Knows and unknows of selected POPs in products and waste and recommendation for monitoring POPs in waste and recycling

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Responsibility

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Samenvatting

Als onderdeel van het Impulsprogramma Chemische Stoffen heeft TAUW, in samenwerking met POPs Environmental Consulting, een onderzoek uitgevoerd naar het vóórkomen van een selectie persistent organische verontreinigende stoffen (POPs) in producten en afval. De onderzochte POPs betreffen SCCP's/MCCP's, UV-328, Dechlorane Plus, PFOS, PFOA en PFHxS. Deze rapportage beschrijft de huidige kennis en omissies hierin over deze POPs in productgroepen of afvalstromen en geeft advies over het monitoren van deze POPs in productgroepen, recycling of afvalstromen.
Het rapport geeft een overzicht van de verschillende productgroepen waarin industriele POPs met opzet zijn toegevoegd in het verleden. Daarbij wordt de concentratierange van de POPs in deze toepasingen beschreven. Hierbij is zowel gebruik gemaakt van informatie over het toepassen als studies naar de concentraties in afvalstormen waarin deze stoffen worden verwacht.
Het rapport geeft een overzicht van de meest voorkomende toepassingen van de industriele POPs die recent zijn toegevoegd aan de POPs-lijst. Daarbij is het rapport gericht op de POPs waar het ministerie de focus op heeft gelegd. Per POP is vermeld in welke producten de POP is toegepast, wat dit betekent voor afvalstromen en recycling en wordt advies gegeven hoe die kunnen worden gemonitord. Er zijn 4 gebieden waarbinnen de bovengenoemde POPs wijdverbreid zijn gebruikt, namelijk in gebouwen en installaties, voertuigen, elektrische en elektronische apparatuur en textiel. Over het algemeen geldt dat recyclaat van een van deze afvalstromen via een gestandaardiseerde methodologie op de hierboven genoemde POPs gemonitord zou moeten worden. Voor plastics van e-waste zijn gestandaardiseerde methoden ontwikkeld, maar voor de overige stromen ontbreken deze methoden en moeten ze worden ontwikkeld. Hierbij moet worden gerealiseerd dat het nemen van goed representatieve samples zeer arbeidsintensief is en dat als de monsters genomen zijn zij het beste direct op alle mogelijk aanwezige POPs kunnen worden geanalyseerd. Focussen op slechts één POP is veel minder efficiënt.

SCCP/MCCP

SCCPs/MCCPs komen voornamelijk voor in producten geproduceerd in China en India en worden grotendeels in die landen toegepast in producten. Aangeraden wordt om de mengsels van SCCPs/MCCPs en de gerelateerde producten die worden geïmporteerd in Nederland (of de rest van de EU) te monitoren. Gerelateerde producten zijn metaalbewerkingsvloeistoffen, smeermiddelen en vetvloeistoffen voor het looien van huiden. Voor de monitoring van CCPs/MCCPs wordt geadviseerd om te kijken naar gechloreerde paraffine PVC met brandvertragers of weekmakers, rubber en gespoten PUR-schuim. Het is ook relevant om te kijken naar producten uit EU-landen waar naar verwachting niet op gechloreerde paraffine wordt gemonitord en waar goedkope producten gewild zijn. Voor afval en recycling is het goed om de volgende stromen te monitoren: pvc-kabelafval, afgewerkte olie, automotive schredderresidu en plastic van auto’s uit China.

UV-328

UV-328 wordt toegepast als additief voor UV-absorptie in autolak, landbouwplastics, papier en plastics. Er is een tekort aan data over UV-328 in producten, afval en recycling. Als er wordt gemonitord op UV-328 wordt het aangeraden om ook te analyseren op Benzotriazole UV stabilisatoren (BUV) waarvoor in de EU beperkingen bestaan. Er moet worden onderzocht of UV-328 en BUV zou kunnen worden gemonitord met behulp van FT-IR prescreening. Deze methode kan dan worden gebruikt om auto-onderdelen te analyseren op het vóórkomen van UV-328. Daarnaast wordt ook aangeraden om PET-recyclaat voor voedselcontact toepassingen te analyseren met hele lage detectielimieten. Andere materiaalstromen die moeten worden geanalyseerd zijn plastics uit bouwmaterialen en landbouwplastics en gerecyclede plastics uit de transportsector, inclusief bumpers.

Dechlorane Plus

Dechlorane Plus (DP) wordt momenteel niet meer geproduceerd maar is in het verleden vooral toegepast binnen de transport- en luchtvaartsector. Monitoring van Dechlorane Plus wordt voornamelijk aanbevolen op recyclaat uit de voertuigverwerking- en transportsector. Ook het recyclaat uit de verwerking van plastics uit elektrische en elektronische apparatuur en bouw- en sloop materiaal moeten worden gemonitord op het vóórkomen van DP.

PFOS, PFOA en PFHxS

PFOS, PFOA en PFHxS zijn in het verleden breed toegepast. De monitoring van deze POPs wordt belangrijk geacht bij de recycling van textiel, textiel uit voertuigen, vloerkleed en tapijt recycling en de recycling van pesticide verpakkingen.

Chemicaliën en producten die onbedoeld POPs kunnen bevatten

Naast materialen die de voorgenoemde POPs kunnen bevatten en via recycling weer in nieuwe producten terecht kunnen komen zijn er ook POPs die kunnen worden gevormd tijdens de productie van primaire specifieke chemicaliën en producten. Dit omvat onder andere PCBs in pigmenten en kleurstoffen en PCB in siliconen. HCB is een POP die kan worden gevormd tijdens de productie van TCPA, een stof die wordt gebruikt in de productie van pigmenten. Phthalocyanide pigmenten en kleurstoffen kan verschillende POPs bevatten waaronder PCDD/PCDF, PCB en HCB. Omdat men op EU-niveau in het proces zit om nieuwe (UTC) grenswaarden op te stellen voor HCB en PCB wordt er geadviseerd om deze UPOPs in producten waarin zij mogelijk voorkomen te monitoren.

Bij de bepaling van monitoringsmethodes kan worden geleerd van kleinschalige initiatieven in Nederland, maar ook van buitenlandse initiatieven zoals uit Japan, Duitsland en Zwitserland.

Trefwoorden: POP, POPs, Monitoring, SCCP, MCCP, UV-328, Dechlorane Plus, PFOS, PFOA, PFHxS

Summary

TAUW, in collaboration with POPs Environmental Consulting, conducted an explorative study on the occurrence and knowledge gaps of a selection of Persistent Organic Pollutants (POPs) in products and waste. The study was part of the Chemical Substances Impulse Program of the Dutch Ministry of Infrastructure and Water management. The investigated POPs include SCCPs/MCCPs, UV-328, Dechlorane Plus, PFOS, PFOA, and PFHxS. The report gives an overview on the current knowledge and gaps on these POPs in products and compiles recommendations for monitoring these POPs in product groups, recycling or waste streams.
The current report gives an overview of the different product groups in which industrial POPs have been intentionally used in the past, with associated concentration range of POPs used in these product groups. This includes information on use application of POPs in products and also includes data from monitoring studies with concentrations in waste streams in which these substances may be expected.
The report gives an overview on the major use of new listed industrial POPs in which the Ministry was interested and related product, waste and recycling flows which are recommended for monitoring studies. The report also gives an overview on the 4 areas where these POPs have been mainly used, namely in buildings and construction, vehicles, electrical and electronical equipment and textiles. In general, recycled materials should be monitored for the above-mentioned POPs using standardized methodologies. While for plastics from e-waste standardized methods have been developed, they are missing for the other sectors and should be developed. It is stressed that the generation of representative samples from e.g. electronic waste or end-of-life vehicles is a laborious work and that for such samples all potentially relevant POPs and possibly other chemicals of concern should be analyzed.

SCCPs/MCCPs

SCCPs/MCCPs are primarily manufactured in China and India and a large share is added there into products. It is recommended to monitor SCCPs/MCCPs in CP mixtures and related products imported to The Netherlands/European countries for SCCP content. Related products are e.g. metal working fluids, lubricants, and leather fatliquors. It is advised to monitor chlorinated paraffins in products of plasticized or flame retarded PVC, rubber, and PUR spray foams. Monitoring of products could consider other EU countries where CP monitoring is not expected, and cheap products are preferred. For wastes and recycling it is recommended to monitor the recycling of PVC cable sheathing, used oil, and automotive shredder residue and plastics from cars made in China.

UV-328

UV-328 is used as an additive for UV absorption in automotive plastics and paint, agricultural plastics, paper, and plastics. There is a lack of monitoring data of UV-328 in products, waste and recycling. It is recommended to analyze in monitoring of UV-328 also other Benzotriazole UV stabilizers restricted in the EU as SVHC. For this it should be assessed if (handheld) FT-IR could possibly be used for pre-screening of UV-328 and other BUVs in products. It is recommended to analyze PET recyclates used for food contact materials using low detection limits. Other products to monitor for UV-328 are plastics in construction, and agricultural plastics as well as recycled plastics from the transportation sector including bumpers.

Dechlorane Plus

Dechlorane Plus (DP) is no longer produced, and has been mainly used in motor vehicles in the past. Overall DP seems a flame retardant of lower relevance. Monitoring of DP is primarily recommended for plastic recyclates from motor vehicle and materials from the aviation sector. Recycled materials from the processing of electrical and electronical equipment and construction and demolition materials could also be monitored for the presence of DP.

PFOS, PFOA and PFHxS

PFOS, PFOA, and PFHxS have been widely used in the past. Monitoring of these POP's is considered important in the recycling of textiles, textile waste from ELVs, carpet, and pesticide packaging.

Unintentional POPs in chemicals and products

Apart from materials containing the aforementioned POPs being recycled and used in new products, POPs can be unintentionally formed during the production of specific chemicals or products. These include PCBs in pigments and dyes, and PCBs in silicones. HCB can be formed in the production of TCPA, which is used in the production of pigments. Phthalocyanine dyes and pigments can contain several unintentional POPs including PCDD/PCDF, PCB and HCB. Considering that the EU is setting unintentional trace contaminant (UTC) limits for HCB and PCB, recommendations are given for the monitoring of these UPOPs in potentially impacted chemicals.

When determining monitoring methods, lessons can be learned from former studies in the Netherlands, as well as from foreign initiatives from e.g. China, Japan, Germany, and Switzerland.

Keywords: POPs, unintentional POPs, Monitoring, SCCP, MCCP, UV-328, Dechlorane Plus, PFOS, PFOA, PFHxS

1 Introduction and objective

TAUW, in collaboration with POP's Environmental Consulting have been asked by the Ministry of Infrastructure and Water Management to conduct an explorative research about POP-measuring in products and waste streams. This research takes place as part of the Chemical Substances Impulse Program of the Ministry of Infrastructure and Water Management.

The current report gives an overview of the different product groups in which POPs have been deliberately used in the past, with associated concentration range of POPs used in these product groups. This includes information on use application of POPs in products and also includes data from monitoring studies with concentrations in waste streams in which these substances may be expected.

For the major newly listed POPs (SCCPs/MCCPs, UV-328, Dechlorane Plus and PFOS/PFOA/PFHxS) their main uses, available major studies and lack of studies are described in Chapters 2 to 5. Additionally, information is given on well-substantiated and different sets of selection criteria that have been applied to select POPs and (possibly) relevant product groups in which these POPs may be present. For these POPs individual recommendations for monitoring waste and recycling are made for follow-up research with measurements. Furthermore, in Chapter 6 the major use sectors of industrial POPs and related wastes (transport, buildings/construction, electrical and electronic equipment, textiles and agricultural plastics) are shortly described and recommendations on monitoring of POPs are made with appropriate links to the suggestions of monitoring individual POPs in Chapters 2 to 5.

For brominated flame retardants (BFRs) that are listed as POPs (POP-BFRs) no specific individual chapter for their further monitoring has been developed. However, they are integrated and highlighted in Chapter 6 as major POPs to be further monitored in the major (former) use sectors and what gaps exist which are recommended to be filled.

The report makes clear how these POPs can be measured in the recommended product groups or waste streams by mentioning sampling protocols like CENELEC specification or elaborated methods developed by other best practice case studies. Best practice case studies are referenced, and some are shortly described. For product groups where no standard methodology for sampling has been developed, the report proposes to develop a standardized method (e.g. there is not yet a systematic methodology for generating a representative automotive shredder residue sample).

Additionally, we have added a chapter (Chapter 7) on unintentional POPs and unintentional trace contaminants (UTCs) in chemicals and products which is currently a relevant issue since a UTC limit for hexachlorobenzene (HCB) has recently been set to 10 mg/kg (European Commission 2022a) and the UTC for PCBs is currently discussed with an initial proposed UTC (European Commission 2021a) which is currently further developed and might be published soon.
In Chapter 7 information on chemicals which might have challenges to meet the UTC limit are compiled with available monitoring data from Japan and other countries and the lack of monitoring on the European market is stressed with associated recommendations for a monitoring of these chemicals.

By this approach and information, the current report can serve for preparation for possible future research projects aimed at targeted measurements in specific products/waste streams. All recommended further monitoring and future follow-up research could provide insights into the actual presence of POPs in different product groups and reveal information gaps. This can contribute to understanding the potential consequences of lowering/establishing limits for UTCs for the respective POP substances and/or for the major specific product groups or applications. This report contains a wide range of recommendations for monitoring waste and recycling flows, and it could be useful to cooperate with other EU countries in such monitoring. For some waste streams it is mentioned that monitoring is ongoing in other European countries or that it should be explored what research and monitoring is planned (e.g. in Germany).

2 SCCPs and MCCPs

2.1 Background

Chlorinated paraffins (CPs) are produced in high production volumes above 1 million t/year since more than a decade (Chen et al. 2022). Chemically, they are polychlorinated unbranched 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}), medium-chain CPs (MCCPs; C_{14} to C_{17}) and long-chain CPs (LCCPs; C≥18).
SCCPs with a chlorine content of more than 48 % by mass have been listed in the Stockholm Convention in 2019 under Annex A with a wide range of specific exemptions covering most of the major application areas. MCCPs, LCCPs or other CP mixtures containing more than 1 % of SCCPs are also POPs. MCCPs with a chlorine content above 45 % are proposed for listing as POPs at COP12 in 2025.
Chlorinated paraffins, including SCCPs, have been produced commercially since the 1930s. The total historical production of SCCPs is estimated to 8.8 Mt, for the MCCPs to 18.5 Mt and the total CP amount to 32.5 Mt (Chen et al. 2022). In India and China (as well as in several other countries) the produced technical CP mixtures are not categorised according to chain length but according to chlorine content (30 to 70 %) and often contain mixtures of SCCPs and MCCPs (Chen et al. 2021; Xia et al. 2021). The production of CPs worldwide has increased during the last 15 years to more than 1,300 kt per year (Figure 1). Major production is in China which reached 1,100 kt in 2014 with possibly some decrease in recent years (Figure 1; Chen et al. 2022). The second largest production is in India with 226.4 kt in 2010 and an estimated increase to more than 350 kt in 2020 (Chen et al. 2022). Productions in all other countries are considerably lower with reported annual CP amount for most recent reported years of 45 kt in EU (2010), 40 kt in USA (2011), 27 kt in Russia (2011), 20 kt in Egypt (2008), 12 kt in Jordan (2015) and 10 kt in South Africa (Chen et al. 2022).
Based on measured data of CP mixtures and products containing CPs mixtures and related SCCP content, it is estimated that a maximum of 440 kt/year SCCPs were produced in 2014 which slightly declined but with still more than 400 kt/year in 2020 largely present in mixtures (Chen et al. 2021; 2022). The total production amount of MCCPs is estimated to approx. 750 kt/year in recent years (Chen et al. 2022). Total CPs are still produced and used in large volumes with more than 1 million tonnes per year (Chen et al. 2021, 2022; Figure 1).
The estimated amount of SCCPs consumed in the EU can give an indication for EU specific assessment of waste and recycling (European Commission 2021b; Figure 2):

- First data describing the EU SCCP market are available for the year 1994: In 1994, more than 13,000 tonnes of SCCPs were used in EU15 Member States, out of which 9,380 tonnes were used in metal working fluids, 695 tonnes in sealants, 1,310 tonnes as flame retardants in rubbers and 183 tonnes as flame retardants in textiles, 390 tonnes in leather processing and 1,150 tonnes in paints and coatings

- Last specific data on SCCP use are for 2007/2008[1] and were 530 tonnes, was distributed in different applications as follows: 237 tonnes (45 % of total) were used in sealants, 101 tonnes (19 % of total) in paints and coatings, 162 (31 % of total) tonnes as flame retardants in rubbers, and 29 tonnes (or 6 % of total) flame retardants in textiles (BRE 2008)

It was assumed by the report for the European Commission that after the listing as Substance of Very High Concern (SVHC) under REACH in 2008 the amounts decreased and the production and use of SCCPs in the EU ceased at the latest in 2012 when SCCPs were listed in Annex I of the EU POP Regulation (European Commission 2021b). For the Netherlands it was concluded that in 2008 there was no use of SCCPs or any imports of articles containing 1 % or more of SCCPs (European Commission 2021b). BRE et al. (2008) suggest that SCCPs in Europe have been substituted mainly by MCCPs.
However, on the other hand, the production and use of SCCPs/MCCPs increased in China from 2000 on and later also in India (Chen et al. 2022). In China more than 90 % of these SCCPs/MCCPs were/are directly used in products mainly in PVC (more than 70 %) and at lower levels in rubber (more than 10 %) and PUR spray foam (Chen et al. 2021; Figure 3). PVC and rubber were imported in consumer products into the EU (Appendix 1). Also, there is a high uncertainty what amounts of SCCPs (and MCCPs) were imported in PVC in the construction sector and in other rubber products like conveyor and transmission belts. Therefore, we assume that the conclusion drawn in the report for the European Commission (2021b) that since 2008, hardly any SCCPs were contained in products sold on the European market, could be a considerable underestimation.
China is the largest producer of SCCPs and MCCPs and includes more than 90 % directly in products (Chen et al. 2021). More than 70 % is used in PVC products (Chen et al. 2021, 2022; Figure 1).

