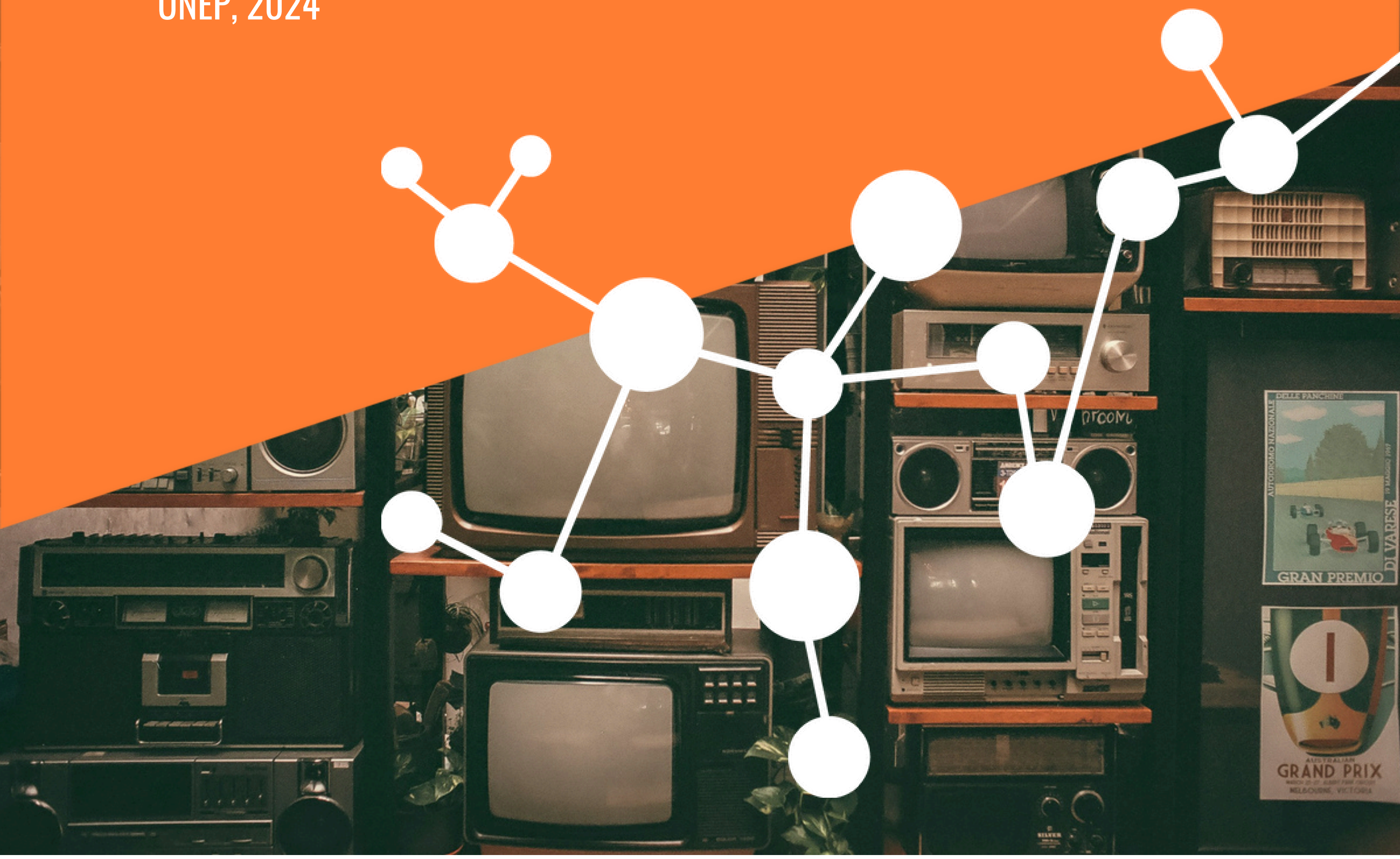
GUIDANCE

Sectoral Guidance for Inventories of POPs and Other Chemicals of Concern in Buildings/Construction, Electrical and Electronic Equipment and Vehicles

UNEP, 2024



UN environment programme

global environment facility
INVESTING IN OUR PLANET

ACKNOWLEDGEMENT

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

GEF is a family of funds dedicated to confronting biodiversity loss, climate change, pollution, and strains on land and ocean health. Its grants, blended financing, and policy support help developing countries address their biggest environmental priorities and adhere to international environmental conventions. Over the past three decades, the GEF has provided more than $23 billion and mobilized $129 billion in co-financing for more than 5,000 national and regional projects.

Recommended citation: *UNEP (2024), Sectoral Guidance for Inventories of POPs and Other Chemicals of Concern in Buildings/Construction, Electrical and Electronic Equipment and Vehicles.* This citation ensures proper acknowledgment and attribution in accordance with applicable standards.

DISCLAIMER

UN environment programme

gef global environment facility INVESTING IN OUR PLANET

Table of Contents

Abbreviations and Acronyms

ABS	Acrylonitrile butadiene styrene
ABSy	Anti-lock braking systems
ASR	Automotive shredder residues
BBP	Benzyl butyl phthalate
BFR	Brominated flame retardant
c-DecaBDE	Commercial Decabromodiphenyl ether
c-OctaBDE	Commercial Octabromodiphenyl ether
c-PentaBDE	Commercial Pentabromodiphenyl ether
CAS	Chemical Abstracts Service
CFCs	Chlorofluorocarbons
CMR	Carcinogenic, mutagenic, or reprotoxic
CoC	Chemicals of concern
CPs	Chlorinated paraffins
C&D waste	Construction & demolition waste
DBP	Dibutyl phthalate
DDT	Dichlorodiphenyltrichloroethane
decaBDE	Decabromodiphenyl ether; BDE-209
DEHP	Bis(2-ethylhexyl) phthalate
DIBP	Diisobutyl phthalate
DP	Dechlorane Plus
ECHA	European Chemical Agency
EDC	Endocrine disrupting chemicals
EEE	Electrical and electronic equipment
ELV	End-of-life vehicles
EPI	Emerging policy issue
EPS	Expanded polystyrene
ESM	Environmentally sound management
F-gases	Fluorinated gases
FAO	Food and Agriculture Organization of the United Nations
FR	Flame retardant
GHG	Greenhouse gas
GWP	Global warming potential
HBB	Hexabromobiphenyl
HBCD(D)[1]	Hexabromocyclododecane
HCFCs	Hydrochlorofluorocarbons
heptaBDE	Heptabromodiphenyl ether
hexaBDE	Hexabromodiphenyl ether
HFCs	Hydrofluorocarbons
HIPS	High impact polystyrene
MEAs	Multilateral Environmental Agreements
MCCPs	Medium-chain chlorinated paraffins
NIAS	Non-intentionally added substances
NIP	National Implementation Plan
NSO	National statistical office

[1] Abbreviation of hexabromocyclododecane in the Convention is HBCD while in scientific literature HBCDD is used.

ODS	Ozone-depleting substances
OPFR	Organophosphorus flame retardant
PAHs	Polycyclic aromatic hydrocarbons
PBDDs	Polybrominated dibenzo-*p*-dioxins
PBDEs	Polybrominated diphenyl ethers
PBDFs	Polybrominated dibenzofurans
PCBs	Polychlorinated biphenyls
PCDDs	Polychlorinated dibenzo-*p*-dioxins
PCDFs	Polychlorinated dibenzofurans
PCNs	Polychlorinated naphthalenes
PCP	Pentachlorophenol and its salts and esters
PeCB	Pentachlorobenzene
PFASs	Per- and polyfluorinated alkylated substances
PFBS	Perfluorobutane sulfonate
PFHxS	Perfluorohexane sulfonic acid
PFOA	Perfluorooctanoic acid; Perfluorooctanoate
PFOS	Perfluorooctane sulfonic acid; Perfluorooctane sulfonate
PFOSF	Perfluorooctane sulfonyl fluoride
PIR	Polyisocyanurate
POPRC	POPs Review Committee
POPs	Persistent organic pollutants
PUR	Polyurethane
PVC	Polyvinyl chloride
RoHS	Restriction of Hazardous Substances
SAICM	Strategic Approach to International Chemicals Management
SC	Stockholm Convention
SCCPs	Short-chain chlorinated paraffins
SF6	Sulfur hexafluoride
t	Tonnes; metric tons
tetraBDE	Tetrabromodiphenyl ether
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environmental Programme
USEPA	United States Environmental Protection Agency
UV-328	2-(2H-Benzotriazol-2-yl)-4,6-di-tert-pentylphenol
WEEE	Waste electrical and electronic equipment
XPS	Extruded polystyrene

Tables

Figures

1 Introduction and Method

Industrial persistent organic pollutants (POPs) are present in plastics and wood in buildings and construction, in plastics in electrical and electronic equipment (EEE), vehicles/transport, textiles and other consumer goods. These uses result in indoor human exposure, environmental releases and food chain contamination, and generation of POP-contaminated waste and recycling cycles, particularly for plastics (UNEP 2023a). Since POPs can cause birth defects, cancer, immune system dysfunction, and reproductive problems in humans and wildlife (Carpenter 2013), exposure to these products and uses should be minimized; the transfer to recycling processes needs to be eliminated. For the environmentally sound management of POPs and materials containing POPs, robust inventories need to be developed to facilitate the control of POP-containing products in end-of-life and reduce and minimize exposure to humans and release into the environment.

1.1 From inventories of individual POPs to a sectoral approach of POPs inventory

A POPs inventory compiles information on past and present production and current uses, stocks and waste of a chemical listed in the Stockholm Convention (SC) on Persistent Organic Pollutants in the country. As many POPs are used in the manufacture of products/articles which may have a long service life, a comprehensive inventory should estimate the amount of POPs in the products/articles in the country (e.g. in buildings, EEE, or vehicles) along the whole life cycle, thus contributing to the provisions of Article 6 of the Convention on management of waste. An inventory could also address sites that may have been contaminated by production, use, or accidental releases of POPs.

The main objective of developing an inventory is to acquire information to regulate and manage POPs and POPs waste appropriately and to update a country's National Implementation Plan (NIP) and the related action plans for POPs management and destruction to comply with the requirements of the SC (e.g. Article 15 reporting; Article 6 on waste). Objectives are further described in the general guidance of POPs inventories (UNEP 2020a).

A range of inventory guidance documents[2] under the Stockholm Convention for individual POPs has been developed (see Table 1) to support Parties in developing and updating their NIPs. In POPs inventories, individual POPs are often addressed based on inventory guidance documents. However, it is prudent for a POP inventory team to collect comprehensive information on all POPs present and relevant to a specific sector. Additionally, in the final waste management of a sector, information on all potentially relevant POPs should be available.

This guidance aims to facilitate a sectoral assessment of POPs inventories to improve coordination in information gathering. The sectoral approach should ensure that individual stakeholders in the different sectors or government ministries are approached by a single inventory team for POP data, thereby saving time and money in the inventory development process.

Table 1: List of Stockholm Convention POPs inventory guidance document

Title	Source
General guidance on POPs inventory	UNEP 2020a
Guidance on preparing inventories of PBDE including decaBDE	UNEP 2021a
Guidance on preparing inventories of hexabromocyclododecane (HBCD)	UNEP 2021b
Guidance on preparing inventories of PCN	UNEP 2021c
Guidance on preparing inventories of PCP	UNEP 2021d
Detailed guidance on preparing inventories of SCCPs	UNEP 2019a
Draft guidance on preparing inventories of PFOS and related chemicals	UNEP 2017a
Guidance on preparing inventories of PFOS, PFOA and PFHxS	UNEP 2023b
Guidance on sampling, screening and analysis of POPs	UNEP 2021e

[2] http://www.pops.int/Implementation/NationalImplementationPlans/Guidance/tabid/7730/Default.aspx

1.2 Option of addressing other chemicals of concern listed under other multilateral environmental agreements (MEAs) or international frames

POPs are only one category of chemicals of concern (CoC) in these sectors. Other relevant CoC are addressed, for example, by the Basel and Rotterdam Conventions, the Minamata Convention on Mercury, and the Montreal Protocol on Substances that Deplete the Ozone Layer. Moreover, a range of CoC have been flagged under the Strategic Approach to International Chemicals Management (SAICM) as “Emerging Policy Issues” (e.g. hazardous substance within the life cycle of electrical and electronic products, lead in paints and endocrine disrupting chemicals) or “Other Issues of Concern” (per- and polyfluoroalkyl substances (PFAS)).

When developing POPs inventories, gathering information on other CoC can be taken as an option considering the synergy approach of other MEAs related to chemicals and wastes, and aiming for integrated management of POPs and other CoC where appropriate.

In the three sectors (EEE, transport and construction/buildings), most POPs are contained in plastic and other polymers, which make up a relevant share of the overall stock of plastic worldwide: approximately 30% of plastic production is used in these three sectors (Geyer *et al.* 2017). Considering the long service life in these three sectors (Geyer *et al.* 2017), likely more than 50% of all plastic stocks are contained in these sectors today and will become more relevant for plastic management and recycling in the future. Only a share of plastics in these sectors is impacted by POPs. An inventory of POPs and plastics in these sectors can contribute to environmentally sound management (ESM) and a safer circular economy for plastic, which is an aim of different UN agencies and programmes.[3]

1.3 Methodologies for developing the inventory in specific sectors containing multiple POPs

1.3.1 Scope of this document

The approach for this guidance is to support gathering inventory information from three sectors with multiple presence of POPs and other CoC, thus facilitating data gathering and an overview of sectors:

- POPs in the **building and construction sector** and options to assess other CoC (Section 2)
- POPs in the **EEE sector** and options to assess other CoC (Section 3)
- POPs in the **transport sector** and options to assess other CoC (Section 4)

These sectors are considered to be of particular concern due to the presence of multiple POPs and related exposure risk to mixtures of POPs and other CoC that can negatively affect human health (Imm *et al.* 2003; Takahashi *et al.* 2017; Lucattini *et al.* 2018). The sectors were selected since these multiple POPs are impacting large material and waste categories relevant to a circular economy. Furthermore, hazardous chemicals in the life cycle of EEE are an emerging policy issue of SAICM. A SAICM report on “Chemicals of Concern in the Building and Construction Sector” provides an overview of the challenges that CoC pose in this sector towards a circular economy (UNEP 2021f).

1.3.2 Developing a POPs inventory

Parties are required to take measures on POPs to eliminate or reduce releases to prevent and minimize adverse effects on human health and the environment. Preparing an inventory that gives a full picture of how POPs are used requires various sources and data collection methods. The general guidance on a POPs inventory (UNEP 2020a) describes a general method process to be taken in making an inventory, which consists of a five-step approach (Figure 1; for details see UNEP 2020a). Such an approach is also used in the inventory guidance documents for individual POPs

[3] https://buildingcircularity.org/plastics/; https://www.unido.org/events/circular-economy-solutions-address-plastic-pollution; https://www.undp.org/publications/plastics-and-circular-economy-community-solutions

(Table 1) and is recommended for gathering POPs data for the three sectors, taking into account the detailed inventories guidance documents.

Several different data collection methodologies can be selected and used for gathering information for POPs inventories (Step 2), i.e. indicative method, qualitative method and quantitative method. For more information on those methodologies, please refer to Section 2.3 of the "General guidance on POPs inventory development" (UNEP 2020a).

Collecting inventory-related data (Step 3) is a multi-step process that can include a tiered approach (Figure 1). This approach provides flexibility to Parties with varying priorities and capacities[4] and allows for scaling of the work according to the findings (UNEP 2020a). An initial assessment (Tier I) is carried out to obtain an overview of the relevant uses and stakeholders to be contacted in the key sector under investigation. Tier I methods usually rely on available literature, internet searches and statistics in combination with calculations based on already existing information, such as risk profiles and risk management evaluation documents adopted by the POPs Review Committee.

The main inventory (Tier II) follows the Tier I assessment and generates detailed data on the main sectors through interviews and questionnaires to national stakeholders, and further identifies missing information. This would include such actions as detailed information collection from national statistical office, customs, industry and other stakeholders, and possibly including site visits.

If needed and resources are available, a more in-depth inventory, including sampling and analysis (Tier III), can be conducted after evaluation of the data gathered in the Tier II inventory. Higher-tier methods involve more resource-intensive data collection activities and often yield more accurate results. For some applications, country- or region-specific actions could be considered; for example, in cooperation with regional centres.

Figure 1: Five-step approach for the development of POPs inventories (UNEP 2020a)

Step 1:	**Initiating the inventory development process**
	Establishing a national inventory team
	Identifying relevant stakeholders
	Defining the scope of the inventory
	Developing a workplan
	Contacting the stakeholders
Step 2:	**Choosing data collection methodologies**
	Indicative method
	Qualitative method
	Quantitative method
Step 3:	**Collecting and compiling data**
	Tier 1: Initial assessment
	Tier II: Main inventory
	Tier III: In-depth inventory
Step 4:	**Managing and evaluating the data**
Step 5:	**Preparing the inventory report**

[4] The complexity ranges from the use of statistics (at the lower level) to resource-intensive data collection and country-specific monitoring (at higher levels).

This sectoral guidance aims to streamline and harmonize POPs inventories. It helps inventory teams coordinate data gathering and inventory development across the three sectors. Stakeholders are approached for all relevant POPs information in a coordinated manner, minimizing time and effort for both inventory teams and stakeholders. The guidance also supports the planning phase by providing an overview of POPs use in various sectors (see Table 3, Table 10 and Table 13)

The assessment of the three sectors can include other CoC relevant to the management of the materials of the sectors, in particular in end-of-life and recycling (see Section 1.5).

After collecting and compiling data from the three sectors, the compiled information should be analysed and evaluated (Step 4) and fed into the inventory reports of individual POPs groups (Step 5) and the NIP report (Figure 1). Assumptions and estimations should be marked and uncertainties described. Data gaps should also be highlighted and limitations for validating information and suggestions to gather further data possibly involving sampling and analysis (Tier III) should be recorded.

For developing the inventory part on waste, establishing a classification of wastes that is used consistently will help ensure comparability of inventory information collected from various sources and over time. Wastes should also be classified in a way that serves the objectives of developing the inventory, such as for the planning of disposal facilities. This is straightforward for the three sectors considered in this guidance with the related waste streams: construction and demolition (C&D) waste, e-waste and end-of-life vehicles (ELVs).

1.4 POPs present in the sectors

To date, 34 substances or groups of substances are listed as POPs by the Stockholm Convention. They are grouped into pesticides, industrial chemicals and unintentional POPs. Fifteen of the industrial POPs are present in at least one of the three sectors addressed by this sectoral guidance (Table 2). For most of these POPs detailed, inventory guidance documents are available and can be consulted for detailed inventory assessment (Table 1).

The POP candidate MCCP proposed for listing by the POPs Review Committee (POPRC)[5] (Table 2) at COP12 in 2025 is included in the assessment and the current guidance. POPs that are still used and formerly used POPs for the three sectors are distinguished in the individual sector sections. For POPs where production has ceased, only the current in-use stock and the waste and recycling need to be assessed, while for POPs that are still used in production, the entire life cycle needs to be assessed, including production, import and current use. For these POPs, the period of production/use is mentioned so that the inventory can be targeted at buildings built, or EEE and vehicles produced in these periods.

