://doi.org/10.1016/j.chemosphere.2021.132674.

three generic NCM codes (i.e., NCM 29033929: Other brominated derivatives; NCM 29039929: Other halogenated derivatives containing only bromine; and NCM 29093019: Other aromatic ethers). Thus accurate data was no longer available.

18.2.2 Challenges with unspecific HS Codes

Only some POPs-specific HS Codes have been developed which include a range of POP pesticides and PFOS and PFOSF, and some PFOS related substances (see Table 32). However, for most industrial POPs, HS Codes are not specific yet (e.g., decaBDE, PBDEs listed in 2009; HBCDD, PFOA and related substances, SCCPs and MCCPs).

Unspecific HS Codes can result in an overestimation of imports of a certain POP which has been described by Korucu et al. (2015)[193] for the first PFOS inventory of Turkey for the time before specific HS Codes for PFOS were available in 2017.

18.2.3 Challenges with data reliability in the UN Comtrade database

Another challenge is the inconsistent reporting of countries to the UN Comtrade database. This might explain, for example, why the global import data for the HS Code under which PBDEs are normally traded (HS 290930 "aromatic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives") show reasonable import data of PBDE imports of countries over time (Figure 3) corresponding to the time trend of global production data (Figure 1), while the assessment of export data from Israel does not show any exports under this HS Code. Since the reporting to the UN Comtrade database is voluntary, there is no incorrect reporting but just an allowed lack of reporting.

Also, the inconsistency in reporting imports and exports for POPs with specific HS Codes likely explains the observation that exports and imports for POPs do not (necessarily) match. For example, for specific PFOS data, the global exports and global imports for a specific HS Code do not correspond as global exports: the total global imports for PFOS (HS 2904.36) from 2017-2022 were 3,348 tonnes while the total global exports for this period were only 604 tonnes, which means that many countries have not reported their exports of PFOS (or PFOS waste).

Therefore, for an assessment of the trade of POPs using HS Codes, it is recommended to assess import and export data of countries and consider that the countries do not necessarily report all exports or imports. For the assessment of the imports to the own country, the governmental policy of reporting all data could be clarified to understand the reliability of the data.

Table 32. HS Codes for listed POPs and HS categories under which POPs are normally imported

New listed POPs (2009-2022)	**HS Code (chemical)**	**HS Code (mixtures, preparations or articles containing the chemical)**	**Comments**
Alpha-Hexachlorcyclohexan	2903.81	3808.59* 3824.85**	
Beta-Hexachlorcyclohexan			
Lindane	2903.81	3808.59* 3824.85**	
Chlordecon*	No specific HS Code		
Hexabromobiphenyl (HBB)*	No specific HS Code	3824.88**	
PFOS	2904.31	3808.59*	

193 Korucu MK, Gedik K, Weber R, Karademir A, Kurt-Karakus PB (2015) Inventory development of perfluorooctane sulfonic acid (PFOS) in Turkey: challenges to control chemicals in articles and products. Environ Sci Pollut Res Int. 22, 14537-14545. DOI 10.1007/s11356-014-3924-2.

New listed POPs (2009-2022)	HS Code (chemical)	HS Code (mixtures, preparations or articles containing the chemical)	Comments
Potassium perfluorooctane sulfonate	2904.34	3824.87**	
Lithium perfluorooctane sulfonate	2904.33		
Ammonium perfluorooctane sulfonate	2904.32		
Diethanolammonium perfluorooctane sulfonate	2922.16		
Perfluorooctane sulphonyl fluoride	2904.36		
Hexa-/HeptaBDE (c-OctaBDE)	2909.30		**Non-specific HS code** for Aromatic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives
Tetra-/PentaBDE (c-PentaBDE)	2909.30		
DecaBDE	2909.30		
PeCB	29039300		
Endosulfan	2920.30	3808.59*; 3824.84**	
HBCD	No specific HS Code		
HCBD	2903299090		
PCN	No specific HS Code		
PCP	2908.11	3808.59*	
SCCP	under consideration	3824.89**	
Dicofol	38089190		Non-specific insecticide
DDT	2903.92	3808.52*; 3824.84 **	
PFOA	No specific HS Code		
PFHxS	No specific HS Code		
PCBs	271091	3824.85**	