[1] The information provided by Euro Chlor for years 2008/2009 was likely representative of the sales in 2007

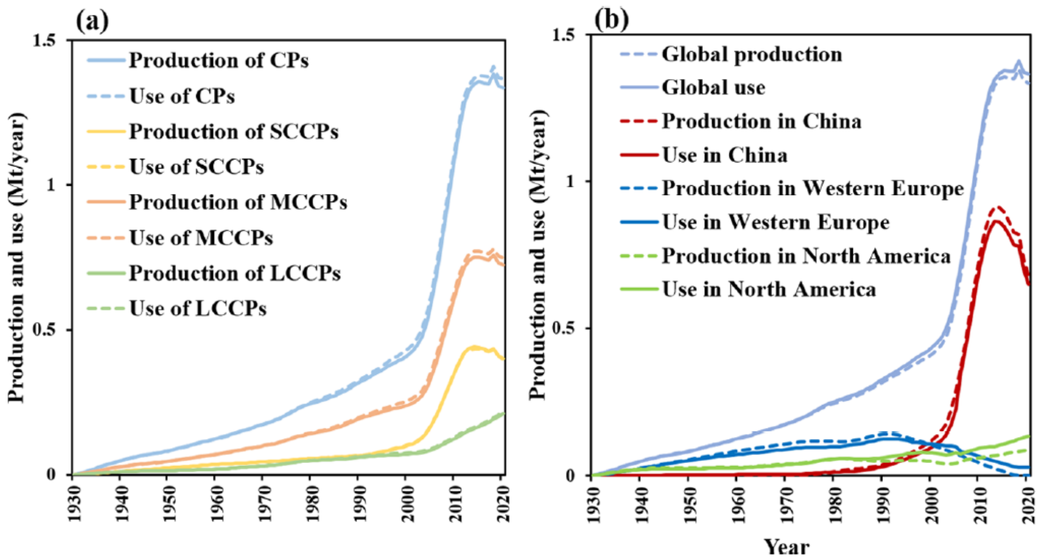

Figure 1: a) Global production of SCCPs, MCCPs and LCCPs: b) CP production and use in China, Europe, and North America (Chen et al. 2022)

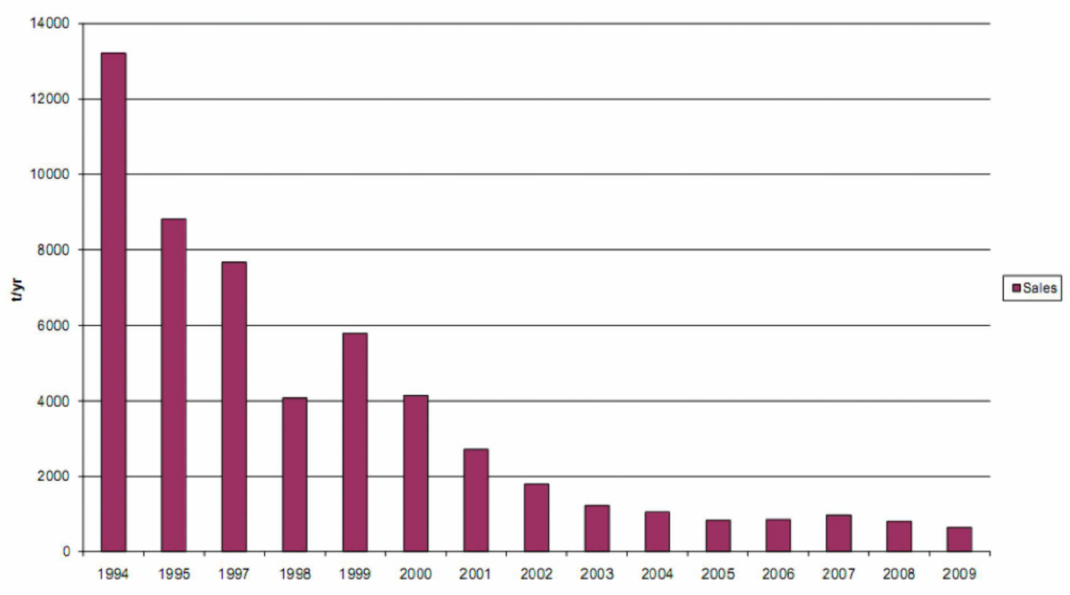

Figure 2: SCCPs consumed in the EU from 1994 to 2009 (RPA 2010)

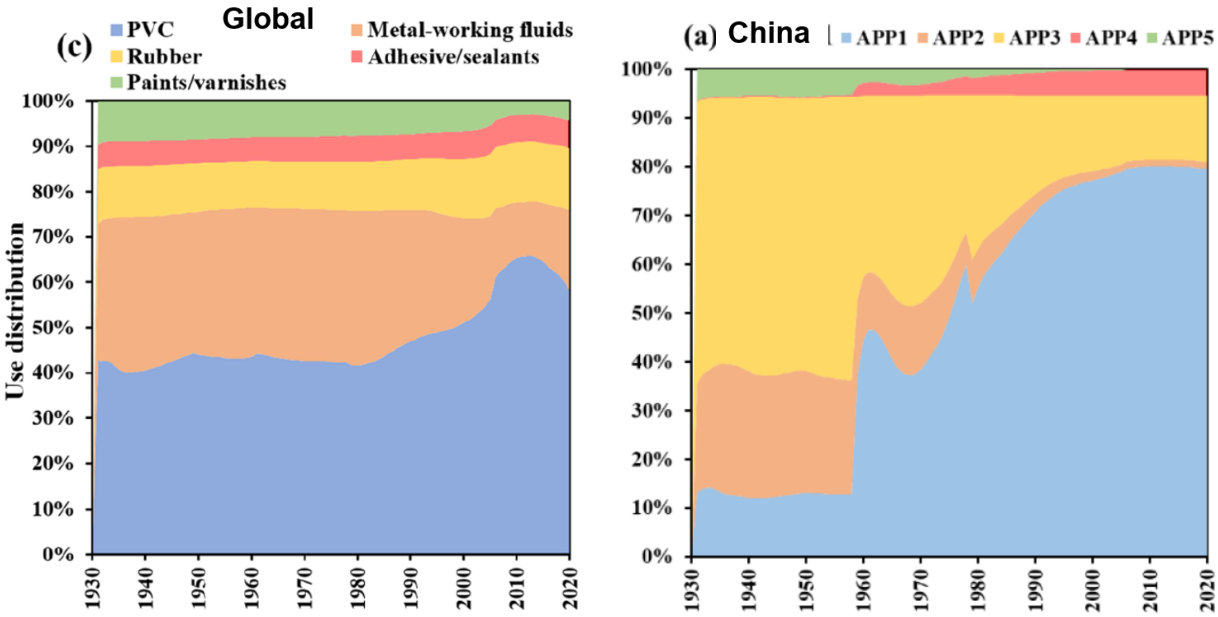

Figure 3: Time trend of distribution of CP use among five major end-use applications globally and in China (Chen et al. 2022)

2.2 Levels of SCCPs/MCCPs in products

Table 1 gives an overview on the major uses of SCCPs (and MCCPs) and related concentrations in products. PVC as overall major use sector from 2005 to 2020 was considered by European studies and in the Stockholm Convention only as secondary plasticizer with a maximum of 10 % in plasticized PVC. However, studies from China demonstrate that it is used as primary plasticiser with up to 52.8 % SCCPs (Chen et al. 2021; Weng et al. 2023). In 17 soft PVC curtain samples analysed the SCCP content ranged from 1.8 to 52.8 % (mean 21.9 %) and for MCCPs the content was between 0.6 and 18.7 % (mean 8.4 %) (Weng et al. 2023). This shows that SCCPs and MCCPs are also used as primary plasticizers in PVC. The major use of PVC is in construction (see Figure 6).

Table 1: Use sectors, applications, and concentrations of SCCPs/MCCP in products*

Uses and application	SCCP content	Source
PVC (e.g. cables, shower curtains; consumer goods)	Up to 10% Up to 52.8%	BTHA 2016; KEMI 2016 Weng et al. 2023
EVA foam (mats; others)	Up to 7%	BTHA 2016
Rubber (see Table 2)	0.1 – 17% 10 – 17% in conveyor belts 10 – 17% for other rubber products	ECB 2008 RPA 2010
Paints/coatings (See Table 3)	2.5 – 10% in intumescent coatings 5.0 – 20% anti-corrosive/protective coatings 1 – 10% in road markings	RPA, 2010 ECB 2008 RPA, 2010
Leather fat liquoring (Chapter 5.1.4) (e.g. leather for furniture; clothes)	1% (in leather) 20% in fat-liquoring mix	ECB 2000 RPA 2010
Adhesives/sealants PUR spray foam sealants	5 – 14% 20 – 30% 30 – 50%	ECB 2008 Danish EPA 2014 Chen et al. 2021 Brandsma et al. 2021
Textiles (flame retardant backcoating; paint)	4 – 15% in backcoating of textiles	BTHA, 2016; RPA, 2010
Metal working fluids (e.g. high pressure additives, cutting and drilling fluids)	5 – 70% in oil-based cutting fluids Average 50% <1% in emulsion-based cutting fluids	BUA 1992 ECB 2000, 2005 BUA 1992
Lubricants (e.g. rail, ship, automotive, industrial machinery, power generation (e.g. wind power facilities, electric generators))	1 – 60% 30 – 70%	MSDSs Sloan (1986)

*Since China and India use mixtures of SCCP and MCCP it does not make sense to differentiate. Often these are mixtures of SCCP and MCCP in varying shares

Table 2: Rubber applications that contain CPs and may contain SCCPs/MCCPs (BRMA 2001)

Rubber application that may contain SCCPs	Chlorinated paraffins content (% wt)
Conveyor belting	10 – 16.8
Rubber cable cover	3.8
Rubber hose	6.2
Industrial roller coverings	up to 20
Pipe seals	4
Fire resistant rubber products	10
Shoe soles	6.5
Industrial sheeting	13

Table 3: Paints and coatings that contain CPs and may contain SCCPs
(Environment Agency for England and Wales 2007; von Eckhardt & Grimm 1967; RPA 2010)

Paints and coatings that may contain SCCPs	Chlorinated paraffins content (% wt)
Organic solvent borne intumescent coating for structural steel	20-30
Plastisol[2] screen printing inks for textiles	10-25
Organic solvent borne chlorinated rubber systems for swimming pools/fishponds	5-20
Organic solvent borne chemical and water-resistant coatings	5-20
Organic solvent borne floor and wall paints	5-10
Intumescent coating for ferrous substrates	5-10
Intumescent coating for timber-based boards	2.5-10
Organic solvent borne acrylic container coatings	2-10
Organic solvent borne road marking paints	5-8
Organic solvent borne zinc rich (epoxy) primers	2-5
Organic solvent borne chlorinated rubber primers and topcoats	1-5
Organic solvent borne vacuum metallising lacquers	1-5
Organic solvent borne flame retardant coating for wood	1-5

2.3 Selected studies interesting for SCCP/MCCP monitoring

2.3.1 SCCPs in consumer products in the EU

The SCCPs and MCCPs added to products in China are exported to other countries mainly in PVC or rubber products (Babayemi et al. 2021; Guida et al. 2022). By this mechanism large volumes of products have likely entered the EU in consumer products like toys, sports articles, and cables. Such cases have been reported by the European Rapid Exchange of Information System (RAPEX) (see Annex 1 Table 21; UNEP 2019a). When these consumer products enter end-of-life, theses PVC, rubber and other polymer materials might end in recycling and in recyclates.

2.3.2 SCCPs/MCCPs in agricultural PVC plastic films

PVC foils are used in agricultural films with associated release of additives (Wang et al. 2021). In an initial screening of PVC in 4 plastic films, SCCPs were detected in one film at 100 mg/kg, and MCCPs were found at concentrations ranging from 70 to 1600 mg/kg, indicating certain use of CPs in PVC films (Chen et al. 2021).

The Netherlands has large agricultural activities and therefore agricultural plastic might be a relevant plastic category to monitor if partly PVC films are used. Furthermore, Wageningen University has a project on ‘Circular Use of Plastics in Agriculture and Horticulture’. In such a project or in an additional monitoring SCCPs/MCCPs and UV-328 (see Section 3.4.5) could be monitored.

[2] Plastisol is a suspension of PVC or other polymer particles in a liquid plasticizer (e.g. SCCP, MCCP, other CPs)

2.3.3 SCCPs/MCCPs in tyres

Flame retardants and CP plasticizer are normally not added to rubber tyres and therefore tyre production is not considered as a relevant use of SCCPs/MCCPs.
In the Netherlands, an assessment of car tires and their recycled products, such as rubber granulates and playground tiles, was conducted to measure the concentrations of SCCPs, MCCPs, and LCCPs (Brandsma et al. 2019). Total CP (C_{10}–C_{30}) concentrations ranged from 1.5 to 67 mg/kg in car tires, 13 to 67 mg/kg in rubber granulates, and 16 to 74 mg/kg in playground tiles. Sampling and analysis of POPs in car tires and related recyclates is sufficiently assessed for The Netherlands.
The authors suggested that the low CP content (maximum of 67 mg/kg compared to the provisional low POP content of [100 mg/kg], [1 500 mg/kg] or [10 000 mg/kg] (UNEP 2023)) detected in car tires indicates contamination during the manufacturing process rather than intentional CP application.

2.3.4 SCCPs and MCCPs in recycled products

In addition to the levels of SCCPs/MCCPs in products, also recycling of products containing SCCPs/MCCPs is an area of concern with a need of monitoring and control.
A study from Thailand demonstrated uncontrolled recycling of SCCPs/MCCPs and restricted phthalates, based on an investigation of four household flexible PVC product groups (cable sheaths; vinyl boots, flooring sheets, and hoses) (Ramungul et al. 2023). A versatile pyrolysis/thermal desorption gas chromatography-mass spectrometry (Py/TD-GC-MS) method was employed to simultaneously screen 18 target plasticizers in these products. Di-(2-ethylhexyl) phthalate (DEHP) and diisononyl phthalate (DINP) were the most frequently detected primary plasticizers. CPs were also detected in most samples, except for boots. The other plasticizers detected include other ortho-phthalates and non-phthalates. These results of plasticizer 'cocktails' in new products with a maximum of seven plasticizers found in a single product document the recycling of plasticized PVC in new products including SCCPs (Ramungul et al. 2023).

2.4 Recommendations for monitoring SCCPs/MCCPs in product groups or residual streams

2.4.1 CP products

The two major CP producing countries (China and India) are likely still producing mixtures of SCCPs and MCCPs (Chen et al. 2021, 2022). While China has ratified SCCPs and announced to restrict the production by the end of 2023, it might take time that the companies can eliminate SCCPs in the CP mixtures. Furthermore, India has not ratified SCCPs and will likely further produce CP mixtures containing SCCPs.
Therefore, it is recommended to monitor CP mixtures and related products imported to The Netherlands and Europe for SCCP content. Related products are e.g. metal working fluids, lubricants, and leather fatliquors. Sampling could be conducted also in other EU countries in which monitoring of CPs are not expected due to lack of capacity.
A best practice analysis of CP technical mixtures has recently been published with analysis of all chain length and chlorination degree (Guida et al. 2023).

2.4.2 Plasticised/flame retarded PVC, rubber, PUR spray foam and possibly other products

It is also recommended to continue the monitoring of plasticized PVC and rubber products like the RAPEX survey **but more targeted towards other products with particular high use in China and likely India (Chen et al. 2021):**

A) Plasticized PVC in the construction sector like flooring and walls, in particular imports from the major producers of CPs which, at least until recently, contained SCCPs (China and likely India)

B) Soft PVC shower curtains and similar PVC products which have a high frequency of SCCP use in China (Chen et al. 2021; Weng et al. 2023)

C) Rubber belts and transmission belts. These products, in particular imported from China and likely India (large producers of rubber), might contain SCCPs. Also, the other major global rubber producing countries (Thailand, Indonesia, and Vietnam) are using CPs. Vietnam was registered as the only countries for an exemption for using 15,000 t SCCPs in production[3] and recently also China registered for exemptions. Therefore, imports of plasticised rubber have a risk of SCCP contamination and are worth a monitoring study

D) PUR spray foam. A first monitoring in the Netherlands has shown frequent use of CPs in PUR spray foam, but mainly MCCPs (up to 50 %!) and LCCPs were detected with low levels of SCCPs (Brandsma et al. 2021) indicating that PUR spray foams in The Netherlands comply with the EU regulation. The PUR spray foams in the Chinese survey on the other hand contained high levels of SCCPs (Chen et al. 2021)

Recommended option: Also, for these product groups, the sampling could go beyond The Netherlands to other EU countries where CP monitoring is not expected and cheap products are preferred e.g. Romania, Bulgaria or even Serbia[4]. Another option is to do such a study in selected African countries where SCCP/MCCP levels in human milk are high (Krätschmer et al. 2023), the levels in house dust are extremely high (Brits et al. 2020) and imports of plasticized PVC, rubber and PUR foam are considered high and likely are the major sources (Babayemi et al. 2022). Amsterdam University (Prof. De Boer; Dr. Brandsma) already has a cooperation with a researcher in South Africa (Dr. Martin Brits; PhD in The Netherlands) and conducted the CP house dust study in South African (Brits et al. 2020).
Another option for monitoring of such products in a developing country could be Suriname having close links to The Netherlands as former colony and Dutch speaking country. Suriname has developed and updated good Stockholm Convention National Implementation Plan (Dr. Weber and members of TAUW/Deventer were the international consultants) and Prof. Victorine Pinas (Professor at de Korn University Suriname and KU Leuven) has publish related research (Pinas et al. 2022).

[3]https://chm.pops.int/Implementation/Exemptions/SpecificExemptions/ShortchainchlorinatedparaffinsRoSE/tabid/7595/Default.aspx
[4] Serbia has an excellent NGO AlHEM which works on chemicals including chemicals in products and cooperated e.g. the German Environment Agency on SVHC in products https://en.alhem.rs/who-is-alhem/

Prof. Pinas is a member of the Stockholm POP Review Committee and has co-authored the study on ‘Enhancing scientific support for the Stockholm Convention’s implementation’: (Wang et al. 2022).

2.4.3 Plastics from e-waste in particular cables

Data from Switzerland on POPs in plastic from waste electrical and electronic equipment (WEEE) indicate that SCCP and MCCP levels in European WEEE were low, as WEEE samples from 2011 in Switzerland can be seen as representative for the EU (Taverna et al. 2017). The WEEE samples from 2011 included mainly articles produced before 2005, but the global SCCP/MCCP production has mainly increased after 2005. Due to major production and export of electrical and electronic equipment (EEE) in/from Asia, the levels of SCCPs and MCCPs in WEEE plastic might have increased in the last 20 years. This might in particular be relevant for PVC cable sheathing where monitoring of consumer products in the EU revealed that a large share of products above the regulatory limit of 1500 mg/kg were cables (see Annex 1; UNEP 2019a).
Therefore, it is recommended to monitor SCCPs, MCCPs and LCCPs in sheathings of waste cables and in particular in recycling of PVC cables. In this monitoring also other POPs could be included like POP-BFRs or dechlorane plus which are however considered as less relevant.

2.4.4 Plastics from ELVs

In a first monitoring of SCCPs and MCCPs in European automotive shredder residues (ASR) relative low levels were detected (Norwegian Environment Agency 2021). It is recommended to generate more data on SCCPs/MCCPs in ASR. This could e.g. include assessment of ASR from Chinese cars or monitoring plastics parts from Chinese ELVs, in which most likely a higher amount of SCCP and MCCP might be included considering the high production and use of SCCPs/MCCPs in China (Chen et al. 2021, 2022).

2.4.5 Rubber recycling other than tires

A Dutch study already monitored SCCPs, MCCPs and LCCPs in tyres and detected low levels (Brandsma et al. 2019; Section 2.3.3). It is recommended to monitor recycling of plasticised rubber products like conveyor belts and transmission belts in Europe which have a much higher risk of containing SCCPs/MCCPs and had an exemption for use.

