Draft guidance on preparing inventories of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants

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Secretariat of the Basel, Rotterdam and Stockholm Conventions

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Abbreviations and acronyms

ABS	Acrylonitrile-butadiene-styrene
ATSDR	Agency for Toxic Substances and Disease Registry
ASR	Automotive shredder residue
BAT/BEP	Best available techniques/best environmental practices
BFR	Brominated flame retardant
BTBPE	1,2-Bis(2,4,6-tribromophenoxy)ethane
c-pentaBDE	Commercial pentabromodiphenyl ether (containing tetraBDE and pentaBDE)
c-octaBDE	Commercial octabromodiphenyl ether (containing hexaBDE and heptaBDE)
c-decaBDE	Commercial decabromodiphenyl ether (containing decaBDE; BDE209)
CBO	Community-based organizations
COP	Conference of Parties
CRT	Cathode ray tube
CSO	Civil society organisation
DBDPE	Decabromodiphenyl ethane
DDC-CO	Dechlorane plus
decaBDE	Decabromodiphenyl ether
DSI	Detailed site investigation
EEE	Electrical and electronic equipment
ELV	End-of-life vehicle
EMPA	Eidgenössische Materialprüfungs- und Forschungsanstalt
EPS	Expanded polystyrene
EQS	Environmental Quality Standards
ESM	Environmentally sound management
EVA	Ethylene vinyl acetate copolymer
FEQGs	Federal Environmental Quality Guidelines (Canada)
GC/MS	Gas chromatography/mass spectrometry
HBB	Hexabromobiphenyl
HBCD	Hexabromocyclododecane
hexaBDE	Hexabromodiphenyl ether homologue
heptaBDE	Heptabromodiphenyl ether homologue
HIPS	High impact polystyrene
HS	Harmonized Commodity Description and Coding Systems
IATA	International Air Transport Association
IT	Information technology
LCD	Liquid crystal display
MCV	Maximum concentration value
NIP	National implementation plan
nonaBDE	Nonabromodiphenyl ether homologue

octaBDE	Octabromodiphenyl ether homologue
PBB	Polybrominated biphenyl
PBDD	Polybrominated dibenzo-*p*-dioxin
PBDE	Polybrominated diphenyl ether
PBDF	Polybrominated dibenzofurans
PBT	Polybutylene terephthalate
PC	Personal computer
PCBs	Polychlorinated biphenyls
PCNs	Polychlorinated naphthalenes
PE	Polyethylene
PFOA	Perfluorooctanoic acid; perfluorooctanoate
PFOS	Perfluorooctanesulfonic acid; perfluorooctane sulfonate
pentaBDE	Pentabromodiphenyl ether homologue
PIC	Prior Informed Consent
POPs	Persistent organic pollutants
POP-PBDEs	Persistent organic pollutants-polybrominated diphenyl ethers (listed PBDEs)
PP	Polypropylene
PPE	Polyphenylene ether
PPO	Polyphenylene oxide
PSI	Preliminary site investigation
PST	Post shredder technologies
PUR	Polyurethane
PVC	Polyvinyl chloride
PWB	Printed wiring/circuit board
RoHS	Restriction of the use of certain hazardous substances in electrical and electronic equipment
SAICM	Strategic Approach to International Chemical Management
SCCP	Short-chain chlorinated paraffins
TBBPA	Tetrabromobisphenol A
tetraBDE	Tetrabromodiphenyl ether homologue
triBDE	Tribromodiphenyl ether homologue
TTBP-TAZ	2,4,6-tris(2,4,6-tribromophenoxy)-1,3,5-triazine
UP	Unsaturated polyester
WEEE	Waste electrical and electronic equipment
XRF	X-ray fluorescence
XPS	Extruded polystyrene

1 Introduction

1.1 POP-PBDEs and HBB in the Convention

In May 2009, the Conference of the Parties amended the Stockholm Convention (SC) on persistent organic pollutants (POPs) to add certain brominated flame retardants (BFRs) to Annex A:

- Major polybrominated diphenyl ethers from commercial pentaBDE and commercial octaBDE:
  - Tetrabromodiphenyl ether (tetraBDE) and pentabromodiphenyl ether (pentaBDE); [1]
  - Hexabromodiphenyl ether (hexaBDE) and heptabromodiphenyl ether (heptaBDE). [2]
- Hexabromobiphenyl (HBB).

In May 2017, the Conference of the Parties amended Annex A through its decision SC-8/10 to list decabromodiphenyl ether (decaBDE; BDE-209) present in commercial decabromodiphenyl ether (c-decaBDE), with specific exemptions for the production and use (Table 1; Table 2). The production and use of decaBDE shall be eliminated except for Parties that have notified the Secretariat of their intention to produce and/or use it in accordance with Article 4. Part IX of Annex A to the Stockholm Convention provides details about specific exemptions for the production and use of decaBDE (Table 1; Table 2).

While the PBDEs listed in 2009 where listed with an exemption for recycling, there is no exemption for the recycling of decaBDE containing products. The listed PBDEs are referred to in this document as POP-PBDEs.

Table 1. Specific exemptions for decabromodiphenyl ether (BDE-209; c-decaBDE)

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

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

The production and use of c-decaBDE shall be eliminated except for Parties that have notified the Secretariat of their intention to produce and/or use it in accordance with Article 4.

[1] With the main congeners 2,2',4,4'- tetrabromodiphenyl ether (BDE-47 CAS No. 40088-47-9) and 2,2',4,4',5-pentabromodiphenyl ether (BDE-99 CAS No. 32534-81-9) and other tetra and pentabromodiphenyl ethers present in commercial pentabromodiphenyl ether.

[2] With the main congeners 2,2',4,4',5,5'-hexabromodiphenyl ether (BDE-153, CAS No: 68631-49-2), 2,2',4,4',5,6'-hexabromodiphenyl ether (BDE-154, CAS No: 207122-15-4), 2,2',3,3',4,5',6-heptabromodiphenyl ether (BDE-175, CAS No: 446255-22-7), 2,2',3,4,4',5',6-heptabromodiphenyl ether (BDE-183, CAS No: 207122-16-5) and other hexa- and heptabromodiphenyl ethers.

Specific exemptions for parts for use in vehicles may be available for the production and use of commercial decabromodiphenyl ether (c-decaBDE) limited to the following, as presented in Table 2 below.

Table 2. Specific exemptions for decaBDE for parts for use in vehicles

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

Like all POPs, these chemicals possess toxic properties, resist degradation, and bioaccumulate (UNEP 2014a,b; UNEP 2015a,b). They are transported through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in ecosystems.

Parties to the Convention, for which the amendments have entered into force[3], have to meet the obligations under the Convention leading to the elimination of the listed BFRs. Due to the complexity and magnitude of usage of the POP-PBDEs, eliminating them represents a challenge for many Parties.

[3] Amendments shall not enter into force for those Parties that have submitted a notification pursuant to the provisions of paragraph 3(b) of Article 22 of the Stockholm Convention. In accordance with paragraph 4 of article 22, the amendment will not enter into force with respect to any Party that has made a declaration regarding the amendment to the Annexes in accordance

These chemicals have been widely used in many industrial sectors for the manufacture of a variety of products and articles, including consumer articles. For example, POP-PBDEs have been used in the electronics industry for the manufacture of plastic casings for computer equipment and in the transport industry (see Table 2).

C-decaBDE has been used in the same applications as those in which c-pentaBDE, c-octaBDE and HBB were used in the past (see chapter 3). The guidance and information that is relevant for an inventory of c-decaBDE are is some cases equally useful for an inventory of the other POP-PBDEs. Countries that have not yet undertaken an inventory of POP-PBDEs may find it efficient to assess their situation with respect to all POP-PBDEs. Therefore, when appropriate and to facilitate the development of inventory of POP-PBDEs as a class, this document provides information and guidance that are also relevant to POP-PBDEs listed under the Stockholm Convention in 2009 and therefore the POP-PBDE inventory can be compiled with this detailed guidance document.

Since known production of HBB stopped in 1970s, the majority of products and articles that contain HBB were disposed of decades ago. As a result, an inventory of HBB may be of limited relevance in many countries and is not addressed in depth in this guidance.

1.2 Purpose of the guidance document

Under Article 7 of the Stockholm Convention, Parties are required to develop and endeavour to implement a plan for the implementation of their obligations under the Convention. This national implementation plan (NIP) has to be updated with information on how Parties, for which the amendments have entered in force[3], will address obligations arising from amendments to the Convention to list new chemicals, in accordance with decision SC-1/12 of the COP.

Although POPs inventories are not explicitly mentioned in the Convention requirements, their development and the picture of the chemical in the country they provide will help Parties prioritise and develop actions that are relevant, focused, proportional, and cost-effective.

To develop effective strategies that can lead to the elimination of the listed BFRs, Parties need to acquire a sound understanding of their national situation concerning these chemicals. Such information can be obtained through an inventory of listed BFRs. By decisions SC-2/7 and SC-7/10, the Conference of the Parties recommended that Parties follow, as appropriate, Phase II of the guidance for developing NIPs (UNEP 2017a), and if appropriate undertake inventories, not only of the existence of the new chemical, but also the institutional arrangements and infrastructure related to it. Thus, the establishment of inventories is one important element to consider when developing, revising or updating of NIPs. The main purpose of this document is to provide guidance to Parties of the Convention on the establishment of inventories of the POP-PBDEs listed under the Convention in 2009 and 2017. A brief reference is also made to HBB to facilitate Parties understanding on this chemical and on the potential relevance of undertaking an inventory for it.

This document will be of use to national focal points for the Convention, the coordinator of the NIP review and update process, and task teams responsible for establishing the inventory. It will also be of interest to other stakeholders concerned with the elimination of POP-PBDEs and HBB.

1.3 Other guidance documents to be consulted

This guidance is intended to be used in conjunction with the General guidance on POPs inventory development (UNEP 2019a) which provides a general description of the process of developing an inventory for POPs. Users can also consult other guidance documents to support review and updating of NIPs available on the website of the Stockholm Convention.[4]

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with paragraph 4 of Article 25. Such Parties shall deposit their instruments of ratification regarding the amendment, in which case the amendment shall enter into force for the Party on the ninetieth (90) day after the date of deposit with the Depositary.

[4] http://chm.pops.int/tabid/7730/Default.aspx.

Additional information that users may find useful for the inventory have been developed under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal which provide guidance on the development of inventories and the environmentally sound management of wastes consisting of, containing or contaminated with POPs, including the following:

- General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (UNEP 2019b);
- Draft technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with PBDEs (UNEP 2018);
- Methodological guide for the development of inventories of hazardous wastes and other wastes under the Basel Convention (UNEP 2014c).

Since the current detailed inventory document covers all POP-PBDEs, an additional POP-PBDE inventory for PBDEs listed 2009 according to the former inventory guidance (UNEP 2015c) is not needed.

1.4 Objective of the inventory

The main objective of the inventory is to understand the national situation regarding POP-PBDEs in order to devise strategies for meeting the requirements of the Stockholm Convention with regard to these chemicals, including updating the NIP. More specifically, the objectives are to:

- Establish the country baseline and take stock of the country situation in relation to POP-PBDEs;
- Provide the basis for development of a strategy in the NIP;
- Identify the need to register for the specific exemptions for POP-PBDEs;
- Identify areas where the country needs financial or technical support for implementing strategies for the elimination of POP-PBDEs.

The inventory should generate information about POP-PBDEs at all stages of their life-cycle including the following:

- Production of decaBDE, its import or export;
- Use of decaBDE in the manufacturing of articles;
- Stockpiles of POP-PBDEs;
- Import and export of POP-PBDE containing articles;
- Presence of articles containing POP-PBDEs on the market and in use;
- Presence of articles containing POP-PBDEs in the waste and recycling streams;
- Disposal practices for POP-PBDEs and articles containing POP-PBDEs when they become waste;
- Potential POP-PBDE or HBB contaminated sites.

Collected information on the above will also provide broad understanding of the sources of POP-PBDE emissions, potential for human and environmental exposure and the risks that they pose to human health and the environment in a country. Information collected as part of the inventory can serve as a basis for Parties to fulfil the reporting requirement in accordance with Article 15 of the Stockholm Convention and to report to the COP on measures taken to implement the provisions of the Convention and the effectiveness of such measures.

The inventory process is usually iterative. In establishing the inventory of POP-PBDEs for the first time, Parties could also identify resources and technical capacity needed to further refine and update the inventory.

1.5 Structure of the guidance

The structure of the guidance is as follows:

- **Chapter 1** outlines the purpose of the guidance and the major objectives for undertaking an inventory;
- **Chapter 2** provides necessary background information on the POP-PBDEs and HBB for undertaking the inventory;
- **Chapter 3** outlines the five main steps involved in conducting a general inventory of POP-PBDEs. It also provides an overview of considerations that are important for planning the inventory and defining its scope;
- **Chapter 4** provides guidance on inventory of production of c-decaBDE and related import/export;
- **Chapter 5** provides guidance on developing an inventory of the use of c-decaBDE in the manufacturing of products in particular in exempted uses (specific electrical and electronic equipment (EEE), parts for vehicles, textiles, polyurethane (PUR) foams);
- **Chapters 6** provides guidance on inventory of POP-PBDEs in EEE and related waste (WEEE) and recycling;
- **Chapter 7** provides guidance for the inventory of POP-PBDEs in the transport sectors;
- **Chapter 8** provides guidance for the inventory of POP-PBDEs in textiles;
- **Chapter 9** provides guidance for the inventory of POP-PBDEs in buildings and construction;
- **Chapter 10** provides guidance on developing an inventory of potentially contaminated sites.