**Subheadings 3808.52 and 3808.59 cover only goods of heading 38.08, containing one or more of the following substances : alachlor (ISO); aldicarb (ISO); aldrin (ISO); azinphos-methyl (ISO); binapacryl (ISO); camphechlor (ISO) (toxaphene); captafol (ISO); chlordane (ISO); chlordimeform (ISO); chlorobenzilate (ISO); DDT (ISO) (clofenotane (INN), 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane); dieldrin (ISO, INN); 4,6-dinitro-o-cresol (DNOC (ISO)) or its salts; dinoseb (ISO), its salts or its esters; endosulfan (ISO); ethylene dibromide (ISO) (1,2-dibromoethane); ethylene dichloride (ISO) (1,2-dichloroethane); fluoroacetamide (ISO); heptachlor (ISO); hexachlorobenzene (ISO); 1,2,3,4,5,6- hexachlorocyclohexane (HCH (ISO)), including lindane (ISO, INN); mercury compounds; methamidophos (ISO); monocrotophos (ISO); oxirane (ethylene oxide); parathion (ISO); parathion- methyl (ISO) (methyl-parathion); penta- and octabromodiphenyl ethers; pentachlorophenol (ISO), its salts or its esters; perfluorooctane sulphonic acid and its salts; perfluorooctane sulphonamides; perfluorooctane sulphonyl fluoride; phosphamidon (ISO); 2,4,5-T (ISO) (2,4,5-trichlorophenoxyacetic acid), its salts or its esters; tributyltin compounds.*

***Subheadings 3824.81 to 3824.89 cover only mixtures and preparations containing one or more of the following substances: oxirane (ethylene oxide); polybrominated biphenyls (PBBs); polychlorinated biphenyls (PCBs); polychlorinated terphenyls (PCTs); tris(2,3-dibromopropyl) phosphate; aldrin (ISO); camphechlor (ISO) (toxaphene); chlordane (ISO); chlordecone (ISO); DDT (ISO) (clofenotane (INN); 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane); dieldrin (ISO, INN); endosulfan (ISO); endrin (ISO); heptachlor.*

18.2.4 Challenge that products or materials containing POPs additives are not labelled and assigned an HS Code

Products like soft PVC or rubber containing SCCPs as an additive, or plastic or textiles containing PBDEs, are not labelled, and there is currently no labelling or information requirement to indicate that these products could be linked to an HS Code signifying the inclusion of a POP.

While there are a few HS Codes for mixtures, preparations, or articles containing a wide list of POPs (see Table 32), these HS Codes are unspecific as can be seen in the footnote of Table 32. Also, products and articles containing SCCPs, PFOS or decaBDE are not traded under these HS Codes but under the respective HS Code of the product (e.g., certain HS Codes for PVC or rubber containing plasticizers; see Table 33, Table 34).

For certain products or materials that most likely have a high risk of being contaminated with certain POPs, the HS Codes of these products or materials might be used for an assessment of the import of POPs in these products, in particular, if monitoring data are available which give a rough impact factor of these product categories. Such monitoring has been performed for SCCPs and MCCPs in PVC, rubber and other products in China.[188] These SCCP and MCCP impact factors of PVC and rubber from China were used for the development of initial SCCP and MCCP import inventories for Brazil[194,195] and Nigeria and can be used for an initial assessment of how much SCCPs and MCCPs might have been imported in a country in the past 20 years.

For most other products, such as certain EEE listed as exemption for decaBDE, the share of impacted products is rather low and no monitoring data are available yet. These products can be included in the PBDE inventory by considering the impact factors given for different EEE categories.