2.4.6 Waste oils

Since SCCPs and MCCPs are partly used in lubricants (including cars) and metal cutting fluids, they might end in waste oils similar to PCBs in the past. While the risk of CP contamination is mentioned in some publication (Guida et al. 2020; Nevondo & Okonkwo 2021; Guida et al. 2022), there is no study investigating and measuring waste oils for CPs. Therefore, it is recommended to measure waste oil recycling in The Netherlands for the presence of SCCPs and other CPs. The presence or absence of CPs in waste oils gives an indication if further monitoring in products like lubricants or metal working fluids is needed.

3 UV-328

3.1 Background and listing

UV-328 absorbs the full spectrum of UV light in a fully reversible and non-destructive process. It is therefore used as a UV absorber to protect surfaces from discoloration and degradation under UV/sunlight. Most of its use is in surface coatings and paints (e.g. clear coat automotive finishes), and as an additive in plastics (e.g. transparent plastics, food packaging) (UNEP 2022).
UV-328 has been newly listed in the Stockholm Convention in 2023.
UV-328 has been listed with a wide range of exemptions for production and use (Table 4).

Table 4: Use exemptions for UV-328 in POPs listing of the Stockholm Convention

Applications	Duration of exemption
Land-based motor vehicles (i.e. cars, motorcycles, agriculture and construction vehicles and industrial trucks)	According to Article 4 (i.e. five years)
Replacement parts for: a) Land-based motor vehicles b) Stationary industrial machines used in agriculture, forestry and construction c) LCDs in medical and in-vitro diagnostic devices d) LCDs in instruments for analysis, measurements etc.	Until end of service life of the articles or 2044, whichever comes earlier
Industrial coating applications	According to Article 4 (i.e. five years)
Cellulose triacetate film in polarizers	
Photographic paper	
Mechanical separators in blood collection tubes	

3.2 Use of UV-328 in products

Table 5 gives an overview on the major uses of UV-328 and related concentrations in products like plastics, coatings or paints (e.g., polyurethanes, poly(methyl methacrylate), polycarbonates, including copolymers, soft polyvinylchloride, (co)polymers of olefins, other acrylic (co)polymers, rubber and elastomers). (ECHA 2020).
In the EU suppliers of articles containing UV-328 in a concentration above 0.1 % w/w need to submit information on these articles from 5 January 2021 to the SCIP database (Substances of Concern In articles as such or in complex objects (Products))[5] established under the Waste Framework Directive. By 1 March 2022 the total number of factsheets (entries) related to UV-328 in the SCIP database was 315,251 (UNEP 2022c).

[5]https://echa.europa.eu/scip-database

According to the data supplied by the companies, UV-328 by itself is mainly used in motor vehicles, including motorcycles, and their components and accessories, including seats (≥ 65,720 registered factsheets) followed by components and accessories of optical, photographic, cinematographic, medical, surgical or veterinary's instruments and apparatus, as well as measuring instruments and apparatus; including liquid crystal devices, sheets and plates of polarizing material, oxygen therapy, aerosol therapy, artificial respiration or other therapeutic respiration apparatus and other breathing appliances (≥4,993), Components and accessories of optical, photographic, cinematographic, medical, surgical or veterinary's instruments and apparatus, as well as measuring instruments and apparatus; including liquid crystal devices, sheets and plates of polarizing material, oxygen therapy, aerosol therapy, artificial respiration or other therapeutic respiration apparatus and other breathing appliances (≥ 1,826), plastics and plastic articles, including self-adhesive plates, sheets, film, foil, tape, strip and other flat shapes, of plastics, whether or not in rolls (≥ 1,570) and other products (≥ 645). In mixtures that are incorporated in motor vehicles, including motorcycles, and their components and accessories, UV-328 is mainly used in adhesives and sealants (≥ 53,536) and paints and coatings (≥ 47,131) but also in fiber, leather, rubber and polymerized materials preservatives (≥ 875) and in gypsum (≥ 620).
In coatings, the typically recommended concentration of UV-328 is between 1 and 3 % (by weight, based on solids) (Hangzhou Sunny Chemical Corp Ltd. 2003). For the consumer use in automotive clearcoat finish and topcoat glaze for boats, concentrations of UV-328 ranging up to 10 % were identified in material safety data sheets in the USA (as reported in ECCC and Health Canada, 2016).

Table 5: Use sectors, applications and concentrations of UV-328 in products

Uses and application	UV-328 content	Source
Clearcoat finish (automobile); topcoat glaze (boat)	Up to 10%	ECCC and Health Canada 2016
Coating	1 to 3%	Hangzhou Sunny Chemical Corp Ltd. 2003
Resin and paint (automotive)	0.1 to 1%	JAPIA 2021
Plastics	0.1 to 1%	Hunan Chemical BV 2016
PC (construction, automobile)	0.15 to 0.3%	Disheng Technology 2017
PE (construction; packaging)	0.2 to 0.4%	Disheng Technology 2017
PS	0.2 to 0.5%	Disheng Technology 2017
PVC (construction)	0.2 to 0.5%	Disheng Technology 2017
Polyester (textiles)	0.3 to 0.5%	Disheng Technology 2017

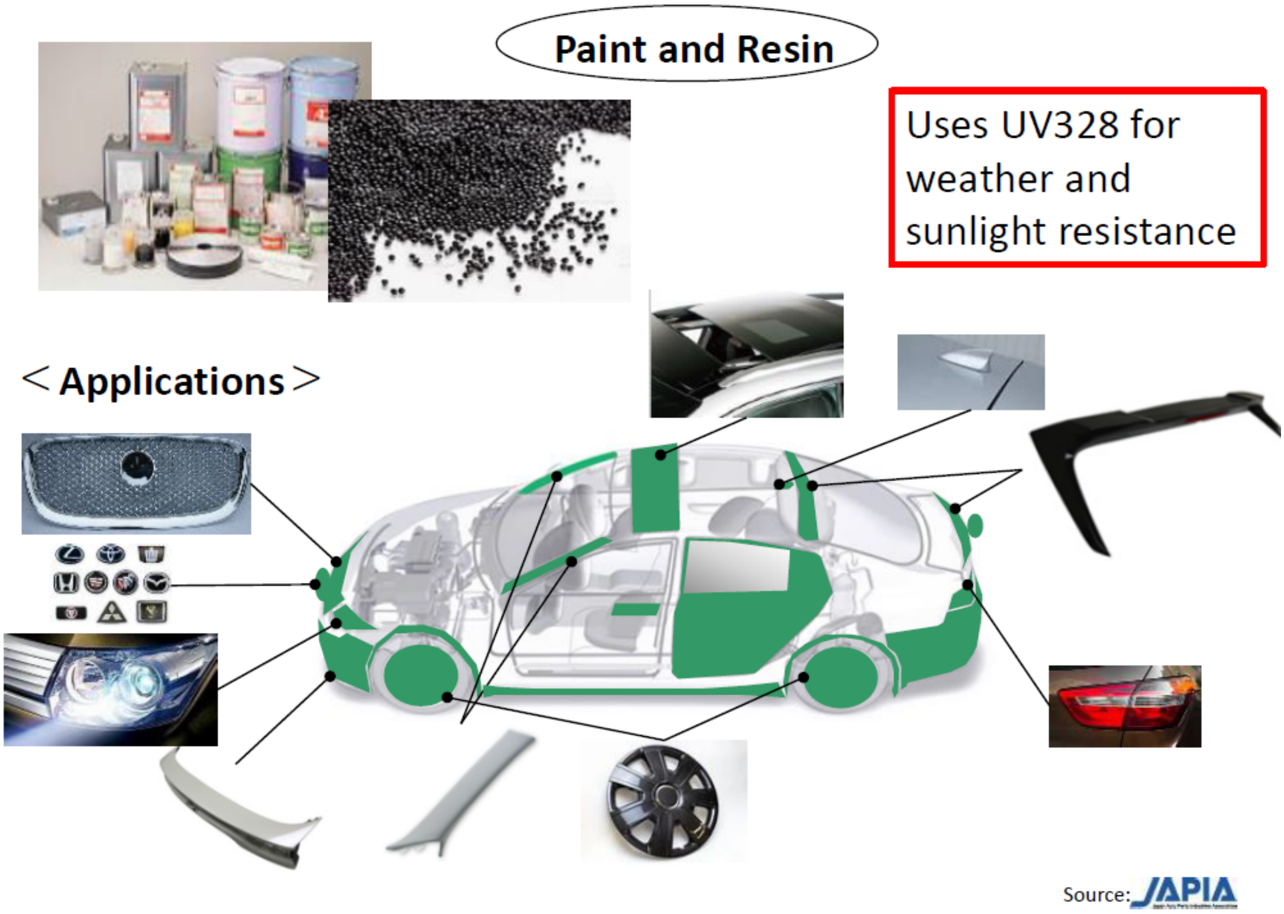

Figure 4: Use of UV-328 in vehicle parts (METI 2023)

3.3 Some relevant monitoring data of UV-328 in plastics and recycling

Overall, the data on UV-328 in products, waste and recycling is relatively scarce since UV-328 has only been listed as POPs in 2023. Below are some key studies compiled which gives a first insight into UV-328 in waste and recycling.

3.3.1 Packaging materials

Several studies have found UV-328 in plastics and packaging materials (Chang et al. 2013; Rani et al. 2017; Zhang et al. 2016). UV-328 were detected in milk packaging and snack packaging together with other UV absorbers in the range of 25–76 µg/g (0.0025–0.0076 % by weight) (Zhang et al. 2016). **UV-328 were also detected in commercial polyethylene terephthalate (PET) beverage packaging at 2.01 µg/g** and in low-density polyethylene (LDPE) at 13.9 µg/g packaging (Chang et al. (2013). Rani et al. (2017) reported concentrations in the range of 0.0027–0.4 µg/g in newly-produced plastics.

3.3.2 Monitoring of UV-328 and other Benzotriazole UV stabilizers (BUVs) in agricultural plastic

An assessment of UV absorbers in 6 different types of biodegradable plastic products in China revealed a total concentration ranging from 0.037 to 1,139 mg/kg (Yao et al. 2023). Various UV absorbers, including UV-328, UV-234, UV-326, UV-329, UV-360, UV-P, as well as BP (benzophenone), BP-3, and BP-12, were detected in plastic bags, garbage bags, food packaging bags, plastic lunch boxes, tableware, product packing bags, and mulch films. The biodegradable mulch films showed significantly higher UV absorber concentrations (mean: 1,139 mg/kg) compared to other sample categories (mean: 0.037–0.19 mg/kg). Specifically, UV-328 and BP-1 were the predominant UV absorbers in the biodegradable mulch films, with levels ranging from 727 to 1,063 mg/kg and 317 to 506 mg/kg, respectively (Yao et al. 2023).
Furthermore, a second study on UV absorbers in mulch films found notably higher levels in bioplastic, which were 400 times higher compared to PE mulch films (Li et al. 2023).
Biodegradable plastic films are usually made of bio-based polymers, which are brittle and prone to crack. It is necessary to add UV stabilizers to mitigate degradation (Li et al. 2023). Carbon black is generally used for UV stabilization in mulch films, while its UV absorption spectrum is relative narrow and cannot completely prevent the aging of the films when used alone. To maintain stability within the planting cycle of biodegradable mulch, organic UV absorbents are also frequently added by manufacturers to extend its lifetime, which may also cause the accumulation of these chemicals in soils. This second study also assessed soil contamination, revealing that the average UV absorber concentration was up to 10 times higher in soils mulched with biodegradable films compared to soils mulched with PE films (Li et al. 2023).
Both studies concluded that there may be a potential risk of UV absorber contamination and exposure in the environment due to the widespread use of biodegradable plastics.

3.3.3 Monitoring of polyethylene plastic recyclates for UV-328 by IPEN

Brosché et al. (2021) analyzed 24 samples of plastic pellets sold as high-density polyethylene (HDPE), purchased from recycling facilities in 23 countries, mostly low- and middle-income countries. These samples underwent testing to determine the presence of UV stabilizers, including UV-328 (and polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCD)) at µg/kg levels.
UV-328 was detected in 71 % of the samples, **with concentrations ranging from 0.0001 to 0.33 mg/kg. Therefore, all samples were below 1 mg/kg).** Other UV stabilizers, such as UV-234, UV-326, UV-327, and UV-329, were also detected often in higher concentration (Brosché et al. 2021).

3.3.4 Monitoring of plastic recyclates for UV-328 (and other POPs) in UNEP GMP

UNEP initiated a screening study of POPs in recycled pellets and shreds in 9 countries in Africa (2), Asia (4), and the Group of Latin America and the Caribbean (GRULAC) region (3) as part of the Global Monitoring Plan (GMP) (UNEP 2023a). A range of POPs were analysed in various types of recycled plastic pellets/shreds, including the listed UV-328 (but also Dechlorane Plus, HBCD, PBDEs, per- and polyfluorinated alkylated substances that are listed as POPs (POP-PFAS), and SCCPs/MCCPs). The data has been compiled in another report (UNEP 2023a). **The results of the analysis revealed that the presence of UV-328 in the analyzed samples was generally low. In fact, for the majority of the samples, UV-328 contents were below the limit of quantification (LOQ; 0.1 mg/kg), indicating trace levels of this UV absorber (Table 6). Out of the 117 analyzed samples, only 20 exhibited UV-328 contents above 0.1 mg/kg (Table 6).** These quantifiable UV-328 contents varied across plastic samples from several countries, including Argentina, Brazil, Chile, Nigeria, Thailand, and Vietnam. Interestingly, there was no clear correlation observed among polymer types (and countries), suggesting a complex use and distribution pattern of UV-328 in plastics.

Quantifiable UV-328 contents ranged from 0.11 to 17.5 mg/kg, with certain plastic types exhibiting higher concentrations. **Specifically, plastics such as** acrylonitrile butadiene styrene **(ABS),** expanded polystyrene **(EPS),** high density polyethylene **(HDPE),** high impact polystyrene **(HIPS),** polyethylene **(PE),** polyethylene terephthalate **(PET),** polypropylene **(PP), and** polyvinyl chloride **(PVC) showed UV-328 contents in the order of hundreds µg/kg. Notably, the highest concentrations in the order of thousands µg/kg were found in PE (1.05 mg/kg), HIPS (3.6 mg/kg), and PVC (17.5 mg/kg) pellets.**

Such an assessment of UV-328 and other POPs could be conducted in The Netherlands (and other European countries). Priority would have plastic recyclates with known frequent use of POPs in plastic such as HIPS, ABS, polycarbonate/acrylonitrile-butadiene-styrene (PC-ABS).

Table 6: UV-328 contents (µg/kg) in plastic samples (UNEP 2023a)

Samples	Country	Polymer	UV-328	Samples	Country	Polymer	UV-328
1 Pellet Arg	Argentina	HDPE	175	**N47**	Nigeria	PP	< 100
21 Pellet Arg MDPE	Argentina	MDPE	< 100	**N48**	Nigeria	LDPE	< 100
23 Pellet Arg PMMA	Argentina	PMMA	< 100	**N49 ***	Nigeria	HDPE	< 100
06 Brazil PE	Brazil	PE	< 100	**N50 ***	Nigeria	ABS	< 100
17 Brazil PSAI	Brazil	HIPS	612	**N51 ***	Nigeria	PVC	< 100
26 Brazil PP	Brazil	PP	< 100	**N52 ***	Nigeria	ABS	< 100
CMP-PA-CL	Chile	PA	< 100	**N53 ***	Nigeria	HDPE	< 100
QCT-ABS-CL	Chile	ABS	< 100	**N54 ***	Nigeria	PET	< 100
04CHL-Rec	Chile	ABS	< 100	**N55 ***	Nigeria	PET	< 100
16CHL-Rec *	Chile	PET	354	**N56 ***	Nigeria	HIPS	< 100
GHA G3	Ghana	Unkown	< 100	**N57 ***	Nigeria	PET	< 100
GHA G5	Ghana	Unkown	< 100	**N58 ***	Nigeria	HIPS	< 100
IND 1	Indonesia	HDPE	< 100	**N59**	Nigeria	HDPE	< 100
IND 4	Indonesia	PE	< 100	**N60**	Nigeria	LDPE	< 100

Our reference R001-1293732EJS-V01-sss-NL

Samples	Country	Polymer	UV-328	Samples	Country	Polymer	UV-328
IDN 13	Indonesia	ABS	< 100	**N61 ***	Nigeria	PP	< 100
IDN 24 *	Indonesia	PET	< 100	**N62 ***	Nigeria	ABS	< 100
N01 *	Nigeria	LDPE	< 100	**004 TH EPS**	Thailand	EPS	876
N02 *	Nigeria	LDPE	< 100	**005 TH HIPS**	Thailand	HIPS	324
N03 *	Nigeria	HDPE	< 100	**009 TH HIPS**	Thailand	HIPS	< 100
N04 *	Nigeria	PVC	< 100	**010 TH HIPS**	Thailand	PP	< 100
N05 *	Nigeria	HDPE	< 100	**020 TH PC**	Thailand	PC	< 100
N06 *	Nigeria	HDPE	< 100	**021 TH HDPE**	Thailand	HDPE	< 100
N07 *	Nigeria	HDPE	< 100	**022 TH GPPS**	Thailand	ABS	< 100
N08 *	Nigeria	LDPE	< 100	**023 TH ABS**	Thailand	ABS	< 100
N09 *	Nigeria	LDPE	< 100	**024 TH ABS**	Thailand	ABS	< 100
N10	Nigeria	LDPE	< 100	**025 TH ABS**	Thailand	ABS PC	< 100
N11 *	Nigeria	PVC	< 100	**031 TH HIPS**	Thailand	HIPS	< 100
N12 *	Nigeria	PVC	< 100	**032 TH HIPS**	Thailand	HIPS	< 100
N13 *	Nigeria	PP	< 100	**033 TH PP**	Thailand	PP	< 100
N14 *	Nigeria	PVC	110	**034 TH HDPE**	Thailand	HDPE	< 100
N15 *	Nigeria	HDPE	< 100	**037 TH ABS**	Thailand	ABS	250
N16 *	Nigeria	LDPE	< 100	**038 TH ABS**	Thailand	ABS	201
N17 *	Nigeria	LDPE	< 100	**039 TH HIPS**	Thailand	HIPS	112
N18 *	Nigeria	HDPE	181	**040 TH HIPS**	Thailand	HIPS	3598
N19 *	Nigeria	HDPE	177	**041 TH GPPS**	Thailand	GPPS	< 100
N20 *	Nigeria	HDPE	< 100	**042 TH HIPS**	Thailand	HIPS	< 100
N21 *	Nigeria	HDPE	< 100	**043 TH GPPS**	Thailand	GPPS	< 100
N22 *	Nigeria	PVC	< 100	**044 TH ABS**	Thailand	ABS	< 100
N23 *	Nigeria	PVC	< 100	**045 TH HIPS**	Thailand	HIPS	< 100
N24 *	Nigeria	PP	< 100	**046 TH HDPE**	Thailand	HDPE	< 100
N25 *	Nigeria	PP	< 100	**048 TH HDPE**	Thailand	HDPE	< 100
N26	Nigeria	HDPE	< 100	**049 TH HDPE**	Thailand	HDPE	< 100
N27 *	Nigeria	PVC	17475	**051 TH PP**	Thailand	PP	380
N28 *	Nigeria	ABS	< 100	**052 TH PP**	Thailand	PP	< 100
N29	Nigeria	GPPS	< 100	**053 TH PP**	Thailand	PP	< 100
N30	Nigeria	PP	< 100	**054 TH HDPE**	Thailand	HDPE	< 100
N31	Nigeria	GPPS	< 100	**055 TH PP**	Thailand	PP	< 100
N32 *	Nigeria	HDPE	< 100	**056 TH PP**	Thailand	PP	249
N33 *	Nigeria	HDPE	< 100	**067 TH HDPE**	Thailand	HDPE	< 100
N34 **	Nigeria	PVC	< 100	**068 TH PP**	Thailand	PP	149
N35 **	Nigeria	PVC	< 100	**069 TH PP**	Thailand	ABS	< 100
N36 *	Nigeria	HDPE	< 100	**070 TH PP**	Thailand	ABS	200
N37 *	Nigeria	PP	< 100	**071 TH ABS**	Thailand	ABS	< 100
N38 *	Nigeria	PET	< 100	**2 Vietnam PVC ****	Vietnam	PVC	111

Samples	Country	Polymer	UV-328	Samples	Country	Polymer	UV-328
N40 *	Nigeria	PET	< 100	**15 Vietnam ABS ***	Vietnam	ABS	< 100
N43	Nigeria	HDPE	< 100	**18 Vietnam HIPS ***	Vietnam	HIPS	272
N44	Nigeria	HDPE	< 100	**22 Vietnam PE**	Vietnam	PE	1053
N45	Nigeria	LDPE	< 100	**30 Vietnam PP**	Vietnam	PP	< 100
N46 *	Nigeria	HDPE	< 100				

* Shreds; ** Powder; ABS = acrylonitrile butadiene styrene; GPPS = general purpose polystyrene; HDPE = high-density polyethylene; HIPS = high-impact polystyrene; LDPE = low-density polyethylene; PA = polyamide; PE = polyethylene; PET = Polyethylene terephthalate; PMMA = polymethyl methacrylate; PP = polypropylene; PS = polystyrene; PVC = polyvinyl chloride.