Table 2: POPs present in the three sectors and their use

POP (main production and use period)*	Building and construction	Electrical and electronic equipment	Transport
c-PentaBDE (1970-2004)	Former use	Minor former use	Major former use
c-OctaBDE (1970-2004)	Minor former use	Major use	Minor former use
decaBDE (since 1970s)	Major use	Major use	Major use
HBCD (1980 to 2021)	Major former use	Minor former use	Minor former use
HBB (1970 to 1976)		Former use	Former use
SCCP (Since 1930s)	Major use	Minor use	Minor use
MCCP[6] (Since 1930s)	Major use	Use	Use
PFOS (1960 to 2012)**	Former use	Former use	Former use

[5]http://www.pops.int/TheConvention/ThePOPs/ChemicalsProposedforListing/tabid/2510/Default.aspx
[6] MCCPs are suggested for listing as POP at COP12 in 2025 (UNEP 2023c)

POP (main production and use period)*	Building and construction	Electrical and electronic equipment	Transport
PFOA (since 1960s)	Former use	Minor use in product	Use
PFHxS (1960 to 2021)	Former use	Former use	Former use
PCB (1940 to 1980)	Major former use	Former use	Minor former use
PCN (1930 to 1970s)	Minor former use	Minor former use	Minor former use
PCP (1930 to 2015)	Major former use	Not relevant	Minor former use
DDT, aldrin, dieldrin, endosulfan, lindane, mirex (1940 to 2000)	Former use	Not relevant	Not relevant
Dechlorane Plus (DP)	Use	Use	Use
UV-328	Major use	Major use	Major use

**Main period for production and use in these sectors*
***Major production/use stopped in 2002 by 3M*

1.5 Option for considering further chemicals of concern addressed by other global actions under selected MEAs relevant to the three sectors

An important component of effective POPs management is the use or the expansion of synergies between the different conventions on chemicals and waste as well as SAICM. When developing POPs inventories, gathering information on other CoC can be considered to align with the synergy approach of other chemicals and waste-related MEAs, aiming for integrated management of POPs and CoC where appropriate.

For screening/identifying and selecting other CoC in this guidance, priority chemicals addressed by other MEAs relevant to the three sectors have been compiled. These include the Basel Convention, Minamata Convention, Rotterdam Convention and Montreal Protocol, as well as the Strategic Approach to International Chemicals Management (SAICM) (now Global Framework on Chemicals). For some conventions, inventories are developed and can be coordinated for these sectors in a synergistic approach (e.g. for mercury), although no particular inventory activities for SAICM's issues of concern have occurred. This methodical approach supports the synergy of chemicals conventions and international chemical management promoted by UNEP (UNEP 2015, 2017b, 2022). For CoC (other than POPs) that are addressed under MEAs or SAICM, information on uses in the respective sectors have been compiled (see Sections 2.5, 3.5 and 4.5).

2 Inventory of POPs in the Building and Construction Sector and Options to Assess Other Chemicals of Concern

2.1 Introduction to the building and construction sector and inventory of POPs and other CoC

2.1.1 Background

The building and construction sector is one of the most chemical-intensive sectors downstream of the chemical industry. Driven by rapidly accelerating urbanization, the global construction sector is expected to grow by 3.5% annually with its chemicals market estimated to grow by 6.2% annually between 2018 and 2023 (UNEP 2019b). Some of the chemicals present in plastic and other materials in building and construction are POPs (e.g. HBCD, PBDEs, SCCPs, PCB, PFOA) or other CoC (UNEP 2021f). They pollute the indoor environment and pose a threat to human health and the environment (Lucattini *et al.* 2018; Blumenthal *et al.* 2022).

Construction and demolition (C&D) waste is the largest waste stream accounting for more than 30% of all waste with a total amount of 10 billion tonnes/year and is increasing worldwide with the largest share of waste disposed to landfills (Wu *et al.* 2019; Purchase *et al.* 2021; Al-Otaibi *et al.* 2022).

Given the large waste volumes that will need to be managed in the future, industrial countries are transitioning to a more circular economy for C&D waste. This involves controlled deconstruction to better recover individual waste fractions and manage pollutants (Bavarian Environment Agency 2019; USEPA 2022). As part of the deconstruction approach, plastic materials from buildings also need to be managed in an environmentally sound manner with possible separation of plastic containing POPs and recycling of plastic fractions free of POPs and other CoC (UNEP 2021f; UNEP 2021g). Initial projects on assessing the recycling potential of plastic from C&D waste have been conducted (e.g. German Environment Agency 2021).

The service lives of buildings and construction materials can span several decades to over a century (Li *et al.* 2016; UNEP 2021f). Consequently, a significant portion of plastic materials and foams with POPs additives used in the last 70 years remains in use in buildings and construction. The same applies to other chemicals or materials of concern. During this long service life, various actors, including, residents living in the buildings, workers and those involved in building, renovating, or demolishing, may come into contact with building products containing POPs or other CoC.

The environmentally sound management of C&D waste containing POPs and other CoC is crucial to ensure that the impacts of legacy chemicals on human health and the environment are minimized. Identification and inventory of material stocks in the built environment containing CoC is the first step, which enables environmentally sound dismantling. To increase material recycling and avoid re-introduction of CoC into secondary raw materials, research and development of technologies for sound recycling and separation of building products that contain CoC should be advanced (UNEP 2021f).

A share of the plastic in buildings contains POPs that are still produced and used (Section 3.2) or some legacy POPs where production has stopped, but which are still in use in buildings (Section 4.3), or chemicals that have POPs properties and are currently evaluated for listing in the Stockholm Convention (Section 2.4). Other CoC may be found in plastic or non-plastic building materials (Section 2.5).

2.1.2 Assessment and inventory of POPs and other CoC in the building and construction sector

The buildings and construction sector is a major use area of plastics containing additives listed as POPs, such as brominated flame retardants (HBCD and PBDEs) in insulation foams (Li *et al.* 2016; UNEP 2021a), or PBDEs used in a wide range of other plastic materials in construction (Table 4, 2.2.1 and 2.3.2), SCCPs and MCCPs**Error! Bookmark not defined.** in PVC, polyurethane (PUR) and other polymers (Guida *et al.* 2020; Brandsma *et al.* 2021; Chen *et al.* 2021) (Sections 2.2 and 2.3).

Table 3 provides an overview of POPs in buildings and construction and their major or minor use and period of use. It also indicates what information to collect for the inventory and who are the major stakeholders to possibly have information, like government ministries or national statistical offices (NSO). In addition, Table 3 lists references to the respective inventory guidance where detailed information on individual POPs and the calculation for inventory development can be found.

Besides POPs, other CoC were and are still used in construction, such as lead in paints (SAICM emerging policy issue[7]) and other lead materials, PFAS (SAICM issue of concern[8]), and asbestos (see Section 2.5), which could be assessed in a sectoral inventory approach together with POPs. This seems particularly relevant for applications like paints where POPs (SCCP/MCCP[6], PCB, HBCD, PFASs, PCP), and lead, tar oil (PAHs) and organotin were used in the same application.

The inventory of POPs and other CoC in buildings and construction is essential for the ESM of C&D waste. Governmental institutions and other stakeholders responsible for planning, guiding and supervising C&D waste management should be aware of POPs and other CoC present to guide and supervise C&D waste effectively. This ensures optimal resource recovery, including plastics and the ESM of POPs and other CoC-containing materials. The POP inventory should compile the amount of impacted plastic/products and related POPs, and describe the current waste management status of individual waste fractions containing POPs.

In the construction sector, POPs are mainly present in plastics and other polymers. In the inventory assessment for the construction sector, the total amount of plastic categories impacted by POPs or other CoC should be compiled and the current waste management of the individual plastic fractions containing POPs/CoC should be described in the inventory. This can contribute to an overall plastic inventory and the management of plastic waste containing POPs or other CoC (UNEP 2023a).

[7] https://saicmknowledge.org/program/lead-paint
[8] https://saicmknowledge.org/program/perfluorinated-chemicals

Table 3: POPs used in the building and construction sector, inventory information which can be collected, data sources and estimated priority level

POP	Application in building and construction	Use period*	Information to be collected for inventory (along the life cycle)	Potential data source**	Inventory guidance	Priority (recom. Tier)
DecaBDE	PUR and XPS insulation, cladding panels, PE/PP films, cables and electrical ducts and fittings or piping insulation	Current and former uses. New use is allowed in polyurethane (PUR) foam for building insulation	Current import/new use for construction. Amount of plastic used in construction 1970 to 2020 containing or potentially containing decaBDE. Amount and management of plastic in C&D waste.	NSO; Ministry of Construction; plastic association; customs, producers and importers of plastic, waste management (WM) agency; planning/permitting departments; disaster management agencies;	PBDE inventory guidance (UNEP 2021a)	High (Tier II and III)
c-PentaBDE (tetraBDE and pentaBDE)	Flame retardants in PUR foam, PVC in cables, wires, floor mats, industrial sheets	Former use (1970 to 2004)	Amount of plastic used in construction 1970 to 2004 containing or potentially containing c-PentaBDE. Amount and management in C&D waste.		PBDE inventory guidance (UNEP 2021a)	Medium (Tier II and III)
HBCD	Major flame retardant in EPS/XPS; interior textiles (e.g. roller blinds)	Former use (1970 to 2021)	Amount of EPS/XPS used in construction 1970 to 2021; period of use of HBCD in EPS/XPS in the country & amount. Amount & management in C&D waste.	EPS/XPS producers, importers	HBCD inventory guidance (2021b)	High (Tier II)
SCCPs (and MCCPs[6])	In PVC in cables, flooring, and roofing; PUR spray foam, adhesives, rubber, sealants, paints and coatings	Current and former uses. SCCP is exempted for use in PVC, paints and adhesives	Current import/new use for construction. Total amount of PVC/PUR spray used in construction 1970 till today; share of PVC containing plasticizer; amount of SCCP/MCCPs[6] in these plastics. Amount & management in C&D waste.	Ministry of Construction; plastic association; PVC, sealants, paints producers & importers, WM agency	SCCP inventory guidance (UNEP 2019a)	High (Tier II and III)
PCBs	Sealants, paints, plasters, adhesives, floor finishes, cables, anticorrosion coatings	Former use (1950 to ca. 1975)	Former use of PCB in sealants, paints/coatings, cables in the country. Current remaining use in construction; Amount & management in C&D waste.	NSO; Ministry of Construction; producer & importers of sealants, paints, cables	PCB inventory guidance (UNEP 2019e)	Medium (Tier II and III)
PCNs	Paints and coatings, cables and wood treatment	Former use (1940 to 1980)	Former use of PCN in sealants, paints/coatings, cables in the country.	Producers of sealants, paints, cable	PCN inventory guidance (UNEP 2021c)	Low (Tier I)
PFOA	Paints, lacquers and sealants, carpets and floor covering. fixed fire extinguishing systems	Current and former uses	Current use of PFOA in construction; Former use in these applications and amount in use and end-of-life management	Ministries for Construction and Industry; associations, producers and	PFOA/PFOS inventory guidance (UNEP 2023b)	Medium (Tier I and II)

POP	Application in building and construction	Use period*	Information to be collected for inventory (along the life cycle)	Potential data source**	Inventory guidance	Priority (recom. Tier)
PFOS	Carpets and floor covering, paints and varnishes, coatings; foam in fixed fire extinguishing systems	Former uses (mainly use before 2002) Firefighting foam until now	Former use in these applications and amount in use; amount & management in C&D waste (e.g. carpets; firefighting foams).	importers of paints, coatings, lacquers, sealants; producers/ importers of synthetic carpets floor covering,		Medium (Tier I and II)
PFHxS	Carpet and floor covering, paints, coatings, plaster, drywall, facade materials, textile and plastic insulation,	Former use (until 2021)	Former use in these applications and amount in use; Amount & management in C&D waste.		No	Low (Tier I and II)
PCP	Used as preservative in wood and timber products	Former use (1940 to 2015; some countries earlier phase out)	Period of use of PCP in wood treatment in country; Amount of treated wood; use type of treated wood; Amount & management of treated wood C&D waste	NSO; Ministries of construction, forestry and agriculture; wood industry & importers	PCP inventory guidance (UNEP 2021d)	Medium (Tier II and III)
POP-Pesticides	POP-pesticides use as insecticides or fungicides in wood in construction (DDT, aldrin, chlordane, dieldrin, endosulfan, lindane, mirex)	1950 to 1990s; In some countries DDT is still used for indoor residual spraying	Period of use of POP pesticides in wood treatment in country; amount of treated wood; uses areas of treated wood; Amount & management of treated wood in C&D waste	NSO; Ministries of construction, forestry and agriculture; wood industry & importers	No	Low to high depending on region (Tier II)
Dechlorane Plus	FR in polymers in roofing materials & other building materials, non-woven PVC wallpaper, latex paint, laminated floorboards, fibre board, sealants, line pipes, sound absorbing foam and EPS	Since 1960 until 2024 (last production stopped 2023).	Amount of DP used in construction until now. Period of use of DP in PVC and roofing materials in the country & amount. Amount & management in C&D waste.	Ministry of Construction; plastic and PVC association; producers and importers of plastic and the applications in column 2	No	Medium (Tier I and III)
UV-328	UV-absorber in polymeric materials, fillers, paints, lacquers, varnishes, adhesives, wood coatings	From 1970 until now	Amount of UV-328 used in construction. Period of use of UV-328 in a country related to the applications in column 2; amount & management in C&D waste.	Ministry of Construction; Industry association; producers and importers of the applications in column 2	No	Medium (Tier I and III)

**Plastics and most other uses in construction have a long service life of several decades up to over a century.*
***Details on stakeholders which can be consulted are compiled in the individual inventory guidance documents.*

2.2 Currently used POPs in the construction sector and assessment

POPs that are still used in the construction sector are decaBDE, PFOA, SCCPs and UV-328 (Table 3). For these POPs, the entire supply chain and life cycle (production – import/export – use – end-of-life) should be assessed in an inventory to adequately address and control the individual POPs and impacted materials used in the construction sector.

2.2.1 DecaBDE in buildings and construction

DecaBDE was a major flame retardant used in construction until around 2017 when it was listed under the Stockholm Convention. It is estimated that 20% of total c-DecaBDE production, approximately 320,000 tonnes, was used in buildings (Abbasi *et al.* 2019). Assuming a concentration of 5 to 10% c-DecaBDE in construction polymers (Table 4), this translates to 3.2 to 6.4 million tonnes of decaBDE-containing polymers in buildings, highlighting the need for proper inventory and management.

DecaBDE has been used in a wide range of plastics, including extruded polystyrene (XPS), PE insulating foam, PE, PP and PVC plastic sheeting (Table 4). DecaBDE also received a specific exemption for use in PUR foam insulation in construction, and therefore its use might continue (UNEP 2021a). Due to the long service life, the largest share of PBDE-containing polymers used in the past 40 years in construction is to a large extent still in use. Therefore, the following should be assessed for decaBDE in the inventory of POPs in buildings:

- If decaBDE is still used in new PUR foam in construction and estimated amount.
- If decaBDE is still used in other new plastic uses not exempted (see Table 4) and estimated amount.
- Amount of all polymers containing decaBDE in current use in buildings installed in the past 50 years (see Table 4).
- Amount of plastic waste in construction and demolition waste (total) and share of plastic containing decaBDE and other current and former used POPs (see below).

Please note that the share of PBDE-containing individual polymers is not known and needs to be assessed by a Tier III inventory for a country.

Table 4: POP concentration in polymers/plastic* in construction (UNEP 2021b with additions)

POP	Uses	Content (% wt)**	References
HBCD	Expanded polystyrene (EPS)	0.5-1%	UNEP 2021c
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
SCCP/MCCP[6], (DecaBDE)	PVC plastic sheeting	5-20% (5%)	Morf *et al.* 2003; Chen *et al.* 2021
SCCP/MCCP[6]	PVC hosepipes for plumbing	0.5%-10%	Chen *et al.* 2021
SCCP/MCCP[6]	PVC flooring, roofing, wallpaper	0.5%-10%	Chen *et al.* 2021
SCCP/MCCP,[6] PCB, PCNs	Cables	0.5%-10%	Chen *et al.* 2021
SCCP/MCCP[6]	PUR sealants	10-50%	Chen *et al.* 2021; Brandsma 2021

**Please note that only a minor unknown share of the polymer contains POPs.*
***Concentration range for intentional POP additive.*

2.2.2 SCCPs in buildings and construction

Short-chain chlorinated paraffins (SCCPs) have substituted polychlorinated biphenyls (PCBs) for some building materials (sealants, paints and cable additives). Primary uses of SCCPs[9] (and POP candidate MCCPs; see Section 2.4.1) in construction were used as plasticizers in polyvinyl chloride (PVC) (Chen *et al.* 2021; Babayemi *et al.* 2022; Chen *et al.* 2022). In addition, SCCPs (and MCCPs) are also used as plasticizers and flame retardants in paints, adhesives, sealants, rubber and other polymeric materials (UNEP 2019a). SCCPs were listed as POPs in 2017 with a range of exemptions (PVC, waterproofing and fire-retardant paints, adhesives) and are still used in a wide range of materials in buildings and construction. MCCPs[6] are currently being assessed by the POPRC for inclusion in the Stockholm Convention. The following would be assessed for an inventory:

- If SCCPs (and MCCPs) are still used in new construction materials (PVC, PUR spray foam, rubber, paints) and the related amount.
- If SCCPs (and MCCPs) are still used in other uses not exempted (e.g. sealants) and related amount.
- Amount of polymers containing SCCPs (and MCCP[6]) installed the past 50 years in the current building stock.
- Amount of plastic waste in construction and demolition waste (total) and share of plastic containing SCCPs and MCCPs[6].

2.2.3 UV-328 in buildings and construction

2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol (UV-328; CASRN 25973-55-1) is a substituted phenolic benzotriazole (BZT), and is listed under the Stockholm Convention (UNEP 2023d).

UV-328 is used as a UV absorber in many polymers (e.g. polyolefins, polyurethanes, PVC, polyacrylate, unsaturated polyester, polycarbonate and elastomers) and products. In the building sector, UV-328 was and is still used in paints and coatings, sealants, fillers, lacquers, varnishes and wood coatings (UNEP 2021f). UV-328 can be assessed together with other POPs (SCCPs, decaBDE, PCBs) in paints, coating and sealants.

2.2.4 PFOA, PFOS, PFHxS and other PFASs in buildings and construction

PFOS, PFOSF and related compounds have been listed under the Stockholm Convention since 2009, and PFOA and related compounds and PFHxS and related compounds were listed in 2019 and 2022, respectively. Long-chain perfluorocarboxylic acids (PFCAs), their salts and related compounds have been evaluated by POPRC and are proposed for listing as POP at COP12 in 2025 (UNEP 2023c).