Table 33. HS Codes of selected categories of PVC, which contain additives like plasticiser or flame retardants possibly including SCCPs or MCCP used in high amounts as PVC additives in China

HS Codes	PVC HS Classifications
(3904)	(Polymers of vinyl chloride or of other halogenated olefins, in primary forms)*
39042	Vinyl chloride, other halogenated olefin polymers; plasticized poly(vinyl chloride), in primary forms, mixed with other substances
391530	Vinyl chloride polymers; waste, parings and scrap
391810	Floor, wall or ceiling coverings; of polymers of vinyl chloride, whether or not self-adhesive, in rolls or in the form of tiles
392043	Plastics: polymers of vinyl chloride, containing by weight not less than 6% of plasticisers; plates, sheets, film, foil and strip (not self-adhesive), non-cellular and not reinforced, laminated, supported or similarly combined with other materials
392049	Plastics: polymers of vinyl chloride, containing by weight, less than 6% of plasticisers; plates, sheets, film, foil and strip (not self-adhesive), non-cellular and not reinforced, laminated, supported or similarly combined with other materials
392112	Plastics; plates, sheets, film, foil and strip, of polymers of vinyl chloride, cellular

**PVC in primary form and rigid PVC does not contain plasticizer.*

194 Guida Y, Capella R, Kajiwara N, Babayemi OJ, Torres JPM, Weber R (2022) Inventory approach for short-chain chlorinated paraffins for the Stockholm Convention implementation in Brazil. Chemosphere 287, 132344. https://doi.org/10.1016/j.chemosphere.2021.132344
195 Guida Y, Weber R (2019) Preliminary inventories of selected POPs by Tier I and II in Brazil and research needs towards Tier III inventory for Polychlorinated naphthalenes (PCNs) and Short-chain chlorinated paraffins (SCCPs). Report for Basel, Rotterdam and Stockholm Convention Secretariat.

Table 34. HS Codes of selected categories of rubber, which contain additives like plasticizer or flame retardants possibly including SCCPs

HS Codes	Rubber HS Classifications
400400	Rubber: waste, parings and scrap of rubber (other than hard rubber) and powders and granules obtained therefrom
4007	Vulcanised rubber thread and cord
4008	Plates, sheets, strip, rods and profile shapes, of vulcanised rubber other than hard rubber
4009	Tubes, pipes and hoses, of vulcanised rubber (other than hard rubber), with or without their fittings (e.g., joints, elbows, flanges)
4010	Conveyor or transmission belts or belting, of vulcanised rubber
4015	Articles of apparel and clothing accessories (including gloves, mittens and mitts), for all purposes, of vulcanised rubber other than hard rubber
4016	Articles of vulcanised rubber other than hard rubber

18.3 Listing of exemptions

As introduced in Section 1.2, the production and use of POPs is allowed for the Parties listed in the register of specific exemptions in accordance with the provisions of Part VII of Annex A. Relevant information on the specific exemptions[196] and acceptable purposes[197] for production and use can be found on the Stockholm Convention website. The Convention's website also gives information regarding the Parties that have registered for the specific exemption or acceptable purposes. The register of specific exemptions is updated regularly by the Secretariat. Expired exemptions can be viewed as well. The information also contains a section on the estimated quantity of production and use. However, for most of the registered exemptions for production and use no data are provided by Parties.

Although the register of specific exemptions provides some information on (exempted) production and uses of POPs, it must be emphasized that it does not cover the entire current production and use of these POPs. Reasons are various; for example, for most of the registered exemptions for production and use no data are provided by Parties. In addition, POPs in products are not labelled, and the HS Code does not even provide an unequivocal assignment for POPs and POPs in products. Therefore, Parties might not be aware that products that are imported into their countries and enter the market are listed POPs or contain listed POPs as additives or in trace amounts. Even several production companies are likely not aware that their products contain listed POPs and market them. This is, in particular, the case for the more than 100 PFOA-related compounds which can degrade to PFOA, and for CP mixtures that contain SCCPs.

Furthermore, there are a range of Parties to the Convention that ratified the Convention in accordance with paragraph 4 of Article 25 of the Convention. This means they have not ratified major POPs,[198] which are still produced in their country. This includes potential producers of POPs like Bangladesh, China, or India known to have e.g. large productions of chlorinated paraffins which might contain SCCPs.

The listing of exemptions gives only limited information on the production and use of several POPs. However, with this report information gaps on production and use could partly be filled by compilation of information from peer-reviewed science publications and other reports (see Section 18.1).