3.4 Recommendations for monitoring UV-328 and other BUVs in product groups or residual streams

More data are needed for UV-328 in products, waste and recycling. In such a monitoring other Benzotriazole UV stabilizers (BUVs) restricted in the EU as SVHC should also be monitored.

- UV-320 CAS 3846-71-7; 2-Benzotriazol-2-yl-4,6-di-tert-butylphenol
- UV-327 CAS 3864-99-1; Tinuvin 326; 2,4-Di-tert-butyl-6-(5-chlorbenzotriazol-2-yl)phenol
- UV-350 CAS 36437-37-3; 2-(2H-Benzotriazol-2-yl)-6-(sec-butyl)-4
- UV-326; CAS 3896-11- 5; Tinuvin 326; 2-(2′-hydroxy -3′ -tert-butyl-5′-methylphenyl)-5-chloro benzotriazole; Bumetrizole
- UV-329; CAS number 3147-75-9; Tinuvin 329; 2-(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)phenol; Octrizole) and known to be produced/used

3.4.1 Development of a screening method for UV-328 (and other BUVs)

Brominated, chlorinated and fluorinated POPs[6] can be pre-screened by XRF[6] which can reduce efforts and costs in monitoring (UNEP 2021a). UV-328 does not contain a halogen or metal and can therefore not be pre-screened by XRF. It should be assessed if FT-IR might be an option to screen for UV-328 and other BUVs. Handheld FT-IR are meanwhile available: E.g. the '*Agilent 4300 Handheld FTIR spectrometer incorporates lightweight ergonomics, ease of use, ruggedness, and flexibility in one system. Weighing only ~2 kg, it is ideal for mobile non-destructive testing in field and nonlaboratory environments*' (Agilent website)[7].

If a screening method could be developed for BUVs or even UV-328 specific, then they could be used to screen vehicle parts like bumpers which might be used for screening studies or for separation and phase out of UV-328 or BUVs.

[6] The detection limit of the three halogens is quite different: For bromine the detection limit is around and below 5 mg/kg and for chlorine with handheld XRF around 100 mg/kg and laboratory equipment below 20 mg/kg. Normal handheld XRF do not detect fluorine but specialized XRF can detect fluorine around 100 mg/kg.

[7] https://www.agilent.com/en/product/molecular-spectroscopy/ftir-spectroscopy/ftir-compact-portable-systems/4300-handheld-ftir

3.4.2 UV-328 (and other BUV) in recyclates

The initial studies of screening plastic recyclates for UV-328 focussed on low- and middle-income countries (UNEP 2023a). It is recommended to analyse a broad range of plastic recyclates since UV-328 has been applied in a wide range of plastic types. The study could be conducted similarly to the UNEP GMP study in plastic pellets from 9 low-/middle-income (UNEP 2023a;). Sampling of recyclates could be carried out in The Netherlands and other EU countries.
Recommended priority polymers for monitoring are:

A) PET recyclates

One important type of plastic recyclates to measure are PET recyclates since this is the only plastic recyclate allowed to be used in the recycling to produce new food contact materials (European Commission 2022b). As mentioned, a Chinese study detected UV-328 in PET revealing that UV-328/BUVs are partly used in PET applications. Therefore, they might enter PET recycling. For food contact materials the monitoring should go lower than 1 mg/kg, rather to 1 µg/kg or even lower, so that the data on levels are collected and revealed by governmental monitoring along with risk discussion and not only by NGOs (e.g. Brosche et al. 2021).

B) Recyclates from other polymer types

A wide range of polymers can be impacted by UV-328. But the highest levels are found HIPS, ABS and PVC (UNEP 2023a). However also some PP and PE were impacted. Therefore, it is recommended to monitor a broad range of plastic recyclates. Such monitoring of plastic recyclates could be started with known high-risk plastic sectors.

- Plastic recyclates produced from the ELVs/transport sector (see also below Section 3.4.3)
- Plastic recyclates produced from the construction & demolition (C&D) sector
- Plastic recyclates produced from the WEEE sector

Recyclates should be assessed from the European market (e.g. recyclates produced in the Netherlands or other EU state) and also recyclates if they are imported to the EU.

3.4.3 Monitoring UV-328 in the transport sector

The largest share of UV-328 has been used in vehicles in a wide range of applications (Figure 4). There are however no monitoring data on UV-328 in the transport sector. Therefore, it is recommended to monitor UV-328 and other BUVs in the transport sector in individual parts similar to the study of Kajiwara et al. (2014) which gives a good insight into PBDEs and HBCD in Japanese cars.
In this monitoring also other selected POPs can be monitored in these plastics (Dechlorane Plus, PBDEs, PFASs, SCCPs/MCCPs) since there is a general lack of good POPs screenings of plastic parts in vehicles (an exemption is the study of Kajiwara et al. (2014) while, on the other hand, higher recycling rates are needed in the transport sector.
One major use of UV-328 have been bumpers and grills (METI 2023; Figure 4).

Bumpers are frequently recycled to new bumpers and are one of the few applications where closed loop recycling of plastics is practiced for vehicles. Therefore, bumpers and grills and their recycling should be a relevant part of UV-328/BUVs screening in vehicles.
Also, other major plastic parts considered to be treated with UV-328 and other BUVs (Figure 4) could be screened in individual ELVs to get an idea of the frequency of use.

3.4.4 UV-328 in buildings

UV-328 and other BUVs has been used in buildings and construction in a range of applications. Monitoring of POPs in construction is rare and no systematic study of POPs in construction and demolition waste has been conducted with the exemption of monitoring of PCBs (e.g. in Switzerland Kohler et al. 2009). We suggest integrating UV-328/BUV monitoring in a larger monitoring of plastics/polymers in buildings (Section 6.1.3).

3.4.5 Monitoring of UV-328 and other BUVs in agricultural plastic

Studies in China revealed that BUVs are used in agricultural plastics including UV-328, in particular in biodegradable plastics (Yao et al. 2023). The Netherlands have a project on circular economy of agricultural plastic at Wageningen University including bioplastics[8]. The project aims to close the loop for plastic products used in agri- and horticulture. In the project three end-of-life scenarios of plastics will be explored, being mechanical recycling, industrial composting and programmed biodegradation in soil. It is recommended to monitor BUVs in agricultural plastics in The Netherlands and possibly monitor BUVs in the current project[8].

[8] https://www.wur.nl/en/project/circular-use-of-plastics-in-agriculture-and-horticulture.htm

4 Dechlorane Plus

4.1 Background and listing

Dechlorane Plus (DP) (CAS No. 13560-89-9) is a polychlorinated flame retardant that consists of two stereoisomers, syn-DP (CAS No. 135821-03-3) and anti-DP (CAS No. 135821-74-8).
The isomers are present in the technical product in a ratio of about 1:3 or 25 % syn-DP and 75 % anti-DP (UNEP 2022b). Dechlorane Plus has been listed as POP in Annex A of the Stockholm Convention in May 2023 with a range of exemptions (Table 7; UNEP 2023b).
According to ECHA, between 70 % - 90 % of the DP was used in motor vehicles, corresponding to 81- 161 tonnes per year in the EU (ECHA 2022). Communication with stakeholders also indicate that DP is used in electronics, aerospace and defence applications, medical devices, marine applications and in various machinery (gardening, forestry and other industrial). According to ECHA, it may also be used in fabrics, textiles and apparels, and plastic articles, but this has not been confirmed by consulted stakeholders (ECHA 2022).
There is/was no manufacture of DP within EU but in the USA and later in China. There was **one active registration of DP: a company based in the Netherlands called ADAMA Agriculture BV** (Adama 2019). They first registered as a supplier in 2017, and updated their registration dossier in 2018, 2019 and 2020, before notifying a 'ceased manufacture' **to ECHA on 31 May 2021 (ECHA 2022).** ADAMA – the 'only representative' for the Chinese company Jiangsu Anpon Electrochemical Company Ltd, which they recently acquired – was previously the only supplier of DP in the EU (ADAMA 2019).
China stopped the production of Dechlorane Plus in 2023 and also India is not producing DP. Therefore, there is no known Dechlorane Plus production globally and new products on the market since 01/2024 should not contain intentionally added DP.

Table 7: Specific exemptions listed for Dechlorane Plus in the Stockholm Convention

Chemical	Activity	Specific exemption
Dechlorane Plus CAS No. 13560-89-9 "Dechlorane Plus" includes its syn-isomer (CAS No. 135821-03-3) and its anti-isomer (CAS No. 135821-74-8).	**Production** Use	**None** In accordance with part XI of this Annex: Aerospace Space and defence applications Medical imaging and radiotherapy devices and installations Replacement parts for, and repair of, articles in applications in accordance with the provisions of paragraphs 2 and 3 of part XI of this Annex

4.2 Use of Dechlorane Plus in products

Still REACH registration data indicate that the volume of DP placed on the EU market was in the range of 10 – 100 tonnes/year (downgraded from 100 – 1 000 tonnes/year by the REACH registrant in October 2020). However, based on information from the stakeholder consultation carried out from April to June 2020, DP was estimated to be used in volumes of between 90 and 230 tonnes/year in the EU in 2020, with a central estimate of 160 tonnes/year. Motor vehicles were considered to be the main user of DP, with an estimated consumption ranging from 81 to 161 tonnes in 2020 (Table 8; ECHA 2022). After stop of production of DP in 2023 it is considered that the use stopped in 2024.

DP was also imported to EU in articles. According to information from the previously active REACH registration, DP is used as a flame retardant in adhesives/sealants and polymers. In the EU 93 % were used in polymers in wire coating and printed circuit board housing, other plastics and rubber parts (ECHA 2022).

Furthermore, our survey indicates that DP is used as an extreme pressure additive in greases. In these applications DP is used in motor vehicles, aerospace and defence applications, marine, garden and forestry machinery, electrical and electronic equipment, including consumer electronics and medical devices. Another confirmed minor use is in fireworks.

Table 8: Volumes of Dechlorane Plus used 2020 in the EU (ECHA 2022)

Sectors	**Low-volume scenario**		**High-volume scenario**	
	Share of total	**EU volume (t/y)**	**Share of total**	**EU volume (t/y)**
Automotive	90%	81	70%	161
Aviation	2%	2	2%	5
Other, including computer, electronics and imported articles etc.	8%	7	28%	64
All	**100%**	**90**	**100%**	**230**

4.3 Some relevant monitoring data of Dechlorane Plus in plastics and recycling

Overall, the data on DP in products, waste and recycling is relatively scarce since DP has only been listed as a POP in 2023. Below are some key studies compiled which gives a first insight into DP levels in waste and recycling.

4.3.1 Monitoring of Dechlorane plus in WEEE plastic

In the national monitoring of WEEE plastic in Switzerland in 2011 the average Dechlorane Plus content was 33 mg/kg total WEEE or **110 mg/kg WEEE plastic** (Taverna et al. 2017).
In the Swiss monitoring DP was present in WEEE (2011) in a considerably lower concentration compared to e.g. DecaBDE (approx. 1/10)
(Taverna et al. 2017; See also Table 18 in Section 6.3.3).

A recent monitoring of some WEEE plastic fractions in a Norwegian study detected DP only in the rejected fractions (likely after density separation) at measurable levels (15 mg/kg) while levels in separated WEEE plastic were below quantification limit (1 mg/kg) (Norwegian Environment Agency 2021) indicating that DP average levels in these measured WEEE plastic fractions were around 5 mg/kg if considering that in the separation about 1/3 of the plastics was rejected.
This demonstrates that DP is present in considerably lower levels in WEEE plastic (1/10 or less of DecaBDE). The comparison of the Swiss study with WEEE from 2011 and the Norwegian study with WEEE from 2021 indicates that the DP levels might have decreased in the past 10 years, but more data are needed to make such claims/conclusions.

4.3.2 Monitoring DP in automotive shredder residues

Initial data of DP in automotive shredder residues (ASR) has been measured in European ASR (Norwegian Environment Agency 2021). Regarding Dechlorane Plus, one shredder sample measured 12 mg/kg, whereas in the majority of samples the detected levels were below 1 mg/kg which was the limit of quantification (Norwegian Environment Agency 2021).

4.3.3 Monitoring of plastic recyclates for DP in the UNEP GMP project

UNEP initiated a screening study of POPs in recycled pellets and shreds in 9 countries in Africa (2), Asia (4), and the GRULAC region (3) as part of the Global Monitoring Plan (GMP) (UNEP 2023a). A range of POPs were analysed in various types of recycled plastic pellets/shreds, including the listed DP, (but also HBCD, PBDEs, UV-328, POP-PFAS, and SCCPs/MCCPs).
In the monitoring of **DP in 100 recycled pellet samples, DP was predominantly found below the limit of quantification (LOQ) of 1 mg/kg**. **Only three samples exhibited measurable Dechlorane Plus contents above the LOQ**: 1.0 mg/kg for a PP recyclate, 1.2 mg/kg in a HIPS recyclate, and 3.4 mg/kg in another HIPS. These impacted samples originating from the larger sampling campaign in Thailand. The pellets were produced using local feedstocks derived from automotive parts, electronic wastes, and unidentified post-consumer residues.

The limited detection of DP in the analyzed recyclate pellet samples highlights its relatively low prevalence in recycled plastics at the applied detection limit of 1 mg/kg. These findings suggest that, within the context of recycled pellets, DP is rather a minor plastic additive and only detected above 1 mg/kg in certain flame retarded plastic fraction.

4.4 Recommendations for monitoring Dechlorane Plus (and other dechloranes[9]) in product groups or residual streams

Overall DP seems a flame retardant of considerable lower relevance compared to DecaBDE, Decabromodiphenyl ethane (DBDPE) or TBBPA with considerable lower DP levels in WEEE plastic (see Table 18 Section 6.3.3) or ASR light fraction. The global production of DP has likely stopped after China stopped DP production in 2023. Therefore, DP has in our opinion a low relevance in waste and recycling. This needs, however, some more assessment and data for documentation.

4.4.1 Dechlorane Plus and possibly other dechloranes in recyclates

The initial studies of screening plastic recyclates for DP established data from recyclates of low- and middle-income countries (UNEP 2023a; Section 4.3.3). It is recommended to analyse plastic recyclates from major flame retarded plastic use sectors in The Netherlands or other EU countries to generate data from recycling in the EU.

A) Plastic recyclates produced from the ELVs/transport sector (see also Section 4.3.2)
Since in the EU between 70 % - 90 % of the DP was used in vehicles (ECHA 2022), it is suggested to do some monitoring of DP in recycling of plastics from ELVs. In such measurements DP should be measured in major recyclates produced from ELVs. It is suggested to analyse also rejected fractions e.g. from sink/float separation for DP.
Since DP has been used in wires, also composite samples of waste cable sheaths from vehicles could be analysed or cable sheath recyclates if this is practiced in The Netherlands.

B) Plastic recyclates produced from the WEEE (see also Section 0)
DP has also been used in plastics in EEE and while it is known that this was a minor use in the EU (ECHA 2022), the use pattern in Asia is not known. Recyclates from WEEE should be assessed from the European market (e.g. recyclates produced in the Netherlands or other EU state) and also recyclates which are imported to the EU. Sampling of recyclates could best be conducted in companies producing recyclates from WEEE plastic like MGG in Austria[10]. It is recommended that also the rejected fraction in sink/float separation should be analysed.

C) DP in plastics in construction and demolition (C&D) waste
DP has likely been used to some extent in the construction sector. It is likely not worth the effort to specifically measure DP in the construction sector. However, if plastic fractions are recycled from C&D waste then it is recommended to measure DP (and other POPs) in these recyclates.

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[9] Dechlorane 602, 603 and 604
[10] https://mgg-polymers.com/

5 PFOS,PFOA and PFHxS

5.1 Background

The production of PFOS has stopped but certain products such as synthetic carpets, other textiles are likely still in use and enter the waste stream.
PFHxS was used in the same applications as PFOS and has substituted PFOS for some time. The total historic production and use is not clear. Also, PFHxS production has stopped in China and therefore probably globally.
PFOA and related compounds received a range of exemptions and PFOA and in particular PFOA-related substances are still produced and used in products.
Information on major uses and related waste will be compiled along with available data. Challenges in monitoring of listed PFAS and need for further data will be compiled.

5.2 Use of POP-PFAS

The use of POP-PFAS is complex and not elaborated here. For further reading it is recommended to consult the recent review of PFAS use (Glüge et al. 2020) and the POPs-PFAS inventory guidance (UNEP 2023c). Also, it is recommended to consult the OECD document on side-chain fluorinated polymers (SFPs) (OECD 2022) since by far the largest share of e.g. PFOS in the EU (>90 %) has been applied in surface treatment of **carpets, textiles, furniture and paper** likely largely in the form of SFPs (Fricke & Lahl 2005).