The key design and content features of this guidance are as follows:

- Step by step approach: The guidance is designed to provide a step-by-step and a tiered approach that can be followed and implemented by a wide variety of users. A five-step approach is provided for the overall inventory from the planning stage to preparation of the inventory report (see Chapter 3). Furthermore, a tiered approach (Tier I Initial assessment; Tier II Basic Inventory; Tier III In-depth inventory) provides the flexibility to countries with different capacities to develop an inventory. More detailed and specific guidance on stakeholders, data collection and other information for key sectors can be found in Chapters 3 to 9.
- Questionnaires and inventory format: Questionnaire examples are provided in the Annex to support the gathering of information as described above.

While tables for compilation of data are given as examples, no specific inventory format is suggested in this inventory guidance to keep it flexible considering the tiered approach.

2 Background information on listed POP-PBDEs and HBB

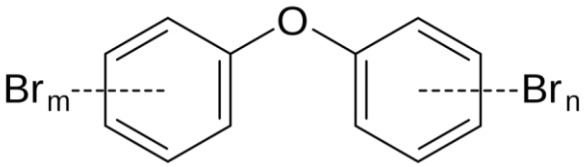
2.1 Characteristics of PBDEs and HBB

Polybrominated diphenyl ethers (PBDEs; Figure 2-1, Table 3) are a group of industrial aromatic organobromine chemicals that have been used since the 1970s as additive flame retardants in a wide range of - mainly - consumer products. PBDEs were produced with three different degrees of bromination, and marketed as commercial pentaBDE (c-pentaBDE), commercial octaBDE (c-octaBDE) and commercial decaBDE (c-decaBDE) (Alaee et al., 2003; Prevedouros et al., 2004; SFT, 2009). Chemical names, CAS number and trade names of PBDEs are listed in Table 3.

Typical homologue distributions of c-pentaBDE and c-octaBDE are shown in Tables 4 and 5.

The octaBDE and nonaBDE homologues present in the mixture are not listed in the convention. They, however, can be similarly to decaBDE degraded to POP-PBDEs by debromination (UNEP, 2010b, 2010c).

Table 3: Chemical identity/names, CAS number, trade names and structure of PBDEs

Chemical names and synonyms	**DecaBDE:** CAS: Benzene, 1,1'-oxybis[2,3,4,5,6-pentabromo-] IUPAC: 2,3,4,5,6-Pentabromo-1-(2,3,4,5,6-pentabromophenoxy)benzene; decabromodiphenyl ether, decabromodiphenyl oxide, DBDPE[5], DBBE, DBBO, DBDPO **OctaBDE:** Diphenyl ether, octabromo derivative (octabromodiphenyl ether) **PentaBDE**: Diphenyl ether, pentabromo derivative (pentabromodiphenyl ether)
CAS number	Commercial pentaBDE (CAS 32534-81-9) Commercial octaBDE (CAS 32536-52-0) Commercial decaBDE (CAS 1163-19-5); In the past CAS no. 109945-70-2, 145538-74-5 and 1201677-32-8 were also used and were formally deleted, but may still be in practical use by some suppliers and manufacturers.
Molecular formula and structure (general):	$C_{12}H_{10-m-n}Br_{m+n}O$ (m + n = 1–10)  **Figure 2-1:** Structure of polybrominated diphenyl ethers (PBDEs)
Trade name:	**DecaBDE:** DE-83R, DE-83, Bromkal 82-ODE, Bromkal 70-5, Saytex 102 E, FR1210, Flamecut 110R. **OctaBDE**: DE-79; Bromkal 79-8DE; **PentaBDE**: DE-71 Bromkal 70DE; Bromkal 70-5DE

[5] DBDPE is also used as an abbreviation for Decabromodiphenyl Ethane CAS no. 84852-53-9.

Table 4: Composition of c-pentaBDE*(La Guardia et al., 2006; SFT, 2009; Schlummer et al., 2011)

Categories of PBDE	TriBDE		TetraBDE	PentaBDE		HexaBDE		HeptaBDE
Congener	BDE-17	BDE-28	BDE-47	BDE-99	BDE-100/85	BDE-153	BDE-154	BDE-183
Content	Traces	Traces	Major	Major	Minor	Minor	Traces	Traces
Distribution for calculations*	0.5%**		**33%*****	**58%*****		**8%*****		**0.5%*****

*The homologue distribution in commercial PBDE has a variation depending on producer or production lot. For inventory purposes, a distribution considered as an average distribution of PBDE homologues in products was chosen.

**TriBDE is not listed as a POP and therefore does not need to be included in the inventory.

***The percentage of the PBDE homologues that are POP-PBDEs.

Table 5: Composition of c-octaBDE* (derived from La Guardia, 2006; SFT, 2009; Schlummer et al., 2011)

Categories of PBDE	HexaBDE		HeptaBDE			OctaBDE			NonaBDE		DecaBDE
Congener	BDE-154	BDE-153	BDE-183	BDE-180	BDE-171	BDE-197	BDE-203	BDE-196	BDE-206	BDE-207	BDE-209
Content	Traces	Minor	Major	Traces	Traces	Major	Minor	Minor	Minor	Minor	Traces
Distribution for calculations*	**11%*****		**43%*****			35%**			10% **		1%***

*The homologue distribution in commercial PBDE has a variation depending on producer or production lot. For inventory purposes a distribution considered as an average distribution of PBDE homologues in products was chosen.

**OctaBDE and nonaBDE are not listed as POPs and therefore do not need to be included in the inventory.

***The percentage of the PBDE homologues that are POP-PBDEs.

In c-decaBDE historically a range of 77.4–98% (normally ≥97%) of decaBDE, and smaller amounts of the congeners of nonaBDE (0.3–21.8 %) and octaBDE (0–0.85%) has been reported (Chen et al., 2007; ECHA 2012a; US EPA 2008; RPA 2014). **Since normally ≥97% of c-decaBDE is decaBDE, no recalculation between c-decaBDE and decaBDE is made or proposed by this guidance.**

It should be noted that trace amounts of polybrominated dibenzo-*p*-dioxins and polybrominated dibenzofurans (PBDD/Fs) have been reported as impurities in some c-decaBDE products (Hanari et al., 2006; Ren et al., 2011) and higher levels are found in decaBDE/PBDE containing plastic (Sindiku et al., 2015).

Hexabromobiphenyl (HBB is listed in Annex A to the Convention. The major congeners of commercial HBB (FireMaster FF-1) were largely 2,2',4,4',5,5'-hexabromobiphenyl (PBB 153), accounting for 50–60% of the total mass, followed by 2,2',3,4,4',5,5'-heptabromobiphenyl (PBB 180; 10–15%), and 2,2',3,4,4',5'-hexabromobiphenyl (PBB 138; 5–10%) (Pijnenburg et al., 1995).

2.2 Former and current production of commercial PBDE mixtures and HBB

2.2.1 Production of PBDEs

C-pentaBDE was produced in China, the European Union (EU), Israel, Japan, and the United States (UNEP, 2006a, 2010b; Li, 2012; Li et al., 2014). Production in the EU ceased in 1997. It is assumed that since the late 1990s POP-PBDEs were mainly produced in the United States and to a lesser extent in China and production ended in 2004 (UNEP, 2006a, 2010b; Li, 2012; Li et al., 2014).

C-octaBDE was produced in the Netherlands, France, the United States, Japan, United Kingdom and Israel. Production stopped in the EU, United States and the Pacific Rim in 2004, and there is no information indicating that it is being produced in developing countries (Annex 3; BSEF 2007).

C-decaBDE was produced in China, the EU, India, Japan, Israel and the United States. Production no longer takes place in the EU, Japan or Canada and is likely phased out also in the United States (Secretariat of the

Rotterdam Convention 2018; UNEP 2014a,b; USEPA 2012). The export of the major Harmonized System (HS)[6] Code for decaBDE from Israel indicate that decaBDE export/production has significantly reduced and largely stopped (Figure 3-). Among the BFR producing countries, China and India are known to produce and export c-decaBDE (UNEP 2014a,b). China reduced the production volume but is likely still the largest producer and supplier with an annual production in 2013 of around 21,000 tonnes (Ni et al., 2013).

The compilation of PBDE production data prepared for the POPs Review Committee (POPRC) of the Stockholm Convention estimated the total production of all PBDEs from 1970 to 2005 as between 1.3 million and 1.5 million tonnes (Table 6; UNEP, 2010a). The total amounts of c-pentaBDE and c-octaBDE used in the world were estimated at around 100,000 tonnes each. The production of c-decaBDE,[7] was estimated at over 1.1 to 1.25 million tonnes until 2005 (see Table 6).

Table 6: Estimated total global production of PBDE commercial mixtures, 1970–2005

Commercial mixture	Tonnes
c-pentaBDE	91,000 to 105,000
c-octaBDE	102,700 to 118,500
c-decaBDE	1,100,000 to 1,250,000

Source: UNEP, 2010a; derived from Schenker et al., 2008 and Li et al., 2010

2.2.2 Production of HBB

Approximately 5,400 tonnes of HBB were produced in the US from 1970 to 1976 and for no other country production of HBB has been recorded (UNEP, 2006b). Available information suggests that production and use of HBB ceased in most, if not all, countries in the 1970s (UNEP 2006b). Therefore, HBB is also of low relevance considering the low production volume.

2.3 Former and current uses of POP-PBDEs and HBB

The main manufacturing sectors that have used POP-PBDEs are as follows:

- Electrical and electronics industry;
- Transport industry;
- Furniture industry;
- Textiles and carpet industry;
- Construction industry;
- Industries recycling PBDE containing plastic or other materials.

2.3.1 Current and former uses of c-decaBDE

C-decaBDE is a general purpose additive flame retardant, that is physically combined with the material in which it is used to reduce the flammability and the rate at which flames spread. Applications include plastics/polymers/composites, textiles, adhesives, sealants, coatings and inks (e.g., ECHA 2012, 2013, RPA 2014, Sakai 2006, Tables 7 and 8). It is compatible with a wide variety of polymers and materials (see Table 8).

[6] The Harmonized Commodity Description and Coding System (HS) is an internationally recognized classification system for the majority of goods in international trade. It is developed and maintained by the World Customs Organization and is used by customs authorities worldwide for identifying traded products, including chemicals.

[7] DecaBDE is degraded over time to the lower brominated PBDEs including POP-PBDEs (UNEP, 2010b, 2010c).

The major use sectors of c-decaBDE were plastic and polymers in electrical and electronic equipment (EEE), transport, construction and textiles. In the 1990s and early 2000 it was estimated that the major decaBDE use was EEE with up to 90% of decaBDE imported to the EU in EEE products (RPA 2003). An estimate for the share of decaBDE use for the US in 2010[8]: automotive and transportation 26%, building and construction 26%, textiles 26%, EEE 13% and others 9% (Danish EPA, 2013) which might have been similar for the EU at that time (RPA 2014). After restriction of some uses like electronics in the EU in 2005, the share shifted with an increase in use of textiles of up to 50% for the EU (RPA 2014).

In EEE decaBDE was/is used in plastics/polymers include e.g., housings of computers and TV sets, wires and cables, (BSEF 2013, USEPA 2014, Table 7). Typically, c-decaBDE is used in plastics/polymers at loadings of 5–15% by weight, though in some cases loadings as high as 20% (ECHA 2012) have been reported. Because of the restrictions on the use of c-decaBDE in EEE in important markets (e.g., Europe, China), many large electrical- and electronic companies have transitioned away from c-decaBDE (KemI, 2005; USEPA 2014). Continued use is allowed in plastic housings and parts used for heating home appliances (Table 2).

In vehicles decaBDE is used in fabrics, reinforced plastics, under the hood or dash polymers or in cables and (Tables 7 and 8). A wide range of decaBDE use in vehicle parts is exempted (Table 2).

In the textile sector, c-decaBDE was/is used to treat a wide range of synthetic, blended and natural fibres (ECHA 2013). Main end uses are upholstery, window blinds, curtains, mattress textiles, tentage (e.g., military tents and textiles, also commercial marquees, tents and canvasses) and transportation (e.g., interior fabrics in cars, rail passenger rolling stock and aircraft) (Table 7). Continued use is exempted for textile products that require anti-flammable characteristics, excluding clothing and toys (Table 2).

In the building and construction sector decaBDE was/is used e.g., in polyurethane (PUR) and XPS insulation, cladding panels, PE/PP films, cables and electrical ducts and fittings or piping insulation (See Tables 7 and 8). Continued use is allowed for the manufacturing of PUR foam for building insulation (Table 2).