PFOA and related compounds are used in side-chain fluorinated polymers in paints and lacquers in exterior and interior architectural paints and sealants (UNEP 2021f). In the past, PFOS, and PFHxS and related compounds were used in buildings and construction (Green Science Policy Institute 2021; UNEP 2021f). PFOS and related compounds have been used in carpets and floor covering, coatings, paint and varnishes, sealants and adhesive products. For PFHxS, occurrences have been reported in the same uses and plastic façade materials, foam/plastic/textile insulation, drywall, paint, plaster, polishing agents and damp proofing/impregnation products (UNEP 2021f).

2.3 Formerly used POPs in the construction sector and current stock in buildings

Due to long service life (Section 2.1), the largest share of POPs that have been used in the construction sector in the last 70 years are still present in buildings and need to be considered in the POPs inventory. These formerly used POPs in the construction sector include HBCD, c-PentaBDE, PCBs, PCNs and PCP for which inventory guidance documents exist (Table 1).

[9] If SCCPs occur in mixtures at concentrations greater than or equal to 1% by weight are considered POPs and listed under the Stockholm Convention.

2.3.1 HBCD in buildings and construction

HBCD was a major additive flame retardant used in construction in expanded and extruded polystyrene foams (EPS/XPS) (UNEP 2017c; 2021b) from 1970 until 2021 when exemption on production and use stopped. EPS and XPS materials are used in a variety of applications throughout the construction sector (Overview Table 5). Depending on the flammability standards in a country, HBCD may have been used in these identified applications.

For the inventory, the amounts of EPS and XPS installed as insulation foam in buildings from the 1970s to 2021 would be assessed. The share of EPS/XPS foam that is still present and likely contains HBCD would be estimated and related HBCD amount calculated (UNEP 2017c; 2021b).

Table 5: HBCD in EPS and XPS applications in buildings (UNEP 2017c)

Type of PS	Former use of HBCD in polystyrene
EPS (HBCD concentration 0.5 to 0.7%)	Flame-retarded EPS insulation, including: - Flat roof insulation; pitched roof insulation - Floor insulation; ‘slab-on-ground’ insulation - Insulated concrete floor systems - Interior wall insulation with gypsum board - Exterior wall insulation or external insulated composite systems - Cavity wall insulation boards and loose fill - Insulated concrete forms (ICF) - Foundation systems and other void-forming systems - Load-bearing foundation applications - Core material for EPS used in sandwich and stressed skin panels - Floor heating systems - Sound insulation in floating floors - EPS drainage boards
EPS	EPS concrete bricks, EPS concrete
EPS	Soil stability foam (for civil engineering use)
EPS	Seismic insulation
EPS	Other molded EPS articles, such as ornaments, decorations, logos, etc.
XPS (HBCD concentration 0.8 to 3%)	- XPS insulation boards: - Cold bridge insulation floors - Basement walls and foundations - Inverted roofs; ceilings; cavity insulation - Composite panels and laminates

2.3.2 PentaBDE in buildings and construction

It is estimated that 27,000 tonnes of c-PentaBDE (20% of total production) has been used in buildings from the 1970s to 2004 (stop of production) with major use in the United States (Abbasi *et al.* 2019). C-PentaBDE has been used in the building sector in rigid PUR foam insulation (UNEP 2021a) (Table 4). C-PentaBDE can be assessed in buildings together with decaBDE and SCCP/MCCP[6] inventory in PUR foams with an estimate of former use.

2.3.3 Dechlorane Plus in buildings and construction

Dechlorane Plus (CAS No. 13560-89-9) is a polychlorinated flame retardant that contains 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 2019c). It was listed under the Stockholm Convention in 2023 with exemption (UNEP 2023d); production stopped in December 2023 (UNEP 2024a).

Dechlorane Plus has been used as a flame retardant in many polymers and as non-plasticizing flame retardant in thermoplastic (e.g. polypropylene, polyester, acrylonitrile butadiene styrene (ABS), natural rubber, polybutylene terephthalate (PBT), nylon and styrene butadiene rubber (SBR) block copolymer) and thermosets (e.g. epoxy and polyester resins, polyurethane foam, polyurethane rubber, silicon rubber, ethylene propylene diene monomer rubber and neoprene). The amount of DP in these materials ranges from 8% in polybutylene terephthalate up to 40 % in silicon rubber. In the building sector, DC is included, for example, in cable coatings, plastic roofing materials, nonwoven PVC wallpaper, latex paint, laminated floorboards, fibre boards, solid wood boards, glue, sealants, PVC line pipes, sound-absorbing foams and EPS panels (UNEP 2021f).

2.3.4 PCBs and PCNs in buildings and construction

It is estimated that approximately 25% of the total world PCB production (approx. 375'000 tonnes) was used in open applications, mainly in the construction sector (UNEP 2021c; UNEP 2021f). PCBs and PCNs have been used in construction in particular in sealants, coatings, paints, adhesives and cables (UNEP 2019e; UNEP 2021c). Overall, the use of PCBs in these uses was considerably higher than that of PCNs. The major use of PCBs in open uses was from the 1950s to 1975 while PCNs were mainly used from 1930 to 1960 (UNEP 2021c). PCBs are detected in industrial, public and residential buildings. Examples in the industrial sector include hydropower, nuclear power, coal/gas power plants, water treatment plants and military installations (UNEP 2019e).

The major use for PCBs in buildings was in elastic sealants with no reported use for PCNs. Paints and anti-corrosion coatings were another major open application of PCBs until the 1970s and possibly early 1980s (UNEP 2021c). PCNs have been used in underwater paints and lacquers until the beginning of the 1980s (UNEP 2021c; Potrykus *et al.* 2015).

It is generally believed that open applications of PCBs were phased out in the early 1980s. Due to the long lifetimes of these products however, PCBs are still present in the built environment.

A major use of PCNs was as a flame retardant in cables from 1930 to 1960 (Jakobsson & Asplund 2000). Cables containing PCBs (used in the 1960s/1970s) and PBDEs (used since the 1970s) have been used more recently, as well as those containing SCCPs.

PCBs and PCNs have been substituted by SCCPs/MCCPs[6] in the major uses in construction (sealants, paints, coatings and adhesives) (see Section 2.2.2) and should be assessed and quantified together.

2.3.5 PCP and other POP-pesticides in buildings and construction

PCP was a major wood preservative for indoor and outdoor use since the 1930s, e.g., in wooden buildings such as half-timbered houses, on windows, doors, roof trusses, staircases or stair railings, on wooden panelling of walls or ceilings, in stables, on fences and other constructions. Use for utility poles and cross-arms is still exempted (UNEP 2021d). Some countries phased out PCP in wood treatment already in the 1980s while others continued the use until recently. For PCP-treated wood, the high levels of unintentional PCDD/PCDF present in PCP should be considered in the inventory, as well as the related contamination of the environment with PCP and PCDD/PCDF from treated wood along the life cycle and related emissions and contaminated sites[10] (wood treatment sites, use of PCP treated wood and end-of-life management) (Huwe *et al.* 2004; Weber *et al.* 2018; UNEP 2021d; Petrlik *et al.* 2022).

In addition, DDT, aldrin, dieldrin, endosulfan, lindane, mirex, and chlordane and possibly other POP-pesticides have been used as insecticides or fungicides in wood in construction from the 1940s to 1990s (Kurata *et al.* 2005; UNEP 2021e) and would be included in the inventory if they were used in wood treatment in the country/region.

[10] Some case studies on contaminated sites are provided in the PCP inventory guidance (UNEP 2021d). A table of emission factors based on the details in this section is provided in Appendix 1 in the PCP guidance (UNEP 2021d).

The total amount of treated wood in buildings and construction would be estimated, as well as the share of wood treated with PCP and the share of other POPs. Also, the amount and share of other hazardous wood preservatives like chromated copper arsenate creosote containing polycyclic aromatic hydrocarbons (PAHs) (see Section 2.5.1), tributyltin compounds (Section 2.5.5) or lead paint would be assessed. The end-of-life management of wood in C&D waste would be assessed and ensured that waste wood that is contaminated with POPs is not recycled into furniture or wood chips for animal bedding, but disposed of in an environmentally sound manner.

2.4 POP candidates in buildings and construction

One POP candidate (MCCPs) is used as a plastic additive in buildings. For this POP candidate, no inventory guidance has been developed yet but the SCCP inventory guidance can be considered. In a first preliminary inventory available information would be compiled from all stakeholders. Since only limited information on the frequency and concentration in buildings and construction is available, the generation of monitoring data (Tier III) would be useful. Considering SC Article 9, validated studies/data can be sent to the BRS Secretariat serving as a clearinghouse mechanism for information on POPs (UNEP 2021j).

2.4.1 MCCPs (POP candidate) in buildings and construction

Chlorinated paraffins with carbon chain lengths in the range C14-17 (CAS No: 85535-85-9) and chlorination levels at or exceeding 45 percent chlorine by weight (MCCPs) meet the Annex D criteria (UNEP 2021h).

MCCPs are produced in high volumes and buildings and construction is a major use sector mainly in PVC, PUR spray foam and rubber (Brandsma *et al.* 2021; Chen *et al.* 2021). MCCPs are also used in adhesives including chlorinated rubber coatings, polysulphide, acrylic and butyl sealants in building and construction and in sealants for double and triple glazed windows. Moreover, MCCPs are used as plasticisers and flame retarding agents in paints and coatings. These paints are mainly used by professional painters, but are to some extent also used in private households.

MCCPs use are in the same applications as SCCPs and were considered as alternatives before MCCPs were evaluated as POP (UNEP 2019d), thus the two CP mixtures can be assessed together. Initial measurement of PVC cables in C&D waste contained 99 000 mg MCCPs/kg (Norwegian Environment Agency 2021).

2.5 Assessment of other chemicals of concern present in buildings and construction

This section aims to provide an overview on selected CoC in the building and construction sector listed under other MEAs and/or SAICM, aiming for a synergistic approach of MEAs implementation and an integrated management of POPs and other CoC where appropriate. The objective is to provide a first overview of how certain CoC link to products of the building and construction sector and to provide initial information to possibly consider these CoC coordinated with POPs inventory activities as a basis for (future) integrated sector-specific management.

Table 6 provides an overview of selected CoC, and their major use in the building and construction sector as a basis for their identification. More detailed information can be found in the SAICM document on “Chemicals of Concern in the Building and Construction Sector” (UNEP 2021f) and in Huang *et al.* (2022).

Table 6: Identified other CoC in buildings and construction related to MEAs or SAICM

CoC	MEA or SAICM	Short description	Use in building and construction	Relevance
Asbestos	Rotterdam Convention	Classified as carcinogenic	Used in a variety of building insulation materials	High

CoC	MEA or SAICM	Short description	Use in building and construction	Relevance
Polycyclic aromatic hydrocarbons (PAHs)	UNECE LRTAP Convention	Many PAHs are carcinogenic, mutagenic, or reprotoxic (CMR)	Treated wood (creosote); corrosion protection coating and paint; tar roofing; asphalt; tar-based adhesives;	Medium
Phthalates	SAICM EPI (EDCs)	EDC (DEHP, DBP, BBP, DIBP)	Plasticizer in soft PVC flooring, wallpaper and cables	Medium
Halogenated OPFR	SAICM EPI[14]	Certain halogenated OPFR are carcinogen or reprotoxic	Major flame retardants in PUR and polyisocyanurate (PIR) foams; other plastics	Medium
CFCs, HCFCs, HFCs	Montreal Protocol	Ozone-depleting substances; GHGs	Blowing agents present in insulation foams and air conditioners	High
Lead	Lead in paints is an EPI under SAICM	adverse effects in all age groups particularly on the developing nervous system of children	Pigments in paints: stabilizers in PVC (window profiles, pipes, fittings, flooring, and roofing); lead sheeting for wall, noise attenuation and damp proofing, lead pipes	High
Mercury compounds	Minamata Convention	Harms the nervous system, brain, heart, kidneys; impacts neurodevelopment	Used in lamps and as catalyst in PU elastomers; contained in ash fillers	Medium
Tributyltin compounds	Rotterdam Convention Annex III	Neurotoxic and immunotoxic	Biocides in anti-fouling paints, preservatives for wood and others. Organotin stabilizers impurity (PVC)	Medium
Manufactured nano-materials	EPI under SAICM	The combination of particle size with certain hazards may affect impacts	Various uses	Low

2.5.1 Polycyclic aromatic hydrocarbons (PAHs) in tar and bituminous compounds, and carbon black

PAHs are listed in the UNECE's Convention on Long-range Transboundary Air Pollution. Tar contains high levels of PAHs and was used in construction in a range of products. A distinction is made between tar (high PAH content) and bitumen (low PAH content). Tar oil was used in the past and may be present in older buildings and construction, while bitumen was predominantly used in the last few decades. The most common applications of PAH-containing products in buildings are tar and pitch-containing adhesives underwood parquet, mastic asphalt and asphalt floor panels, as well as roofing felts and sealing sheeting made of tar or bitumen. Tar was applied and bituminous paints are still applied in the base area of buildings and constructions for waterproofing walls or insulations that have direct contact with soil. Tar or bituminous coatings are sometimes also found on pipes indoors and may also contain asbestos. Tar cork (tar-bonded granulated cork panels) was used indoors for the insulation of pipes and walls.

Creosote/tar oils were used on a large scale as wood preservatives on railway sleepers. Wooden sleepers were/are reused as construction materials (retaining walls, stairways, exterior tables and seating, sandboxes) in urban residential areas, public parks, sports grounds, school grounds and children's playgrounds, which is restricted in some countries (Held 2008; UNECE & FAO 2021). Creosote/tar oils were also applied on wooden posts, fences, blacktops and joint grouts.

Plastic and rubber materials may be contaminated with PAHs when they contain mineral oils as plasticizer and/or carbon black as a pigment (UBA 2016).

2.5.2 Certain phthalates in buildings and construction

Phthalates are primarily (>90%) used as plasticizers in soft PVC. Large amounts of plasticized PVC containing phthalates were and are used in buildings and construction in cables, pipes, foils and roof sheeting, sealants, extruded articles (e.g. hoses or pool liners and other endless formed plastic profiles), window shades, flooring and wallpapers/covering for more than 60 years and represents the largest stock of phthalates.

Certain phthalates are endocrine-disrupting chemicals (EDCs). EDCs are a SAICM Emerging Policy Issue (EPI). The EU has restricted DEHP, dibutyl phthalate (DBP), benzyl butyl phthalate (BBP) and diisobutyl phthalate (DIBP) in toys, childcare articles, and all indoor and outdoor articles with prolonged contact with human skin (European Commission 2018).

2.5.3 Halogenated organophosphorus flame retardants in buildings and construction

Halogenated organophosphorus flame retardants (OPFRs) are major flame retardants used in PUR and PIR insulation foams in construction. Halogenated OPFRs have hazardous properties including tris(2-chloroethyl) phosphate (TCEP; toxic for reproduction), tris(1,3-dichloroisopropyl) phosphate (TDCPP; carcinogen), tris(2-chloroisopropyl) phosphate (TCPP; toxic for reproduction) (Van der Veen and de Boer *et al.* 2012; European Commission 2022). High releases of the carcinogenic TDCPP and TCPP in leachates of landfills in Africa (Sibiya *et al.* 2019), Brazil (Cristale *et al.* 2019) and China (Qi *et al.* 2019) indicate relevant disposal of OPFR-containing waste such as polymers from C&D waste (and WEEE or vehicles) in landfills.

2.5.4 Certain metals and metalloids in buildings and construction

2.5.4.1 Lead in buildings and construction

Lead has been used in construction mainly in paints and in water pipes. Lead in paints was and is a major application of lead in construction. Lead is added to paint to increase durability and resist moisture that causes corrosion. Lead can be found in paints for interiors and exteriors of homes, schools, public and commercial buildings (UNEP 2021f). SAICM identified lead paint as an emerging policy issue.[11] Further applications for lead in buildings include stabilizers in PVC products, such as in window profiles, pipes, fittings, flooring and roofing. Lead applications also include sheeting for wall cladding, noise attenuation and damp proofing.

For the inventory, past and current use of lead paints, water pipes and other lead uses in buildings would be assessed as well as the situation of end-of-life management of lead-containing materials in C&D waste.

Table 7: Overview of documented applications and occurrences of lead in products potentially relevant for the building and construction sector (UNEP 2021f)

Applications	Products/material
Lead in paints	Large stock of former use; still used in construction in some countries
Lead in water pipes	Still in use in plumbing, soft solder used chiefly for soldering tinplate and copper pipe joints, is an alloy of lead and tin. Also in faucets and fixtures
Lead in roofs and cornices	Lead sheet for roofing, especially connection areas (chimney and skylight).
Lead in PVC	Stabilizers in PVC products: window profiles, pipes, flooring, and roofing
Other uses	Lead is used in tank linings and electrical conduits

[11] https://saicmknowledge.org/program/lead-paint

2.5.4.2 Mercury in buildings and construction

Mercury and mercury compounds have been used in a variety of products, some of which are relevant to the building and construction sector. One application of mercury in buildings (and under the category e-waste; see also 3.5.1.4) are fluorescent lamps (tubes and compact fluorescent lamps (CFLs)), high-intensity discharge (HID) lamps (mercury vapor, metal halide, (most) high-pressure sodium, low-pressure mercury discharge, etc.), cold cathode (ultraviolet and (some) "neon") light sources and energy efficient mercury lamps currently phased-out under the Minamata Convention which called for a ban of the import, export and manufacture by 2020.

Other documented mercury applications in the building and construction sector include the use of mercury compounds as catalysts in PU elastomers (UN Environment 2019) that were used in products like hardeners and resins for plastic materials, plastic flooring materials, or jointing compounds and the use of mercury compounds as biocides in paints. Levels in PUR floors (e.g. Tartan) were 1000 to 2000 mg/kg (ATSDR 2006).

A few fixed installations in buildings built from 1930 to the 1960s contained mercury-containing equipment such as mercury-containing Gas Pressure Regulators and mercury-containing Boiler Heating Systems (USEPA 2011). Furthermore, some thermostats contain mercury switches where mercury is contained in one or more glass bulbs inside the thermostat (USEPA 2011). For the inventory in buildings, the past and current use of mercury in buildings would be assessed in the frame of the Minamata Convention and the related mercury inventory considering the mercury Toolkit (UN Environment 2019).

2.5.5 Tributyltin in buildings and construction

Tributyltin compounds, such as tributyltin oxide, tributyltin benzoate, tributyltin chloride, tributyltin fluoride, tributyltin linoleate, tributyltin methacrylate and tributyltin naphthenate, are a group of chemicals that are characterized by three butyl groups being covalently bonded to a tetravalent tin centre.

The major applications of tributyltin compounds in buildings are as biocides in anti-fouling paints, wood preservatives (decks, shingles, shakes, wood siding, fences, railings, floors, outdoor furniture, structural lumber, beams, timber, sills, millwork, roofs, trim, clapboards, plywood, porches) and preservatives for other applications (USEPA 2008).