5.3 Monitoring of PFAS in products and waste

A study on PFAS in products and waste steams have been conducted for the Netherlands commissioned by the State Secretary for the Environment and conducted by Arcadis Nederland B.V. to create insight in the presence of PFAS in products, production and recycling processes and waste (Arcadis 2021). It also aimed to identify significant exposure routes and release pathways of PFAS in products and waste to humans and the environment. All in all, 129 samples of products, dust from productions, processes, recycling and waste have been tested using three types of PFAS-analysis (screening for extractable organic fluorine (EOF; target analysis for 42 individual PFAS and the Total Oxidizable Precursor assay (TOP)). In several industries higher PFAS levels in dust have been measured than in household and office dust (Arcadis 2021).
A rough estimate was made of the loads of PFAS in the different categories based on the amount of products used in the Netherlands and the concentrations that were measured in this study (Arcadis 2021):

Highly relevant (>100 kg/year):
- Water and stain repellent products, including treated textile, carpets and leather.
- Paper recycling.

Moderately relevant (10-100 kg/year):
- Sewage sludge.
- Cleaning agents.
- Fluoroelastomer products.
- Pesticides.

Low relevance (<10 kg/year):
- Fluoropolymer products.
- Firework.

5.4 Recommendations for monitoring POP-PFAS (and other PFASs) in product groups or residual streams

The monitoring of PFAS in waste is challenging in particular when considering:
- That a large share of POPs-PFAS in wastes/products is likely present as PFAS precursor and that there are more than 100 precursors for each POP-PFAS. Therefore, the Total Oxidizable Precursor (TOP) Assay measurements are likely required for such monitoring as has been done for some samples in the Dutch study (Arcadis 2021). To treat larger waste fractions like ASR with TOP-assay is difficult but should be considered
- That a large share of POP-PFAS is included in side-chain fluorinated polymers (SFPs) and that TOP-assay not necessarily sufficiently degrade. A method has been published for measuring PFASs in SFPs (Liagkouridis et al. 2021)
- A method for screening PFAS in textiles has been proposed (Drage et al. 2023)

5.4.1 Recommendation of monitoring POP-PFAS in textile waste and recycling

Recycling rates of textiles are still below 20 %, with only Europe reporting recycling rates slightly above 20 % (Bureau of International Recycling 2022). In recent years some companies established large scale textile recycling like Re:claim (just went in operation)[11] or Renewcell (currently bankruptcy[12]). The Netherlands has established extended producer responsibility (EPR) scheme for textile in 2023 (Uitgebreide Producentenverantwoordelijkheid (UPV)) for promoting reuse and recycling[13] and activities of recycling textiles which likely result from this regulatory frame could be guided by monitoring of POP-PFAS and other chemicals of concern (CoCs). Textiles from the transport sector including vehicles are treated with PFAS. These textiles end in the light fraction of ASR. The Netherlands had a large EU project on post shredder technology (ARN RECYCLING B.V. 2015). It is recommended to assess what recyclates come out of this project and monitor PFAS in the fibre fraction including assuring to degrade the side-chain fluorinated polymers (considering Liagkouridis et al. 2021).

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11 https://www.letsrecycle.com/news/polyester-recycling-plant-opens-as-part-of-project-reclaim/

12 https://www.renewcell.com/en/

13 https://business.gov.nl/regulation/collecting-recycling-textiles-upv/

5.4.2 Recommendation of monitoring carpets and carpet recycling

A major use of PFOS (and likely also PFOA/PFHxS related substances) has been in synthetic carpets and rugs for stain repellency. The German PFOS inventory estimated that the largest PFOS stock was in synthetic carpets. Carpets are recycled to some extent as insulation material or as padding material for seats in cars (Cure Afvalbeheer 2024). It is recommended to analyse some recycled fluff for PFAS including total fluorine and TOP-assay appropriate to determine PFAS in SFPs (Liagkouridis et al. 2021). Initial monitoring was conducted in the Dutch study which found mostly low levels in materials from recycled carpets but high levels in a sample from a carpet recycling facility (Arcadis 2021).

5.4.3 Recycling of pesticide containers

Fluorinated high-density polyethylene (HDPE) containers can release PFAS into pesticides and the environment (USEPA 2021). Over the past two decades, the industry developed a CleanFarms initiative working with national authorities, farm unions and licensed waste operators to establish and monitor collection, recovery, and recycling schemes of used plastic pesticide containers in Europe[14].

It is recommended to monitor PFAS in the recycling of pesticide containers. The USEPA developed a method for extraction and analysis of PFAS in HDPE containers (USEPA 2024).

It is also recommended to monitor pesticides in the recycling of pesticide containers and monitor toxicity of these recycled plastics with bio-assay panel (e.g. from BDS in Amsterdam; Pieterse et al. 2015). In the Netherlands pesticide containers are collected (https://chemischafvalnederland.nl/en/chemical-waste/dispose-of-pesticides/ https://www.storl.nl/) but it is not clear if they are partly recycled or incinerated.

5.4.4 Assessment of studies on PFAS in waste and recycling in other countries

It is recommended to assess activities of monitoring PFAS in waste and recycling in other countries. E.g. the methodology developed in the UK at the Birmingham University research group for textile waste (Drage et al. 2023) will likely be applied to practical monitoring and the German environment agency (UBA) has an ongoing project to monitor PFAS in waste.

[14] https://croplifeeurope.eu/circular-economy/

6 POPs monitoring for major use categories of POPs in plastics

A wide range of persistent organic pollutants (POPs) listed under the Stockholm Convention has been used or is used as plastic additives or is otherwise related to plastics in the major use sectors electrical and electronic equipment (EEE), transport, buildings & construction (Table 9; Weber 2022). This includes various flame retardants (e.g., c-PentaBDE, c-OctaBDE, decaBDE, HBCD, Dechlorane Plus), (Table 9; Charbonnet et al. 2020). These sectors represent at the same time major plastic uses (Figure 5 and Figure 6).

The recently listed UV absorber (UVA) UV-328 (2-(2H-Benzotriazol-2-yl)-4,6-bis(2-methylbutan-2-yl)phenol) has also been used in the above-mentioned plastic-use sectors (Table 9) and in plastic packaging, including food packaging (Chang et al. 2013; Zhang et al. 2016; Rani et al. 2017), which is the largest plastic-use sector (Figure 5). Furthermore, UV-328 has been detected as a plastic additive in agricultural plastics (Li et al. 2023; Yao *et al.* 2023), another relevant plastic-use sector (Figure 5). Additionally, short-chain chlorinated paraffins (SCCPs) and the POP candidate medium-chain chlorinated paraffins (MCCPs)[15] appear to be present to some extent in the packaging sector, including some food and feed packaging (Dong et al. 2020; Wang et al. 2022), and likely also in some agricultural plastic, particularly in PVC.

Therefore, several POPs are present to some extent in all major plastic-use sectors and require control in their use and recycling. It needs to be stressed that only some portion of the plastics in these uses may contain POPs, and the majority of them do not, making them potentially recyclable from a POPs-perspective. However, plastics containing POPs are normally not labelled regarding their POP content. Therefore, monitoring of plastics in these sectors is necessary to detect POP contamination and determine their presence. It also involves verifying compliance with regulatory limits, such as the low POP content limits of the Basel Convention, thereby classifying if waste is a POP waste. Additionally, it is essential to monitor recycled plastics in these major POP-use sectors to ensure compliance with limits for unintentional POPs in products, as defined, e.g., in Annex I of the European POP directive (European Commission 2019). These POPs limits can be applied, for example, in the assessment of recyclates.

While in Chapter 2 to Chapter 5 recommendations are given for individual POPs or POPs groups including background information on studies and gaps for the individual POPs, this chapter gives an overview on the major use sectors of POPs with relevant waste and recycling flows.

For some POPs a range of studies on their presence in the individual use sectors such as EEE/WEEE or the transport sector has been conducted. However, for other POPs, especially recently listed POPs (e.g. SCCPs/MCCPs, Dechlorane Plus, and UV-328), there are only limited data on products, waste, or recycling.

It should be stressed that the generation of representative samples from e.g. WEEE or ELVs is a quite laborious work and it is recommended that for such samples all potentially relevant POPs and possibly other CoCs should be analysed (see e.g. Taverna et al. 2017).

[15] MCCPs meet the Annex D criteria and is recommended for listing as a POP by the POPRC (UNEP 2023d)

Table 9: POPs used as plastic additive or other plastic related use in major use sectors (Abbasi et al. 2019; Weber 2022 with additions)

POP (main production and use period)[a]	**Building & Construction Sector**	**Electrical and electronic equipment**	**Transport Sector**	**Textiles**
c-PentaBDE (1970-2004)	Former use	Minor former use	Major former use	Former use
c-OctaBDE (1970-2004)	Minor former use	Major former use	Minor former use	Former use
decaBDE (since 1970s)	Major use	Major use	Major use	Major use
HBCD (1980 to 2021)	Major former use	Minor former use	Minor former use	Former use
HBB (1970 to 1976)	Not relevant	Former use	Former use	Not relevant
SCCP (Since the 1930s)	Major use	Minor use	Minor use	Minor use
MCCP[15] (Since the 1930s)	Major use	Use	Use	Minor use
PFOS (1960 to 2012)[b]	Former use	Former use	Former use	Former use
PFOA (since 1960s)	Use	Minor use in product	Use	Use
PFHxS (1960 to 2021)	Former use	Former use	Former use	Former use
PCB (1940 to 1980)	Major former use	Major former use[c]	Former use[c]	Minor former use
PCN (1930 to 1970s)	Minor former use	Minor former use	Minor former use	Not relevant
PCP (since 1930)	Major use	Not relevant	Minor use	Former use
Lindane (1950 to 2000)	Former use	Minor former use[d]	Not relevant	Minor former use
DDT, Endosulfan, Driens	Former use	Not relevant	Not relevant	Not relevant
Mirex (1950 to 2000)	Former use	Former use	Former use	Not relevant
Dechlorane Plus (DP)	Use	Major use	Major use	Use
UV-328	Major use	Use	Major use	Use

[a]Main period for production and use in these sectors;
[b]Major production/use stopped 2002 by 3M; in the first list of exemptions the use in coatings of carpets, textile and paper was included which stopped since largely alternatives have been used.
[c]Considering also PCB containing capacitors which during shredding get crushed and contaminate shredder waste of electronics or vehicles including plastics.
[d]The use of lindane in plastics in e.g. cables was a minor use (Vijgen et al. 2022).

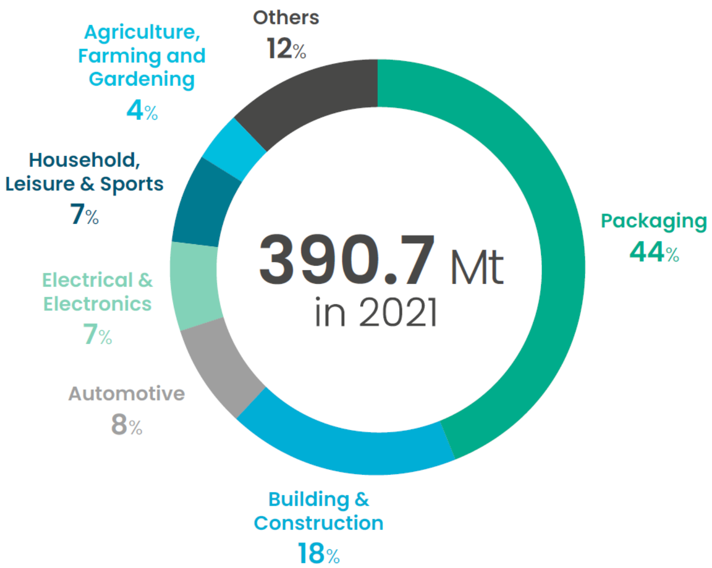

Figure 5: Global plastic production and share of the major plastic use sectors in 2021

(Source: Conversio Market & Strategy GmbH in Plastics Europe (2022))

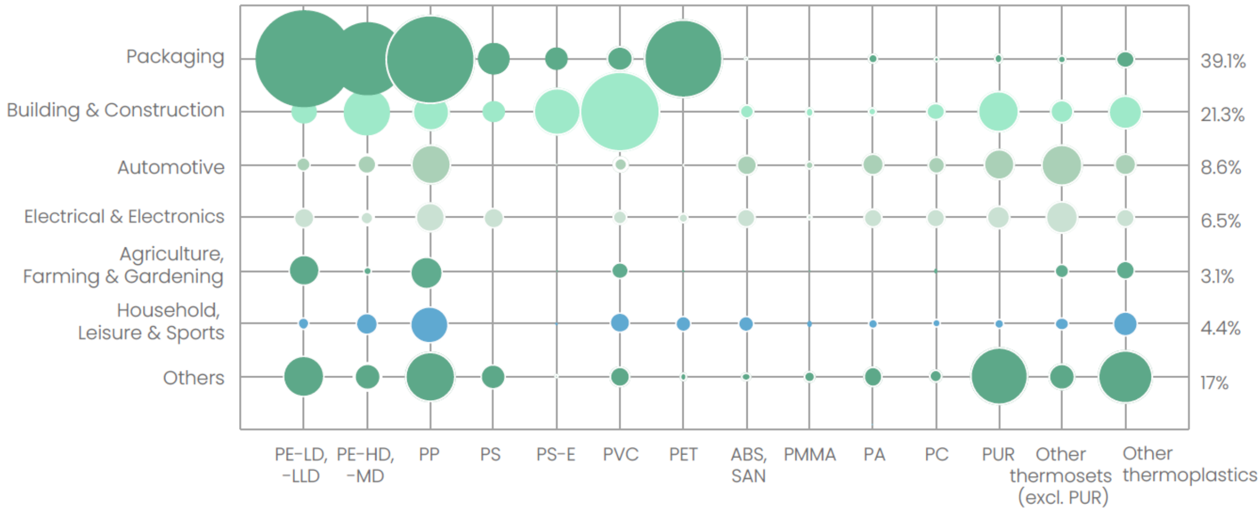

Figure 6: Plastic type and application based on the demand of European plastics converters

(Source: Conversio Market & Strategy GmbH in Plastics Europe (2022))

6.1 POPs in buildings and construction and recommendation for monitoring

6.1.1 Background on plastics in buildings

The construction sector is the second largest consumer of plastics, accounting for approximately 18 % of the global plastic production. In 2015, this sector consumed 65 Mt of plastic, a figure that increased to 70 Mt in 2021 (see Conversio Market & Strategy GmbH in Plastics Europe (2022) and Figure 5). The major plastic types used in buildings & construction are PVC, PUR, HDPE/MDPE, PP, and PS, including EPS/XPS (Figure 6).
The major plastic products used in buildings and construction include:

- Insulation materials (mainly EPS/XPS, Polyurethane (PUR), Polyisocyanurat (PIR), PP)
- Pipes for electrical conduits, rainwater and sewage pipes, and plumbing (PP, PVC)
- Insulation on cables, insulation tapes (PVC, Nylon, PP, PE)
- Flooring tiles and rolls (PVC, PP, PE, linoleum[16])
- Roofing (e.g., PC, unplasticized PVC, fiber-reinforced plastic)
- Windows and doors, along with their frames, and greenhouses (PE, PVC, PC)
- Domes/sky lights (PC, PMMA)
- Storage tanks (HDPE, PP)

6.1.2 POPs in plastics in buildings and other construction

Buildings and construction are a major area of plastic use containing additives listed as POPs (Table 9; UNEP 2021c; Weber 2022). Due to fire risk associated with plastics and flammability regulations (Charbonnet et al. 2020), flame retardants are often applied to plastics used in buildings. Major brominated flame retardants used include HBCD in insulation foams (Li et al. 2016; UNEP 2021d) and PBDEs in insulation foams and a wide range of other plastic materials (Table 10). Table 9 provides an overview of the POPs used in plastics in buildings and construction, indicating whether they are used majorly or minimally and the time periods of use. Table 10 gives an overview on the concentration range these POPs were used in plastics in construction.
SCCPs and MCCPs, frequently produced as SCCP/MCCP mixtures, are high-volume POPs currently produced at approximately 1.4 million tonnes per year (Guida et al. 2020; Chen et al. 2022). They are mainly used (about 70 %) as plasticizer in PVC (Chen et al. 2021; Chen et al. 2022; Figure 1), which was exempted in the Stockholm Convention). Approximately 60 to 70 % of PVC is used in the construction sector (Figure 6; Plastics Europe 2022). Furthermore, SCCPs and MCCPs are major flame retardants in polyurethane (PUR) spray foam (Brandsma et al. 2021; Chen et al. 2021).
Another use of POPs in construction is in paints, sealants and coatings, where POPs (SCCPs/MCCPs, PCBs, HBCD, and PFASs) are or were frequently used.

[16] https://en.wikipedia.org/wiki/Linoleum

Due to their long service life, plastics containing POPs that have been used in construction over the past 60 years are still in use to a large extent (Li et al. 2016; Weber et al. 2018; Chen et al. 2022.

For example, PCBs used in high volumes in sealants and paints from the 1950s to approximately 1975 are still in use to more than 50 % (Weber et al. 2018). Since 1970s SCCPs/MCCPs were used in sealants and paints in buildings.

Table 10: POP concentration in polymers/plastic in construction (Weber 2022)*

POP	Uses	Content (% wt)**	References
HBCD	Expanded polystyrene (EPS)	0.5–1%	UNEP 2021c,d
HBCD, DecaBDE	Extruded polystyrene (XPS)	1–3%	Morf et al. 2003
DecaBDE, PentaBDE	PUR foam in insulation	4–13%	Leisewitz & Schwarz 2000
DecaBDE, PentaBDE	PUR foam fillers	22%	Leisewitz & Schwarz 2000
DecaBDE	PE insulating foam	20%	Morf et al. 2003
DecaBDE	PE and PP plastic sheeting	10%	Morf et al. 2003
DecaBDE, PentaBDE, HBCD	Roller blind and curtain	4%	Kajiwara et al. 2013
DecaBDE	Adhesive layer of reflective tapes	1–5%	RPA 2014
DecaBDE, PentaBDE	Intumescent paint	2.5–10%	RPA 2014
PCB, PCN, SCCP/MCCP	PVC based paints/coatings	5% to 20%	Jartun et al. 2009; UNEP 2021c
SCCP/MCCP, (DecaBDE)	PVC plastic sheeting	5–20% (5%)	Morf et al. 2003; Chen et al. 2021
SCCP/MCCP	PVC hosepipes for plumbing	0.5%–10%	Chen et al. 2021
SCCP/MCCP	PVC flooring, roofing, wall paper	0.5%–10%	Chen et al. 2021
SCCP/MCCP, PCB, PCNs	Cables	0.5%–10%	Chen et al. 2021
PCBs, SCCPs/MCCPs	Various elastic sealants	5% to 25%	Kohler et al. 2005
SCCP/MCCP	PUR sealants	10–50%	Chen et al. 2021; Brandsma 2021

*Please note that only a minor unknown share of the polymers contain POPs
**Concentration range for intentional POP additive

6.1.3 Recommendations on monitoring POPs in plastics from construction

6.1.3.1 Development of a standardized methodology for taking representative samples

POPs in buildings are not systematically monitored and there is a lack on monitoring of POPs in buildings with only a few larger systematic studies on PCB in sealants and paints (Kohler et al. 2005; Jartun et al. 2009). Information of the presence of POPs and CoCs in buildings is in particular relevant for management of POPs and other CoCs in buildings and future recycling of plastics and other polymers from this sector. Therefore, guidance documents are needed for the assessment of buildings during renovation and for demolition.