Table 7: Non-exhaustive overview of sectors/industries where decaBDE was/is used, identified end uses and applications (UNEP 2014d based on: BSEF 2006, RPA 2014, USEPA 2014, Annex E Bulgaria)

Sector/ industry	Applications	End use
Electric and electronics industry	Electric and electronic equipment (EEE)	▪ housings and internal components of TVs ▪ mobile phones and fax machines ▪ audio and video equipment; remote controls ▪ communications cables; building cables ▪ wire and cables, e.g., heat shrinkable tubes ▪ connectors in E&E equipment ▪ circuit breakers; coils of bobbins ▪ printing and photocopy machine components - toner ▪ cartridges and connectors ▪ scanner components ▪ heating fans and hair dryers
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) ▪ electric and electronic equipment

[8] Where the use of decaBDE in EEE has been restricted by the EU RoHS directive since 2006

Sector/ industry	Applications	End use
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
Textiles and furniture	Textiles and furniture	▪ automotive textiles ▪ upholstery textiles e.g. sofas, offices chairs, mattresses ▪ filters for cookers ▪ blinds, draperies, blackout curtains ▪ geotextiles, wall coverings ▪ households/furniture appliances ▪ PU flexible foam ▪ tents and tarps ▪ interliners; foam fillings ▪ carpets ▪ other
Buildings/construction		▪ Insulation (PUR and formerly XPS foams) ▪ facing laminates for insulation panel ▪ cladding panels ▪ film for use under the roof and to protect building areas ▪ cables and electrical ducts and fittings ▪ piping insulation and pipes

Table 8: Overview over plastic types where c-decaBDE were/is used and their applications (ECHA 2012, PlasticsEurope 2013, ICL Industrial Products 2012 as cited in RPA 2014 and UNEP 2014d)

Plastic	Type	Typical applications
Polypropylene (PP)	Polyolefin	Injection moulded parts, stadium seating, shipping pallets, roofing membranes, cladding panels
Polyethylene (PE)	Polyolefin	PE/wood composites, power cables, conduits, electrical connectors and boxes, wire and cable insulation, heat shrinkable material
Ethylene Vinyl Acetate (EVA)	Polyolefin / Elastomer	Wire and cable insulation, extrusion, coatings
High Impact Polystyrene (HIPS)	Polystyrenic	Plastic parts, panels, keyboards, casings, TV
Acrylonitrile / Butadiene Styrene (ABS)	Polystyrenic	General appliance moulding, car bumpers
Polyphenylene Oxide / Polystyrene blends (PPO/PS)	Polystyrenic	Instrument housings and internal components in electrical equipment
Polyethylene Terephthalate (PET)	Polyester	Textile fibres, plastic parts, switches, sockets, electrical appliances
Polybutylene Terephthalate (PBT)	Polyester	Circuit breakers, sockets and electrical connectors, textiles, switches
Polyamides (nylon)	Engineering thermoplastic	In injection moulding for transport apps. (e.g. wheel covers, handles, chair and seat-belt mechanisms, under hood applications). High temp. engineering application, textile fibres, coils, electrical components
Polycarbonates (PC) including PC/ABS	Engineering thermoplastic	Mirror housings, lights for cars, bumpers, window housings for trains and aircraft, casings, panels, keyboards
Polyimides (PI)	Engineering thermoplastic	Bearings in aircraft, seals, gaskets
Melamine	Thermoset	Textile finishing

Unsaturated Polyester Resins (UPR)	Thermoset	Articles for construction (modular building parts, roofing materials, porch canopies); fibre reinforced plastics, automobile parts
Epoxy resins	Thermoset	Adhesives, electronics, construction, aerospace
Ethylene Propylene Diene Monomer (EPDM)	Elastomer	Car radiator hoses, roofing membranes, cable and wire insulation
Styrene Butadiene Rubber	Elastomer	Latex, carpet reinforcements, interior redecoration.
Thermoplastic Polyurethanes (TPU)	Elastomer	Automotive, wire and cable applications, gaskets
Emulsions/coatings PVC, Ethylene Vinyl Chloride emulsion acrylic	Waterborne emulsions	Adhesive applications (e.g. wall coverings, furniture, flooring), protective coatings, saturation of fibrous materials (paper, textiles)

2.3.2 Former uses of c-pentaBDE

It is considered that between 90% and 95% of the use of c-pentaBDE was for the treatment of PUR foam. These foams were mainly used in automotive and upholstery applications. Minor uses included textiles, printed circuit boards, insulation foam, cable sheets, conveyer belts, lacquers and possibly drilling oils (Table 9; UNEP, 2007a). The total amount of c-pentaBDE used for these minor uses is estimated to account for 5% or less of the total usage (SFT, 2009; UNEP, 2010b). Alcock et al. (2003) estimated that 85,000 tonnes of c-pentaBDE were used overall in the United States and the remaining 15,000 tonnes in Europe. There may have been production and use in Asia but reliable data are not available.

An approximate distribution of global c-pentaBDE use of 36% in transport, 60% in furniture and a 4% residual in other articles is considered to be reasonable and is generally consistent with the analytical data for different waste streams (UNEP, 2010b). Table 9 summarizes the former uses of c-pentaBDE in various materials and applications.

Table 9: Former uses of c-pentaBDE in polymers/resins, the applications and articles (UNEP 2009)

Polymers/resins	Applications	Articles
Polyurethane (PUR)	Cushioning materials, packaging, padding, construction	Furniture, transportation, sound insulation, packaging, padding panels, rigid PUR foam construction
Textiles	Coatings	Back coatings and impregnation for carpets, automotive seating, furniture in homes and official buildings, aircraft, underground
Epoxy resins	Circuit boards, protective coatings	Computers, ship interiors, electronic parts
Rubber	Transportation	Conveyor belts, foamed pipes for insulation
Polyvinylchloride (PVC)	Cable sheets	Wires, cables, floor mats, industrial sheets
Unsaturated (Thermoset) polyesters (UPE)	Circuit boards, coatings	Electrical equipment, coatings for chemical processing plants mouldings, military and marine applications: construction panels
Paints/lacquers	Coatings	Marine and industry lacquers for protection of containers
Hydraulic oils	Drilling oils, hydraulic fluids	Off shore, coal mining

The average content of c-pentaBDE in PUR foam is reported to be around 3–5% (wt %) for upholstery, cushions, mattresses, and carpet padding (ENVIRON, 2003; UNEP, 2010a; see Table 10) used in particular in countries with flammability standards for these applications (e.g., United States, United Kingdom). PUR foam in the transport sector might have been used in lower concentrations for applications like seats or arms/head rests at 0.5–1 wt % (Ludeka, 2011). Considering the approximately 100,000 tonnes of c-pentaBDE and a use of 4% in PUR foam, the historic production of c-pentaBDE treated foam can be conservatively estimated to be approximately 2.5 million tonnes. This number might have been significantly higher considering that a major application (PUR foam in transport in the United States) used

c-pentaBDE at a lower level. Furthermore, recycling of contaminated PUR foam mixed together with non-impacted PUR foam led to increased total quantities of POP-PBDEs-contaminated PUR foam materials.

Table 10: Usage of pentaBDE in PUR foam

PUR foam density/use area	PentaBDE in polymer (wt %)	Source
19 kg/m^3	5.45	Cambell, 2010
24 kg/m^3	4.30	Cambell, 2010
29 kg/m^3	2.77	Cambell, 2010
PUR foam in (US) transport (seating, head/arm rest)	0.5–1	Ludeka, 2011
older carpet padding	2–5	Ludeka, 2011
lamination to headliner fabric	Up to 15	Ludeka, 2011

2.3.3 Former uses of c-octaBDE

The main former use of c-octaBDE was in acrylonitrile-butadiene-styrene (ABS) polymers, accounting for about 95% of c-octaBDE supplied in the EU. The treated ABS was mainly used for housings/casings of electrical and electronic equipment (EEE), particularly for cathode ray tube (CRT) housings and office equipment such as copying machines and business printers.[9] Other minor uses were high impact polystyrene (HIPS), polybutylene terephthalate (PBT), and polyamide polymers (Table 11). Although the majority of these polymers were used in electronics, there was also some use in the transport sector.

Other minor uses include nylon, low density polyethylene, polycarbonate, phenol formaldehyde resins, unsaturated polyesters, adhesives and coatings (UNEP, 2010a, 2010b) (Table 11).

Typical concentrations in the major applications were between 12 wt% and 18 wt%, with approximately 100,000 tonnes of c-octaBDE at an application rate of 15 wt%. The primary treated polymers can be estimated at approximately 800,000 tonnes (Alaee et al., 2003, UNEP 2007b). Considering the recycling of c-octaBDE in new plastic products (secondary contamination), the total quantity of impacted plastics is likely to be considerably higher than this. But POP-PBDE concentrations in these recycled plastics are lower (Chen et al., 2009; Sindiku et al., 2014, 2015).

Table 11: Former uses of c-octaBDE in polymers/materials, the applications and products (ESWI 2011)

Polymers/materials	Application	Articles
Acrylonitrile-Butadiene-Styrene (ABS)	Polymer casings/parts in electric and electronic appliances	Computer- and TV casings (CRTs); office equipment; (other electronic equipment)
High Impact Polystyrene (HIPS)	Polymer casings/parts in electric and electronic appliances	Computer- and TV casings (CRTs); office equipment
	Cold-resistant layer	Refrigerator
Polybutylene-Terephthalate (PBT)	Polymer casings	Electronic appliances
	Transport sector	Connectors in vehicles
	Household	Iron
Polyamide-Polymers	Textiles	Furniture
	Construction	Pipes and plastic foil

2.3.4 Former uses of HBB

HBB was used as a flame retardant in three main commercial products (Neufeld et al., 1977; IPCS, 1994; ATSDR, 2004; UNEP 2006b):

- ABS thermoplastics (plastic for constructing business machine housings and in industrial (e.g., motor housing) and electrical (e.g., radio and TV parts) sectors);

[9] In some regions such as Europe and Japan, CRT monitor housing and copying machines are already normally treated separately.

- PUR foam for automotive upholstery;
- Coatings and lacquers.

Due to the small production (5400 t) and early use before 1976, most HBB-containing materials were disposed of decades ago (ATSDR, 2004). This is confirmed for electronics where in the large study on BFRs in European WEEE plastic HBB was not detected (BAFU 2017) and in the WEEE plastic monitoring study in France only one sample in a two years sampling campaign contained HBB at low level (7 mg/kg) (Hennebert & Filella 2018). Levels in food were mostly below detection limits (EFSA, 2010). Hence, HBB is of minor relevance for the inventory and implementation process.[10] Therefore, HBB and HBB-containing articles are not further mentioned in this guidance document. Furthermore, since the former uses were identical to that of POP-PBDEs, the materials addressed by managing POP-PBDEs will at the same time address the few articles containing HBB.

2.4 POP-PBDEs in material/recycling flows and at end-of-life

2.4.1 Background

A main challenge for the elimination of POP-PBDEs is the identification of existing stockpiles and articles containing POP-PBDEs and their disposal at end-of-life (Abbasi et al., 2015; Babayemi et al., 2014; UNEP, 2010a,b; Shaw et al., 2010). In all regions, a large proportion of PBDE containing materials end and/or ended up in landfill sites (Alcock et al., 2003; Babayemi et al., 2018, 2014; Dannon-Schaffer et al., 2014; ESWI, 2011; Keet et al., 2010; Morf et al., 2003; Petreas & Oros, 2009; Weber et al., 2011). Large quantities of old EEE and WEEE were - and in some cases still are - exported from industrial countries/regions (e.g., United States, Europe and Japan) to developing countries for reuse or recycling. Inappropriate technologies for WEEE recycling have resulted in large contaminated areas in developing countries and exposure of recyclers and the general population (Shaw et al., 2010; Wong et al., 2007; UNEP, 2010a, 2010b). In some industrial countries PBDE containing materials are partly thermally recovered or destroyed (Leslie et al., 2013; Morf et al., 2003, 2008; Sakai et al., 2004; Vyzinkarova & Brunner, 2013; Kajiwara et al., 2021) but even Switzerland, with a historic policy of incineration, has large stocks in landfill (Morf et al., 2007).

Large volumes of PBDE containing materials are recycled globally and will continue to enter new consumer products (Babayemi et al., 2014; Chen et al., 2009; Gallen et al., 2014; UNEP, 2010a, 2010b). In some countries or regions regulations exist on managing PBDE containing materials (e.g., European Commission, 2010). In these countries the recycling rates of PBDE containing materials might reach 10 to 20% (Leslie et al., 2013; Vyzinkarova & Brunner 2013). In some other countries policy is fragmented or not existing (Li et al., 2013) and recycling rates might be higher (Haarman, 2016). Other identified uses of c-decaBDE flame-retarded plastics such as buildings, construction materials and in the transportation sector (cars, airplanes, trains and ships) might be recycled in particular when considering the need to move to a (more) circular economy.

While the POP-PBDEs listed in 2009 (c-octaBDE and c-pentaBDE) with a recycling exemption that allows recycle under certain conditions, no recycling exemption exist for decaBDE. However, decaBDE with its high historic production volume of more than 1 million tonnes compared to ca. 100,000 t for c-pentaBDE and c-octaBDE is present in considerably higher levels in e.g., plastic in WEEE or vehicles (Table 33).

. To support Parties to prevent or reduce releases of polybrominated diphenyl ethers (PBDEs) from the uses/applications under the specific exemptions listed in the Convention, a “Guidance on best available techniques and best available practices relevant to the polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants” has been developed and updated to include considerations relevant to decaBDE (UNEP 2021a). The guidance addresses BAT and BEP for the recycling of PBDE-containing articles (excluding decaBDE), focusing on the key material recycling flows –

[10] A good indicator for the low relevance of HBB in a country is the level in human milk, which was below detection limit in the frame of the Global Monitoring Project by the World Health Organization (WHO) and UNEP.

namely electrical and electronic equipment (EEE) / Waste EEE (WEEE), vehicles in the transport sector, and polyurethane foam, as well as BAT and BEP for the use of decaBDE in polymer/plastic and textile applications listed as specific exemptions under the Convention. Recycling processes for both WEEE and ELV (e.g. vehicles and PUR foam) follow a precise logic: either parts are separated manually at the beginning of the treatment process or, as in most cases where mechanical recycling takes place, the separation process of brominated flame retardants-containing plastics occurs at the end of the recycling process before the extrusion of the recyclable content, based on different methods (UNEP 2021a). The separated plastics that contain brominated flame retardants are subsequently treated in appropriate BAT/BEP incinerators or thermal facilities, resulting in energy recovery (UNEP 2021a). In order to sort out c-decaBDE containing wastes for environmentally sound management and to avoid and/or minimize recycling of articles that contain c-decaBDE, the compiled effective screening and separation techniques are necessary for material containing BFRs. When screening and separation techniques are not readily available and concentrations are assumed to be above the low POP content , recycling should be avoided (UNEP 2015a, UNEP 2021a). Failure to do so will inevitably result in wider human and environmental contamination and the dispersal of PBDEs into matrices from which recovery is not technically or economically feasible. Furthermore, PBDEs should not be diluted since this would not reduce the overall quantity in the environment (UNEP 2015a).