Tributyltin compounds have been listed in Annex III of the Rotterdam Convention since 2008 and in 2017, this listing was extended with industrial uses of tributyltin compounds (UNEP 2017d). Due to concerns regarding the persistence, the potential for bioaccumulation and high toxicity of tributyltin compounds to the aquatic environment, many countries have severely restricted or banned the uses of these compounds as biocide in antifouling paints.

Table 8: Overview of documented applications and occurrences of tributyltin compounds in products potentially relevant for the building and construction sector (UNEP 2021f)

Applications	Products/material
Wood preservatives	Paint, stains and waterproofing to be applied to exterior wood, such as decks, shingles, shakes, wood siding, fences, railings, floors, structural lumber, beams, timber, sills, roofs, plywood, clapboards and porches Pressure or vacuum impregnation of wood for industrial uses
Material preservatives/biocide	Drywall, joint compound, medium density fibre board, particulate board; building material adhesives; polyurethane foams Polymers used for flooring, tiles and carpeting
Impurity in organotin stabilizers for PVC	Rigid construction applications foamed sheeting, for use in external decking and railing, sheeting including foamed panels, vinyl mini-blinds Pipes and molding including all pipe types such as sewer pipes, rainwater goods and drinking water pipes Profile extrusion for windows, door frames, doors and decorative profiles

2.5.6 Asbestos in buildings and construction

Based on their chemistry and fibre morphology, asbestos minerals are categorized into the two groups of amphibole and serpentine asbestos (WHO 2007; UNEP 2021f). The term “amphibole asbestos” refers to five naturally occurring fibrous minerals, namely crocidolite, amosite, tremolite, actinolite and anthophyllite. Chrysotile belongs to the “serpentine asbestos” group and is most commonly found in building materials. All six asbestos minerals have been classified as carcinogenic to humans by the International Agency for Research on Cancer (IARC 2018).

The five amphibole asbestos minerals have been included in Annex III of the Rotterdam Convention. Only chrysotile asbestos is not listed in Rotterdam Annex III. Chrysotile asbestos was a candidate chemical that has been recommended by the Chemicals Review Committee for listing in Annex III to the Rotterdam Convention, but for which the Conference of the Parties (COP) has not yet been able to reach a consensus. Amphibole and serpentine asbestos minerals have been widely used and represent still relevant hazards in a wide variety of building materials, e.g. in thermal insulation elements (pipes, boilers, pressure, vessels, calorifiers), millboard, cement profiled sheets, bitumen products (roofing felts and shingles, bitumen roofing, etc.), wall plaster, filler, reinforced plastic and resin composites. For the inventory, the past and current use of asbestos products in buildings would be assessed and can be linked to National Asbestos Profiles promoted by the World Health Organization (WHO 2007; BAuA 2014; Arachi *et al.* 2021).

Table 9 summarizes the names and chemical identities of the six asbestos minerals. In addition to these minerals, other fibrous minerals are structurally similar but not technically classified as asbestos (UNEP 2021f).

Table 9: Summary of names and chemical identities of the amphibole asbestos minerals

	CAS number	Listed in Rotterdam Annex III
Amphibole asbestos		
Crocidolite	12001-28-4	Yes
Amosite	12172-73-5	Yes
Tremolite	77536-68-6	Yes
Actinolite	77536-66-4	Yes
Anthophyllite	77536-67-5	Yes
Serpentine asbestos		
Chrysotile	12001–29–5	No

2.5.7 Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) in buildings and construction

Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are listed in the Montreal Protocol on Substances that Deplete the Ozone Layer, mandating a global phase-out of ODS.[12] F-gases (fluorinated gases), such as hydrofluorocarbons (HFCs), do not contribute to ozone depletion but are potent greenhouse gases (GHGs) and are addressed by the Kigali Amendment to the Montreal Protocol which mandates a global reduction of HFC uses. Sulfur hexafluoride has the highest known global warming potential (GWP) and has been used in insulated glazing windows as a filler to improve their thermal and acoustic insulation performance (Harnisch and Schwarz 2003).

CFCs, HCFCs and HFCs have been widely used as blowing agents for foam products, some of which are relevant for the building and construction sector in insulations (polyurethane (PUR), EPS/XPS, phenolic, PIR). ODS contained in building insulation (so-called “ODS banks”) and F-gases

[12]https://ozone.unep.org/treaties/montreal-protocol#

in insulation foam can be assessed and inventoried together with POPs in this use (HBCD, PBDEs, SCCP/MCCP).

Inventory activities would be coordinated with the Montreal Protocol and GHG assessments for UNFCCC. The Montreal Protocol does not provide for environmentally sound management of existing stocks of ozone-depleting substances in building materials, which represents a blind spot for the Protocol (Blumenthal *et al.* 2022). Therefore, in addition to cooperation in inventory activities, the future activities on POPs destruction for insulation foams within the Stockholm Convention could support the destruction of the large CFCs, HCFCs and HFCs stock in these uses.

2.5.8 Manufactured nanomaterials and nanoparticles in buildings and construction

Nanotechnology and manufactured nanomaterials are emerging policy issues under SAICM.[13] The buildings and construction sector is a relevant field of application of nanomaterials and nanoparticles primarily in surface coatings, concrete, window glass, insulation and steel (Zhu *et al.* 2005; Pacheco-Torgala and Jalalib 2011; Mohajerani *et al.* 2019). Following the precautionary principle, a preliminary inventory might assess what nanomaterials are used and/or what substances are present in nanomaterial form in construction. This can support the assessment of actual impacts in use and/or C&D management at a later stage on a case-by-case basis. For some substances, the size of the particles applied, and the area of application, in combination with its hazards, such as carbon nanotubes and other nanofibres (Gibb *et al.* 2017; Kobayashi *et al.* 2017), may affect the severity of adverse health or environmental impacts. In particular, the end of life management and fate need further assessment (Suzuki *et al.* 2018).

[13] https://saicmknowledge.org/program/nanotechnology

3 Inventory of POPs in the Electronics Sector and Options to Assess Other Chemicals of Concern

3.1 Introduction to the electronics sector and the need to inventory POPs and other CoC

3.1.1 Background

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 needed to be managed in an environmentally sound manner; this e-waste volume is expected to increase in the future (Forti *et al.* 2020; UNEP 2021g; Baldé *et al.* 2024). While the quality and value of the plastic may be high, the recycling rates are low due to the presence of legacy additives listed as POPs (e.g. PBDEs and HBCD) in WEEE plastic and the complexity of the EEE plastic mixtures (UNEP 2021g).

Releases of hazardous substances from EEE/WEEE can impact human health and the environment through all stages of the life cycle of EEE: During manufacturing, workers and surrounding communities may come into direct contact with CoC, which can result in significant adverse effects (ILO 2012). Many POPs and other CoC are not chemically bonded and can be released in the EEE use phase from treated plastic materials into the indoor environment (by volatilization, leaching and abrasion) contaminating air and dust with related human exposure (Rauert & Harrad 2015; Lucattini *et al.* 2018; Jin *et al.* 2019). Used EEE and e-waste often are exported from industrial countries to developing countries, where large releases and contamination occur from open burning of WEEE plastic (ILO 2012; Lebbie *et al.* 2021; Petrlik *et al.* 2022). This includes the releases of POPs additives from the plastic and heavy metals as well as highly toxic PCDD/PCDF and brominated and brominated-chlorinated analogues (PXDD/PXDF; PCDD/PCDF), which are formed during combustion (Weber *et al.* 2003; Shaw *et al.* 2010; Houessionon *et al.* 2021). On the other hand, valuable metals are recovered in many countries from WEEE by formal and informal recycling.

Inefficiently and poorly sorted WEEE plastic results in the contamination of recyclates with restricted and hazardous substances, which results in POP contamination of new products, such as children's toys and kitchen utensils (Puype *et al.* 2015; Kuang *et al.* 2018, Kajiwara *et al.* 2020: UNEP 2023a). In addition, PBDD/PBDF, which have recently been proposed as a POP by Switzerland for evaluation in the POPRC (UNEP 2024b), are present in high concentrations in BFR-containing WEEE plastic (Sindiku *et al.* 2015) and are transferred, for example, to children's toys at significant levels (Petrlik *et al.* 2018, Behnisch *et al.* 2023).

One major challenge is that manufacturers usually do not disclose information on additives in plastics and information is therefore unavailable at end-of-life. This lack of information about the presence of CoC in products and wastes complicates separation and recycling, undermines the circular economy approach, and can be a risk for recyclers and consumers of recycled products.

3.1.2 Assessment and inventory of POPs and other CoC relevant to the EEE/WEEE sector

Considering the need to move to a more circular economy for electronics (UNEP 2021i) end-of-life management and recycling require considerable improvement. When recycling and recovering plastic and other materials from WEEE, it is important to consider that a share of the plastics in WEEE contains POPs. This includes both currently produced and used POPs (Section 3.2), as well as legacy POPs, which are no longer produced but are still present in EEE that remains in use (Section 3.3; Table 10).

Additionally, plastic and other parts of EEE/WEEE contain other CoC (Section 3.5), including POP candidates (Section 3.4). POPs and other CoC need to be managed at the end-of-life in an environmentally sound manner with the destruction of plastic containing POPs, or removal of other CoC and pollutants and recycling of the clean plastic fractions (UNEP 2021g). The inventory of POPs and other CoC in EEE and WEEE is one basis for the establishment of environmentally sound management of WEEE, including detoxification and recycling of related plastic.

The governmental institutions (and other involved stakeholders) responsible for planning, guiding and supervising the end-of-life management of e-waste should know about POPs and other pollutants present, as well as about valuable materials present in e-waste to ensure optimal recovery of resources, including plastics and environmentally sound management of POPs and other pollutants. EEE is a major use area of plastics containing additives listed as POPs such as brominated flame retardants (PBDEs and, to a lesser extent, HBCD) in different major plastic materials, such as ABS, HIPS and others (Table 10).

Table 10 provides an overview of POPs in EEE, their major or minor use and their period of use. Table 10 also gives an overview of the information needed for the inventory, key stakeholders such as ministries or national statistical offices (NSOs) that might have this information, and references to detailed inventory guidance on individual POPs and calculation methods.

The inventory of POPs and other CoC in EEE/WEEE is essential for the environmentally sound management (ESM) of WEEE. Governmental institutions and other stakeholders responsible for EEE/WEEE management should have an overview of POPs (Section 3.2 and 3.3) and other CoC (see Section 3.5) to oversee WEEE recovery of resources including plastics and ensure ESM of materials containing these substances.

In the inventory assessment, the amount of POPs in new EEE, particularly in the plastic components of EEE currently in use and stock, should be compiled (Table 10). Additionally, the amount of WEEE fractions containing POPs should be estimated, and the waste management and recycling situation should be assessed.

The inventory of POPs in plastics of EEE/WEEE is expected to address the following:

- The total amount of plastic present in EEE and WEEE and the share of plastic containing POPs.
- For POPs currently produced the use in new EEE products produced and imported in exempted and non-exempted uses.
- POPs in second-hand EEE imported in the inventory year (and in previous years).
- POPs in EEE stocks in use and/or stored in households, and public and private sector institutions and organizations.
- POPs entering the waste stream in WEEE plastic (synergy Basel Convention).
- POPs in WEEE plastics used in recycling (from domestic and imported WEEE plastic).
- Total amount of POPs disposed to landfills in the past.

All hazardous chemicals in EEE are an emerging SAICM policy issue,[14] particularly CoC were used in EEE such as PFAS (SAICM issue of concern[15]), heavy metals like mercury or lead, phthalates (EDCs SAICM emerging policy issue) and asbestos (see Section 3.5), which could be assessed in a sectoral inventory approach together with POPs.

In the inventory assessment, the total amount of POPs impacted plastics and related POPs amount should be compiled (see e.g. UNEP 2021a). It is recommended that a rough overall estimate of plastic in EEE/WEEE is established considering that the average plastic content of EEE is 20% (UNEP 2021a) and therefore can be estimated if the amount of EEE and WEEE is known. The status of current waste management of the individual plastic (and other waste) fractions containing POPs should also be described in the POPs inventory. This can contribute to an overall plastic inventory as a basis for an ESM of plastic waste (UNEP 2023e) considering POPs and other CoC present in plastic (UNEP 2023a).

[14] https://saicmknowledge.org/epi/hazardous-chemicals-electronics
[15] https://saicmknowledge.org/program/perfluorinated-chemicals

Table 10: POPs used in electronics sector, inventory information which can be collected, potential data sources and estimated priority level

POP	Application in EEE	Use period*	Information to be collected (along life cycle)	Potential data source**	Inventory guidance	Priority (recom. Tier)
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	Current import/new use in WEEE. Amount of plastic in EEE containing decaBDE and amount of decaBDE. Amount/management of WEEE plastic	National Statistical Office (NSO), Ministry of Environment, Ministries of Industry & Telecommunication); customs, producers, importers and retailers of EEE Producers and vendors of flame retardants WEEE management sector; plastic recycling sector	PBDE inventory guidance (UNEP 2021a)	High (Tier II and III)
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)	Amount of plastic in EEE containing c-OctaBDE and amount of c-OctaBDE. Amount & management of WEEE plastic		PBDE inventory guidance (UNEP 2021a)	Medium (Tier II)
c-PentaBDE (tetraBDE/ pentaBDE)	Flame retardant in PVC cables, printed circuit boards, and PUR foam	Former use (1970 to 2004)	Amount of plastic in EEE containing c-PentaBDE and amount of c-PentaBDE. Amount & management of WEEE plastic		PBDE inventory guidance (UNEP 2021a)	Low (Tier II)
HBCD	Minor flame retardant used in HIPS in CRT casings and other plastic parts	Former use (1970 to 2013)	Amount of HBCD containing HIPS in EEE. Amount, management and recycling of HIPS in WEEE.		HBCD inventory guidance (2021b)	Low (Tier I)
SCCP (and MCCP***)	Plasticizer and FR in cables and other PVC and rubber parts	Current and former uses. SCCP is exempted for use in PVC	Current import/new use in EEE Share of cables and PVC/rubber containing SCCPs in EEE Amount & management of cables.	Ministries of Environment and Industry; producers and importers of EEE	SCCP inventory guidance (UNEP 2019a)	Medium (Tier II and III)
PCBs and PCNs	Capacitors in certain equipment, such as ballasts in fluorescent lamps; cables (PVC and others)	Former use (PCBs 1950 to 1980s; PCNs 1930s to 1960s)	Former use of PCB in capacitors in EEE and cables; Amount, management and recycling of cables.	NSO; Ministries of Environment and Industry; International research; Waste sector	PCN and PCB inventory guidance (UNEP 2021c; (UNEP and PEN 2016; UNEP 2019e)	High (PCBs) Low (PCNs) (Tier II and III)

POP	Application in EEE	Use period*	Information to be collected (along life cycle)	Potential data source**	Inventory guidance	Priority (recom. Tier)
PFOA	Medical devices; non-intentional in fluoropolymers	Current and former uses	Current use; former use in these applications and end-of-life management	NSO; Ministries of Health Associations, producers and importers of medical devices,	PFOA, PFOS and PFHxS inventory guidance (UNEP 2023b)	Low (Tier I) (small amount)
PFOS	Medical devices	Mainly before 2002	Former use in these applications and end-of-life management of equipment			Low (Tier I) (small amount)
Dechlorane Plus	Flame retardant use for wire and printed circuit board housing, other plastics and rubber parts	Former and current uses	Current and former use and end-of-life	Ministries of Environment and Industry; manufacture of specific products; NSO	Not developed	Medium (Tier I and Tier III)
UV-328	UV absorber in liquid crystal displays	Since 1970s	Amount of crystal displays in medical and in-vitro diagnostic devices and in liquid crystal displays in instruments		Not developed yet	Medium (Tier I and III)

**EEE and plastics in EEE have a wide service life span of a few years (e.g. mobile phones) to some EEE with a service life of more than 30 years.*
***Details on stakeholders which can be consulted are compiled in the individual inventory guidance documents (see column "Inventory Guidance").*

3.2 Inventory of current intentionally used POPs in the EEE sector

Some POPs are still used to varying degrees in new EEE. These include decaBDE (with certain exemptions for EEE), SCCPs (mainly in PVC), PFOA and UV-328. Additionally, the POP candidate MCCPs is used in plastics (mainly in PVC) in electronics (Section 3.4). For these POPs currently in use, it is essential to assess the entire supply chain and life cycle, encompassing production, import/export, use, recycling and end-of-life stages.

3.2.1 DecaBDE in EEE

DecaBDE has been a major flame retardant in WEEE plastic since 1980s. Because of the restrictions on the use of c-DecaBDE in EEE (e.g. in Europe in 2006), many large EEE companies have transitioned away from decaBDE already before 2010 and most use ended around 2015 (UNEP 2021a). Some continued use is allowed in plastic housings and parts used for heating home appliances. The typical average decaBDE content in polymer fractions of different WEEE categories (see Table 11) has been compiled under the Stockholm Convention's PBDE inventory guidance. Details on inventory development can be found in the guidance for developing the decaBDE/PBDE inventory (UNEP 2021a).

Table 11: Hexa/heptaBDE (of c-octaBDE) and decaBDE concentrations in polymers in relevant EEE categories (UNEP 2021a; data from Europe; Wäger *et al.* 2010; Hennebert & Filella 2018)

Relevant EEE	**Total polymer fraction (mean)**	**∑hexa/heptaBDE content (mean) in plastics**	**decaBDE content (mean) in plastics**
	$f_{Polymer}$ [in % by weight]	$C_{\sum hexa/heptaBDE;Polymer}$ in [kg/tonne]*	$C_{decaBDE;Polymer}$ in [kg/tonne]*
Cooling/freezing appliances; washing machines	25%	**<0.05**	**<0.05**
Heating appliances	30%	**<0.05**	**0.8**
Small household appliances	37%	**<0.05**	**0.17**
ICT equipment. w/o monitors	42%	**0.12**	**0.8**
CRT monitor casings	30%	**1.37**	**3.2**
Consumer equipment w/o monitors (1 composite sample)	24%	**0.08**	**0.8**
TV CRT monitor casings	30%	**0.47**	**4.4**
Flat screens TVs (LCD)	37%	**0.009**	**2.7**

**RoHS limit for c-OctaBDE is 1,000 mg/kg or 1 kg/t. The Basel provisional low POPs contents for PBDEs are 1,000 mg/kg (1 kg/t), or 500 mg/kg (0.5 kg/t) or 50 mg/kg (0.050 kg/t) (UNEP 2019b).*

3.2.2 SCCP in EEE

SCCPs (and POP candidate MCCPs; see Section 3.4.1) are used as plasticizers and flame retardants in plastics, cables, rubber and polymeric materials in EEE, particularly in PVC. SCCPs were listed as POPs in 2017, with a range of exemptions which recently expired, and are still used in EEE. MCCPs are proposed by the POPRC for listing at COP12 in 2025 (UNEP 2023c) and are also currently used. The following would be assessed for an inventory:

- If SCCPs and MCCPs are still used in EEE products (e.g. in PVC cables) and the related amount.
- If SCCPs (and MCCPs) are still present in EEE products in other uses not exempted and related amount.