The Bavarian Environment Agency published a guidance on controlled deconstruction of buildings, considering the management of pollutants, including POPs (Bavarian Environment Agency 2019). The guidelines emphasize that selective/controlled dismantling today is a standard in deconstruction of buildings in Germany and that it is essential to assess pollutants during a pre-investigation of the building. (Bavarian Environment Agency 2019).

Similarly, Switzerland published a guidance «construction and demolition waste» which outlines the legal basis for the disposal of C&D waste (Schweizer Bundesamt für Umwelt 2020).
In particular, specifications for determining pollutants and the creation of a disposal concept are defined, e.g., for PCBs and CPs, and the disposal of asbestos-contaminated C&D waste is regulated. However, brominated or fluorinated POPs are not mentioned in the guidance documents yet. Furthermore, both guidance documents are in German. Therefore, there is a lack of guidance documents for a comprehensive assessment of POPs and other CoCs in buildings and for deconstruction of buildings. It is recommended that such a guidance is developed for appropriate management of POPs and other CoCs in buildings and C&D waste and recycling. This should also include monitoring strategies of POPs & other CoCs in buildings.

6.1.3.2 Lack of screening of POPs in plastics in construction and need for monitoring

For the nearly 2 million tonnes of PBDEs produced, it is estimated that more than 20 % were used in plastics in buildings (Table 11; Abbasi et al. 2019). Due to the long service life of plastics in buildings of 30 to 50 years, the largest remaining PBDE stocks is likely in buildings, while for EEE/WEEE, vehicles and furniture a large share of PBDEs has entered end of life (Abbasi et al. 2015). While the different uses of PBDE in buildings are known (UNEP 2021b), no monitoring data on PBDE in these plastics in use or in construction has been published to indicate the frequency of use.
It is also probable that the largest share of stocks of SCCPs and MCCPs is likely in buildings considering the major use of SCCPs/MCCPs in PVC (Chen et al. 2021) and the major use of PVC in buildings (Figure 6; Plastics Europe 2022).
While monitoring and information for PCB in sealants and paints are available from high-income countries such as Germany, Norway, Sweden, Switzerland or USA (Kohler et al. 2005; Jartun et al. 2009; Weber and Herold 2015; USEPA 2023) a similar monitoring is missing for PBDEs, SCCPs/MCCPs, UV-328 and Dechlorane Plus.
A systematic monitoring of POPs in buildings is essential, for example, to understand former use of technical PBDE mixtures in construction, including major use, frequency, and time of use. Hardly any monitoring data for the newly listed POPs, UV-328 and Dechlorane Plus, in buildings and C&D waste are available. Therefore these newly listed POPs should be included in such screening as appropriate. Therefore, such systematic monitoring in buildings and in C&D waste and recycling is recommended. Since PCBs and PCNs have been substituted by SCCPs/MCCPs in major polymer uses in construction (sealants, paints/coatings, and adhesives) (Table 9 and Table 10), monitoring for these uses can be combined.

Table 11. Percentage of commercial PBDEs in major uses and average lifespan of product type (Abbasi et al. 2019 with additions on lifespan for low-income countries)

Use area	c-PentaBDE	c-OctaBDE	c-DecaBDE	Lifespan*[years]
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-income countries

6.1.4 POPs in wood in construction

Wood used in construction was a major application for pentachlorophenol (PCP) and also a range of other POPs have been applied (e.g. lindane, DDT, endosulfan, PCBs, PCNs) for wood treatment in construction including timber wood mainly from the 1950s to 1980s. Other wood treated with PCP and possibly other POPs has been used as utility poles and cross arms and for railway sleepers. Due to the long service life some of this wood is still in use and can enter recycling.
It is recommended to assess current wood recycling and reuse of wood in The Netherlands and possibly monitor certain fraction of recycled wood.

6.2 POPs in the transport sector and recommendation for monitoring

6.2.1 Plastics in the transport sector

The transport sector plays a crucial role in the flow of materials, encompassing cars, industrial vehicles, trains, ships, and airplanes. Currently, there are 1.45 billion vehicles worldwide, of which 1.1 billion are passenger cars. These passenger cars alone contain approximately 200 million tonnes of plastics. With a lifetime of approx. 15 years, it can be estimated that approx. 14 million tonnes of plastic waste are generated each year exclusively from end-of-life passenger vehicles (Weber 2022).
The plastics present in vehicles are very diverse and include thermoplastics and thermosets, such as foams, rubbers, and synthetic textiles, which are increasingly used in the manufacturing of modern cars. Plastics and other polymers in commercial vehicles comprise about 50 % of all interior components, including safety subsystems, doors, and seat assemblies. Aiming to reduce weight, the average content of plastic/polymers in cars has increased over the last 50 years. While cars produced in the 1970s contained 50 kg plastic/polymers, this figure rose to 160 kg in 2008, and for some years now, the average cars contain more than 200 kg plastic/polymers, including approx. 25 kg of synthetic textiles (Szeteiova 2010; American Chemistry Council 2016).
Various types of plastic are used in the transport sector in different proportions (Box 3; and Figure 6 page 38), of which PP, PUR, HD/MDPE, PA (polyamide), PC, and ABS/SAN (styrene acrylonitrile resin) are the most commonly used.

6.2.2 POPs in plastics in the transport sector

A wide range of POPs are present in the transport sector such as brominated flame retardants (PBDEs, HBCD), SCCPs/MCCPs Dechlorane Plus, UV-328, and PFOA/PFOS related compounds (Table 12). Furthermore, several POPs have received exemptions for the continued production or use in vehicles, such as decaBDE (Table 13), Dechlorane Plus (Table 14), and UV-328 (Table 15). The lists of exemptions also specify in what plastic parts the respective POPs might be present.

PBDEs are the most extensively studied POPs in vehicles, as transport was a major use (Abbasi et al. 2019; Table 11) and has exemptions for decaBDE use in vehicles under the Stockholm Convention (Table 13; UNEP 2021a). Their major use was/is in back-coated textiles, such as rear decks, upholstery, headliners, automobile seats, headrests, sun visors, trim panels, and carpets (see case study Section 6.2.4.1.) (Kajiwara et al. 2014). Furthermore, depending on the flammability standard, also PUR foam can be flame-retarded in cars, especially in those manufactured in the US, where 90 % of c-PentaBDE was used, mainly in seats, headrests, or armrests until 2004 (Abbasi et al. 2019; UNEP 2021b), as confirmed by monitoring studies in Japan and the Netherlands (Leslie et al. 2013; Kajiwara et al. 2014). Furthermore, a range of small plastic parts in the powertrain, such as cables and electrical connectors, can contain decaBDE (Table 13). Also, for Dechlorane Plus and UV-328 the major use was/is in vehicles (see Section 0 and 0).

Currently, there is no data available on which producers have used POPs in which model. Therefore, only XRF screening in currently used vehicles (or end-of-life vehicles) and subsequent instrumental analysis could clarify the presence or absence of these POPs in the respective vehicles.

HBCD has been used until approx. 2013 in low volumes in vehicles and has only been detected in a few floor coverings so far (Kajiwara et al. 2014; Section 6.2.4.1). In addition, HBCD-containing polystyrene foam has been used in refrigeration trucks/vans and is likely still present in such vehicles today.

HBB is of minor relevance overall, with only approx. 5,400 t produced in the United States from 1970 to 1976 (UNEP 2021a). Therefore, only cars and other vehicles produced in those years in the US might contain treated PUR foam and possibly other plastic/polymers, and a few of such HBB-containing cars might still be in use or available for sale as vintage cars.

Table 12: POPs used in the transport sector and related use period.

POP	Application in transport sector	Use period*
DecaBDE	Use in private and public transportation; in maritime, aviation and land transport, as well as astronautics	Current and former uses. Continued use is allowed for a range of plastic parts
c-PentaBDE (tetra/pentaBDE)	Flame retardants in PUR foam (seat, head rest) and textiles in vehicles from US	Former use in vehicles (1970 to 2004)
HBCD	EPS/XPS insulation in refrigerator trucks. Minor use in transport textiles (seating, floor coverings)	Former use (1970 to 2013)
HBB	Vehicles in the United States	1970 to 1976
SCCPs/MCCPs15	Plasticizer and FR in cables and other PVC and rubber parts in vehicles	Current and former uses. Use of SCCP is exempted in PVC
PFOA	Side chain fluoropolymers in textiles and carpets; impurity in fluoropolymers	Current and former uses
PFOS	Side chain fluoropolymers in textiles and carpets	Former uses (main use before 2002)
Dechlorane Plus	Use as flame retardant in plastic in the automotive and aviation sector	Continued use
UV-328	Bumpers; liquid crystal panels and meters; paint; resin used for interior and exterior parts	Continued use

*Vehicles and plastics in vehicles have a long service life in low- and middle-income countries, often 30 years and longer;

Table 13: Specific exemptions under the SC for decaBDE parts for use in vehicles

Specific exemption	Application
(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 (MAC) pipes, powertrains, exhaust manifold bushings, under-hood insulation, wiring and harness under hood (engine wiring, etc.), speed sensors, hoses, fan modules and knock sensors; (ii) Fuel system applications such as fuel hoses, fuel tanks and fuel tanks under body; (iii) Pyrotechnical devices and applications affected by pyrotechnical devices such as air bag ignition cables, seat covers/fabrics (only if airbag relevant) and airbags (front and side); (iv) Suspension and interior applications such as trim components, acoustic material and seat belts.
(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, head rests, sun visors, trim panels, carpets**.

Table 14: Specific exemptions under the Stockholm Convention for Dechlorane Plus in vehicles

Specific exemption	Exempted application
Replacement parts for, and repair of, articles where Dechlorane Plus was originally used in the manufacture of those articles and may be available, limited to the following applications, until the end of the service life of the articles or 2044, whichever comes earlier:	Motor vehicles (covering all land-based vehicles, such as cars, motorcycles, agricultural and construction vehicles, and industrial trucks; applications include cables, wire harnesses, connectors, and insulation tapes);
	Aerospace (such as aircraft engine fan case rub strip products and voidfilling and edge-sealing products, aircraft engine manufacturing repairs, electrical items, structural panels, and aircraft cabin interiors);
	Space (such as satellites, probes and other exploration equipment, manned cabins and laboratories, heat-insulating materials for rocket motors, and ground support equipment);
	Defence (such as naval vessels, missiles, launch platforms, ordnance, communication equipment, radar and lidar systems, and support equipment)
	Stationary industrial machines (such as tower cranes, concrete plants, and hydraulic crushers; applications include cables, wire harnesses, connectors, and insulation tapes) for use in agriculture, forestry and construction;
	marine, garden, forestry, and outdoor power equipment.

Table 15: Specific exemptions under the SC for UV-328 in vehicles

Specific exemption	Exempted application
Replacement parts for articles where UV-328 was originally used in the manufacture of those articles until the end of the service life of the articles or 2044, whichever comes earlier	Motor vehicles (covering all land-based vehicles, such as cars, motorcycles, agricultural and construction vehicles, and industrial trucks);
	Stationary industrial machines (such as tower cranes, concrete plants, and hydraulic crushers) for use in agriculture, forestry, and construction;

6.2.3 Monitoring POPs in new vehicles, vehicles in current use, and vehicle parts

Overall, there is a lack of monitoring data of POPs in the transportation sector. Only a few studies have conducted screening of a limited number of POPs, in particular PBDEs (e.g., Leslie et al. 2013; Kajiwara et al. 2014; Redin et al. 2017; Liu et al. 2019).
For newly listed POPs like Dechlorane Plus and POP-PFAS initial data are available for automotive shredder in Europe (Norwegian Environment Agency 2021). Given the listed exemptions in the Stockholm Convention for Dechlorane Plus (Table 14) and UV-328 (Table 15), more monitoring in used and new vehicles is needed.

6.2.3.1 Methodology used for monitoring of POPs in new and in-use vehicles and spare parts

POPs can be monitored in new vehicles on the market or in imports. However, sample collection is typically destructive and, therefore, challenging in new vehicles. One non-destructive option to screen POPs in products is the use of wipe tests developed for no destructive screening by research groups in Australian and the Netherlands (Gallen et al. 2014).

For this simple wipe test, respective samples are treated with a pre-cleaned filter paper folded into quarters and wetted with isopropanol, then wiped firmly in concentric circles towards the middle of the area. Rinsing this filter paper allows for the determination of BFRs present, even in a semi-quantitative manner (Gallen et al. 2014). In the test, c-OctaBDE congeners, decaBDE, and tetrabromobisphenol A (TBBPA) were detected with relatively high accuracy (>75 %) when confirmed by destructive chemical analysis (Gallen et al. 2014). Such wipe tests can likely also screen for other POPs additives. XRF is another non-destructive screening option, although it can only determine bromine or chlorine content (UNEP 2021c).
Monitoring of POPs in spare parts is another approach to monitor POPs in vehicles. Exemptions for vehicle (spare) parts for decaBDE (Table 13), Dechlorane Plus (Table 14), and UV-328 (Table 15) have been granted and the listed parts could be screened with a priority.
Gallen et al. (2014) screened 125 car accessories using XRF screening and wipe tests but did not find any part with bromine concentration above 1 %. Nevertheless, the study primarily focused on brominated compounds and specific product categories.

6.2.4 Methodology used for monitoring POPs in plastics in end-of-life vehicles (ELVs)

6.2.4.1 Sampling and analysis of plastic/polymers from individual ELVs (Japan)

Monitoring of individual vehicles and compiling those studies is useful to get a detailed overview of the use of PBDE mixtures (or other additives), including:

- The age distribution of the use of e.g. PBDEs, SCCPs, MCCPs, Dechlorane Plus, UV-328
- The regional distribution of the use of PBDEs SCCPs, MCCPs, Dechlorane Plus, UV-328
- Whether specific POPs use is associated with certain companies or products

When conducting such a study, the following information is recorded in the sampling process, if available:

- Producer and model name
- Country of origin (since several large producers were/are producing in different regions/countries with different flammability standards and, therefore, flame retardant use)
- Production year

To date, only one study has screened PBDEs and HBCD in vehicles in detailed. It examined 515 materials/components in 43 Japanese and 2 US vehicles produced between 1993 and 2012 using XRF (Kajiwara et al. 2014; Liu et al. 2019). The XRF survey showed that 32 out of 515 materials/components investigated (6.2 % of the total) contained ≥0.1 % of bromine.

The sampled components with bromine content above 0.1 % were further analysed for PBDEs and HBCD in the laboratory. Major components that contained PBDEs (or other FRs) ≥0.1 % by weight included seat fabric, floor covering, and soundproof materials (Table 16). The predominant PBDE detected was decaBDE, mainly in seat fabric. Furthermore, PUR foam in seats and headliner from a US car contained c-PentaBDE which is similar to the study in the Netherlands (Leslie et al. 2013). 90 % of c-PentaBDE was used in the USA (likely affecting all of North America) which has high toxicity/health cost (Attina et al. 2016) and bioaccumulation potential. Lower levels and cost are considered for the EU (Trasande et al. 2015).

HBCD were found only in two floor coverings (Table 16), indicating lower relevance.

Plastic parts of car seats, floor mats, and dashboards did not contain BFRs above 1000 mg/kg in all 45 vehicles (Kajiwara et al. 2014). It needs to be stressed that 60 samples contained bromine levels between ≥0.01 % and ≤0.1 %, and around 50 % of samples had bromine levels between ≥0.005 % and ≤0.01 % (Kajiwara et al. 2014), suggesting contamination from recycling or secondary sources.

The study focus did not include powertrain, under-hood applications, and fuel system applications, which might also contain PBDEs (see Table 13).

The use of PBDEs and HBCD might be different in other regions, as seen for c-PentaBDE in US cars (as seen in this study for Japan and The Netherlands (Leslie et al. 2013) in Section 0).

Similar studies are lacking for European cars. Similar studies are also lacking for other POPs known to have been used in vehicles (Dechlorane Plus, UV-328, POP-PFASs; SCCPs/MCCPs). In addition, certain hazardous phosphorus flame retardants (PFRs), such as the carcinogenic tris(1,3-dichloro-2-propyl) phosphate (TDCPP), substituted PBDEs in PUR foam and possibly textiles are relevant.

- Table 1: PBDE/HBCD (mg/kg) in bromine positive components of 45 vehicles/515 components (Kajiwara et al. 2014)

	n	ID	Br	PBDEs	HBCDs
Seat fabric	16	ELV-03	50,000	78,000	<LOD
		ELV-39	45,000	62,000	<LOD
		ELV-24	41,000	52,000	11
		ELV-07	34,000	46,000	50
		ELV-27	34,000	49,000	0.46
		ELV-11	34,000	43,000	<LOD
		ELV-31	34,000	48,000	<LOD
		ELV-04	32,000	45,000	<LOD
		ELV-42	23,000	26,000	0.21
		ELV-10	5,600	5,500	<LOD
		ELV-46	5,400	<LOD	<LOD
		ELV-01	5,200	<LOD	<LOD
		ELV-43	4,500	7.0	1.8
		ELV-32	3,700	110	0.15
		ELV-47	3,000	0.040	<LOD
		ELV-29	2,600	100	<LOD
Floor covering	4	ELV-43	14,000	2.2	13,000
		ELV-32	5,500	6,700	<LOD
		ELV-25	4,500	16	3,000
		ELV-11	<LOD	16	<LOD
Soundproof material	3	ELV-11	6,000	6,600	<LOD
		ELV-40	2,100	820	<LOD
		ELV-40	1,200	11	<LOD
Seat PUF	2	ELV-10	38,000	52,000	0.17
		ELV-15	2,000	3.4	<LOD
Headliner	1	ELV-30	5,600	8,200	<LOD
Door trim fabric	1	ELV-44	4,200	0.025	450

6.2.4.2 National monitoring of PBDEs in the waste stream, including vehicles (The Netherlands)

The Dutch authorities investigated how waste materials that possibly contain PBDEs are sorted, separated, disposed of, recycled, landfilled, incinerated and/or exported in the Netherlands (Leslie et al. 2013). The relevant background information was collected through interviews with key actors in the waste sector, as well as from reports and scientific literature. For ELVs and WEEE, national organizations coordinated the sampling and processing activities (Leslie et al. 2013). In general, PBDEs were found in very few single car parts. Seats of American cars were identified as PBDE hot spot within ELVs, with concentrations of up to 25,000 µg/g in the PUR foam of a Pontiac car seat (mostly c-PentaBDE congeners) (Leslie et al. 2013).