Furthermore, Article 6, paragraph 2 of the Stockholm Convention mandates its Parties to cooperate closely with the appropriate bodies of the Basel Convention on common issues of relevance such as POPs wastes listed in Annexes I and VIII of the Basel Convention. In this frame a "*Revised technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromodiphenyl ether and heptabromodiphenyl ether, or tetrabromodiphenyl ether and pentabromodiphenyl ether or decabromodiphenyl ether - 2nd draft* (UNEP, 2018) has been developed.

The end-of-life treatment technologies for PBDE containing waste are compiled in the BAT/BEP guidance (UNEP 2021a) and in review articles (Lucas et al., 2018). Due to the current and future relevance of recycling and circular economy some information is compiled here.

2.4.2 Recycling of plastic from EEE and ELVs

The mechanical recycling of plastic for further use is strongly favoured from a waste hierarchy and life cycle assessment perspective. Large quantities of old EEE and WEEE were - and in some cases still are - exported from industrial countries/regions (e.g., United States, Europe and Japan) to developing countries for reuse or recycling (Haarman 2016). Plastics containing POP-PBDEs and other BFRs have been recycled in the production of exposure sensitive products including children's toys, coffee cups, household goods (Chen et al., 2009, 2010; Kuang et al., 2018; Samsonek & Puype, 2013) and are widely present in many consumer products (Gallen et al., 2014). This shows that the flow of plastics containing POP-PBDEs and other flame retardants for recycling are not well controlled in some regions and that plastics containing POP-PBDEs are being mixed with non-flame retarded polymers for the production of items with sensitive uses.

Polymers from end-of-life vehicles or plastic from construction is increasingly recycled partly with separation of bromine (Swerea, 2018; Ignatyev et al., 2014).

2.4.3 Recycling of PUR foam

The recycling of PUR foams into carpet padding/rebond is practiced in particular in the United States and Canada (Ludeka, 2011; Lukas et al., 2018). The extent of this recycling activity in other regions is unknown but appears to be limited (DiGangi et al., 2011). Relevant exposure of PUR recyclers and carpet installers to POP-PBDEs has been demonstrated (Stapleton et al., 2008), and there are obvious risks of further exposure of consumers. A chapter on PUR recycling is included in the SC PBDE BAT/BEP guidance.

2.4.4 Recycling of textiles

The extent of recycling of PBDE-containing textiles is unclear but can be assumed to be small for composite materials such as those used in transport or furniture (UNEP 2010a,b). Activities for the improvement of recycling of synthetic textile are conducted or planned (Ignatyev et al., 2014).

2.4.5 Increased recycling within the frame of circular economy

The recycling of all the major use areas of PBDEs can be expected to increase within the global strive and push for a (more) circular economy. Therefore, the inventory of PBDE containing stocks and flows and their separation and management should be used to support the move towards a clean recycling of affected wastes and materials in cooperation with the implementation of related Basel Convention activities.

2.5 Potential contaminated sites

Sites where PBDEs have been produced, used in manufacturing, or where PBDE containing wastes has been treated, are potentially contaminated with POP-PBDEs (see Chapter 10). Users of this guidance document can utilize the information generated while developing the inventory based on Chapters 4 to 9, while also examining general and hazardous solid waste practice in their countries, to carry out the contaminated site inventory with detailed guidance given in Chapter 10. PBDEs are precursors of brominated dibenzofurans (PBDF) and dibenzo-*p*-dioxins (PBDD). They are largely formed during inappropriate recycling of WEEE and incineration of PBDEs-containing materials and might also be considered in such an assessment (UNEP, 2010b).

3 How to conduct a POP-PBDE inventory

This chapter outlines five broad steps for planning and carrying out a national POP-PBDE inventory. The national focal point of the Stockholm Convention or national coordinator would be responsible for initiating the inventory process. The Steering Committee on POPs that was formed for the original NIP development could be re-established for updating the NIP and involved in the planning of the inventory.

Figure 3-1 gives an overview of the suggested 5-step approach for the PBDE inventory development process.

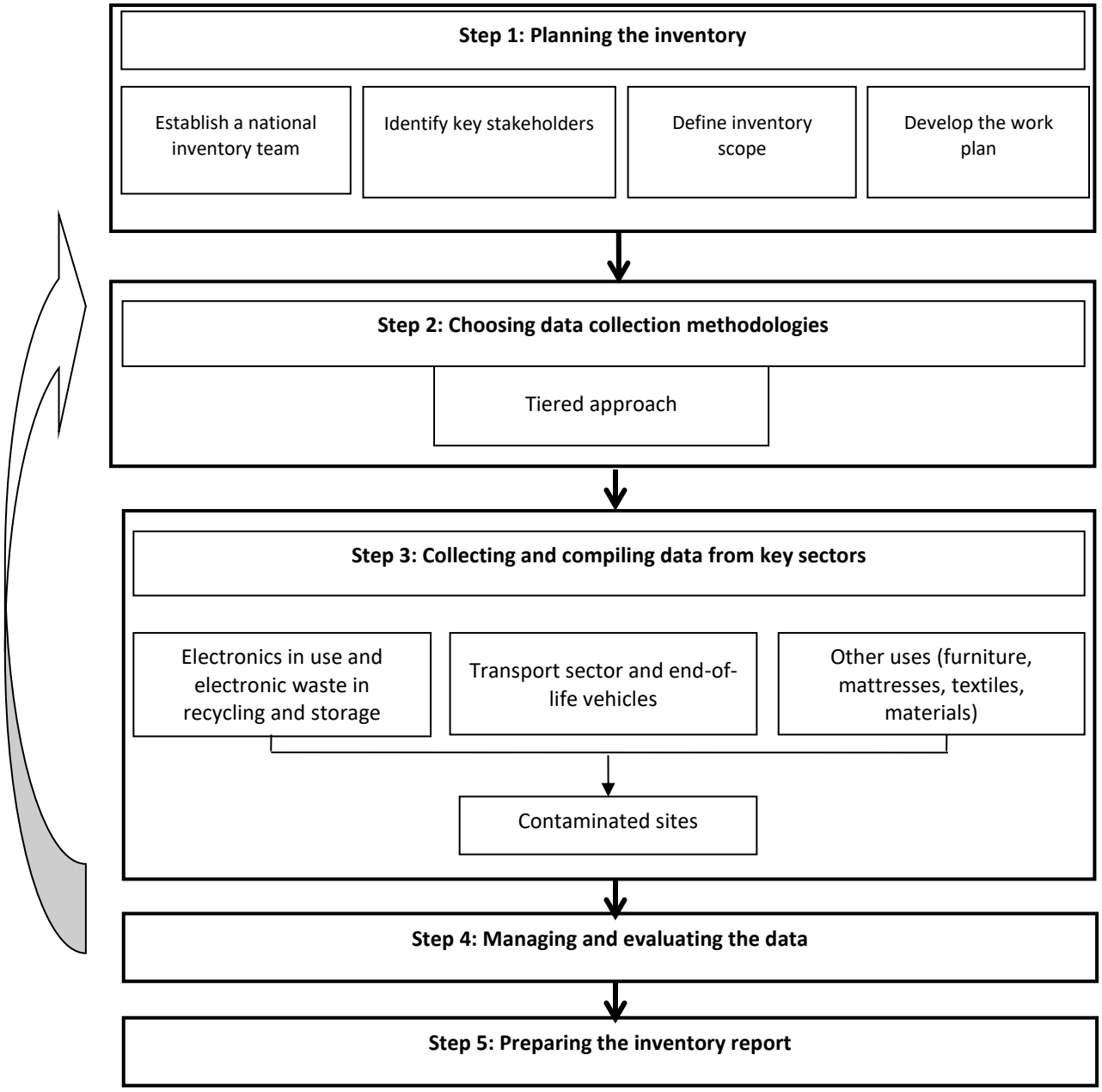


Figure 3-1*:* Suggested 5-step approach for the PBDE inventory development process.

The inventory process is not intended to be conducted in an entirely linear fashion. The inventory team may need to repeat activities in earlier steps depending how the inventory proceeds and which sectors are involved. For example, although the identification of stakeholders is shown in step 1 (Figure 3-1), there may also be a need to identify further stakeholders at different points during data collection in step 3. The arrow going from step 4 (Managing and evaluating the data) back to step 2 (Choosing data collection methodologies) in Figure 3-1 indicates that steps 2 to 4 can be repeated until the data quality

and coverage of the inventory reach a satisfactory level. The inventory team will decide on the complexity of the methodology appropriate for their particular situations, taking into account their financial and technical capacities. For many countries, it could be evident at the beginning of the process that the higher tier approaches requiring complex analyses (see section 3.2) would be out of reach. Others could decide after evaluating the results of the initial inventory to undertake more in-depth data collection (move to a higher tier) in the future, and even include such activities as an action plan in their NIP.

3.1 Step 1: Planning the inventory

The first issue to consider in developing a national inventory is to define the scope of the inventory and target the national relevant sectors for POP-PBDEs. The development of a national inventory of products and articles requires cooperation with the relevant authority in charge of manufacturers of consumer products, suppliers, retailers and the customs service, as well as other relevant authorities and organizations. It is important to clearly define the responsibility for developing the inventory. Parties that have no regulations on POP-PBDEs and decide to do a full inventory are advised to establish a multi-stakeholder national inventory team.

3.1.1 Establish a national inventory team

The national focal point of the Stockholm Convention could establish and/or lead a multi-stakeholder national inventory team to acquire the necessary competences and access to relevant inventory information. This team would comprise government ministries with a mandate for chemicals and waste management, the national customs service, the private sector, non-governmental organizations (NGOs/CSOs), and academics and researchers from universities and research institutes working on old and new POPs, waste management and possibly material flows among others. National POP or waste management consultants and material flow experts, knowledgeable in these issues, could also be hired to facilitate the work of the team.

The national focal point and/or the consultants would brief and educate the team on the Stockholm Convention's mandates, obligations and POPs.

3.1.2 Identify key stakeholders

The first meeting of the national inventory team provides the opportunity to determine the available information in various stakeholder organizations and to brainstorm on how to best proceed with the inventory exercise. As the process of identifying articles containing POP-PBDEs is complex, it is important to identify further stakeholders (using the background information provided in chapter 2).

The inventory development requires cooperation between relevant government authorities and official agencies, producers, importers and distributors, manufacturers, fabricators, community-based organizations and NGOs, organized labour and trade unions, industrial enterprises, other private-sector organizations, the waste management and recycling sector, and users and owners of articles possibly containing POP-PBDEs. Many countries are also engaged in ongoing activities related to the management of EEE/WEEE. Members of these working groups could be invited to join the inventory team, as well as working groups on the management of vehicles and end-of-life vehicles. Depending on the outcome of the scope setting exercise (see section 3.1.3), representatives from the key sectors could be included in the inventory team, while others could simply be asked to provide data/information.

The manufacture of articles containing POP-PBDEs may be inconsiderable due to discontinued POP-PBDE production and mainly related to recycling activities only. Previous activities may have included several manufacturers, suppliers and downstream users; and the supply chain could be further extended to importing and exporting across borders. Some countries may have to identify and describe, for example, professional users of POP-PBDEs-containing articles and materials, the national supply chain and the downstream users of articles containing POP-PBDEs. Table 12 outlines the sectors and stakeholders involved in the use of POP-PBDEs-containing materials.

Table 12: Sectors and stakeholders involved in the use of POP-PBDEs

Use	Stakeholders
For all uses	• Ministry of Environment and Ministry of Industry; • Ministry responsible for waste management • Ministry of labour and ministry for consumer protection • Customs authorities; • NIP coordinator and steering committee; • University groups working on waste management or material flows; • Basel Convention focal point (& stakeholders in Basel activities on WEEE); • NGOs/CSOs working on hazardous chemicals/POPs and hazardous waste.
Electrical and electronic equipment (EEE) and waste electrical and electronic equipment (WEEE)	• Importers and exporters of electronics; • Retailers of electronics and second-hand electronics; • Recyclers of WEEE; waste management experts; • Recyclers and users of polymers from WEEE; • NGOs/CSOs working on WEEE; • Industrial associations and other relevant stakeholders in the country.
Transportation and end-of-life vehicles	• Ministry of transport or other ministry responsible for transport sector; • Industrial associations • Car and other vehicle manufacturers • Association of importers and exporters of cars and other vehicles; • Retailers of vehicles (in particular, second-hand vehicles); • Association and/or main stakeholders of scrap recycling; • Association and/or main stakeholders of polymer recycling; • NGOs/CSOs working on transport; NGOs/CSOs working on POPs; • Other relevant stakeholders in the country.
Textiles	• Association of textile industry • International organization active in the country (Partnership for Sustain. Textiles www.textilbuendnis.com/en/; ZDHC www.roadmaptozero.com/) • Textile manufacturers • Textile importers; textile supply chain
Construction sector	• Ministry responsible for construction/housing • Authorities granting construction permits; • Industry producing insulation foams and other FR polymers in housing; • Construction industry (in particular related to insulation); • Importers/exporters of insulation foams and polymers in construction; • Retailers of insulation boards; • Industrial associations.
Other minor uses not exempted: Furniture Mattresses Rubber	• Importers/exporters of furniture, mattresses, construction materials, rubber; • Retailers of furniture, rubber and related second-hand articles; • Recyclers of polyurethane or other sectors (e.g., textiles, polymers in building materials, rubber), Montreal Protocol focal point; • Industrial associations and other relevant stakeholders in the country.
Contaminated sites	• Affected industries and manufacturers; • Engineering offices specializing in contaminated sites; • University or research institute working on contaminated sites; • Community-based organizations (CBOs) and NGOs; • Organized labour and trade unions; • Government organizations.