A first monitoring of different plastic shredders from WEEE found SCCP levels between 1 mg/kg to 140 mg/kg (Norwegian Environment Agency 2021). Based on the existing initial data, an impact factor of 25 mg/kg SCCPs in WEEE plastic is suggested for calculating the SCCP content in the WEEE plastic inventory.

3.2.3 PFOA and related substances in EEE

PFOA-related polymers have been widely used in wires, cables, tapes, insulators and solder sleeves in the electronics industry (UNEP 2023b). PFOA and other PFAS are/were used in the electronics industry in the production of printed circuit boards, loudspeakers, transductors, digital cameras, cell phones, printers, scanners, satellite communication systems, radar systems and many other products (UNEP 2023b). A share of fluoropolymers present in EEE (including certain medical devices) contain to a certain degree PFOA and can form PFOA in thermal degradation processes (FOEN 2017).

PFOA and related compounds are/were used in the semiconductor industry and are contained in equipment used to manufacture semiconductors (UNEP 2023b). PFOA/PFOS and related compounds have also been used in medical devices, such as video endoscopes, and CCD colour filters, but levels are low (UNEP 2023b) and not relevant for an inventory.

For an inventory, current and former use in the relevant applications and amount in use and end-of-life management would be compiled.

3.2.4 UV-328 in EEE

2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol (UV-328; CASRN 25973-55-1) is a substituted phenolic benzotriazole (BZT), and has been listed under the Stockholm Convention with a range of exemptions including production (UNEP 2023d).

UV-328 is used in EEE as a UV absorber in liquid crystal displays in instruments for analysis, measurements, control, monitoring, testing, production and inspection (such as recorders, infrared radiation thermometers, digital storage oscilloscopes and radiographic testing instruments) other than for medical applications (UNEP 2023d). There are no data of the share of treated displays or average levels in WEEE plastic.

3.3 POPs that have formerly been used in EEE and are present in stock in EEE and WEEE

A range of POPs have formerly been used in plastic in electronics. Due to the maximum service life of certain electronic devices of more than 25 years (Charbonnet *et al.* 2020), most legacy POPs formerly used in EEE are still present in some stock of EEE and WEEE and need to be considered.

3.3.1 C-OctaBDE (hexaBDE/heptaBDE) and c-PentaBDEs (tetraBDE/pentaBDE) in (W)EEE

Production and use of c-OctaBDE and c-PentaBDE stopped in 2004. Therefore, only WEEE produced before 2004 contain these PBDEs as flame retardant. The main application of c-OctaBDE (approx. 90%) was in ABS polymers that were mainly used for plastic CRT casings and office equipment such as copying machines and business printers. The impact factors to calculate hexaBDE/heptaBDE in EEE plastic fractions are compiled in Table 11 and details on inventory can be found in the PBDE inventory guidance (UNEP 2021a). c-PentaBDE was only used in minor amount in EEE in cables and printed circuit boards and concentrations in WEEE plastic are very low (2.4 mg/kg) with minor relevance (Taverna *et al.* 2017)[16].

3.3.2 Dechlorane Plus in (W)EEE

Dechlorane Plus (DP; CAS No. 13560-89-9) is a polychlorinated flame retardant that contains two stereoisomers, syn-DP (CAS No. 135821-03-3) and anti-DP (CAS No. 135821-74-8). DP has been listed under the Stockholm Convention in 2023 (UNEP 2023d) and production stopped recently (UNEP 2024a).

[16] WEEE from 1980/1990s contained considerably higher average c-PentaBDE levels of 32 mg/kg (Taverna *et al.* 2017).

Dechlorane Plus was used as a non-plasticizing flame retardant in thermoplastics (e.g. polypropylene, polyester, ABS, natural rubber, polybutylene terephthalate (PBT)) and thermosets (e.g. epoxy and polyester resins, polyurethane foam, polyurethane rubber, silicon rubber). DP is included in these plastics in EEE (UNEP 2021f). DP is used as an FR in wires and printed circuit boards, housings, other plastics and rubber parts in EEE such as medical imaging applications and radiotherapy devices/installations. A first robust national inventory with quantification of FR contents in WEEE plastic in Switzerland indicates that DP is overall a minor flame retardant in WEEE plastic with an average concentration of 33 mg/kg for WEEE or 110 mg/kg WEEE plastic).

Recent monitoring of some WEEE plastic fractions in Norway detected DP only in the rejected fractions at measurable levels (15 mg/kg) while separated WEEE plastic was below the quantification limit (1 mg/kg) indicating that DP average levels in the total measured WEEE plastic fractions were around 5 mg/kg (Norwegian Environment Agency 2021). Based on this monitoring, a preliminary DP impact factor for WEEE plastic of 40 mg/kg is suggested. DP is present in EEE in a considerably lower concentration than, for example, DecaBDE (approx. 1/10) (Taverna *et al.* 2017; Norwegian Environment Agency 2021). Therefore, a specific DP inventory in EEE is not recommended (except for considering exemptions), but an overall inventory of halogen-containing WEEE plastic covering brominated, chlorinated and fluorinated POPs (PBDEs, HBCD, HBB, PCBs, DP, SCCPs, PFOS, PFOA, PFHxS and candidate MCCPs).

DP was listed with a range of exemptions (UNEP 2023d): Medical imaging and radiotherapy devices and replacement parts of instruments for analysis, measurements, control, monitoring, testing, production and inspection, certain medical devices and in-vitro diagnostic devices. (UNEP 2023d).

3.3.3 HBCD in (W)EEE

HBCD has been a minor additive flame retardant used in high-impact polystyrene (HIPS) for casing (IT equipment and TVs) and other parts of EEE. A robust WEEE plastic inventory of Switzerland indicates that the average concentration of HBCD in WEEE plastic was 42 mg/kg and therefore less than 4% of the average decaBDE content in WEEE plastic (Taverna *et al.* 2017) and has hence a low priority.

3.3.4 Hexabromobiphenyl (HBB) in (W)EEE

Since known production of HBB stopped in the 1970s, the majority of products and articles that contain HBB were largely disposed of decades ago. As a result, an inventory of HBB is not recommended (UNEP 2021a).

3.3.5 PCBs and PCNs in (W)EEE

The major use of PCBs was in transformers and capacitors. This equipment partly ends in e-waste recycling with PCB contamination at e-waste sites (Petrlik *et al.* 2022). PCBs have been used in small capacitors in different EEE (e.g., ballasts in fluorescent lamps, washing machines) until the 1980s. Recycling resulted in some PCB contamination and release when shredding WEEE (UNEP 2008). PCB was also used as a flame retardant in cables before the 1970s and might still impact cable recycling (UNEP 2008).

PCNs have also been used in cables and capacitors, but at lower volumes and mainly from 1930 to 1960s (UNEP 2017e). Therefore, they have low relevance for WEEE recycling and related inventory.

The remaining PCBs in cables could be addressed within an overall inventory and assessment of POPs in cables (PCBs, PCNs, PBDEs, HBCD, SCCPs, DP and POP-candidate MCCPs).

A Swiss national monitoring study found an average PCB concentration of 2 mg/kg in WEEE and stated that they mainly originate from capacitors (Taverna *et al.* 2017).

3.4 POP candidates used in EEE

The POP candidate MCCP is used as a plastic additive in EEE. For MCCPs, no inventory guidance has yet been developed. However, the use of MCCPs is similar to SCCPs and the guidance on SCCP inventory can be applied. Since only limited information on the frequency and concentration of EEE plastics is available, the generation of monitoring data of CPs in EEE/WEEE (Tier III) is needed. Considering Article 9, validated studies/data can be sent to the BRS Secretariat, serving as a clearinghouse mechanism for information on POPs (UNEP 2021j).

3.4.1 MCCPs (POP candidate) in (W)EEE

Chlorinated paraffins with carbon chain lengths in the range C14-17 (CAS No: 85535-85-9) and chlorination levels at or exceeding 45 percent chlorine by weight (MCCPs) meet the Convention Annex D criteria (UNEP 2021h) and the POPRC proposed the listing of MCCPs at next COP12 in 2025 (UNEP 2023c[6]).

MCCPs[6] are still produced in high volumes (approx. 0.7 million t/yr frequently in mixtures) (Chen *et al.* 2022) and used, for example., in PVC, rubber and PUR (Brandsma *et al.* 2021; Chen *et al.* 2021). Major PVC uses in EEE are cables and PVC plastic components. MCCPs are used in the same applications as SCCPs (Section 3.2.2), thus the two CP mixtures can be assessed and managed together. The first monitoring of plastic shredders from WEEE had MCCP levels between 16 mg/kg to 1,700 mg/kg (Norwegian Environment Agency 2021). Based on these initial data a preliminary average concentration of 100 mg/kg MCCP in WEEE plastic might be assumed.

3.5 Assessment of other chemicals of concern that are used or present in EEE/WEEE

All hazardous chemicals in the life cycle of electronics are a SAICM emerging policy issue.[17] In addition to POPs, other CoC can be reintroduced into consumer products by recycling, e.g. antimony (a flame retardant synergist) and heavy metals including cadmium, chromium VI, mercury, and lead.

This section aims to provide an overview of selected relevant CoC in the EEE sector listed under other MEAs and/or addressed by SAICM aiming for a synergistic approach of MEAs implementation and integrated management of POPs and other CoC where appropriate.

The following aspect poses a particular challenge in the EEE sector. Electronic and electrical products contain several other CoC, including such heavy metals as lead, mercury and other metals, phosphorous flame retardants and certain phthalates. In addition to the chemicals under MEAs and SAICM, the EU RoHS Directive[18] is also considered in the EEE sector, as it explicitly represents a substance-specific regulation for the EEE sector and defines various EEE categories, an approach that has already been adopted similarly in countries worldwide.[19]

The objective is to provide a first overview of how certain CoC link to products of the EEE sector and to provide initial information to consider these CoC coordinated with POPs inventory activities as a basis for (future) integrated sector-specific management.

Table 12 provides an overview of selected CoC, and their major use in the EEE sector as a basis for their consideration.

[17] https://saicmknowledge.org/epi/hazardous-chemicals-electronics

[18] The EU RoHS directive, restricts the use of several hazardous materials in EEE. All EEE products sold in the EU must comply with RoHS. RoHS restricts currently the use of ten hazardous substances.

[19] https://rohsguide.com/rohs-future.htm

Table 12: Selected CoC (other than POPs) in EEE related to MEAs or SAICM

CoC	MEA or SAICM	Short description	Use in EEE	Relevance
Heavy metals such as lead, cadmium and mercury	SAICM, Minamata Convention	Toxic metals, neurodevelopmental disorder	Used in a variety of EEE products	High
Polycyclic aromatic hydrocarbons (PAHs)	UNECE LRTAP Convention	Many PAHs are carcinogenic, mutagenic, or toxic for reproduction	Unintentional trace contaminants in black plastics and rubber parts;	Medium
Other PFASs (not POPs)	SAICM	very persistent, very mobile (compounds or degradation product)	Flame retardant (PFBS); NIAS in fluoropolymers (and thermal degradation products)	Medium
Phthalates	SAICM EPI (EDC)	Certain phthalates are EDCs and reprotoxic	Plasticiser in cables and other plastic parts (mainly PVC)	Medium
Halogenated OPFR	SAICM EPI[14]	Certain halogenated OPFR are carcinogen or toxic for reproduction	Major flame retardants in casings and other plastic parts	Medium
Asbestos	Rotterdam Convention Annex III	Classified as carcinogenic to humans	Electrical panels, wire insulation, cable wrap and electrical paper	Medium
CFCs, HCFCs, HFCs	Montreal Protocol	Ozone depleting substances; GHG	Refrigerants in air conditioner, cooling equipment; heat pumps	High

3.5.1 Certain metals and metalloids in (W)EEE

A particularly prominent group of hazardous additives consists of metals of concern, including cadmium, lead, mercury, cobalt, tin and zinc. Mercury, lead and cadmium are of greatest concern for this guidance because of their pollution in the environment and because low-level environmental exposure in children that was previously considered as safe is associated with adverse neurodevelopmental outcomes.

Antinomy, arsenic, cadmium, chromium, copper, nickel, lead and mercury are the most common heavy metals in EEE. Heavy metals are important resources and recovery in BAT smelters operated according to best environmental practice (BEP), and ESM of ashes and slags is required. In simple smelters or if subjecting WEEE to open burning, metals and metalloids are partly released into the environment with related environmental and human exposure.

3.5.1.1 Lead in (W)EEE

Lead is a significant and partly indispensable substance in some parts and components used in EEE and is specifically regulated, for example by the RoHS Directives for EEE in different countries, including China, the EU, India, Japan and Korea).[19] There are RoHS exemptions that allow higher concentrations than the threshold limit of 0.1% for certain parts, components, use cases and functions. Lead is used in solder, electronic components (e.g. chipsets, transistors, diodes, resistors, capacitors), cable sheathing, AC connectors, x-ray shielding, and in the glass of cathode-ray tubes or EEE. For the inventory, past and current use of lead in EEE would be assessed and quantified as well as the flow in WEEE as a basis for control and recovery.

3.5.1.2 Cadmium in (W)EEE

About 75% of cadmium used in manufacturing is for the production of cadmium-nickel rechargeable batteries in some EEE. Batteries are not restricted by the RoHS directive within a threshold limit of 0.01%. Other uses in EEE are in semiconductors (found in most EEE products) as cadmium selenide and as a plating material for resistance to use as a protective shield against corrosion in electronics and other metals corrosion. Cadmium has also been used as stabilizers in PVC and other plastics used in EEE (e.g. cables).

3.5.1.3 Mercury in (W)EEE

Mercury and mercury compounds have been used in a range of products, some of which are relevant to the EEE sector. Mercury in EEE is used in batteries, switches, thermostats and fluorescent lamps. In this guidance, the lamps are also mentioned for the building sector (see Section 2.5.4.2) but should only be considered once.

The development of a mercury inventory in EEE/WEE would be conducted in the frame of the Minamata Convention considering synergies with Stockholm Convention inventory activities.

3.5.1.4 Chromium compounds (in particular hexavalent Cr(VI)) in (W)EEE

Chromium and chromium compounds were applied to get yellow, red and green colours in PVC, polyethylene, polypropylene or lead chromate molybdate sulphate red applied generally in all types of plastics, where red pigments are used (Hansen *et al.* 2014). In particular, hexavalent Cr(VI) is carcinogenic (IARC Group 1) and of high concern.

3.5.1.5 Other hazardous metals or metalloids in (W)EEE

Other metals or metalloids of concern present to some extent in EEE are antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), Nickel (Ni) and organotin compounds (Swedish EPA 2011).

3.5.2 PFAS other than POPs-PFAS in (W)EEE

All PFAS is an issue of concern under SAICM. Perfluorobutane sulfonate (PFBS) (and possibly other PFASs) are used as flame retardant for polycarbonate resins (Garg *et al.* 2020). PFBS is detected at high concentration in soils of e-waste sites in Ghana (275 µg/kg) and Nigeria (266.5 µg/kg and 242.5 µg/kg) (Eze *et al.* 2023). The lithium salt of PFAS such as lithium bis(fluorosulfonyl) imide (LiFSI) and lithium 4,5-dicyano-2-trifluoromethyl-imidazolide (LiTDI) are utilized in fuel cells and battery electrolytes (Brückner *et al.* 2020; Garg *et al.* 2020). PFAS are also used in printers (in related ink).

Fluoropolymers are used in electronics in cables, semiconductors, printed circuit board and antireflective coatings (The Chemours Company 2020). Fluoropolymers can contain PFOA and also form PFOA and other short- and long-chain perfluorinated alkyl acids when thermally treated at a temperature below approx. 700 °C (Ellis *et al.* 2001; Ellis *et al.* 2003; Schlummer *et al.* 2015; FOEN 2017) which is frequently happening in open burning of WEEE plastic and smouldering of printed circuit boards in emerging economies.

3.5.3 Certain phthalates in (W)EEE

Phthalates are plasticizers mainly used in PVC and found in EEE (i.e., cables, wires, connectors and plastic enclosures). Phthalates are also used in medical devices, including in vitro medical devices, and monitoring and control instruments. RoHS restricts four phthalates DEHP, BBP, DBP and DIBP with a threshold limit of 0.1% (European Commission 2015).

3.5.4 Halogenated organophosphorus flame retardants in (W)EEE

Halogenated organophosphorus flame retardants (OPFRs) are major flame retardants used in EEE plastic. Halogenated OPFRs have hazardous properties including tris(2-chloroethyl) phosphate (TCEP; toxic for reproduction), tris(1,3-dichloroisopropyl) phosphate (TDCPP; carcinogen), tris(2-chloroisopropyl) phosphate (TCPP; toxic for reproduction) (Van der Veen and de Boer *et al.* 2012; Chen *et al.* 2019; European Commission 2022) and are therefore considered in the SAICM emerging policy issue.[14] High levels of OPFR contamination at African e-waste sites were reported (Eze *et al.* 2023), highlighting their relevance for developing countries. High releases of the carcinogenic TDCPP and TCPP in leachates of landfills in Africa (Sibiya *et al.* 2019), Brazil (Cristale *et al.* 2019) and China (Qi *et al.* 2019) indicate relevant disposal of OPFR-containing waste such as polymers from WEEE (and C&D waste or vehicles) in landfills.

3.5.5 CFCs, HCFCs and HFCs (F-gases) in (W)EEE

CFCs, HCFCs and HFCs are still used and present in several types of EEE. CFCs, HFCs were or are consumer and commercial refrigerants in refrigeration; air-conditioning and heat pump equipment. Inventory activities would be coordinated with Montreal Protocol activities and the inventory of ODS and GHG.

4 Inventory of POPs in the Transport Sector and Options to Assess Other Chemicals of Concern

4.1 Introduction to the transport sector and the need to assess POPs and other chemicals of concern

4.1.1 Background

Vehicles are a large material flow covering cars, industrial vehicles, trains, ships and airplanes. Today, 1.475 billion vehicles are present globally, including 1.1. billion passenger cars.[20] These passenger cars contain approximately 200 million tonnes of plastics. With an average lifetime of approximately 15 years, every year some 14 million tonnes of plastic waste are generated from passenger vehicles alone, which need to be managed by ESM. The valuable metals – ferrous and non-ferrous metals including precious metals – are recovered to a large extent by formal and informal recycling. On the other hand, plastics and synthetic textiles in vehicles are often not recycled or recovered, but end up as automotive shredder residues (ASR) of about 300 kg for a mid-size car.

Considering the need to move to a more circular economy and a better recovery of resources, plastics and other polymers from vehicles need to be better reused, recycled and recovered as required, for example, by the EU Directive on end-of-life vehicles (European Union 2000). When increasing the recovery and recycling rates, it needs to be considered that vehicles contain a range of hazardous chemicals such as POPs (Section 4.2 and 4.3; Table 13), POP candidates (Section 4.4) in some of the plastics including synthetic textiles. Vehicles also contain other CoC (Section 4.5; Table 13) which need to be managed in an environmentally sound manner.