6.2.4.3 Sampling and analysis of plastic and polymers from shredder fractions of ELVs

As for the WEEE plastic (see Section 6.3.3), a robust assessment and monitoring of the average POP content in ELVs can be conducted by monitoring POPs considering national monitoring of ASR and other screenings (Liu et al. 2019). In high-income countries, shredding is the main end-of-life treatment method for vehicles. After shredding, the shredded material is separated into heavy and light ASR. The light ASR fraction (representing 15 to 25 % of the shredding) contains plastic, polymers, textiles, and rubber, including the main share of POP plastic additives. Furthermore, the shredder fractions can be screened for bromine, indicating PBDEs and other BFRs, and could be further monitored (Danish EPA 2014). These light shredder fractions can be sampled and analysed for the individual POPs present in vehicles (Table 12) that are relevant for further management options. A range of data for PBDEs in ASR are available (UNEP 2021a). Only initial data for Dechlorane Plus, SCCP/MCCP and extractable POP-PFAS have been generated in a recent study of European ASR (Norwegian Environment Agency 2021).

6.2.5 Recommendation for further monitoring of POPs in vehicles

6.2.5.1 Development of a standardized methodology for taking representative samples

While standardized methodologies for taking representative samples of plastic in WEEE have been developed (Wäger *et al.* 2010; CENELEC 2015), a similar standardized sampling procedure is currently lacking for end-of-life vehicles. Therefore, it would be useful to develop a standardized methodology, possibly led by organizations like CENELEC to generate robust data of POPs and other chemicals of concern in ELVs. This would enable the development of robust impact factors of POPs and other CoCs for more reliable inventories and data for a risk assessment for end-of-life management for vehicles in particular the light fraction of automotive shredder residues (ASR) containing plastics, rubber and textile fraction and therefore POPs and other CoCs.

6.2.5.2 Recommendation of more POPs data in ASR with a wide POP spectrum

Currently, only a few robust data for PBDE in ASR are available, mainly from Japan and some from Europe (UNEP 2021a; e.g. 6.2.4.3). Only some initial data on other POPs in ASR, such as Dechlorane Plus, SCCPs/MCCPs and PFOS/PFOA have been generated in an European study (Norwegian Environment Agency 2021). Therefore, there is a need for more POP monitoring data in ASR from different regions, covering relevant POPs.

6.2.5.3 Recommendation for monitoring recyclates from post shredder technology PST

The Netherlands had a large EU project on post shredder technology to reach the required recycling and recovery rates (85 % and 95 %) required by (ARN RECYCLING B.V. 2015).
It is recommended to assess what recyclates come out of these facilities and monitor different POPs groups in the recyclates (see related recommendation of PFAS monitoring in the fibre fraction in Section 5.4.1). In these fractions UV-328 and other BUVs, POP-BFRs, SCCPs/MCCPs and Dechlorane Plus and other Dechloranes can be monitored.

6.2.5.4 Recommendation of more screening for individual plastic part categories and POPs

Up to now, only a few screening studies of PBDEs and HBCD in individual components of vehicles have been published (Leslie et al. 2013; Kajiwara et al. 2014; Redin et al. 2017; Section 6.2.4).
It is recommended that also other POPs present in vehicles are screened in major individual parts (e.g. UV-328 in bumpers and grills see Section 3.4.3).
In such screenings also other chemicals of concern in plastic (UNEP and BRS Secretariat 2023) could be included in the monitoring.

6.2.5.5 Recommendation for POP monitoring in plastics in trains, planes, and ships

While it is known that, e.g., PBDEs have been frequently used in materials in public transport like trains and airplanes (Weber 2022), with related exposure (e.g. Allen *et al.* 2013; Strid *et al.* 2014), there is no robust monitoring study on POPs in plastics (including textiles) used in trains, airplanes, or cruise ships. There is also a complete lack of monitoring of POPs in end-of-life airplanes, ships and trains/trams. These transport categories have a high use of flame retardants which included PBDEs, HBCD and Dechlorane Plus. Also seats and possibly other surface are likely treated with stain repellents possibly containing PFOS, PFOA, PFHxS and related substances including side-chain fluorinated polymers (OECD 2022) containing these POPs and related compounds (e.g. long-chain fluorotelomers). These transport categories have a long service life and therefore the PBDEs, HBCD, SCCP/MCCP and POP-PFAS used in the past decades are likely still present in the respective fleets and are entering end-of-life.

6.3 POPs in EEE/WEEE and recommendation for monitoring

6.3.1 Plastic in EEE and WEEE

In 2022, 62 million tonnes of waste electrical and electronic equipment (WEEE; e-waste) were generated containing more than 12 million tonnes of plastic which need to be managed in an environmentally sound manner (UNITAR & ITU 2024; UNEP 2021b). Plastics are present in virtually all EEE and are commonly used in casings, frames, covers, and small parts of these devices. Various types of plastic are used, including ABS (acrylonitrile butadiene styrene), PS (polystyrene), and PP (polypropylene), which are common in the manufacturing of computer or televisions, for example. Additionally, many other types are used depending on the characteristics needed, as well as the plastic compounds.

The major amount of plastic is found in the following main EEE categories:
Large household appliances (such as freezers, refrigerators, air conditioners, washing machines, dishwashers, clothes dryers, and cookers); small household appliances, which are portable or semi-portable machines designed to perform household task (for example, microwave ovens, toasters, humidifiers, and coffeemakers). Another major category is Information and Communication Technology (ICT) equipment, which includes computers and computer screens, copy/fax machines, scanners, and printers. Lastly, a final relevant category is consumer equipment, including e.g. TVs (both CRTs and flat screens), radios, video cameras, and cameras.

6.3.2 POPs in plastics in EEE and WEEE

Plastic fractions from WEEE are the largest and most relevant products and material streams contaminated with PBDEs. For the recycling and recovery of plastic and other materials from WEEE, it needs to be considered that a share of the WEEE plastic contains POPs that are still being produced and used (see Table 9 and Table 17) and also some legacy POPs whose production has ceased but are present in EEE that is in use (see Table 9 and Table 17).
Table 17 provides an overview of POPs in EEE, their major or minor use, and the period of use. While this is known, the detailed presence and use of POPs in different EEE/WEEE categories and different EEE parts are less known and have only been investigated in some regions or countries (Wäger *et al.* 2010; Sindiku *et al.* 2015; Hennebert and Filella 2018). Furthermore, the amount of POPs in plastic waste changes over time depending on the time of production/use of a certain POP and the service life of a certain product category (Table 11) and therefore monitoring studies should be updated in certain intervals.
The use of different POPs has been specific to different plastic types, such as the predominant use of c-PentaBDE in PUR foam, c-OctaBDE in ABS, HBCD in polystyrenes (EPS, XPS, and HIPS), or SCCP/MCCPs[15] in PVC and PUR spray foams (UNEP 2021b,d; Chen et al. 2021, 2022).

Table 17: POPs used in plastic in electrical and electronic equipment and period of use (Weber 2022)

POP	**Application in EEE**	**Use period***
c-DecaBDE	Flame retardant with use in many plastic types in casings of EEE, cables, and other plastic parts in EEE	Current and former uses. Continued use is allowed for certain casings of electronics
c-OctaBDE (hexaBDE and heptaBDE)	Flame retardant with former use mainly in cathode ray tube casings in TV and computers, office equipment	Former use (1970 to 2004)
c-PentaBDE (tetraBDE/ pentaBDE)	Flame retardant in PVC cables, printed circuit boards, and PUR foam	Former use (1970 to 2004)
HBCD	Minor flame retardant used in HIPS in CRT casings and other HIPS plastic parts	Former use (1970 to 2013)
SCCP/MCCP	Plasticizers and FR in cables and other PVC and rubber parts	Current and former uses. SCCP is exempted for use in PVC
PCBs and PCNs	Cables (PVC and others); (and capacitors);	Former use (PCBs 1950 to 1980s; PCNs 1930s to 1960s)
PFOA	Medical devices; nonintentional in fluoropolymers	Current and former uses
PFOS	Medical devices	Mainly before 2002
Dechlorane Plus	Flame retardant use for wire and printed circuit board housing, other plastics, and rubber parts	Former and current uses
UV-328	UV absorber in liquid crystal displays	Since 1970s

*EEE and plastics in EEE have a wide service life span of a few years (e.g. mobile phones) to some EEE with service life of more than 30 years

6.3.3 Best practice study of monitoring POPs in WEEE plastic

When conducting analysis of POPs in plastics, best practice should be considered. For WEEE plastic standard sampling methodologies have been developed by Switzerland (Wäger et al. 2010) and by CENELEC TS 50625-3-1:2015 (CENELEC 2015). Such sampling protocols are the precondition for generating representative samples.

In a Swiss national monitoring study on hazardous chemicals in WEEE shredder, POPs flame retardants and a wide spectrum of other flame retardants were measured (Taverna et al. 2017; Table 18). The most frequently found halogenated flame retardants were tetrabromobisphenol A (TBBPA), decabromodiphenyl ether (DecaBDE), decabromodiphenylethane (DBDPE), 1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE), and octabromodiphenyl ether (OctaBDE). These five substances were present at levels >100 mg/kg WEEE (>300 mg/kg WEEE plastic). Dechlorane Plus was detected at an average concentration of 33 mg/kg WEEE (100 mg/kg WEEE plastic) (Table 18).

*Table 18: Concentrations of POPs and other flame retardants in Swiss WEEE** sampled 2011 (Taverna et al. 2017)*

Substance in WEEE	**Mean value and uncertainty [mg/kg total WEEE]*** **
PentaBDE	2.4 ± 0.69
OctaBDE	120 ± 33
DecaBDE (BDE 209)	390 ± 45
HBCD	14 ± 4.1
TBBPA	630 ± 85
Decabromobiphenyl (DecaBB)	4.5 ± 2.7
2,4,6-Tribromophenol*	18 ± 1.4
1,2-Dibrom-4-(1,2dibromethyl) cyclohexan (DBE-DBCH)*	19 ± 1.0
2,3,4,5,6-Pentabromtoluol (PBT)*	3.7 ± 0.2
2,3,4,5,6-Pentabromethylbenzol (PBEB)*	3.7 ± 0.2
Hexabromobenzene (HBB)	2.9 ± 1.7
Mirex*	3.7 ± 0.2
2-Ethylhexyl-2,3,4,5-tetrabrombenzoat (EH-TBB)*	3.7 ± 0.2
1,2-Bis(2,4,6-tribromphenoxy)ethanBTBPE	150 ± 14
Bis(2-ethylhexyl)tetrabrom-phthalat (BEH-TEBP)*	3.7 ± 0.2
Dechlorane Plus DDC-CO	33 ± 11
Decabromdiphenylethan (DBDPE)	340 ± 200
2,4,6-Tris(2,4,6-tribromphenoxy)-1,3,5-triazin	14 ± 4.8

* Frequently below the limit of quantification **Without large household appliances ***The values are calculated to total WEEE and was ~three times higher in the approx. 30 % plastic fraction (Taverna 12/2023[17]).

A related Swiss study on monitoring RoHS substances in WEEE plastics in Europe analysed different WEEE categories for PBDEs and HBCD (Wäger et al. 2010). This study showed that the application frequency depends on the type of EEE driven by flammability standards for individual EEE (Table 19; Charbonnet 2020; UNEP 2021b). The impact factor for PBDEs in different WEEE categories was used as a major basis for the inventory impact factors.

Table 19: POP-PBDE content in polymer fractions of different WEEE categories in Europe (UNEP 2021b based on Wäger et al. 2010 and Hennebert and Filella 2018)

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**
2	Small household appliances				<0.1	0.5	**0.17**
3	ICT equipm. 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 (1 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 Convention provisional low POPs limit for PBDEs is currently 1000 mg/kg (1 kg/t) or 500 mg/kg (500 g/t) or 50 mg/kg (50 g/t)

[17] Personal communication with Ruedi Taverna 29.12.2023

A third monitoring we consider best practice is the study of Haarman et al. 2018 on monitoring BFRs including PBDEs and HBCD in large household appliances (LHA) ('White goods') separated into cooling & freezing appliances (CFA) and other LHA (Haarman et al. 2018). The study sampled shredded plastics from different countries (France, Greece, Italy Portugal, Spain, Switzerland and The Netherlands) with a robust sampling protocol to generate representative samples considering TS 50625-3-1:2015 (CENELEC 2015) (Haarman et al. 2018). This study documented that for this WEEE category, the levels are all considerably below 1000 mg/kg PBDEs (Figure 7). However, the study also showed a variability of PBDE levels with one CFA sample around 300 mg/kg PBDEs while for most CFA fractions PBDEs were not detected (Figure 7) since the major plastic of CFA is not flame retarded. The study however also revealed challenge of getting samples completely homogenized and representative and some variation in the measurement of two ISO17025 certified laboratories (Haarman et al. 2018).

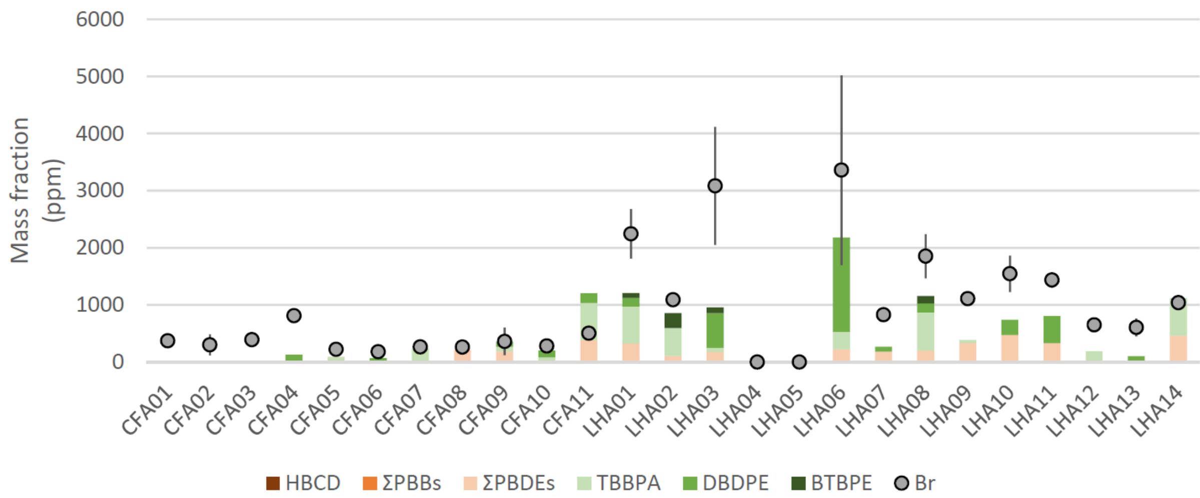

Figure 7: Average of total Br and individual BFRs measured in samples from each lot. Standard deviation of total Br is also displayed

6.3.4 Recommendations of POPs monitoring in plastic waste from WEEE

6.3.4.1 Recommendations of POPs monitoring in plastic waste shreds from WEEE

Only a few robust national studies of POPs in plastic shredder from WEEE are available and all from high-income countries (Schlummer *et al.* 2007; Wäger *et al.* 2010; Taverna *et al.* 2017; Hennebert and Filella 2018; Bill et al. 2022). In particular the national study from Switzerland with robust representative sampling and the analysis of a broad range of additives (Taverna et al. 2017) are useful and should be conducted every 5 or 10 years in Europe to understand the time trend of POPs and other CoCs in WEEE in Europe.
Such national studies of POPs and other chemicals of concern in plastic shredder from WEEE would be interesting for other countries/regions in particular low- and middle-income countries/regions.

Low- and middle income countries which only start WEEE management and plastic recycling might have a higher share of older WEEE with a higher average concentration of legacy POPs additives in the WEEE plastic as e.g. was reported in plastic of cathode ray tube (CRT) casings in Nigeria (Sindiku *et al.* 2015).
Such monitoring should consider robust sampling protocols and sampling standards (for example TS 50625-3-1:2015 (CENELEC 2016)).
All POPs present in WEEE plastic and possibly other chemicals of concern present in WEEE plastic (Taverna et al. 2017; Weber 2022) could be considered for such a monitoring.
By understanding the presence of POPs in different WEEE categories (Wäger et al. 2010; Hennebert and Filella 2018; Bill et al. 2022) risk fractions can be eliminated or better sorted. This can promote a more circular economy with reduced POPs amount in recycled plastic contributing to the implementation of the Stockholm Convention.

6.3.4.2 Recommendation for further monitoring of plastic parts in individual EEE categories

There are only a few studies which have monitored large amounts of individual EEE (for CRT casings see Sindiku et al. 2015) or individual pieces of electronics (Keeley-Lopez et al. 2020). The generation of such data sets are useful to understand the time or regional distribution of POPs use in EEE (Sindiku et al. 2015). The generation of information of individual parts in WEEE (Keeley-Lopez *et al.* 2020) can result in strategies for removing such parts before shredding.
To date, no studies have been published on e.g. individual flat screen TVs, air conditioners and a range of other WEEE. Furthermore, there is a lack of information on the new POPs Dechlorane Plus[18] (DP) and UV-328 in EEE.
It is reported that UV-328 is/was used in EEE as UV absorber in **liquid crystal displays in medical and in-vitro diagnostic devices and in liquid crystal displays in instruments for analysis, measurements, control, monitoring, testing, production, and inspection**. These EEE could be considered for a screening study of UV-328.
DP is found in the plastic of EEE/WEEE, such as cables, printed circuit boards, housings, other plastics, and rubber parts which could be specifically screened.
It needs to be stressed that monitoring POPs in individual equipment and equipment parts is time and cost intensive and might rather be a topic of a PhD (e.g. Sindiku et al. 2015). But also a few governmental studies have conducted such monitoring (best practice study Keeley-Lopez et al. 2020).

18 DP is used as non-plasticizing flame retardant in thermoplastic (e.g. polypropylene, polyester, ABS, natural rubber, polybutylene terephthalate and thermosets (e.g. epoxy and polyester resins, polyurethane foam, polyurethane rubber, silicon rubber).

6.4 Monitoring POPs and other CoCs in textiles

6.4.1 Background

Despite efforts, average recycling rates of textiles is still below 20 %, with only Europe reporting recycling rates slightly above 20 % (Bureau of International Recycling 2022). The implementation of the '2020 Circular Fashion System Commitment' by the international fashion industry, aimed at enhancing textile circularity[19], should lead to an increase in the recycling rate. However, this increase will necessitate monitoring of POPs and other chemicals of concern in textile recycling. In recent years some companies established large scale textile recycling like Re:claim (just went in operation)[20] or Renewcell (currently bankruptcy[21]). The Netherlands has established extended producer responsibility (EPR) scheme for textile in 2023 (Uitgebreide Producentenverantwoordelijkheid, UPV)) for promoting reuse and recycling[22] and activities of recycling textiles which likely result from this regulatory frame could be guided by monitoring of POPs present in textiles (Table 9) and other CoCs.