Making preliminary contact

Making contact with stakeholders at the beginning of the inventory exercise can give them a better understanding of its background, scope and objectives and provide them with an opportunity to communicate their views and questions. This initial feedback can help make the inventory more effective by targeting the relevant areas of national use.

General tools that can be used to identify and contact stakeholders include:

- Telephone interviews;
- Postal communication;
- Email/Web-based information sourcing;
- Face-to-face interviews;
- Phone books;
- National registers.

Consulting with a small number of relevant stakeholders

During the inventory planning stage, it may be more efficient to contact and consult only a small number of relevant stakeholders such as larger manufacturers, national industrial associations and the customs service. Gap analyses conducted in the evaluation of the initial assessment or the preliminary inventory could result in the need to contact some of these stakeholders again to get more information or identify other stakeholders to be contacted to help fill in the information and data gaps.

Holding stakeholder group meetings

There may be a range of stakeholder groups involved depending on the areas of use: electronics, transport, furniture, textiles, mattresses and construction materials, and waste categories and management.

3.1.3 Define the scope of the inventory

Defining the scope of the inventory involves identifying the relevant national sectors to be investigated further. This can be achieved by consulting key stakeholders (see Table 12) and paying special attention to the use categories and life cycle stages discussed in chapter 2. Since the major uses of POP-PBDEs (sections 2.3 and 2.5) are electrical and electronic equipment and uses in the transport sector, these two are likely to be the main focuses of the inventory.

Main information includes:

- Types and quantities of articles containing POP-PBDEs;
- Types of articles containing POP-PBDEs that are recycled, the possible extent of recycling, and the types of articles produced from recycling;
- Types and quantities of POP-PBDEs (chemical) stockpiles and wastes from former and current production and use in industries (countries that produced/produce POP-PBDEs or used/use POP-PBDEs in industries);
- Locations where activities have occurred/occur that could be potentially contaminated with POP-PBDEs.

The following criteria are important in defining the scope of the inventory:

- Obligations for POP-PBDEs under the Stockholm Convention (see Chapter 1);
- Objectives of a POP-PBDE inventory (see Chapter1);
- Existing resources and capacity;
- National priorities.

The degree and depth of the inventory can be defined by consulting the sections below on data methodology (Chapter 3.2) and data collection (Chapter 3.3), and considering the resources needed for an inventory in relevant national sectors using a tiered approach. Minor uses could be considered in the

inventory only if manufacturers in this category are established in the country or existing information indicates that those uses could be relevant.

3.1.4 Develop the work plan

The core inventory team is expected to develop a work plan for the inventory, which can be discussed with the stakeholders. Elements of the plan include:

- Inventory strategy on what needs to be done to identify the sectors;
- Methodologies to be used (see section 3.2);
- Activities needed and assignments;
- Resources allocation including responsibility and budget;
- Timeline and milestones.

The inventory team may need to augment and revise the work plan as the inventory proceeds.

3.2 Step 2: Choosing data collection methodologies

The next step is to choose appropriate methodologies for data collection, using a tiered approach.

3.2.1 Tiered approach

The tiered approach to collecting data in a POP-PBDE inventory is illustrated in Figure 3-2. This approach provides flexibility to a wide range of Parties with varying priorities and capacities. The suggested methodologies for data collection in the three tiers are described in section 3.2.2. Each tier represents a level of methodological complexity. Moving from lower to higher tiers implies a Party is opting for approaches that are progressively more demanding in terms of complexity and data requirements, and therefore more resources may be needed. Lower tier methods usually rely on readily available statistics in combination with estimates for key parameters (provided in this guidance). Higher tiers methods involve more resource-intensive data collection activities and country-specific measurements but should also yield more accurate results.

Parties might endeavour to use methods that provide the highest level of certainty, when for example the preliminary inventory concludes that POP-PBDEs could pose high human health and environmental risks in the country and more accurate data are needed to prioritize risk reduction measures and estimate their costs, while making efficient use of available resources and taking into account available technical capacity. The initial assessment (tier I) provides the inventory team with a general idea of where the problems may lie and, more importantly, which sectors require further investigation. The tier I outputs may be rather qualitative (section 3.2.2) or require (subsequent) verification. The (preliminary) inventory based on tier II focuses on specific sectors considered relevant and would provide information for deciding on management measures. An in-depth inventory (tier III) uses analytical measurement methods to obtain more precise data on sectors.

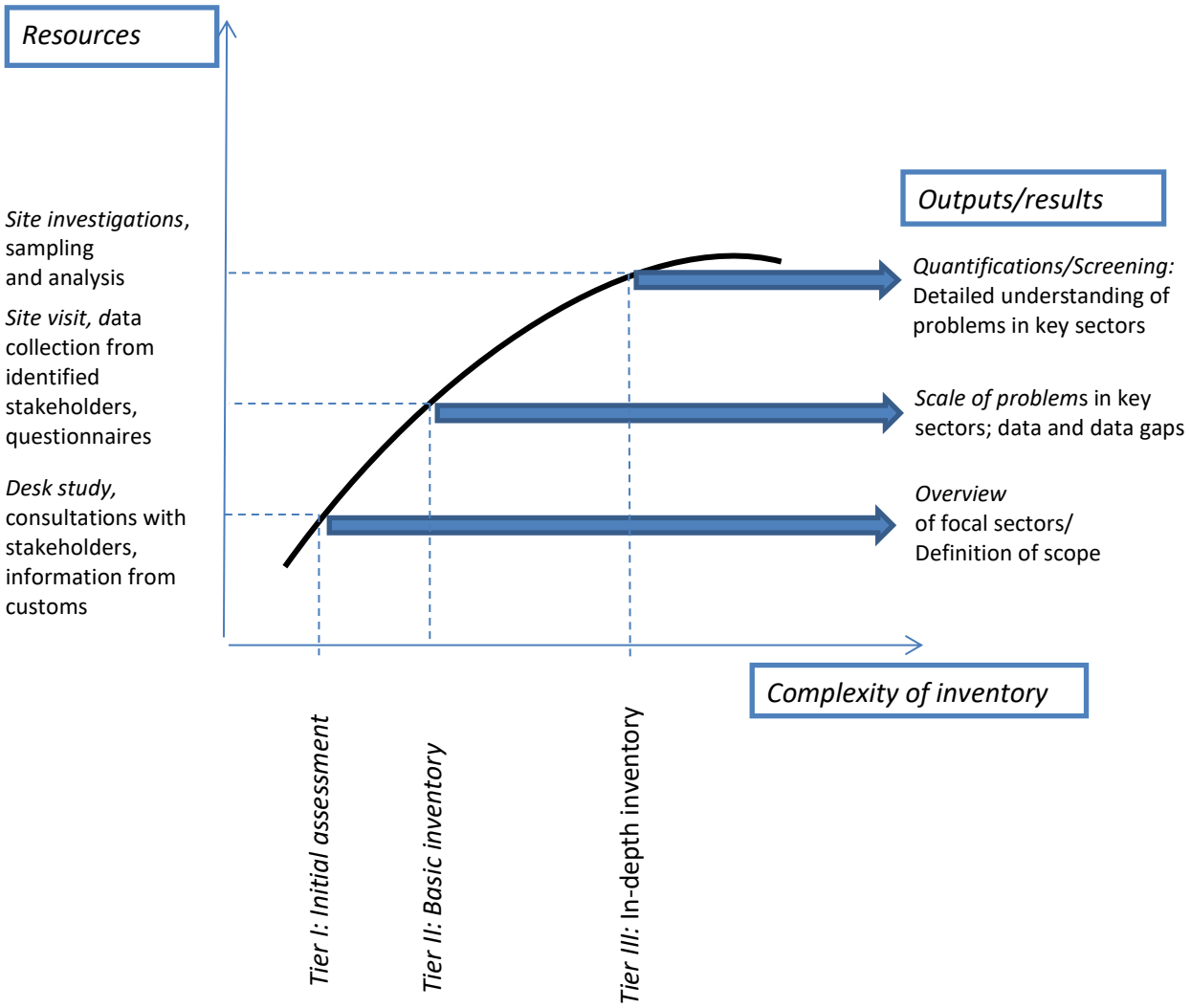


Figure 3-2: The tiered approach to the inventory of POP-PBDEs

Tier I: Initial assessment

Tier I methods usually rely on readily available information and statistics. Methods used for higher tiers involve more resource-intensive data collection activities and possibly country-specific measurements but should also yield more accurate results.

Parties should endeavour to use methods that provide a robust level of certainty. This is especially true when, for example, the preliminary inventory concludes that PBDEs could pose high human health and environmental risks in the country and that more accurate data is needed to prioritize risk reduction measures and estimate their costs.

The initial assessment (Tier I) provides the inventory team with a general idea of where the problems may lie and, more importantly, which sectors require further investigation and what are the information gaps.

Tier I outputs are rather qualitative and require (subsequent) verification. Suggested Tier I activities are described in the individual chapters.

The (basic) inventory (Tier II) builds on Tier I information. Therefore, the Tier I assessment should try to compile all easy accessible information on the potential relevance of production, the major uses and products in use and end-of-life and highlight the gaps as basis for Tier II.

Tier II: Basic inventory

The basic inventory (Tier II) generally compile available information on specific sectors. It involves surveys and site visits to better estimate national data that were identified as missing in the initial assessment. The basic or preliminary inventory generally focuses on the specific sectors present in the country. It involves surveys and site visits to estimate production and use data that were identified as missing in the initial assessment/Tier I. Possible production applications and uses are described and target locations should be identified, followed by site visits.

The team collects information about existing past and present national data on the import and use of POP-PBDEs and articles containing POP-PBDEs from major stakeholders including in depth literature assessment.

Details on suggested activities for Tier II inventory are described within the individual chapters. One outcome of Tier II assessment should be a gap analysis to be addressed by a more detailed Tier III assessment or which can feed into the action plan of the NIP.

Tier III: In-depth inventory

The in-depth inventory—may be undertaken if the basic inventory concludes that POP-PBDEs could pose high human health and environmental risks in the country and more accurate data are needed to prioritize risk reduction measures and estimate their costs. Data collection in this tier relies on the use of analytical methods that may include screening using X-ray fluorescence (XRF) and measurements using gas chromatography and electron capture detector (GC-ECD) or mass spectrometry (GC-MS) (Leslie et al., 2013; Sindiku et al., 2014). It may also involve detailed inspections of sites mentioned in tier II or a compilation of material and substance flow analysis.

3.2.2 Indicative, qualitative and quantitative methodologies

A number of different methodologies can be used for gathering information about POP-PBDEs. The methodologies can be divided into three groups:

- **Indicative method:** provides initial information for further planning of the inventory depending on the amount of resources (i.e., human and financial situation). This method is quick and does not require significant human and financial resources. Activities include desk study of existing information, workshops, and interviews. This method is normally used in the initial assessment.
- **Qualitative and semiquantitative method**: uses questionnaires to obtain more specific data. Data management is based on estimations from known levels of quantities of POP-PBDEs used and total production volumes in production processes, and manufacture of products and articles. Workshops and interviews with stronger obligations (legal tools) may also be helpful in obtaining data from the industry. Impact factors are used for a semi-quantitative assessment of POP-PBDE in materials. This method is normally used in the (preliminary) inventory.
- **Quantitative method**: provides accurate and specific numerical information but needs to be carried out by experts in the relevant fields of POP-PBDEs and the sectors of investigation. This is an advanced stage of the inventory that includes site inspection, sampling and analysis. The investigations are extensive and labour intensive and chemical analysis is costly. This method is normally used in an in-depth inventory.

Four approaches that can be used for data collection are discussed briefly in the next sections.

Desk study of existing information

The desk study involves gathering information about existing past and current national data on former/current production and use of POP-PBDEs (if any), and articles containing POP-PBDEs. This information can be obtained from the customs service, national bureau of statistics, and national central bank; published literature in scientific journals, technical reports or notes, commissioned research reports, development assistance study reports and Internet searches. The information is finally collated, evaluated and verified if possible, and a gap analysis of the data would be undertaken as well.

National sensitization workshop on Stockholm Convention and new POPs including POP-PBDEs

This national workshop involves major stakeholders from all sectors and groups in which products and articles containing POP-PBDEs have been used or are still being used. The national importance of the inventory exercise would be emphasized to participants while also demanding their full cooperation and unhindered release of available data in their custody in the national interest.

Breakout sessions and group meetings can be organized during the workshop to ensure that all sectors in which POP-PBDEs have been used are adequately covered as well as to get consensus on how best to collect and compile data.

Questionnaire surveys

Questionnaire surveys are valuable instruments for data collection in inventory programs. Based on preliminary contact and consultation meetings with stakeholders, a questionnaire with explanatory notes can be developed and sent to the relevant stakeholders or used in interviews. Examples of questionnaire formats that can be used for different sectors are given in annexes 2-5.