The inventory of POPs and other CoC in the transport sector and ELVs is one basis for the environmental management of this sector. Some impact factors for POPs have been developed for passenger cars (e.g. UNEP 2021a; see below) while for other categories (e.g. trains, airplanes, cruise ships) sufficient data for impact factors are not available.

4.1.2 Assessment and inventory of POPs and other CoC relevant to the transport sector

The transport sector was a relevant use area of plastics containing additives listed as POPs such as brominated flame retardants (PBDEs and HBCD), SCCPs/MCCPs and PFOA (Section 4.2 and 4.3). Table 13 provides an overview of POPs and POP candidates in the transport sector, their major or minor use and period of use. Table 13 also gives an overview of what information to collect for the inventory and on references to the respective inventory guidance where detailed information on the individual POP and the calculation for inventory development can be found.

Furthermore, other CoC (Section 2.5) are present in the transport sector such as lead (SAICM emerging policy issue[21]), PFAS (SAICM issue of concern[22]), and asbestos (listed under the Rotterdam Convention), which could be assessed in a sectoral inventory approach together with POPs.

The inventory of POPs and other CoC in the transport sector is one basis for the ESM of end-of-life vehicles. The governmental institutions (and other involved stakeholders) responsible for planning, guiding and supervising the end-of-life management of vehicles should know about POPs and other pollutants, as well as valuable materials present in vehicles to ensure ESM of POPs and other pollutants in end-of-life vehicles (ELVs), in particular during the dismantling of vehicles and the management of automotive shredder residues (ASR) for optimal recovery of resources including plastics.

[20] https://hedgescompany.com/blog/2021/06/how-many-cars-are-there-in-the-world/
[21] https://saicmknowledge.org/program/lead-paint
[22] https://saicmknowledge.org/program/perfluorinated-chemicals

In the inventory assessment, the total amount of POPs impacted by plastic and related POPs amount should be compiled (Table 13). It is recommended that a rough overall estimate of plastic amount in ELV is established considering that the average plastic/polymer content of an average car is 200 kg (UNEP 2021a) and therefore can be estimated if the number of cars is known. Also, the status of current waste management of the individual plastic (and other waste) fractions containing POPs should be described in the POP inventory. This can contribute to an overall plastic inventory as a basis for an ESM of plastic waste (UNEP 2023e) considering POPs and other CoC present in plastic.

An inventory/overview of POPs in the transport sector would therefore:

- Estimate the total amount of plastic and other polymers present in vehicles and generated from ELVs management (for the inventory year).
- Consider the respective concentration of the individual POPs in vehicles (see sections below) to estimate the total amount of the individual POPs in the polymers.
- Get information on the share of ELV polymers that are recycled and the products manufactured.
- Get information on the share of ELV polymers that are not recycled and the final waste treatment.

Table 13: POPs used in the transport sector, inventory information that can be collected, potential data sources and estimated priority level

POP	Application in transport sector	Use period*	Information to be collected (along life cycle)	Potential data source**	Inventory guidance	Priority (recom. Tier)
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 in transport	Current import/new use in transport. Amount of plastic in vehicles containing decaBDE and amount of decaBDE. Amount and management of plastic in ELV/ASR	NSO, ministries (Transport, Industry, Environment), customs, industry; importers; ELV management sector; Waste management agency, metal recycling industry, scrap dealers	PBDE inventory guidance (UNEP 2021a)	High (Tier II and III)
c-PentaBDE (tetra/penta BDE)	Flame retardants in PUR foam (seat, headrest) and textiles in US vehicles	Former use in vehicles (1970 to 2004)	Amount of c-PentaBDE in transport and amount and management of plastic in ELV and ASR			High due to exposure risk (Tier II and III)
HBCD	EPS/XPS insulation in refrigerator trucks. Minor use in transport textiles (seating, floor coverings)	Former use (1970 to 2013)	Amount of refrigerator trucks. Amount of HBCD in transport textiles. Amount and management of plastic in ELV and ASR		HBCD inventory. guidance (UNEP 2021b)	Low (Tier I)
SCCPs (and MCCPs)[6]	Plasticizer and FR in cables and other PVC and rubber parts in vehicles	Current and former uses. Use of SCCP is exempted in PVC	Current import/new use. Share of cables and PVC/rubber containing SCCPs in ELV and ASR; amount & management		SCCP invent. guidance (UNEP 2019a)	Medium (Tier II and III)
PFOA	Side-chain fluorinated polymers in textiles/ carpets; impurity in fluoropolymers	Current and former uses	Current/former use and amount in use and end-of-life management (ASR)	Ministries (Transport, Industry, Environment), industry; importers; ELV management sector; NSO	PFOA, PFOS and PFHxS inventory guidance (UNEP 2023b)	Medium (Tier II and III)
PFOS	Side-chain fluorinated polymers in textiles/ carpets	Former uses (main use before 2002)	Amount in use; amount & management ELV and ASR			Low (Tier I)
Dechlorane Plus	Use as flame retardant in plastic in the automotive and aviation sector	Former use (production stopped 2023)	Current and former use in aviation and automotive components	Ministries (Transport, Industry, Environment), industry; importers; ELV management sector; NSO	No	Medium (Tier II and III)
UV-328	Liquid crystal panels and meters; paint; resin used for interior/exterior parts	Continued use	Current and former use in aviation and automotive components; amount & management		No	Medium (Tier II and III)

**Vehicles and plastics in vehicles have a long service life in particular in emerging economies often 30 years and longer.*
***Details on stakeholders which can be consulted are compiled in the individual inventory guidance documents (see column "Inventory Guidance")*

4.2 Inventory of current intentionally used POPs in the transport sector

POPs that are to some extent still used in the vehicles are decaBDE, SCCPs and PFOA. Some POPs currently evaluated by the POPRC are also likely used in plastics in vehicles such as MCCPs (mainly in PVC cables and other PVC part). For these POPs, the entire supply chain and life cycle (production – import/export – in use – end-of-life) should be inventoried to adequately assess POPs used in vehicles.

4.2.1 DecaBDE in vehicles

DecaBDE is exempted for the use in polymers in vehicles with very detailed description of the uses.[23] A major use of decaBDE was in vehicles (seat textiles and a wide range of plastic parts) where there was not an early restriction (like for electronics by the RoHS directive). Japan, for example, phased out the use of decaBDE in vehicles at the end of 2016 (Liu *et al.* 2019). In North America, a total of 380,000 tonnes of decaBDE was used from 1970 to 2013, with 133,000 tonnes (35%) used in vehicles (Abbasi *et al.* 2015). Also in Japan, decaBDE was the main flame retardant detected in vehicles (Kajiwara *et al.* 2014) and automotive shredder residues. A non-exhaustive list where decaBDE was/is used is shown in Table 14 (UNEP 2021a).

For the inventory, it is estimated that vehicles produced before 2004 contain an average of 80 grams of decaBDE, while vehicles produced from 2005 to 2016 contain an average of 20 grams of decaBDE. Additionally, there is a regional difference for c-PentaBDE in the United States[24] (Box 3; see UNEP 2021a and Section 4.3.1).

Table 14: Non-exhaustive overview of the transport sector where decaBDE was/is used, identified end uses and applications (UNEP 2021a)

Sector/ industry	Applications	End use
Private and public transportation	Automobiles/ mass transportation	▪ fabric (backcoating of article) ▪ reinforced plastics ▪ under the hood or dash polymers - terminal /fuse block - higher amperage wire & cable jacketing (sparkplug wire) ▪ electrical and electronic equipment
Maritime, aviation and aeronautic	Ships, boats, airplanes, space shuttles, rockets	▪ electrical wiring and cables ▪ electric and electronic equipment (as above) ▪ air ducts for ventilation systems - electrical ducts and fittings - switches and connectors ▪ adhesive tape ▪ composite materials e.g. epoxy

Box 1: Calculation formula for estimating PBDEs in a mid-size car (UNEP 2021b)

The average PBDE content in vehicles according to the PBDE inventory guidance (UNEP 2021b):

- 80 grams of decaBDE for vehicles produced until 2004 for all regions, except for the US,[24] with high use of c-PentaBDE; for the US, it is assumed that a car contains 40 grams of decaBDE and 40 grams of c-PentaBDE.
- 20 grams of decaBDE for vehicles produced 2005 to 2016.
- 0 grams of decaBDE/PBDEs for vehicles produced 2017 onwards (if no exemption for decaBDE is made).

[23] http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.8-SC-8-10.English.pdf

[24] It is estimated that 85,000 tonnes of c-pentaBDE were used in the United States, with 36% in transport, 60% in furniture and 4% residual in other articles (Alcock *et al.*, 2003).

Based on this practical approach, the following formula can be used to estimate the PBDE amount in vehicles:

PBDEs in vehicles = Vehicles (1970-2004) x 80 g decaBDE*/vehicle + Vehicles (2005-2017) x 20 g/vehicle

**For the US, it is assumed that the content is 40 grams of decaBDE and 40 grams c-PentaBDE[24] were included in average vehicles before 2005.*

The estimate can be adjusted for larger or smaller cars or buses as appropriate (UNEP 2021b). If own robust PBDE data are available for a country/region, then such data can be used instead of these suggested PBDE impact factors.

4.2.2 SCCP in vehicles

SCCPs have been used in textile finishing as a flame retardant and water-repellent agent for back-coated textiles, including seating upholstery in transport applications, and interior textiles such as blinds and curtains. CPs are used as additive in PVC. Initial measurements in ASR in Japan (2 to 8 mg/kg) (Matsukami *et al.* 2019) and Europe (16 mg/kg) (Norwegian Environment Agency 2021) indicate that levels are low corresponding to an average concentration of approx. 2.4 g SCCP/car[25]) while levels of MCCPs were approx. 20 times higher (see Section 4.4.1).

4.2.3 UV-328 in vehicles

2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol (UV-328; CASRN 25973-55-1) is a substituted phenolic benzotriazole (BZT) and has been listed under the Stockholm Convention in 2023 (UNEP 2023d). UV-328 is an absorber of ultraviolet light and is used in a variety of applications and products to protect surfaces against discoloration and weathering under sunlight. UV-328 has been produced for 50 years and is still produced.

UV-328 has been reported to have three main uses in the automobile sector: in optical polarizing plate and polarizing film for liquid crystal panels and meters mounted on vehicles; in paint; and in resin used for interior and exterior parts (e.g. door handles and levers) (JAPIA 2021). Listed exemption for use are: parts of motor vehicles (covering all land-based vehicles: cars, motorcycles, agricultural & construction vehicles and industrial trucks), such as bumper systems, radiator grills, spoilers, car garnish, roof modules, soft/hard tops, trunk lids and rear window wipers. Use in industrial coating applications for motor vehicles, engineering machines, rail transportation vehicles and heavy-duty coatings for large steel structures are also exempted (UNEP 2023d). UV-328 would be inventoried. There are currently no monitoring data of the average amount of UV-328 in vehicles.

4.2.4 PFOA, PFOS, PFHxS and related compounds in vehicles

PFOA, PFOS, PFHxS and related compounds are present in vehicles in sidechain fluorinated polymers in car seat textiles and carpets (European Commission 2021; Norwegian Environment Agency 2021). PFOA-related compounds are also present in fluoropolymers as unintentional trace contaminant from the production process at low ppm and sub-ppm levels (Wang *et al.* 2014; European Commission 2021).[26] Fluoropolymers are used in vehicles in insulators, semiconductors, solder sleeves, various mechanical components (e.g. wiring, tubing, piping, seals, gaskets, cables), O-rings, V-belts and plastic accessories for car interiors; raw material for components such as low-friction bearings and seals (European Commission 2021). PFOS had an exemption for the use in textiles, upholstery and carpets, but the POPRC concluded in 2012 that the use has likely ended and no exemption is needed (UNEP 2012).

[25] Considering an average ASR amount of 300 kg per car (20% ASR of a mid-size vehicle of 1500 kg).

[26] Major fluoropolymer manufacturers in the US, Japan and EU committed to phase out PFOA and its salts in their operations until the end of 2015 for the USEPA Stewardship Programme (European Commission 2021)

In a first monitoring of extractable[27] PFOA in ASR in Europe, levels were between 0.048 to 0.067 mg/kg[28] (Norwegian Environment Agency 2021) corresponding to an average of ~15 mg/car.[25] Levels of extractable[27] PFOS were lower at 0.006 to 0.020 mg/kg[28] corresponding to ~3 mg/car.[25] Levels of extractable[27] PFHxS were lowest at 0.0006 to 0.0008 mg/kg[29] (Norwegian Environment Agency 2021) corresponding to ~0.2 mg/car.[28] The total amount of PFOA, PFOS, PFHxS and related compounds is likely considerably higher due to the large amount of related compounds. However, no current method is available to appropriately quantify the total related compounds (UNEP 2021e), particularly in side-chain fluoropolymers, which are likely not extracted or only extracted in small amounts.[27] Additionally, some aviation hydraulic fluids previously contained PFOS.

4.3 Assessment of POPs that have formerly been used in the transport sector

A range of POPs have formerly been used in plastic and synthetic textiles in the transport sector. Due to a service life of 15 years in industrial countries and a considerably longer service life in developing countries, vehicles produced in the 1980s and 1990s are frequently still operated in developing countries. Cars older than 20 years receive increasing interest in industrial countries as the demand for classic cars increases despite that they might contain legacy POPs like PCBs, c-PentaBDE or HBCD.

4.3.1 C-PentaBDE in vehicles

C-PentaBDE has partly been used in polyurethane (PUR) foam in seats or head rest in cars, trucks, and other vehicles, mainly in the United States (Abbasi *et al.* 2019; Liu *et al.* 2019). C-PentaBDE was used in the US until 2004. For the inventory, an average PBDE content of 40 g c-PentaBDE (and 40 g decaBDE) is estimated for an individual US passenger car produced before 2005 (see PBDE inventory guidance UNEP 2021a).

4.3.2 HBCD in vehicles

HBCD has been used to a minor extent in the automobile sector in interior textiles such as floor covering (Kajiwara *et al.* 2014) and seating, and also in textile interior in trains, air planes and ships. Overall, the use in cars seems small and an average of 3 grams of HBCD for a passenger car produced between 1980 to 2013 has been established by a Japanese inventory study (Liu *et al.* 2019) and can be used for an inventory estimate. Additionally, XPS containing HBCD were used and can be found in refrigerator trucks and chiller vans produced 1980 to 2021.

4.3.3 HBB in vehicles

HBB has been used as flame retardant in vehicles from 1970 to 1976 in the US; cars produced after 1976 do not contain HBB. For an inventory in vehicles HBB does not need to be considered except for possible presence in classic cars produced in the US from 1970 to 1976 (UNEP 2021a).

4.3.4 Dechlorane Plus in vehicles

Dechlorane Plus (DP; CAS No. 13560-89-9) is a polychlorinated flame retardant that contains two stereoisomers, syn-DP (CAS No. 135821-03-3) and anti-DP (CAS No. 135821-74-8). DP has been listed in 2023 in the Stockholm Convention (UNEP 2023d) and production stopped (UNEP 2024a).

Dechlorane Plus is used as non-plasticizing flame retardant in thermoplastic and thermosets. DP has been used in plastics in vehicles (wire and printed circuit board) and aviation (e.g. cabin interior panels, ducting, engines) (UNEP 2021f). In an initial monitoring in European automotive shredder, DP maximum levels were 12 mg/kg while most samples were below 1 mg/kg (Norwegian

[27] The shredder residues were extracted with methanol.
[28] These levels were detected after applying TOP Assay of the extract (Norwegian Environmental Agency 2021).
[29] At the detected concentration, PFHxS might be considered an unintentional co-pollutant of PFOS.

Environment Agency 2021) indicating that the average Dechlorane Plus concentration in ELVs in Europe is likely below 3 g/vehicle.[25]

Specific exemptions are listed for the use of DP in aerospace, space and defence applications, as well as for replacement parts for, and repair of, articles shall apply where Dechlorane Plus was originally used in the manufacture of 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 (UNEP 2023d).

Since only limited information on the frequency and concentration of DP in the transport sector is available, the generation of monitoring data (Tier III) would be useful. Considering Article 9 of SC, validated studies/data can be sent to the BRS Secretariat serving as a clearing-house mechanism for information on POPs (UNEP 2021j).

4.3.5 PCBs in vehicles

PCBs have been used in brake fluids and coolants in cars produced before the 1980s (USEPA 2018). Furthermore PCB were contained in capacitors which were also installed in electrical equipment in vehicles, e.g. in lighting and headlamps before 1990s. Therefore, automotive shredder residues can be contaminated with PCBs from PCBs in cars produced before 1990 (USEPA 1991). The PCB-concentration in ASR in 1990 had PCB levels between 1.7 mg/kg to 210 mg/kg (USEPA 1991; Boughton 2007) which decreases over time.

4.4 POP candidate in the transport sector

4.4.1 MCCPs (POP candidate) in vehicles

Chlorinated paraffins with carbon chain lengths in the range C14-17 (CAS No: 85535-85-9) and chlorination levels at or exceeding 45 per cent chlorine by weight (MCCPs) meet the Convention Annex D criteria (UNEP 2021h). MCCPs are still produced in high volumes (1 million t/yr) (Chen *et al.* 2022) and added to PVC and rubber (Brandsma *et al.* 2021; Chen *et al.* 2021). Monitoring of ASR in Japan found MCCPs concentration of 54-260 mg/kg (Matsukami *et al.* 2019) and in European ASR 130-210 mg/kg. This corresponds to ca. 50 g/vehicle (16-78 g/vehicle).

Since only limited information on the frequency and concentration in the transport sector is available, the generation of monitoring data of MCCP (Tier III) would be useful. Considering Article 9 of SC, validated studies/data can be sent to the BRS Secretariat serving as a clearing-house mechanism for information on POPs (UNEP 2021j).

4.5 Assessment of selected other chemicals of concern present in the transport sector

This section aims at providing an overview on selected CoC in the transport/vehicle sector listed under other MEAs and/or SAICM with the objective of a synergistic approach for MEAs implementation and management of POPs and other CoC where appropriate.

The collection and evaluation of data about the presence of CoC in the transport sector, coordinated with POPs inventory activities, could serve as a basis for (future) integrated sector-specific management. Table 15 provides an overview of selected CoC, and their major use in the transport/vehicle sector as a basis for their consideration.