196 http://chm.pops.int/Implementation/Exemptions/RegisterofSpecificExemptions/tabid/1133/Default.aspx
197 http://www.pops.int/Implementation/Exemptions/AcceptablePurposes/tabid/793/Default.aspx
198 Weber R (2021) Assessment of newly listed POPs for countries that needs to ratify the amendments or to update NIPs. Secretariat of the Basel, Rotterdam and Stockholm Conventions, United Nations Environment Programme, Geneva.

18.4 Information from Rotterdam and Basel Convention

An important component of effective POP management is the use or the expansion of synergies with the Rotterdam and Basel Convention. These conventions also provide some useful data and information sources on pesticides and industrial chemicals, including POPs, on trade and disposal and handling of chemical waste. The Rotterdam Convention Annex III list contains 12 of the 20 newly listed POPs. The Rotterdam Convention provides technical assistance in risk assessment and management activities under its industrial chemicals support programme.[199] There are four pilot[200] projects on industrial chemical management in low- and middle-income countries and an interactive electronic toolkit, including three country profiles. However, industrial chemicals have a subordinate role relating to production and use data under Rotterdam. For more listed pesticides under Rotterdam, a broader knowledge base of information is provided (see web links).[201,202]

Furthermore, for each chemical listed in Annex III of the Convention and subject to the PIC procedure, a Decision Guidance Document (DGD)[203] is prepared, including some general information about POPs and also a link to the HS Codes (see Section 18.2). The PIC process also provides an insight into the trade (import) responses of chemicals and the countries, but without quantities. Import responses are the decisions provided by Parties indicating whether or not they will consent to import the chemicals listed in Annex III and can be accessed by all Parties for information.[204] This includes specific information regarding notifications[205,206] and information about pesticides,[207] which provides some information about the use of the POPs.

Unfortunately, a large share of industrial POPs are imported to countries in products like SCCPs in PVC, PUR spray foam, or rubber (see Section 5.4 and 5.5), or decaBDE in plastic in EEE (Section 6.4 and 6.5). These products are not labelled and are not covered by the Rotterdam Convention. SCCPs are mainly traded in CP mixtures, for which the PIC procedure currently does not function. A recent study assessing imports of SCCPs and MCCPs to Nigeria concluded that the Rotterdam Convention mechanism currently does not function for these industrial POPs and needs improvement.[75]

An important synergy of the Stockholm and Basel Conventions is in the disposal of POP wastes. The export of POP wastes (from low- and middle-income countries to high income countries with destruction capacity) was considered, for which notifications and national reports under the Basel Convention[208,209] of wastes have to be pre-controlled before waste shipments start and for each waste shipment.

199http://www.pic.int/Implementation/IndustrialChemicals/Globalindustrialchemicalsmanagementlandscape/tabid/1200/language/en-US/Default.aspx
200 http://www.pic.int/Implementation/IndustrialChemicals/Activities/PilotProjects/tabid/4699/language/en-US/Default.aspx
201 http://www.pic.int/Implementation/PICCircular/tabid/1168/language/en-US/Default.aspx
202 http://www.pic.int/Implementation/Pesticides/Pesticidesinformationdatabase/tabid/9454/language/en-US/Default.aspx
203 http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals/tabid/1132/language/en-US/Default.aspx
204 http://www.pic.int/Procedures/ImportResponses/tabid/1162/language/en-US/Default.aspx
205 http://www.pic.int/Procedures/NotificationsofFinalRegulatoryActions/Database/tabid/1368/language/en-US/Default.aspx?tpl=std
206http://www.pic.int/Implementation/FinalRegulatoryActions/FRAEvaluationToolkit/RiskEvaluationsthatsatisfyAnnexII/ListofAnnexIInotifications/tabid/2582/language/en-US/Default.aspx
207 http://www.pic.int/Implementation/Pesticides/tabid/1359/language/en-US/Default.aspx
208 http://www.basel.int/Countries/ImportExportRestrictions/tabid/4835/Default.aspx
209 http://www.basel.int/Countries/NationalReporting/NationalReports/BC2020Reports/tabid/8989/Default.aspx