Questionnaires can be administered through various outreach mechanisms, including postal distribution; supply chain distribution; distribution via trade unions, NGOs, local governments and community leaders; and hand delivery in one-on-one interviews, electronic means, etc. The use of questionnaires together with stakeholder meetings has been successful in previous inventories of POP-PBDEs.

Site inspection, sampling and analysis

Samples of products and articles can be gathered during site inspections of relevant storage facilities, recycling locations, and waste disposal/storage facilities. The screening and analysis of POP-PBDE in articles and products are described in the "*Guidance on Screening and Analysis of POPs in Articles and Products"* (Stockholm Convention Secretariat, 2017)

3.3 Step 3: Collecting and compiling data from key sectors

The following areas need to be addressed within a POP-PBDE inventory in the country by the inventory team:

- Production of POP-PBDEs. Most countries do not produce POP-PBDEs. And only some countries produce chemical agents and preparations used in the manufacture of textiles, foam, synthetic carpets and electronic and electrical articles and devices;
- Industries currently (and formerly) using POP-PBDEs in manufacturing;
- Products and articles containing POP-PBDEs in households, institutional and corporate consumers;
- POP-PBDEs in waste and how they are managed;
- Articles containing POP-PBDEs that are recycled, the possible extent of recycling, and the types of articles produced from recycling, including the life cycle of c-pentaBDE and its potential for emissions and the life cycle of c-octaBDE and its potential for emissions;
- Stockpiles and wastes from current/former production and use in industries (countries that produced/produce POP-PBDEs or used/use POP-PBDEs in manufacturing);

- Sites/locations where activities have occurred that could be potentially contaminated with POP-PBDEs.

The following types of numerical data are collected and compiled in the inventory:

- Quantities of decaBDE produced or imported (Chapter 4);
- Quantities of products manufactured with decaBDE (Chapter 5);
- Quantities of POP-PBDEs present in products (Chapter 6-9);
- Quantities of POP-PBDEs in waste and stockpiles and end-of-life management (Chapter 6-9);
- Sites potentially contaminated from production, use and waste management (Chapter 10)

Data collection approaches will vary from country to country based on the data gathered in steps 1 and 2; they may be by estimations, using statistical data or possibly measurements. Data and estimations of impact factors of POP-PBDEs in certain products for major current /former POP-PBDEs use sectors are provided in Chapters 6 to 9. Additional in Tier III inventory activities, measurements can generate own data by screening and analysis of representative samples (see "*Draft guidance on sampling, screening and analysis of persistent organic pollutants in products and recycling"*) (Stockholm Convention Secretariat, 2021).

3.4 Step 4: Managing and evaluating the data

3.4.1 Data management

Since Parties have different designs and levels of legal framework, political organization and economic support for environmental management, different methodologies will be applied in the data gathering process as described in section 3.3. The management of collected data should be done as consistently and as transparently as possible. During the data processing, all the assumptions and conversion coefficients adopted as a result of expert judgement, where needed, should be noted/recorded and mentioned when the results are presented.

Before the inventory starts, all the data formats including questionnaire survey formats should be determined to anchor the consistency of the data collection as much as possible. If some data conversions and estimations are done by stakeholders, the inventory team should provide training on how to estimate the amount of POP-PBDEs and how to fill out the questionnaire. This will reduce the possibility of errors during the data management activities.

Estimations will be needed to provide the total quantities in a country. Estimations are a valuable tool for providing the data needed when resources are limited. Since direct measurements of POP-PBDEs in products and articles are resource intensive, a (preliminary) inventory could be fully based on estimations in many cases (see section 3.2).

3.4.2 Mechanism for evaluation of the inventory

Some challenges may still exist at the end of the inventory including a lack of information. An evaluation of the process, strategy used, and information collected can take place along with a decision on what further actions are needed to make the inventory more complete.

The evaluation includes identification of the following:

- Gaps and limitations;
- Need for validation of the information compiled in the inventory;
- Further actions needed to make the inventory more complete;
- Further actions needed to meet the requirements of the Stockholm Convention.

Important elements in this evaluation step are to identify any gaps and limitations, and the measures needed to make the inventory more complete. Other ways to involve the stakeholders and other data

collection strategies (see steps 2-4) could then be considered. A gap analysis in the evaluation of the initial assessment or preliminary inventory could result in the need to contact some of the stakeholders again to get more information or identify other stakeholders to be contacted to help fill the gaps.

For inventory sectors with limited information, information campaigns and stakeholder meetings or workshops may be a necessary measure. In some cases, government regulations may be required to ensure that stakeholders report their holdings, cooperate with the national authorities and engage in the national inventory. To draft a regulation and make it come into force can sometimes require a long time (a year at a minimum in some places).

Gaps, limitations and necessary actions to complete the inventory will also be valuable information for the NIP, especially for developing countries with need of financial support for their inventory. It is important for developing countries to identify whether and what technical and financial support will be necessary to complete the inventory. Even if the inventory is very incomplete, the NIP is expected to provide information on gaps and the limitations of a country's resources and capacities — information that is useful to identify technical and financial needs.

It is also important to identify whether the current situation meets the requirements of the Convention. For example the activities needed to fulfil the obligations to elimination decaBDE from recycling. Information on BAT/BEP measures are provided in the *PBDE BAT/BEP Guidance* (UNEP 2021a,b).

The inventory will also require revision at a later stage when the action plan is updated. This can also be done using the strategies described in this guidance.

3.5 Step 5: Preparing the inventory report

The final step for the inventory team is to prepare the POP-PBDEs inventory report. This report will include the inventories of all key sectors investigated (Chapters 4–10), compiled in a single document. Although its aim is to support the development of the NIP, the report, though there is no obligation, can be also used for other purposes such as feeding into Article 15 reporting, developing post NIP projects, and developing effective strategies and action plans for managing listed BFRs to meet the obligations under the Convention. As flame-retarded plastics constitute a considerable portion of the total plastic waste, a PBDE inventory report can also contribute to an overall inventory of plastic for improving the overall plastic management. Therefore, in the report also the total plastic volumes can be noted.

The essential elements of the report are:

- Objectives and scope;
- Description of data methodologies used and how data were gathered, including all the assumptions and conversion coefficients adopted as a result of expert judgement;
- Final results of the inventory for each sector considered a priority for the country (using a format to be provided in this guidance, as such or adapted from that format);
- Results of the gap analysis and limitations identified for completion of the inventory;
- Further actions (e.g., stakeholder involvement, data collection strategies) to be taken to complete the inventory and recommendations.

Other information (e.g., stakeholder list) could be included in the report depending on the national requirements.

4. Inventory of decaBDE production and import/export

4.1. Production of decaBDE

Parties to the Stockholm Convention are allowed to produce decaBDE, if they have notified the Secretariat of their intention to utilize the time-limited specific exemption for production and use of decaBDE for the exempted uses. The Party registering the listed specific exemptions should provide to the Secretariat the information on the production and use of decaBDE. The register of specific exemptions for decaBDE is available on the website of the Stockholm Convention (http://chm.pops.int/Implementation/Exemptions/SpecificExemptions/tabid/1133/Default.aspx).

Countries that are producing decaBDE or formally produced decaBDE should compile data on the current and historic production of decaBDE.

Information on the amount of related current and former generation of wastes from decaBDE production and the historic management and disposal of these wastes should be gathered within the inventory process. The information on stocks of decaBDE from producers should be noted and included in the inventory.

Information on contamination at and around production sites and/or associated landfills and surface water should also be gathered (see Chapter 10).

The inventory on current and former production of c-decaBDE should include data on exports.

4.2. Import and export of decaBDE

DecaBDE can be imported or exported for the use in specific exemptions (see Table 1) by Parties that are registered for those specific exemptions (see Guidance for the control of the import and export of POPs, UNEP 2012b). Such imports and exports should be recorded in the inventory including the quantities.

This chapter only deals with c-decaBDE as substances/technical mixture and not with decaBDE in products. DecaBDE in products is addressed in Chapters 6–9 including import and export.

4.2.1 Import of decaBDE

It has been experienced that the control of import of industrial chemicals is a challenge since the Harmonized System (HS)[11] code for classification are not specific for most POPs (Korucu et al., 2015). Currently also decaBDE does not have a specific HS code. Therefore, HS codes cannot be reliably used for assessing import quantities of decaBDE at the moment. But they can give an indication (Tier I) and can be used for further assessment by Tier II and III approaches.

DecaBDE is normally categorised under the HS Code Heading HS 2909 Ethers, ether-alcohols, ether-phenols, ether-alcohol-phenols, alcohol peroxides, ether peroxides, ketone peroxides (whether or not chemically defined), and their halogenated, sulphonated, nitrated or nitrosated derivatives. DecaBDE might be imported under the following HS codes.

- If 6 digit code is used in 8 digit code the county the correct code is 2909 30 “Aromatic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives” (this HS code is available in the UN Comtrade database[12].
- If 8 digit code is available then the following subcategories might have been used and be assessed:

[11] The Harmonized Commodity Description and Coding System (HS) is an internationally recognized classification system for the majority of goods in international trade. It is developed and maintained by the World Customs Organization and is used by customs authorities worldwide for identifying traded products, including chemicals.

[12] https://comtrade.un.org/

- 2909 3031 “Derivatives halogenated only with bromine”
- 2909 3010 Diphenyl ether
- 2909 3090 Classification of others

- If more than 8 digits are used for the code in the county then the following HS code has been used:
  - 2909309090 Ethers, ether-alcohols, ether-phenols, ether-alcohol-phenols, alcohol peroxides, ether peroxides, ketone peroxides (whether or not chemically defined), and their halogenated, sulphonated, nitrated or nitrosated derivatives.
    - Aromatic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives
  - 2909 3010 00 Diphenyl ether

These codes are not specific for decaBDE. However additional information might be included in the import documents which can inform if individual imports/exports under these HS categories is decaBDE (e.g., chemical name or CAS number, see Table 3). CAS numbers and trade names (see Table 3) may be used in combination with HS code for the search at the custom level.

Please note that importers might use other HS codes for importing decaBDE.

Currently only c-pentaBDE and c-octaBDE are listed under the Rotterdam Convention and are subject to the Prior Informed Consent (PIC) procedure in the frame of Rotterdam Convention. DecaBDE is not yet listed under the Rotterdam Convention but a Decision Guidance Document is under development.[13] The assignment of specific HS codes to the chemicals in Annex III should facilitate the implementation and enforcement of the PIC procedure.[14]

Care should be taken to avoid double counting of import and the respective use of decaBDE in manufacturing of products (see chapter 5) when documenting the life cycle. For example do not double count the quantity of the imported decaBDE and further use of decaBDE in production and use and clearly document this in the report.

4.2.2 Export of decaBDE as chemical

Information on export of decaBDE should be gathered from the chemical industry, chemical associations that are producing or trading decaBDE. All relevant information obtained and gaps, should be included in the inventory. Customs and port authorities can be involved.

For decaBDE, CAS numbers and trade names (see Table 3) may be used in combination with HS codes (e.g., those mentioned Chapter 4.2.1) for the search at the custom level.

Figure 3.3 compiles the export data of HS Code 290930 (aromatic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives) from Israel to major other importing countries. The exports have decreased since 2007 with a strong decrease in recent years (Figure 3-3).

4.3. Step 1: Planning the inventory of production of c-decaBDE and import/export

This first step focuses on defining the scope of the inventory, identifying stakeholders and developing a work plan (see Chapter 3.1).

The inventory of production and export/import of c-decaBDE is expected to address the following:

- Current and former production quantities of c-decaBDE; decaBDE content in c-decaBDE;
- Export quantities of c-decaBDE;

[13] http://www.pic.int/TheConvention/Chemicals/CandidatetoCRC/tabid/1061/language/en-US/Default.aspx.

[14] http://www.pic.int/Portals/5/download.aspx?d=UNEP-FAO-RC-HS-Codes-List-2019.En.pdf.

- Import quantities of c-decaBDE;
- Assessment if PIC procedure is appropriately observed;
- Management and releases of decaBDE and related production waste at the production sites;
- Exposure and exposure risk of workers and other receptors for decaBDE at production site;
- Waste management and releases of decaBDE and other POP-PBDEs to the environment at production sites and risk/status of contaminated sites (see Chapter 10).

Appropriate members of the inventory task team need to be selected to conduct the inventory. Specific stakeholders for the inventory of PBDEs are listed in Table 12 and are selected according to the country situation. The NIP coordinator or task team leader can decide which stakeholders would be included in an inventory team and which stakeholders would just be contacted for an interview or with a questionnaire (Annexes 6).