Table 15: Selected CoC (other than POPs) in vehicles related to MEAs and SAICM

CoC	MEA or SAICM	Short description	Use in vehicles	Relevance
Lead	lead acid battery activities under Basel Convention;	Lead is a toxic metal that causes adverse effects at very low levels; in particular,	Lead-acid batteries; solder	High

CoC	MEA or SAICM	Short description	Use in vehicles	Relevance
	Lead in paints is an SAICM EPI	neurodevelopment disorders in children		
Mercury compounds	Minamata Convention	Harms the nervous system, brain, heart, kidneys. Impacts neurodevelopment	Used in lamps, four-wheel drive anti-lock braking systems (ABSy) and high intensity discharge (HID), active ride control systems (mainly before 2004)	High (for vehicles produced before 2004)
CFCs, HCFCs, HFCs	Montreal Protocol; UNFCCC	Ozone depleting substances; GHG	HFC 134 was widely used as refrigerant for air conditioning in vehicles, high GHG potential	High
Other PFASs (not POPs)	SAICM issue of concern	very persistent, very mobile (compounds or degradation products)	Additive to electrolyte in lithium-ion batteries; side-chain fluoro-polymers in textile/carpet; NIAS in fluoropolymers (and thermal degradation products)	Medium
Halogenated OPFR	SAICM EPI[14]	Certain halogenated OPFR are carcinogen or toxic for reproduction	Major flame retardants in textiles and PUR foam	High

4.5.1 Certain metals and metalloids in vehicles

4.5.1.1 Lead in vehicles

The main use of the total global consumption of lead is for the production of lead-acid batteries mainly used in motorized vehicles (UNEP 2017f). The batteries contain large amount of lead either as solid metal or lead-oxide powder. An average lead battery of an automobile contain 8.4 kg of lead (UNEP 2003a). Lead has also been used in vehicles in solders, finishes on terminations of components, or connector systems. While these lead applications are regulated, for example, under the EU Directive 2000/53/,[30] and have been largely phased out in the last 20 years in other regions to comply for car imports to the EU or to similar regulations in other countries (e.g. Korean RoHS[19]). Vehicles produced prior to 2004 contain higher lead levels.

4.5.1.2 Mercury in vehicles

Mercury has historically been used in vehicles in four-wheel drive anti-lock braking systems (ABSy) and high intensity discharge (HID), active ride control systems, in head and tail lights and under the hood and truck lighting (UN Environment 2019; New Jersey Department of Environmental Protection 2022). Older vehicles (pre-1994) contained mercury switches in the crash sensor module of air bags.[31] Many cars manufactured prior to 2004 contain mercury switches in the ABSy.[31]

[30] The Directive on end-of-life vehicles (ELV Directive) prohibits the use of hazardous substances when manufacturing new vehicles (especially lead, mercury, cadmium and hexavalent chromium) except in defined exemptions when there are no adequate alternatives. The exemptions are listed in Annex II of the Directive. A maximum concentration value up to 0.1 % by weight in homogeneous material for lead.
[31] https://www.newmoa.org/prevention/mercury/projects/legacy/automobiles.cfm

In the US in the 1990s, about 9 tonnes mercury per year were used in tilt switches (such as trunk lights) and ABSy in automobiles with 155-222 tonnes of mercury in automobiles on the road in the USA in 2001 (Griffith *et al.* 2001) and 15-22 tonnes of mercury in automobiles entered the scrap processing system in early 2000 in the USA (UN Environment 2019). Since mercury was used in these applications mainly before 2004,[31] today many of these vehicles have been exported and operate in developing countries. The development of a mercury inventory in vehicles would be conducted in the frame of the Minamata Convention considering the synergy with Stockholm Convention inventory activities. Since for PBDEs also particular data are gathered for cars produced before 2004 (UNEP 2021a), these data can also be used for the mercury inventory and vice versa.

4.5.2 PFAS other than POPs-PFAS in vehicles

All PFAS are an issue of concern under SAICM. After substitution of PFOA in side-chain fluoropolymers in textiles and carpets in vehicles (Section 4.2.3), other PFASs are used in these applications. Fluoropolymers are used in vehicles in cables, semiconductors, printed circuit board and antireflective coatings (The Chemours Company 2020). Fluoropolymers can contain PFOA and other PFAS used in production and form PFOA and other short- and long-chain perfluorinated alkyl acids when thermally treated at temperature below approx. 700 °C (Ellis *et al.* 2001; Ellis *et al.* 2003; Schlummer *et al.* 2015; FOEN 2017) which is prevalent in open burning of plastic and smouldering of printed circuit boards. Analysis of non –polymeric PFAS in ASR showed levels of up to 2 mg/kg (mainly PFBS) corresponding[25] to 0.6 g PFAS for such a car (Norwegian Environment Agency 2021). High PFAS volumes are used in some vehicle battery electrolytes and fuel cells such as lithium bis(fluorosulfonyl) imide (LiFSI) and lithium 4,5-dicyano-2-trifluoromethyl-imidazolide (LiTDI) (Brückner *et al.* 2020; Garg *et al.* 2020).

4.5.3 Certain phosphorous flame retardants (PFRs) in vehicles

Halogenated organophosphorus flame retardants (OPFRs) are major flame retardants used in PUR foams and textiles in vehicles and result in high exposure in cars (Hoehn et al. 2024). Halogenated OPFRs have been found in baby car seats (Stapleton *et al.* 2011). Halogenated OPFRs have hazardous properties including tris(2-chloroethyl) phosphate (TCEP; toxic for reproduction), tris(1,3-dichloroisopropyl) phosphate (TDCPP; carcinogen), tris(2-chloroisopropyl) phosphate (TCPP; toxic for reproduction) (Van der Veen and de Boer *et al.* 2012; Chen *et al.* 2019; European Commission 2022).

Initial monitoring of OPFRs in ASR fractions showed high level between 14 to 870 mg/kg with the highest level in the ASR fraction containing textiles and PUR (Matsukami *et al.* 2019). This corresponds to approx. 5 to 100 g OPFRs/vehicle. High releases of the carcinogenic TDCPP and of TCPP in leachates of landfills in Africa (Sibiya *et al.* 2019), Brazil (Cristale *et al.* 2019) and China (Qi *et al.* 2019) indicate relevant disposal of OPFR containing waste such as polymers from end-of-life vehicles (and C&D waste or WEEE) in landfills.

4.5.4 Certain phthalates in vehicles

Phthalates are plasticizers mainly used in PVC. In vehicles, PVC was used for cables, wires, connectors and plastic parts; phthalates are detected in high concentration in ASR (ELVES 2016). Four phthalates – DEHP, BBP, DBP and DIBP – are restricted in the EU under REACH with exemptions for parts in vehicles (European Commission 2018).

4.5.5 CFC, HCFC and HFCs in vehicles

Since the 1990s, the globally prevailing refrigerant for mobile air conditioning in cars, buses and railway vehicles is 1,1,1,2-tetrafluoroethane (HFC 134a). HFC 134a is a greenhouse gas with a global warming potential (GWP) of 1,430. Prior to 1994 the CFC dichlorodifluoromethane (R-12) with a GWP of 10,900 was used in most vehicle air conditioning applications. HFC 134a is substituted in some regions (e.g. the EU banned it in new cars since 2017) but is still the major refrigerant in vehicle produced before 2017. An inventory of F-gases in vehicles could be developed under the frame of the Montreal Protocol in synergy with developing POP inventories in the transport sector.

4.5.6 Asbestos in vehicles

The following car parts are known to contain(ed) asbestos.

- Hood liners
- Brakes
- Clutches
- Undercoating
- Air conditioning housing
- Gasket material, heat seals, valve rings and packing

Asbestos was used in trains and ships. A Basel Convention technical guideline has been developed for ship dismantling including a section on asbestos (UNEP 2003b). For the inventory, past uses of asbestos in the transport sector would be assessed and can be linked to National Asbestos Profiles promoted by WHO (WHO 2007; BAuA 2014; Arachi *et al.* 2021).

4.5.7 Polycyclic aromatic hydrocarbons (PAHs) in vehicles

Car tyres are produced by using extender oils that contain PAHs (ECHA 2017). These PAHs are being released by cars due to tire abrasion. The European Chemical Agency (ECHA) concluded that the presence of carcinogenic PAHs in granules at the concentration allowed in these mixtures in the EU poses risk for some athletes playing on synthetic turf made from recycled tires (ECHA 2017) and lowering of PAH limits are proposed for tire recycling (UNEP 2013; RIVM 2018).

5 Annex: Case Studies of Sectoral POP Inventories

5.1 Annex 1: Case Study: Inventory of POPs in the Building and Construction Sector in Country A

The case study can be downloaded @ https://www.greenpolicyplatform.org/case-studies/case-study-inventory-pops-building-and-construction-sector-country

5.2 Annex 2: Case Study: Inventory of POPs in the Electronic Sector in Nigeria

The case study can be downloaded @ https://www.greenpolicyplatform.org/case-studies/inventory-pops-electrical-and-electronic-equipment-eee-and-related-waste-weee-nigeria

5.3 Annex 3: Cases Study: Inventory of POPs in the Transport Sector in Nigeria

The case study can be downloaded @ https://www.greenpolicyplatform.org/case-studies/inventory-pops-transport-sector-nigeria

References

Abbasi, G., Buser, A.M., Soehl, A., Murray, M.W. and Diamond, M.L. (2015). Stocks and flows of PBDEs in products from use to waste in the US and Canada from 1970 to 2020. *Environmental science & technology* 49(3), 1521-1528.

Abbasi G, Li L, Breivik K. (2019). Global Historical Stocks and Emissions of PBDEs. Environ Sci Technol., 53(11), 6330–6340. https://doi.org/10.1021/acs.est.8b07032

Al-Otaibi A, Bowan PA, Abdel daiem MM, Said N, Ebohon JO, Alabdullatief A, Al-Enazi E, Watts G. (2022). Identifying the Barriers to Sustainable Management of Construction and Demolition Waste in Developed and Developing Countries. Sustainability. 14(13), 7532. https://doi.org/10.3390/su14137532

Arachi D, Furuya S, David A, Mangwiro A, Chimed-Ochir O, Lee K, Tighe P, Takala J, Driscoll T, Takahashi, K. (2021). Development of the "National Asbestos Profile" to Eliminate Asbestos-Related Diseases in 195 Countries. International journal of environmental research and public health, 18(4), 1804. https://doi.org/10.3390/ijerph18041804

ATSDR (Agency for Toxic Substances and Disease Registry). (2006). Mercury-Containing Polyurethane Floors in Minnesota Schools. Atlanta, GA: U.S. Department of Health and Human Services. Available at URL:
http://www.atsdr.cdc.gov/HAC/pha/MercuryVaporReleaseAthleticPolymerFloors/MercuryVaporRelease-FloorsHC092806.pdf

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

Baldé CP, Kuehr R, Yamamoto T, *et al.* (2024). Global E-waste Monitor 2024. International Telecommunication Union (ITU) and United Nations Institute for Training and Research (UNITAR) Report. Geneva/Bonn.

BAuA (German Federal Institute for Occupational Safety and Health) (2014) National Asbestos Profile for Germany.

Bavarian Environment Agency (2019). Rückbau schadstoffbelasteter Bausubstanz - Arbeitshilfe Rückbau: Erkundung, Planung, Ausführung. (in German)

Behnisch P, Petrlik J, Budin C, Besselink H, Felzel E, Strakova J, Bell L, Kuepouo G, Gharbi S, Bejarano F, Jensen GK. (2023). Global survey of dioxin-and thyroid hormone-like activities in consumer products and toys. Environment International. 178, 108079.

Blumenthal, J., Diamond, M.L., Liu, G. and Wang, Z. (2022). Introducing “Embedded Toxicity”: A Necessary Metric for the Sound Management of Building Materials. Environmental science & technology, 56(14), 9838-9841.

Boughton, B. (2007). Evaluation of shredder residue as cement manufacturing feedstock. Resources, Conservation and Recycling, 51(3), 621-642.

Brandsma SH, Brits M, de Boer J, Leonards P (2021). Chlorinated paraffins and tris (1-chloro-2-propyl) phosphate in spray polyurethane foams - A source for indoor exposure?. Journal of hazardous materials, 416, 125758. https://doi.org/10.1016/j.jhazmat.2021.125758

Brückner, L., Frank, J., Elwert T (2020). Industrial Recycling of Lithium-Ion Batteries—A Critical Review of Metallurgical Process Routes. Metals 10, 1107. https://doi.org/10.3390/met10081107.

Carpenter DO (2013) Effects of persistent and bioactive organic pollutants on human health. ISNB 978-1-118-15926-2, John Wiley & Sons, Inc., Hoboken, New Jersey.

Charbonnet J, Weber R, Blum A (2020). Flammability standards for furniture, building insulation and electronics: Benefit and risk. Emerg. Contam 6, 432-441, https://doi.org/10.1016/j.emcon.2020.05.002

Chen C, Chen A, Li L, Peng W, Weber R, Liu J. (2021). Distribution and Emission Estimation of Short- and Medium-Chain Chlorinated Paraffins in Chinese Products through Detection-Based Mass Balancing. Environ. Sci. Technol. 55, 7335–7343. https://doi.org/10.1021/acs.est.0c07058

Chen C, Chen A, Zhan F, Wania F, Zhang S., Li L, Liu J. (2022). Global Historical Production, Use, In-Use Stocks, and Emissions of Short-, Medium-, and Long-Chain Chlorinated Paraffins. Environmental Science & Technology 56, 7895–7904, https://doi.org/10.1021/acs.est.2c00264

Cristale J, Belé TGA, Lacorte S, de Marchi MRR (2019). Occurrence of flame retardants in landfills: A case study in Brazil. Environmental research, 168, 420-427.

Ellis DA, Mabury SA, Martin JW, Muir DCG (2001). Thermolysis of fluoropolymers as a potential source of halogenated organic acids in the environment. Nature 412, 321–324.

Ellis DA, Martin JW, Muir DCG, Mabury SA (2003). The use of 19F NMR and mass spectrometry for the elucidation of novel fluorinated acids and atmospheric fluoroacid precursors evolved in the thermolysis of fluoropolymers. Analyst 128, 756–764.

ELVES (ELV Environmental Services CLG) (2016). Analysis of Automotive Shredder Residue from the Composition, Recycling and Recovery Trial for End of Life Vehicles in the Republic of Ireland.

European Union (2000). DIRECTIVE 2000/53/EC of the European Parliament And Of The Council of 18 September 2000 on end-of life vehicles. Official Journal of the European Communities 21.10.2000L 269/34

European Commission (2015). COMMISSION DELEGATED DIRECTIVE (EU) 2015/863 of 31 March 2015 amending Annex II to Directive 2011/65/EU of the European Parliament and of the Council as regards the list of restricted substances. Official Journal of the European Union L 322/14.

European Commission (2018). COMMISSION REGULATION (EU) 2018/2005 of 17 December 2018 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards bis(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), benzyl butyl phthalate (BBP) and diisobutyl phthalate (DIBP).

European Commission (2021). Study to support the assessment of impacts associated with the review of limit values in waste for POPs listed in Annexes IV and V of Regulation (EU) 2019/1021. Final Report for DG Environment.

European Commission (2022). COMMISSION STAFF WORKING DOCUMENT Restrictions Roadmap under the Chemicals Strategy for Sustainability SWD (2022) 128 final, Brussels, 25.4.2022

Eze CT, Otitoloju AA, Eze OO, *et al.* (2023). West African e-waste-soil assessed with a battery of cell-based bioassays. The Science of the total environment, 856, 159068. https://doi.org/10.1016/j.scitotenv.2022.159068

FOEN (2017). Additional Information in Relation to the Risk Management Evaluation of PFOA, its Salts, and Related Compounds. Prepared by ETH Zurich on behalf of the Swiss Federal Office for the Environment (FOEN). http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC12/POPRC12Followup/PFOAComments/tabid/5950/Default.aspx

Forti V, Baldé CP, Kuehr R, Bel G (2020). The Global E-waste Monitor 2020 - Quantities, flows, and the circular economy potential. https://www.itu.int/en/ITU-D/Environment/Documents/Toolbox/GEM_2020_def.pdf

Garg S, Kumar P, Mishra V, Guijt R, Singh P, Dumée LF, Sharma RS (2020). A review on the sources, occurrence and health risks of per-/poly-fluoroalkyl substances (PFAS) arising from the manufacture and disposal of electric and electronic products. Journal of Water Process Engineering, 38, 101683.

German Environment Agency (2021). Promoting the high-quality recycling of plastics from demolition waste and enhancing the use of recycled materials in construction products in accordance with the European Plastics Strategy.

Geyer R, Jambeck JR, Law KL (2017). Production, use, and fate of all plastics ever made. Sci Adv 19, 3(7). e1700782. https://doi.org/10.1126/sciadv.1700782.

Gibb A, Jones W, Goodier C, Bust P, Song M, Jin J (2017). Nanotechnology in construction and demolition: what we know, what we don’t. Report submitted to the IOSH Research Committee

Green Science Policy Institute (2021). BUILDING A BETTER WORLD - Eliminating Unnecessary PFAS in Building Materials. https://greensciencepolicy.org/docs/pfas-building-materials-2021.pdf

Griffith C, Gearhart J, Posset H, *et al.* (2001). Toxics in vehicles: Mercury. Ecology Center, Great Lakes United and University of Tennessee Center for Clean Products & Clean Technologies, https://p2infohouse.org/ref/19/18304.pdf

Guida Y, Capella R, Weber R (2020). Chlorinated paraffins in the technosphere: A review of available information and data gaps demonstrating the need to support the Stockholm Convention implementation. Emerging Contaminants 6, 143-154. https://doi.org/10.1016/j.emcon.2020.03.003

Hansen E, Nilsson NH, Lithner D, Lassen C (2014). Hazardous substances in plastic materials. Survey of chemical substances in consumer products. Published by The Danish Environmental Protection Agency, No. 132.

Harnisch J, Schwarz W (2003). Final report on the costs and the impact on emissions of potential regulatory framework for reducing emissions of hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. Ecofys GmbH.

Held D (2008). Eisenbahnschwellen im Garten? Problematische Inhaltsstoffe schränken die Einsatzmöglichkeiten stark ein. Umweltpraxis Nr. 54, 29-32, Oktober 2008.

Hennebert P, Filella M (2018). WEEE plastic sorting for bromine essential to enforce EU regulation. Waste Manage 71, 390-399.

Hoehn RM, Jahl LG, Herkert NJ, Hoffman K, Soehl A, Diamond ML, Blum A, Stapleton HM. (2024) Flame retardant exposure in vehicles is influenced by use in seat foam and temperature. Environmental Science & Technology. 58(20), 8825-8834.

Houessionon M, Ouendo ED, Bouland C, Takyi SA, Kedote NM, Fayomi B, Fobil JN, Basu N. (2021). Environmental Heavy Metal Contamination from Electronic Waste (E-Waste) Recycling Activities Worldwide: A Systematic Review from 2005 to 2017. Int. J. Environ. Res. Public Health 18, 3517.

Huang L, Fantke P, Ritscher A, Jolliet O. (2022) Chemicals of concern in building materials: a high-throughput screening. Journal of Hazardous Materials. 424, 127574.

Huwe JK, Davison K, Feil VJ, Larsen G, Lorentzsen M, Zaylskie R, Tiernan TO (2004). Levels of polychlorinated dibenzo-p-dioxins and dibenzofurans in cattle raised at agricultural research facilities across the USA and the influence of pentachlorophenol-treated wood. Food Addit Contam. 21(2), 182-194.

IARC (2018) Arsenic, Metals, Fibres, and Dusts. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Volume 100C.

ILO (International Labour Organization) (2012). The global impact of e-waste. Addressing the challenge.