6.4.2 6.4.2 Lack of POPs/CoC monitoring in textile and carpet recycling

A recent review conducted by Wageningen University has emphasized the lack of studies monitoring contaminants in textile recycling, underscoring the need for further research (Undas et al. 2023). Monitoring POPs (and other chemicals of concern) in the textile recycling process represents a valuable opportunity to understand the presence of POPs in textiles in end-of-life, similar to what is done with shredded plastics from WEEE (see Section 6.3.3) or ASR of vehicles (see Section 6.2.4.3). Gathering robust data is essential to mitigate the risks associated with textile recycling, whether in the creation of new textile products or in the reuse of textiles containing POPs, such as tents in exposure sensitive contexts[23]. Moreover, recycled textiles are even suggested as possible substrate for low-cost hydroponic systems for growing vegetables (Brockhagen et al. 2021).

Synthetic carpets, where several POPs can be present (including PFOS/PFOA related compounds, PBDEs, and SCCPs/MCCPs), are often subjected to downcycling and repurposed in various applications such as outdoor equestrian areas (manèges), plastic recovery, the production of carpet fibres, automotive padding, and as a growth medium for plants (Changing Markets Foundation 2019). The fate of POPs additives and other chemicals of concern has not been thoroughly investigated in these scenarios or at least has not been published. Additionally, some carpets find a second life in gardens, where they serve as mulch and could release POPs and other chemicals of concern to the environment.

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19 https://www.oneplanetnetwork.org/knowledge-centre/resources/2020-circular-fashion-system-commitment-final-report

20 https://www.letsrecycle.com/news/polyester-recycling-plant-opens-as-part-of-project-reclaim/

21 https://www.renewcell.com/en/

22 https://business.gov.nl/regulation/collecting-recycling-textiles-upv/

23 https://cleaning-hacks.sharkclean.co.uk/15-ways-to-recycle-your-old-festival-tent/

6.4.3 Recommendation of monitoring of POPs in textiles

There is a need for monitoring of POPs in textiles throughout their lifecycle, including the chemicals and chemical mixtures used in their manufacturing, textiles on the market and textile waste **particularly, textiles undergoing recycling, including carpets.**

In the specific case of PFOS, PFOA, and PFHxS-related compounds, it is important to consider that the monitoring process must consider that a large share of POP-PFAS related compounds are likely present within side-chain fluorinated polymers (SFPs) (Fiedler *et al.* 2019; OECD 2022; UNEP 2023c). This aspect introduces unique challenges related to the extraction process.

6.4.3.1 Monitoring POPs in textile recycling

It is recommended to monitor POPs and other CoCs in textile waste and recycling. Samples could be sourced from companies which have started fibre recycling like Re:claim or Renewcell and could include product and waste samples.

Also, it is recommended to assess and possibly monitor the reuse and repurposing of textiles known to be treated with PFAS or BFRs (transport sector (see below 6.4.3.2), uniforms, firefighting gear, tents et cetera).

6.4.3.2 Monitoring textiles from ELVs and other vehicles

Textiles from the transport sector including vehicles are treated with different POPs (POP-BFRs and PFASs). These textiles end up in the light fraction of ASR. The Netherlands had a large EU project on post shredder technology (ARN RECYCLING B.V. 2015). It is recommended to assess what recyclates come out of this project and monitor POPs and other CoCs in the fibre fraction. For PFAS it needs to be assured that the side-chain fluorinated polymers are included (considering e.g. Liagkouridis et al. 2021; see also Section 5.4.1).

6.4.3.3 Monitoring POPs in carpet recycling

A major use of POPs-PFAS has been in synthetic carpets and rugs for stain repellency.

Also, other POPs and CoCs have been used in carpets. Carpets are recycled to some extent as insulation material or as padding material for seats in cars (Cure Afvalbeheer 2024). It is recommended to monitor PFASs (see Section 5.4.2), other relevant POPs and other CoCs in carpet recycling.

6.5 Agricultural plastic

6.5.1 Background and POPs in Agricultural plastic

Agricultural plastics account for around 3.5 to 4 % of all plastic produced, with approximately 12.5 Mt produced in 2017 and 15.6 Mt produced in 2021 (FAO 2021; Plastics Europe 2022a and Figure 5). The major plastic types used are LDPE, linear low-density polyethylene (LLDPE), PP, and PVC (Figure 6). Additives in agricultural plastics can be released directly into the environment, potentially contaminating agricultural soils and affecting food safety. As a result, agricultural plastics are considered as one of the priority sectors of chemicals of concern in plastics (UNEP and BRS Secretariat 2023).

POPs detected in agricultural plastics are in particular UV-328 and other BUVs (Yao *et al.* 2023; Section 3.3.2) as well as SCCP/MCCP (see Section 2.3.2; Chen et al. 2021).

6.5.2 Recommendation of monitoring of POPs in agricultural plastics

It is recommended to screen agricultural plastics for UV-328 and other BUVs (see Section 3.4.5) and agricultural PVC foils and other agricultural PVC for SCCP/MCCP.

In this monitoring also other POPs and CoCs could be monitored with target analysis and non-target screening approaches.

7 Unintentional POPs in chemicals and products

The EU has published a UTC for HCB of 10 mg/kg in 2022 (European Commission 2022a). UTC(s) are currently established for PCBs in chemicals and products (European Commission 2021a). This might impact the production and sale of some chemicals including pigments and it is recommended to monitor related pigments, dyes and other chemicals known to contain or possibly contain HCB or PCB.
The Japanese Government is measuring PCBs in pigments on the Japanese market and reported that several were above their UTC of 50 mg/kg (Table 20). They also initiated research into production of some pigments and suggested BAT limits for HCB and PCB for some chemicals (Government of Japan 2006, 2007). No similar study has been published in the EU the past 20 years while some monitoring has been conducted earlier (e.g. Heindl & Hutzinger 1989).

7.1 Monitoring PCB in pigments and dyes

In recent years PCB have been detected in a range of pigments (Anezaki & Nakano 2014; Anezaki et al. 2014; Hu and Hornbuckle 2010). These pigments are used for consumer products such as paints, plastics, print / magazines or packaging (including food).
The Japanese Ministry of Economy, Trade and Industry (METI) is monitoring the PCB content of pigments imported and used in Japan and have compiled data for batches of a range of pigments exceeding the Basel Convention low POPs limit for PCBs of 50 mg/kg (Table 20). Several of these pigments had PCB levels up to 2000 mg/kg for a Pigment Yellow-83 (Table 20).

Table 20: Pigment batches monitored by the Japanese Ministry of Economy and Trade exceeding 50 mg/kg limit for import or use in Japan (METI 2013)

Name of Pigment	Name of Product	Amount of PCB (mg/kg)
Pigment Red -2 (CAS: 6041-94-7)	ZA-855 Red	37～58 ppm
	PERMANENT RED G-87	52 ppm
	FAST RED F2R (PR-2) POWDER	61 ppm
Pigment Red -112 (CAS: 6535-46-2)	ZA-862 Red	16～121 ppm
	Permanent Red GY	
Pigment Yellow -12 (CAS: 6358-85-6)	Pigment Yellow 1207	1,500 ppm
	Disazo Yellow G 178－4	110 ppm
Pigment Yellow -13 (CAS: 5102-83-0)	DISAZO YELLOW 3GR-M	220 ppm
	DISAZO YELLOW 3GR-M-5	
Pigment Yellow -14 (CAS: 5408-75-7)	SUIMEI YELLOW GGNB	810 ppm
Pigment Yellow -17 (CAS: 4531-49-1)	SUIMEI YELLOW 7G	700 ppm
	SUIMEI YELLOW 7GKT	1000 ppm
Pigment Yellow -55 (CAS: 6358-37-8)	SUIMEI YELLOW DRO-10	1,500 ppm
	SYMULER Fast Yellow 4539	
Pigment Yellow -81 (CAS: 22094-93-5)	SUIMEI YELLOW F10G	79 ppm

Name of Pigment	Name of Product	Amount of PCB (mg/kg)
Pigment Yellow -83 (CAS: 5567-15-7)	SUMIKAPRINT FAST YELLOW HR-M	52～280 ppm
	SUMITONE FAST YELLOW HR-M-5	
	SUMIKAPRINT FAST YELLOW HR-T-2	
	SUMIKAPRINT FAST YELLOW HR	
	PY-2GN	
	SUIMEI YELLOW ERT	2,000 ppm
	SUIMEI YELLOW 5RT	
	Permanent Yellow HR-1183-2	59 ppm
Pigment Yellow -165 (C16H12Cl2N4O)	FAST YELLOW F5G	208 ppm
Pigment Orange -13 (CAS: 3520-72-7)	Orange BO-01	1,000 ppm
Pigment Orange -34 (CAS: 15793-73-4)	SUIMEI PYRAZOLONE ORANGE GR-N	190 ppm

7.2 Monitoring PCB in silicone

The use of bis (2,4)-dichlorobenzoylperoxide (2,4-DCBP) as cross-linking agent for the production of silicone rubber results in the specific formation of specific PCBs (PCB-47, PCB-51 and PCB-68) (Perdih & Jan 1994; Herkert et al. 2018). These PCBs partly remain in the silicone rubber and result in indoor exposure (Herkert et al. 2018). PCB levels in the silicone were reported around 10 mg/kg (Perdih & Jan 1994)

It is recommended to monitor silicone products for PCBs to contribute to the discussion of the PCB UTC limit.

7.3 Monitoring HCB (and possibly other UPOPs) in chemicals and pigments

7.3.1 Tetrachlorophthalic anhydride (TCPA)

TCPA is the primary feedstock for the production of a range of pigments. While no PCDD/PCDF data are available for TCPA, unintentional HCB concentrations as high as 3,000 mg/kg have been detected (Government of Japan 2006, 2007).

It is recommended to monitor TCPA in The Netherlands or the European market for HCB and possibly other UPOPs content.

7.3.2 TCPA-derived pigments

The UPOPs contamination of TCPA is a major source of UPOPs in TCPA-derived pigments. HCB is transferred into TCPA-derived pigments by TCPA used (Government of Japan 2006, 2007). TCPA-derived pigments include e.g. Pigment Yellow 110 (CAS 5590-18-1), Pigment Yellow 138 (CAS 30125-47-4), Solvent Red 135 (CAS 20749-68-2) and Solvent Red 162 (CAS 71902-17-5).

It is recommended to monitor these pigments for HCB and possibly other UPOPs in The Netherlands or better the European market.

7.3.3 Phthalocyanine dyes and pigments

Phthalocyanine dyes and pigments are widely used in paints and plastic. The global production rate in 2011 was about 420,000 tonnes (Linak et al. 2011).
Phthalocyanine dyes contain several unintentional POPs including PCDD/PCDF, PCB and HCB (Heindl & Hutzinger 1989; Ni et al. 2005; UNEP 2013; Anezaki & Nakano 2014).
Two phthalocyanine dyes - Phthalocyanine copper (CAS 147-14-8) and Phthalocyanine green (CAS 1328-45-6) - are listed with PCDD/PCDF and HCB emission factors in the Toolkit (UNEP 2013).
It is recommended to monitor these pigments for HCB, PCB and possibly other UPOPs in The Netherlands or the European market.

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Appendix 1 SCCP in consumer products in the EU

Consumer products assessed in European Union members states and Norway between 2013 and 2017 and found to contain SCCPs levels above regulatory limits (1500 mg/kg) (UNEP 2019a).

Table 21: Consumer products containing SCCPs on the EU market 2013-2017 (UNEP 2019a)

Year	Product	SCCP content mg/kg
2017	Sports equipment: Boxing gloves	4400
	Sports equipment: Gym ball	8500
	Toy pistol (plastic cord)	7000
	Bathtub pillow	17 000
	Electric shaver (cable)	9800
	Hobby/sports equipment: Hot pack	4000
	Hobby/sports equipment: Exercise tube	90 000 (handles)
	Speaker (cord)	10 000
	Radio controlled car (tyres)	17 000
	Claw hammer (Handle)	7000
	In-ear headphones (USB cord)	3000
	LED candle (cord)	13 000
	Power cord	26 000
	Tablecloth	6 000
	Selfie stick (cord)	45 700
	USB cable	16 000
	Bath toy	13 400
	Game controller	43 000
	Plastic doll	8 600
	Babies' sleeping bag/footmuff (packaging)	40 000
	Babies' sleeping bag (anti-slip knobs)	18 000
	Handle (cycle parts)	3 500
	Breastfeeding pillow (packaging)	60 000
	Hammer (handle)	2 800
	Sports equipment: Yoga mat	8 000
	Erotic article	4 400
2016	Lighting chain (cord)	7 000
	Sports equipment: Yoga mat	2 300
	Sports equipment: Abs trainer	4000
	Steering wheel cover	4 600
	Long sleeved sweater (print)	2 300
	Steering wheel cover	3 000
	Motor vehicle sidelight (cable)	2 600
	USB-cord	2 570

Year	Product	SCCP content mg/kg
	Selfie Stick	1 600
	Digital thermometer (cable)	1 100
	Stickers (toys)	9 000
	Stickers (toys)	14 000
	Mobile phone case	4 400
	Sports equipment: Baseball glove	13 600
	All-purpose mat	3 600
	Sports equipment: Yoga mat	6 400
	Sports equipment: Yoga mat	5 400
	Sports equipment: Yoga mat	32 000
	Sports equipment: Yoga mat	69 000
	Sports equipment: Yoga mat	3 500
	Sports equipment: Fitness gloves	1 800
	Rain cover for pushchair	7 300
	Extension lead	47 000
	Extension lead	17 000
2015	Kettle (cable)	36 400
	Game Controller (cable)	19 000
	Rubber knife	2 600
	Mobile phone cover	2 600
	Cloche cover (garden equipment)	4 000
	Toilet seat for children	710
	Plastic doll	3 170
	Toy doctor set (stethoscope)	49 100
	Electric kettle (cord)	5 000
	Beach ball	3 100
	Bouncy toy	5 000
	Bathmat	5 200
	Shower curtain	4 900
	Stickers (toys)	15 000
	Stickers (toys)	2 000
	Bathmat	5 300
	Shower hose	47 000
	Earphones	2 800
2014	Wallet (artificial leather)	1 300
	Handbag (artificial leather)	14 000
	Mobile phone bag (artificial leather)	1 100
	Brush case black (artificial leather)	3 500
	Toiletry bag	11 700
	Handbag (artificial leather)	3 800
	Handbag (artificial leather)	3 200

Year	Product	SCCP content mg/kg
	Bag (artificial leather)	2 700
	Small bag / purse (artificial leather)	1 700
	Wallet case for smartphones (artificial leather)	1 800
	Purse (artificial leather)	2 000
	Pencil case (artificial leather)	5 000
	Handbag (artificial leather)	10 000
	Toiletry bag (artificial leather)	1 300
	Toy car (tyres)	8 300
	Sports equipment: Exercise mat	16 000
	Sports equipment: Exercise mat	49 000
	Sports equipment: Jump rope	22 000
	Plastic cooking set (plastic bag)	8 800
2013	Beauty case	12 000
	Squeeze toy (chicken)	100 000
	Plastic bath toy	71 000
	Pirate slap-on bracelet	31 000
	Doll with accessories	15 000
	Police costume (transparent plastic pocket)	57 000
	Replaceable wall decorative stickers	18 000
	Pirate costume for children	2 800 (belt) and 1900 (vest)
	Plastic toy figures	83 000

Appendix 2 Abbreviations and Acronyms

ABS	Acrylonitrile butadiene styrene
ASR	Automotive shredder residues
BFR	Brominated flame retardant
BRS	Basel, Rotterdam and Stockholm conventions
BUVs	Benzotriazole UV stabilizers
c-DecaBDE	Commercial Decabromodiphenyl ether
c-OctaBDE	Commercial Octabromodiphenyl ether
c-PentaBDE	Commercial Pentabromodiphenyl ether
C&D waste	Construction and demolition waste
CAS	Chemical Abstracts Service
CFA	Cooling and freezing appliances
CoCs	Chemicals of concern
COP	Conference of Parties
CPs	Chlorinated paraffins
DBDPE	Decabromodiphenyl ethane
DDT	Dichlorodiphenyltrichloroethane
decaBDE; BDE-209	Decabromodiphenyl ether
DP	Dechlorane Plus
EEE	Electrical and electronic equipment
EPR	Extended producer responsibility
EPS	Expanded polystyrene
EU	European Union
GMP	Global Monitoring Plan
GRULAC	Group of Latin America and the Caribbean countries
HBB	Hexabromobiphenyl
HBCD(D)	Hexabromocyclododecane
HCB	Hexachlorobenzene
HDPE	High density polyethylene
heptaBDE	Heptabromodiphenyl ether
hexaBDE	Hexabromodiphenyl ether
HIPS	High impact polystyrene
LCCPs	Long-chain chlorinated paraffins
LHA	Large household appliances
MCCPs	Medium-chain chlorinated paraffins
MSDS	Material safety data sheet
PBDEs	Polybrominated diphenyl ethers
PC	Polycarbonates
PCBs	Polychlorinated biphenyls
PCNs	Polychlorinated naphthalenes

PCP	Pentachlorophenol and its salts and esters
PC-ABS	Polycarbonate/acrylonitrile-butadiene-styrene
PE	Polyethylene
PET	Poly(ethylene terephthalate)
PFASs	Per- and polyfluorinated alkylated substances
PFHxS	Perfluorohexane sulfonic acid
PFOA	Perfluorooctanoic acid; Perfluorooctanoate
PFOS	Perfluorooctane sulfonic acid; Perfluorooctane sulfonate
PFOSF	Perfluorooctane sulfonyl fluoride
PIR	Polyisocyanurate
PMMA	Poly(methyl methacrylate)
POPs	Persistent Organic Pollutants
POPRC	Persistent Organic Pollutants Review Committee
POP-BFRs	Brominated flame retardants that are listed as POPs
POP-PFAS	Per- and polyfluorinated alkylated substances that are listed as POPs
PP	Polypropylene
PUR	Polyurethane
PVC	Polyvinyl chloride
RAPEX	Rapid Exchange of Information System (of Europe)
SCCPs	Short-chain chlorinated paraffins
SCIP	Substances of Concern In articles as such or in complex objects (Products)
SFPs	Side-chain fluorinated polymers
SVHC	Substance of very high concern
t	Tonnes; metric tons
TCPA	Tetrachlorophthalic anhydride
tetraBDE	Tetrabromodiphenyl ether
TOP-assay	Total Oxidisable Precursor assay
UNEP	United Nations Environmental Programme
UPV	Uitgebreide Producentenverantwoordelijkheid
UTC	Unintentional trace contaminant
UV-328	2-(2H-1,2,3-Benzotriazol-2-yl)-4,6-bis(2-methylbutan-2-yl)phenol
WEEE	Waste electrical and electronic equipment
XPS	Extruded polystyrene