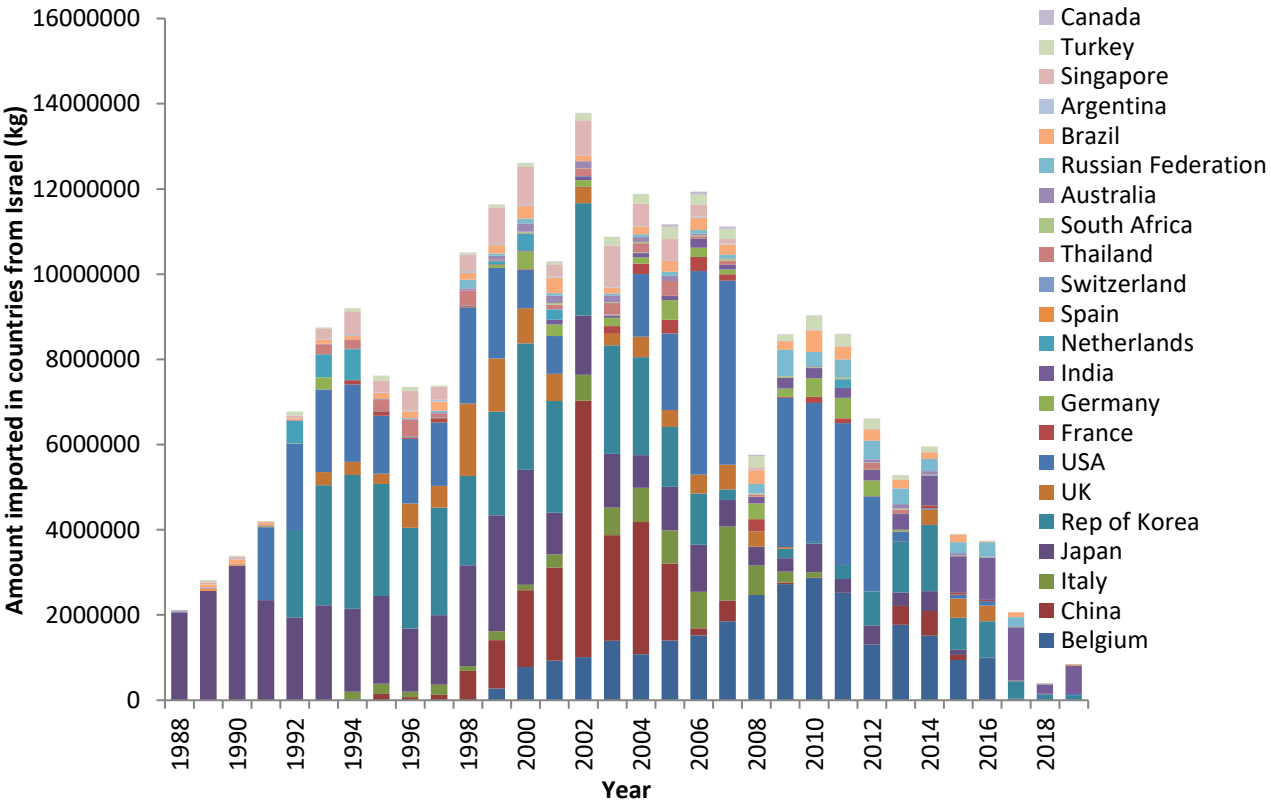


Figure 3-3: Time trend of export of chemicals (kg) under HS 290930 (aromatic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives) from Israel to other countries (1988–2019) (Weber et al., 2021).

4.4. Step 2 and 3: Choosing data collection methodologies and collecting data

4.4.1 Tier I: Initial assessment of the production, import and export of decaBDE

Expected outputs of the initial assessment include:

- *A list of industry associations and authorities relevant for c-decaBDE production;*
- *A list of producers of c-decaBDE;*
- *Importer and exporter of c-decaBDE;*
- *Prior informed consent procedure followed;*
- *HS codes used (see initial list above);*
- *Supply chain stakeholders;*

- *Data on production volumes and trade volumes of c-decaBDE and other PBDEs accessible by desk studies.*

Identify industrial associations, authorities, and national registers

Identify industrial associations, authorities and national registers relevant to production and import/export of decaBDE/PBDEs that can be useful sources for the inventory and compile:

- Information on (potential) manufacturers in the country;
- Data on production volumes of PBDEs from national office/institute of statistics;
- Information on export of c-decaBDE/PBDEs as substance;
- Information on import quantities of decaBDE and companies importing and finally receiving the decaBDE.

Identify national manufacturers and exporter and importers

Perform a desk study identifying companies in the following industrial sectors:

- Companies producing c-decaBDE;
- Companies exporting c-decaBDE (noting CAS number and HS codes);
- Companies importing c-decaBDE (noting CAS number and HS codes).

Following information might be gathered from statistics:

- Production volume of c-decaBDE (including CAS number) and decaBDE content;
- Import quantity of c-decaBDE (including CAS number; HS codes used);
- Export quantity of c-decaBDE (including CAS number; HS codes used);
- Information from Prior Informed Consent (PIC) procedure.

In the Tier I also statistics of former production of c-pentaBDE and c-octaBDE might be gathered if it has not been compiled before.

4.4.2 Tier II: Basic inventory of the production, import and export of decaBDE

Expected outputs of the preliminary inventory include:

- *Detailed information on the production of c-decaBDE;*
- *All producers approached and questionnaires filled out with the responses of identified companies and possibly other stakeholders (associations, exporters and importers);*
- *Compilation of information and data provided by major stakeholders and their supply chain stakeholders on total yearly production, export, and import of decaBDE;*
- *Data on production volumes and trade volumes;*
- *Use of c-decaBDE in the country;*
- *Information in export and import of c-decaBDE;*
- *Overview on domestic supply chain networks.*

Collect of information and data

Refine data assessment from Tier I compilation

- Complete and refine data from Tier I data compilation;
- Investigate information PIC procedure.

Contact the producers of c-decaBDE (as identified in the initial assessment), and related industrial association by visit, telephone, or mail/letter, to:

- Inform them about the purpose of the inventory and its process (see questionnaire);
- Total yearly production of c-decaBDE;
- Impurities in c-decaBDE (other PBDEs; PBDD/Fs); related analytical data for c-decaBDE;
- Material Safety Data Sheets (MSDS) of the technical c-decaBDE;
- Detailed information on use of decaBDE in manufacturing (see Chapter 5);
- End-of-life management of wastes from decaBDE in production and fate;
- Releases of decaBDE and contamination at the individual productions (see also Chapter 9).

Contact importers and exporters of c-decaBDE:

- Import quantity of c-decaBDE;
- Clarification on PIC procedure compliance;
- Downstream users of imported decaBDE (see also chapter 5)
- Export quantity of decaBDE (including related countries and HS codes and PIC procedure);
- Detailed information on decaBDE imported/exported;
- Downstream users of decaBDE;
- Information generated from the inventory of downstream users (see chapter 5).

Information on Material Safety Data Sheets (MSDS) of decaBDE produced, exported and imported and used in production (see Chapter 5) should be compiled and assessed.

The gathering of information in Tier II should have in the early phase a national sensitization and information workshops on the Stockholm Convention and decaBDE production and use (and possibly use of other new listed industrial POPs). Producer, importer and exporter and companies using decaBDE in production as well as other selected stakeholders (see Table 12) would be invited.

Evaluate the information

The evaluation is intended to

- Identify gaps
- Identify actions for filling the gaps

Comparison of information on production and import/export of c-decaBDE (Chapter 4) and the use of c-decaBDE in manufacturing (Chapter 5):

- Comparison of production and import/export of c-decaBDE (Chapter 4) and the quantity used in manufacturing (Chapter 5).

If more information is needed:

- Identify additional stakeholders to be contacted or other sources of use for the inventory (see chapter 3);
- Identify the national supply chain for each industrial sector from information gathered in the previous steps.

The summary of inventory information should be compiled in Table 13 or an adjusted table. Where data are available, an inventory of production, import and export should cover a longer period best from the start of the individual factories producing c-decaBDE (and c-pentaBDE and c-octaBDE). Generating these data would allow a more robust total global PBDE inventory.

Table 13: Current and former production and import and export of c-decaBDE (and other PBDEs)

	Current production or import/export in the inventory year (t)	Total former production or import/export (t)
Production of c-decaBDE		
Production of c-pentaBDE		
Production of c-octaBDE		
Import of c-decaBDE		
Export of c-decaBDE		

* It is assumed that production has stopped in 2004

4.4.3 Tier III: In-depth inventory of the production, import and export of c-decaBDE

The c-decaBDE product can be analysed for PBDE composition to determine the content of decaBDE and lower brominated PBDEs. More toxic unintentional PBDFs might be analysed in c-decaBDE to clarify their relevance in the product and possibly give an indication on the need to modify and optimize production conditions (Hanari et al., 2006; Ren et al., 2011; Sindiku et al., 2015).

The refined data from the Tier III monitoring and assessment should be included or update the Table 13 and included in the inventory report.

4.5. Step 4: Managing and evaluating data; Step 5: Inventory report

In the data evaluation **Step 4** the data compiled in the inventories need to be assessed for completeness and plausibility, possibly including a comparison with data from other countries in the region.

Data gaps may (partly) be filled by extrapolation of available statistical data. If the quality of the data is considered unsatisfactory, additional data collection (Tier II+III) or screening (Tier III) might be undertaken.

The compiled data (draft inventory) should be assessed by stakeholders and possibly by an external expert. Depending on comments further information might need to be gathered or finalized.

As last **Step 5** the compiled information and evaluated data for decaBDE production and export/import would be compiled in a chapter within the inventory report. This should include:

- The methodology used in compilation of the data;
- The calculations made;
- Assumptions made in the calculations;
- All country-specific adjustments and estimates would be noted and described;
- The gaps and uncertainties of the data;
- Possibly further inventory tasks in a next stage (in the NIP implementation).

5. Inventory of decaBDE in manufacturing of products

In this chapter major production sectors are compiled which might use c-decaBDE in the manufacturing of products in particular those uses which are exempted and might be further used (Table 1). The inventory team should assess the presence of these production sectors in the country and the quantity of decaBDE used in these industries as well as the total quantity of goods produced containing decaBDE.

Please note that the inventory of decaBDE in products on the market and in use are described for electronics in Chapter 6; for vehicles in Chapter 7, for textiles in Chapter 8 and for construction in Chapter 9. Care need to be taken that there is no double counting of the use of decaBDE in manufacturing of products (this chapter 5) and decaBDE products on the consumer market (Chapters 6 to 9).

5.1. Use of decaBDE in the manufacturing of products

5.1.1 Use of decaBDE in plastic housing and parts used in electronics

Additives in plastic housings and parts used for heating home appliances, irons, fans, immersion heaters that contain or are in direct contact with electrical parts or are required to comply with fire retardancy standards.

Major polymers in electronics containing treated with decaBDE are high impact polystyrene (HIPS), acrylonitrile butadiene styrene (ABS) co-polymers and also in polymer blends such as polyphenylene oxide/polystyrene (PPO/PS) blends. These plastics are used mainly as casing materials for EEE (US EPA, 2012).

While decaBDE has only been exempted for heating home appliances, some producers of other electronics might still use decaBDE. Therefore, the assessment of decaBDE use in other electronics (see Tables 7, 8, and 11). DecaBDE in EEE equipment in use and stock is addressed in Chapter 6.

Companies producing these parts should be approached for information of current and former use quantities of decaBDE. The percentage in the product and total quantity of products manufactured containing decaBDE should be collected. Information on alternative flame retardants and materials could be gathered. The steps for inventory development and the tiered approach are described below in Chapter 5.2 to 5.4.

5.1.2 Use of decaBDE in parts of vehicles and aircrafts

Parts for use in legacy vehicles defined as vehicles that have ceased mass production has been exempted (as specified in paragraph 2 of Part IX of Annex A to the SC; see Table 2). This includes powertrain and under-hood applications, fuel system applications, suspension and interior applications and pyrotechnical devices and applications affected by pyrotechnical devices (see Table 2). Furthermore, reinforced plastics (instrument panels and interior trim); under the hood or dash (terminal/fuse blocks, higher-amperage wires and cable jacketing (spark plug wires) and electric and electronic equipment in vehicles (Table 2). Companies producing such (spare) parts should be assessed for current production and former production.

The production for the use in aircrafts for which type approval has been applied for before December 2018 and has been received before December 2022 and spare parts for those aircraft are exempted.

DecaBDE is commonly used in polyolefins, namely polypropylene (PP), polyethylene (PE), polyphenylene ether/oxide (PPE or PPO) and ethylene vinyl acetate copolymer (EVA). Their applications include seat cushions or arm rests (Mark, 2009) and also wires and cables, electrical connectors, battery casings, foamed sheets and pipes (Kemi, 2005). PVC for use in some wiring applications can be treated with decaBDE.

Other major treated polymers in vehicles are textiles of seating and floor mats/carpets (Kajiwara et al., 2014; see also Chapter 7.1.3).

Companies producing these parts should be approached for information of current and former use quantities of decaBDE, the percentage in the product and total quantity of products manufactured containing decaBDE would be collected. Information on alternative flame retardants and materials would be gathered. The steps for inventory development and the tiered approach are described below in Chapter 5.2 to 5.4.

5.1.3 Use of decaBDE in textiles

The use of decaBDE has been exempted for textile products that require anti-flammable characteristics except for the use in clothing and toys. The main use areas of flame retarded textiles are public occupancy spaces, high risk occupancy spaces, transport (private and public), and some military uses (See Table 14) DecaBDE (or other BFRs) concentration in textile depends somewhat on the type of textiles.

Therefore, the textile industries producing textiles require anti-flammable characteristics would be assessed for the use of c-decaBDE. The assessment should include the current and former use of c-decaBDE in textile production (see questionnaire Annex 7) including the quantity of c-decaBDE used and quantity of textiles treated with c-decaBDE.

Information on alternative flame retardants and materials would be gathered. The steps for inventory development and the tiered approach are described below in Chapter 5.2 to 5.4.

Other POPs used in textiles

It should be noted that POPs other than PBDEs have been used in textiles as flame retardants (HBCD, SCCPs) (UNEP 2017c; UNEP 2019c) or as water repellents (PFOS, PFOA and related compounds) (UNEP 2015d, 2017d). Within an inventory of decaBDE use in textiles also the former and current use of these POPs can be assessed and their presence in current uses.