Imm P, Knobeloch L, Buelow C, Anderson HA (2009). Household exposures to polybrominated diphenyl ethers (PBDEs) in a Wisconsin Cohort. Environmental health perspectives, 117, 1890–1895. https://doi.org/10.1289/ehp.0900839

Jakobsson E, Asplund L (2000). Polychlorinated Naphthalenes (CNs). In: J. Paasivirta, ed. The Handbook of Environmental Chemistry, Vol. 3 Anthropogenic Compounds Part K, New Types of Persistent Halogenated Compounds. Berlin, Springer-Verlag.

JAPIA (Japan Auto Parts Industries Association) (2021). Response submitted to ECHA's public consultation on the draft risk profile of UV-328.

Jartun M, Ottesen RT, Steinnes E, Volden T (2009) Painted surfaces--important sources of polychlorinated biphenyls (PCBs) contamination to the urban and marine environment. Environ Pollut. 157(1), 295-302.

Jin MT, Li LJ, Zheng JX, Shen SJ, Wang DR (2019) Polybrominated diphenyl ethers (PBDEs) in dust in typical indoor public places in Hangzhou: Levels and an assessment of human exposure. Ecotoxicology and Environmental Safety 169, 325-334.

Kajiwara N, Desborough J, Harrad S, Takigami H. (2013). Photolysis of brominated flame retardants in textiles exposed to natural sunlight. Environ Sci Process Impacts. 15(3), 653–660.

Kajiwara N, Takigami H, Kose T, Suzuki G, Sakai S. (2014). Brominated flame retardants and related substances in the interior materials and cabin dusts of end-of-life vehicles collected in Japan. Organohalogen Compounds 76, 1022-1025. Accessed 12.07.2021 at http://dioxin20xx.org/wp-content/uploads/pdfs/2014/1015.pdf

Kajiwara N, Matsukami H, Malarvannan G, Chakraborty P, Covaci A, Takigami H (2022). Recycling plastics containing decabromodiphenyl ether into new consumer products including children's toys purchased in Japan and seventeen other countries. Chemosphere, 289, 133179.

Kobayashi N, Izumi H., Morimoto Y (2017). Review of toxicity studies of carbon nanotubes. Journal of Occupational Health, 59(5), 394–407. https://doi.org/10.1539/joh.17-0089-RA

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

Kurata Y, Watanabe Y, Ono Y, *et al.* (2005). Concentrations of organic wood preservatives in wood chips produced from wood wastes. J Mater Cycles Waste Manag 7, 38–47. https://doi.org/10.1007/s10163-004-0124-z

Lebbie T S, Moyebi OD, Asante KA *et al.* (2021). E-Waste in Africa: A Serious Threat to the Health of Children. Int. J. Environ. Res. Public Health, 18, 8488. https://doi.org/10.3390/ijerph18168488

Leisewitz A, Schwarz W. (2000) Erarbeitung von Bewertungsgrundlagen zur Substitution umweltrelevanter Flammschutzmittel. Flammhemmende Ausrüstung ausgewählter Produkte - anwendungsbezogene Betrachtung: Stand der Technik, Trend, Alternativen. Report no. 01/27. UBA-Texte. 000171/2. German Environment Agency.

Li L, Weber R, Liu J, Hu J (2016). Long-term emissions of hexabromocyclododecane as a chemical of concern in products in China. Environ Int. 91, 291-300. https://doi.org/10.1016/j.envint.2016.03.007

Liu H, Yano J, Kajiwara N, Sakai S. (2019). Dynamic stock, flow, and emissions of brominated flame retardants for vehicles in Japan. Journal of Cleaner Production 232, 910–924.

Lucattini L, Poma G, Covaci A, Boer J d, Lamoree MH, Leonards PEG (2018). A review of semi-volatile organic compounds (svocs) in the indoor environment: Occurrence in consumer products, indoor air and dust. Chemosphere 201, 466–482.

Matsukami H, Kajiwara N, Kuramochi H. (2019). Chlorinated paraffins and organophosphorus flame retardants in automobile shredder residues from an end-of-life vehicle recycling facility in Japan. Abstract Book SETAC North America 40th Annual Meeting, Toronto, Canada.

Mohajerani A, Burnett L, Smith JV, Kurmus H, Milas J, Arulrajah A, Horpibulsuk S, Abdul Kadir, A. (2019). Nanoparticles in Construction Materials and Other Applications, and Implications of Nanoparticle Use. Materials, 12(19), 3052. https://doi.org/10.3390/ma12193052

Morf L, Taverna R, Daxbeck H, Smutny R. (2003). Selected polybrominated flame retardants PBDEs and TBBPA. Substance flow analysis. Environmental Series No. 338. Environmental hazardous substances. Swiss Agency for the Environment, Forests and Landscape.

New Jersey Department of Environmental Protection (2022). Vehicle Recycling General Permit Information Mercury Switches and Polychlorinated Biphenyls, https://www.nj.gov/dep/dwq/auto_mercurypcb.htm

Norwegian Environment Agency (2021). Environmental Pollutants in Post-Consumer Plastics. Fraunhofer and Rambol for the Norwegian Environment Agency, Case Number M-2059|2021.

Pacheco-Torgala F, Jalalib S (2011). Review Nanotechnology: Advantages and drawbacks in the field of construction and building materials. Construction and Building Materials 25, 582-590https://doi.org/10.1016/j.conbuildmat.2010.07.009

Petrlik J, Behnisch P, DiGangi J. (2018). Toxic Soup: Dioxins in Plastic Toys. Arnika, HEAL, IPEN and BUND. https://arnika.org/en/publications/toxic-soup-dioxins-in-plastic-toys

Petrlik J, Bell L, DiGangi J, Allo'o SJ, Kuepouo G, Ochola GO, Grechko V, Jelinek N, Strakova J, Skalsky M, Drwiega YI, Hogarh J, Akortia E, Adu-Kumi S, Teebthaisong A, Carcamo M, Beeler B, Behnisch P, Baitinger C, Herold C, Weber R. (2022). Review: Monitoring of Dioxins and PCB in Eggs as Sensitive Indicator for Environmental Pollution and Contaminated Sites and Recommendations for Reducing and Controlling Releases and Exposure. Emerging Contaminants 8, 254-279 https://doi.org/10.1016/j.emcon.2022.05.001

Potrykus A, Milunov M, Weißenbacher J (2015). Identification of potentially POP-containing Wastes and Recyclates – Derivation of Limit Values. Report No. (UBA-FB) 002097/E.

Purchase CK, Al Zulayq DM, O'Brien BT, Kowalewski MJ, Berenjian A, Tarighaleslami AH, Seifan M. (2021). Circular Economy of Construction and Demolition Waste: A Literature Review on Lessons, Challenges, and Benefits. Materials. 15(1), 76. https://doi.org/10.3390/ma15010076

Puype F, Samsonek J, Knoop J, Egelkraut-Holtus M, Ortlieb M. (2015). Evidence of waste electrical and electronic equipment (WEEE) relevant substances in polymeric food-contact articles sold on the European market. Food Additives & Contaminants: Part A, 32(3), 410-426.

Qi C, Yu G, Zhong M, Peng G, Huang J, Wang B. (2019). Organophosphate flame retardants in leachates from six municipal landfills across China. Chemosphere, 218, 836-844.

Rauert C. Harrad, S. (2015). Mass transfer of PBDEs from plastic TV casing to indoor dust via three migration pathways - A test chamber investigation. Sci. Total Environ, 536, 568–574.

RIVM (2018). ANNEX XV Restriction Report – PAHs in synthetic turf infill granules and mulches. ANNEX XV Restriction report proposal for a restriction.

RPA (Risk & Policy Analysts). (2014). Support to an Annex XV Dossier on Bis-(pentabromophenyl) ether (DecaBDE). Multiple Framework Contract with Reopening of competition for Scientific Services for ECHA. Reference: ECHA/2011/01 Service Request SR 14.

Schlummer M, Sölch C, Meisel T, Still M, Gruber L, Gerd W. (2015). Emission of perfluoroalkyl carboxylic acids (PFCA) from heated surfaces made of polytetrafluoroethylene (PTFE) applied in food contact materials and consumer products. Chemosphere 129, 46-53.

Shaw SD, Blum A, Weber R, Kannan K, Rich D, Lucas D, Koshland CP, Dobraca D, Hanson S, Birnbaum LS (2010). Halogenated Flame Retardants: Do the Fire Safety Benefits Justify the Risks? Reviews on Environmental Health 25(4) 261-305,

Sibiya I, Poma G, Cuykx M, Covaci A, Adegbenro PD, Okonkwo J (2019). Targeted and non-target screening of persistent organic pollutants and organophosphorus flame retardants in leachate and sediment from landfill sites in Gauteng Province, South Africa. Science of the total environment, 653, 1231-1239.

Sindiku O, Babayemi JO, Tysklind M, Osibanjo O, Weber R, Schlummer M, Lundstedt S (2015). Polybrominated Dioxins and Furans (PBDD/Fs) in e-waste plastics in Nigeria. Environ Sci Pollut Res Int. 22, 14462-14470. DOI 10.1007/s11356-015-5260-6

Stapleton HM, Klosterhaus S, Keller A, Ferguson PL, Van Bergen S, Cooper E, *et al.* (2011). Identification of flame retardants in polyurethane foam collected from baby products. Environ Sci Technol. 45(12), 5323-5331.

Suzuki, S., Part, F., Matsufuji, Y., Huber-Humer, M. (2018). Modeling the fate and end-of-life phase of engineered nanomaterials in the Japanese construction sector. Waste Management, 72, 389-398.

Swedish EPA (2011). Recycling and disposal of electronic waste - Health hazards and environmental impacts. Report 6417, March 2011.

Takahashi S, Tue NM, Takayanagi C, Tuyen LH, Suzuki Go (2017). PCBs, PBDEs and dioxin-related compounds in floor dust from an informal end-of-life vehicle recycling site in northern Vietnam: contamination levels and implications for human exposure. J. Mater. Cycles Waste Manag. 19, 1333-1341.

Taverna R, Gloor R, Zennegg M, Birchler E (2017). Stoffflüsse im Schweizer Elektronikschrott. Report for the Swiss Federal Office for the Environment. Umwelt-Zustand Nr. 1717, 164 pp.

The Chemours Company (2020). The Role of Fluoropolymers in Consumer Electronics and Communications for Smart Cities.

UN Environment (2019). Toolkit for Identification and Quantification of Mercury Sources, Reference Report and Guideline for Inventory Level 2, Version 1.5 November 2019. UN Environment, Chemicals and Health Branch, Geneva, Switzerland.

UNECE and FAO (2021). Draft Catalogue of wood waste classifications in the UNECE Region.

UNEP (2003a). Technical guidelines for the environmentally sound management of waste lead-acid batteries.

UNEP (2003b). Technical guidelines for the environmentally sound management of the full and partial dismantling of ships.

UNEP (2008). Guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants; Part III Source category (k): Shredder plants for the treatment of end-of-life vehicles.

UNEP (2012). Report of the Persistent Organic Pollutants Review Committee on the work of its eighth meeting. UNEP/POPS/POPRC.8/16.

UNEP (2013). Revised technical guidelines for the environmentally sound management of used and waste pneumatic tyres. Basel Convention Technical Guideline.

UNEP (2015). Cooperation and coordination between the secretariats of the Basel, Rotterdam and Stockholm conventions and the Strategic Approach. SAICM/ICCM.4/INF/24

UNEP and PEN (PCB Elimination Network) (2016). Polychlorinated Biphenyls (PCB) Inventory Guidance. https://wedocs.unep.org/20.500.11822/31250

UNEP (2017a). Guidance for the inventory of perfluorooctane sulfonic acid (PFOS) and related chemicals listed under the Stockholm Convention on Persistent Organic Pollutants. Draft Revised January 2017

UNEP (2017b). Towards a Pollution-Free Planet Background Report. United Nations Environment Programme, Nairobi, Kenya

UNEP (2017c). Guidance for the inventory of Hexabromocyclododecane (HBCD) (Draft March 2017) http://www.pops.int/Implementation/NIPs/Guidance/GuidanceforHBCD/tabid/5332/Default.aspx

UNEP (2017d). Listing of tributyltin compounds in Annex III to the Rotterdam Convention'. Secretariat of the Basel, Rotterdam and Stockholm Conventions, United Nations Environment Programme, RC-8/5.

UNEP (2017e). Draft guidance on preparing inventories of polychlorinated naphthalenes (PCNs). Draft March 2017. UNEP/POPS/COP.8/INF/19

UNEP (2017f). Draft practical guidance for the development of inventories of used lead-acid batteries. Secretariat of the Basel Convention.

UNEP (2019a). Detailed guidance on preparing inventories of short-chain chlorinated paraffins (SCCPs). Secretariat of the Basel, Rotterdam and Stockholm Conventions, United Nations Environment Programme, Geneva.

UNEP (2019b). 'Global Chemicals Outlook II', United Nations Environment Programme, Nairobi, 2019

UNEP (2019c). Proposal to list Dechlorane Plus (CAS No. 13560-89-9) and its syn-isomer (CAS No. 135821-03-3) and anti-isomer (CAS No. 135821-74-8) in Annexes A, B and/or C to the Stockholm Convention on Persistent Organic Pollutants. UNEP/POPS/POPRC.15/3.

UNEP (2019d). Preliminary draft guidance on alternatives to short-chain chlorinated paraffins (SCCPs). UNEP/POPS/COP.9/INF/21.

UNEP (2019e). Consolidated Guidance on PCB in Open Applications. Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva. Available at: http://www.pops.int/Implementation/IndustrialPOPs/PCB/Guidance/tabid/665/Default.aspx -> open applications

UNEP (2020a). General guidance on POPs inventory development. Revised from document UNEP/POPS/COP.9/INF/19/Add.1. Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva

UNEP (2020b). Proposal to list UV-328 in Annex A to the Stockholm Convention on Persistent Organic Pollutants. UNEP/POPS/POPRC.16/4

UNEP (2021a). Draft guidance on preparing inventories of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants. Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva.

UNEP (2021b). Guidance on preparing inventories of hexabromocyclododecane (HBCD). Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva

UNEP (2021c). Guidance on preparing inventories of PCN. Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva

UNEP (2021d). Guidance on preparing inventories of PCP. Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva

UNEP (2021e). Draft guidance on sampling, screening and analysis of persistent organic pollutants in products and recycling. Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva.

UNEP (2021f). Chemicals of Concern in the Building and Construction Sector. Geneva 5 May 2021. https://wedocs.unep.org/bitstream/handle/20.500.11822/35916/CoCBC.pdf

UNEP (2021g). Guidance on best available techniques and best environmental practices relevant to the polybrominated diphenyl ethers listed under the Stockholm Convention. UNEP/POPS/COP.10/INF/18

UNEP (2021h). Proposal to list chlorinated paraffins with carbon chain lengths in the range C14-17 and chlorination levels at or exceeding 45 per cent chlorine by weight in Annexes A, B and/or C to the Stockholm Convention on Persistent Organic Pollutants

UNEP (2021i). Towards a Circular Economy for the Electronics Sector in Africa: Overview, Actions and Recommendations.

UNEP (2021j). Guidance for strengthening regulatory framework and voluntary agreements for regular monitoring of products or articles that may contain new POPs. Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva.

UNEP (2023a). Chemicals in Plastic: A technical report. https://www.unep.org/resources/report/chemicals-plastics-technical-report

UNEP (2023b). Guidance on preparing inventories of PFOS, PFOA and PFHxS. Secretariat of the Basel, Rotterdam and Stockholm conventions, United Nations Environment Programme, Geneva

UNEP (2023c). Report of the Persistent Organic Pollutants Review Committee on the work of its nineteenth meeting. UNEP/POPS/POPRC.19/9

UNEP (2023d). Report of the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants on the work of its eleventh meeting. UNEP/POPS/COP.11/31

UNEP (2023e). Technical guidelines on the environmentally sound management of plastic wastes. UNEP/CHW.16/6/Add.3/Rev.1.

UNEP (2024a) Production, use and trade of POPs newly listed in the Stockholm Convention 2009 to 2022. https://www.greenpolicyplatform.org/research/production-use-and-trade-pops-newly-listed-stockholm-convention-2009-2021

UNEP (2024b) Proposal to list polyhalogenated dibenzo-p-dioxins and dibenzofurans in Annex C to the Stockholm Convention on Persistent Organic Pollutants. UNEP/POPS/POPRC.20/5

USEPA (United States Environmental Protection Agency) (1991). PCB, lead, cadmium levels in shredder waste materials, report EPA 560/5-90-008A; 1991

USEPA (2008). Reregistration Eligibility Decision for the Tributyltin Compounds: Bis(tributyltin) oxide, Tributyltin benzoate, and Tributyltin maleate (Case 2620).

USEPA (2011). Fact Sheet: Before You Tear it Down, Get the Mercury Out. https://www.epa.gov/sites/default/files/2015-10/documents/before_you_tear_it_down.pdf

USEPA (2018). Preventing and Detecting PCB Contamination in Used Oil Best management practices for commercial and municipal used oil collection centers and recyclers. https://www.epa.gov/system/files/documents/2022-04/pcbs_in_used_oil_fact_sheet_corrected2.pdf

USEPA (2022). Deconstruction Manuals for Construction and Demolition (C&D) Projects. https://www.epa.gov/smm/deconstruction-manuals-construction-and-demolition-cd-projects

Van der Veen, I. and de Boer, J. (2012). Phosphorus flame retardants: properties, production, environmental occurrence, toxicity and analysis. Chemosphere 88(10), 1119-1153.

Wäger P, Schluep M, Müller E (2010) RoHS substances in mixed plastics from Waste Electrical and Electronic Equipment. Final Report Swiss Federal Laboratories for Materials Science and Technology Empa.

Wagner U, Schneider E, Watson A, Weber R (2014) Management of PCBs from Open and Closed Applications – Case Study Switzerland. Report for GIZ.

Wang, Z., Cousins, I. T., Scheringer, M., Buck, R. C., Hungerbühler, K. (2014). Global emission inventories for C4-C14 perfluoroalkyl carboxylic acid (PFCA) homologues from 1951 to 2030, Part I: production and emissions from quantifiable sources. Environment international, 70, 62–75. https://doi.org/10.1016/j.envint.2014.04.013

Weber R, Kuch B (2003) Relevance of BFRs and thermal conditions on the formation pathways of brominated and brominated-chlorinated dibenzodioxins and dibenzofurans. Environ Int. 29, 699-710.

Weber R, Herold C, Hollert H, Kamphues J, Blepp M, Ballschmiter K (2018). Reviewing the relevance of dioxin and PCB sources for food from animal origin and the need for their inventory, control and management. Environmental Sciences Europe. 30, 1-42.

WHO (2007). Outline for the Development of National Programmes for Elimination of Asbestos-Related Diseases. https://apps.who.int/iris/rest/bitstreams/65845/retrieve

Wu H, Zuo J, Yuan H, Zillante G, Wang J. (2019). A review of performance assessment methods for construction and demolition waste management. Resour. Conserv. Recycl. 150, 104407.

Zhu W, Bartos PJM, Porro A. (2004). Application of nanotechnology in construction. Materials and Structures 37, November 2004, 649-658.