Table 14: Use of decaBDE treated textiles in major areas and uses (RPA 2010)

Areas of use	Specific applications of textiles
Transport	• Passenger cars; busses; • Trains; Airplanes; Ships
Public occupancy spaces	• Curtains and other draperies of theatres, hotels, conference rooms, student dormitories • Mattress ticking in hotels
High risk occupancy spaces	Furniture and mattresses of nursing homes, hospitals, prisons
Military	• Tarps; tents • Protective clothing

5.1.4 Use of decaBDE in polyurethane (PUR) insulation, other polymers in construction and other PUR foam uses

Polyurethane (PUR) foam for building insulation is exempted under the Stockholm Convention. The use of decaBDE in PUR foam was and is not a major use of decaBDE. In the past rather PentaBDE was used in PUR foam in insulation (Morf et al., 2003).

The concentration of PBDEs in PUR foams in insulation is 4–13% (Leisewitz & Schwarz, 2000) and therefore higher compared to flexible PUR foam in vehicles or furniture. The FR concentration of foam fillers is higher and reported to about 22 % (Leisewitz & Schwarz, 2000).

DecaBDE is used in a range of other polymers such as polyethylene, polypropylene and PVC (Tables 8 and 39). These uses are not exempted and need to be restricted. However, the decaBDE treated polymers already in use/stock in buildings can further be used and are included in the inventory of PBDE in construction for future management (see Chapter 9).

Therefore, the construction and insulation industries would be assessed for the use of c-decaBDE in PUR foam and in other polymers. The assessment should include the current and former use of decaBDE in insulation foam (see questionnaire Annex 7) including the volumes of decaBDE used and volumes of other plastic and polymers in construction treated with decaBDE in the past. Information on alternative flame retardants and materials would be gathered.

PUR foam is increasingly recycled into PUR rebond material which is also used in construction as insulation material and as carpet pad with related exposure (Stapleton et al., 2008; DiGangi et al., 2011).

The steps for inventory development and the tiered approach are described below in Chapter 5.2 to 5.4.

Other POPs used in insulation and other plastic/polymers in construction

It should be noted that also other POPs have been used as flame retardants in insulation foam (HBCD; PentaBDE) but also toxic organophosphorus FRs like TCPP. SCCPs are still used in PUR foam and other polymers in construction in particular PVC (UNEP 2019c). Currently also PFOA and related substances are used in construction (Green Science Policy Institute 2021). Furthermore, PCNs and PCBs have been used

in the past in polymers and coatings/paints in construction (UNEP 2017e). Within an inventory of decaBDE use in construction, also the former and current use of these POPs should be assessed and considered where feasible (see Chapter 9).

5.2. Step 1: Planning the inventory of decaBDE in manufacturing of products

Step 1 focuses on defining the scope of the inventory of c-decaBDE use. This includes the assessment of manufacturing products which might add decaBDE as flame retardant, identifying stakeholders and companies and developing a work plan (see section 3.1).

All the industrial sectors where c-decaBDE is possibly used in the manufacturing of products (see 5.1) should be assessed for the current and past use of decaBDE in these productions. For this assessment industries and productions possibly using c-decaBDE in the country should be evaluated.

Considering the information on exempted and former major uses, the inventory of decaBDE in the manufacturing of products is expected to assess the following:

- DecaBDE used in the production of plastic housings and parts used for heating home appliances (exempted use) and EEE plastic manufacturing in non-exempted uses;
- DecaBDE in parts for exempted uses in vehicles and aircrafts (Table 2);
- DecaBDE used in the production of textiles;
- DecaBDE used in the production of polyurethane foam;
- Recycling of decaBDE containing materials into new products (plastic; PUR rebond, textiles).
- Status and the possible need of labelling of products containing decaBDE;
- Management and releases of decaBDE at the production sites;
- Exposure and exposure risk of the workers and other receptors at the individual production sites using decaBDE;
- End-of-life management and fate of wastes containing decaBDE or other POP-PBDEs at production sites.
- Alternatives used in the different sectors.

Appropriate members of the inventory task team need to be selected to conduct the inventory of the individual sectors. Specific stakeholders for the inventory of decaBDE are listed in Table 12 and are selected according to the country situation. The NIP coordinator or task team leader can decide which stakeholders would be included in an inventory team and which stakeholders would just be contacted for an interview or with a questionnaire (Questionnaires are in Annex 7). The inventory task team can be extended as appropriate during the inventory process.

5.3. Step 2 and 3: Choosing data collection methodologies and collecting data

5.3.1. Tier I: Initial assessment of decaBDE use in manufacturing of products

Expected outputs of the initial assessment include:

- A list of relevant industrial associations and authorities of the potential use sectors in the country (see chapter 5.1);
- A preliminary list of identified industries, companies and supply chain stakeholders;
- Initial information on relevant productions possibly using c-decaBDE in the country;
- A list of products potentially containing decaBDE that are likely manufactured in the country;
- Preliminary information on recycling activities of materials potentially containing decaBDE;

- A preliminary list of industries using or having potentially used decaBDE in the past and might have generated contaminated sites and landfills (see also Chapter 10)
- A compilation of information for Tier II inventory

Identify industrial associations, authorities, and national registers

Identify industrial associations, authorities and national registers relevant to the sectors listed in chapter 5.1 that can be useful sources for the inventory and compile:

- Information on potential manufacturers in the country;
- Knowledge on the former and current use of c-decaBDE in industrial sectors;
- Data on production volumes of industrial sectors potentially using decaBDE in production (chapter 5.1) from national office, institute of statistics or associations.

Identify national manufacturers

Perform a desk study identifying companies in the following industrial sectors:

- Productions of plastic housings and parts used for heating home appliances (exempted use) and other electronics (non-exempted use);
- Productions of exempted parts for the use in vehicles (Table 2) and other parts in vehicles which requiring anti-flammable characteristics and possibly use decaBDE;
- DecaBDE used in the productions of textiles requiring anti-flammable characteristics;
- DecaBDE used in the production of PUR foam for insulation (exempted use) and other PUR foams requiring anti-flammable characteristics (not exempted);
- Industries recycling potentially decaBDE (and other POP-PBDEs) containing materials (e.g., e-waste plastic, PUR foam and other polymers from construction; polymers from vehicles,).

Following information might be gathered from statistics on production volumes of the sectors:

- Import of c-decaBDE or sourcing in the country by the individual production sectors (information from and for Chapter 4).
- Quantity of plastic housings and parts used for heating home appliances (exempted use) and other plastic from electronics requiring (non-exempted use);
- Quantity of exempted parts for the use in vehicles (Table 2) and other parts in vehicles which are flame retarded and might use decaBDE (not exempted);
- Quantity of PUR foam used in insulation (exempted use) and other PUR foams requiring anti-flammable characteristics (not exempted);
- Quantity of textiles requiring anti-flammable characteristics (Table 14). In this assessment also clothing and toys requiring anti-flammable characteristics (not exempted!) would be included for evaluation and restriction.

In the Tier I for some of the production sectors only the total production volume or formulations potentially using decaBDE might be found. This information is valuable and should be noted. An initial communication with industry association of the different use sectors might give an indication of the use of decaBDE in the individual sectors. Details should be clarified in Tier II and III assessments.

5.3.2. Tier II: Basic inventory of decaBDE use in manufacturing of products

Expected outputs of the basic inventory include:

- Detailed information on the individual sectors using or potentially using decaBDE in the manufacturing of products (Chapter 5.1);
- Contact established to the respective industry associations and users/companies;

- Major users approached and questionnaires filled out with the responses of identified companies and possibly other stakeholders (associations; related research institutes);
- Compilation of information and data provided by major stakeholders and their supply chain stakeholders on total yearly use/consumption of c-decaBDE;
- Total quantity of products manufactured containing decaBDE;
- Quantity of products produced from recycled plastics or PUR foam containing decaBDE (not exempted) or other POP-PBDEs (exempted) and decaBDE content in the recycled material and in the products;
- Additional stakeholders identified and contacted, and key industries selected as most relevant sectors in the country;
- Overview on domestic supply chain networks;
- Alternatives used in the individual sectors in particular in the exempted uses.

Collection of information and data

Contact the major factories and stakeholders in each industrial sector (as identified in the initial assessment), by telephone, mail or letter, to:

- Inform them about the purpose of the inventory and its process (see questionnaires)
- Ask them on the use of c-decaBDE in their processes
- Total yearly consumption of c-decaBDE in the individual industrial processes
- Total amount of products produced with decaBDE
- Detailed information on c-decaBDE used (decaBDE content, other PBDEs and other impurities);
- Final decaBDE content in the products in the individual use sectors;
- Downstream users and sales of products and upstream suppliers;
- End-of-life management and fate of decaBDE in the individual use sectors;
- Releases of decaBDE in the individual productions and associated contamination (see also Chapter 10);
- Alternative to decaBDE used in the manufacturing of the different products;
- Use information generated from other inventory on upstream suppliers (producers or importers see Chapter 4) and downstream users/sales (see chapter 6) in the collected information.

Information on Material Safety Data Sheets (MSDS) of the manufactured products should be gathered and assessed.

The gathering of information in Tier II can have in the early phase a national sensitization and information workshops on the Stockholm Convention and PBDE use (and possibly use of other new listed industrial POPs). Details on exemptions and restrictions would be communicated and discussed.

Such workshops can have breakout groups on the individual sectors to be investigated further. Further stakeholder meetings can be included in a work plan targeting these sectors with a need for further investigation.

Evaluate the information

The evaluation is intended to:

- Identify gaps;
- Identify actions for filling the gaps.

Comparison of information on manufacturing of products containing decaBDE and products on the market (Chapter 6 to 9).

The information which is generated by the inventory on manufacturing of product and the information on products on the market and in import/export of products should be compared. Here parallel investigations downstream and upstream in the national supply chain of the industrial sectors can be conducted and compared:

- Comparison of amount of products manufactured in the sectors with the total product amount on the market (see Chapter 7) and the import and export quantity to understand if the quantities match. For example, compare the total amount of decaBDE in textiles or PUR production delivered to the respective manufacturers, as provided by suppliers, and the total amount used in manufacture of c-decaBDE treated textiles or PUR foam, as provided by manufacturers. If there are gaps in the data, further investigation in cooperation with the respective industries and industry associations should be conducted.
- Comparison of production and import of c-decaBDE produced and imported (Chapter 4) and the amount used in productions.

If more information is needed:

- Identify additional stakeholders to be contacted or other sources of use for the inventory (see Chapter 3).
- Further assessment in industries where the use of c-decaBDE in processes is uncertain
- Identify the national supply chain for each industrial sector from information gathered in the previous steps.

Information from manufacturing gathered might either contain the information on the total c-decaBDE used in the productions or the total quantity of products containing decaBDE produced. Both data are relevant and should be compiled.

If the total product volume of c-decaBDE containing products are known then the following equation can be used to estimate the total quantity of decaBDE used in the manufacturing of products (plastic in electronics or vehicles; textiles or PUR):

$$T_{decaBDE} = PQ_{tot} \times C_{decaBDE}$$

PQ_{tot}= Total quantity of products manufactured with decaBDE additive (e.g. textiles, PUR, plastic in electronics or vehicles)

T_{decBDE}= Total quantity of decaBDE used in the manufacturing of products per year or period

$C_{decaBDE}$= % of decaBDE in the product / 100

If total quantity of c-decaBDE use is known for a sector then the following equation can be used to estimate the total quantity of decaBDE containing products manufactured (e.g. textiles, PUR, and plastic in electronics or vehicles):

$$PQ_{tot} = T_{decBDE}/C_{decaBDE}$$

The summary of inventory information should be compiled in Table 15 or a modified table including key information. Where data are available, an inventory should cover the use of decaBDE in the production of a longer period best for the total period of the use of the industry or at least for the product lifetime or service life of a product. Generating this data set would allow an estimate of products still in use containing decaBDE if performing a dynamic substance flow analysis in Tier III assessment (here also export and import of the products need to be considered).

Table 15: Total uses of decaBDE in manufacturing of products in the inventory year and/or for the period where information were available

Uses of DecaBDE	Total quantity of products containing decaBDE	Concentration of decaBDE in products	Total use of DecaBDE
Plastic in EEE			
Plastics/polymers in vehicles			
Textile sector			
Polyurethane			
Recycled decaBDE* containing plastic in production			
Recycled decaBDE* containing foam in production			

*The recycling of decaBDE containing products is not exempted by the Stockholm Convention

Gathering information on alternatives

In the Tier II approach also the availability and use of alternative to c-decaBDE in the different manufacturing of products would be gathered and compiled (Table 16). This information will also be important to decide if an exemption for the use of c-decaBDE in any of the exempted uses are needed and the particular use would then be registered.

Table 16: Information gathered on alternatives for uses of c-decaBDE in manufacturing*

Alternatives to c-decaBDE	Please note alternatives used in these applications	Comments regarding performance and cost
Plastic in EEE		
Plastics/polymers in vehicles		
Textile sector		
Polyurethane		

*The table can be extended and modified as appropriate

Assessment and inventory of end-of-life management at production sites using decaBDE in manufacturing of products

Within Tier II it is also expected that the amount of waste generated at production sites is assessed and quantified and data then compiled. The questionnaires in Annex 7 and Annex 5 contain a section to gather information on the management of wastes.

In the end-of-life evaluation, information on the recycling, reuse, treatment, destruction and disposal of decaBDE containing wastes would be gathered. Since recycling of decaBDE is not allowed according the Stockholm Convention listing, specific management of decaBDE containing products is needed that these products/materials do not negatively impact recycling to avoid (cross) contamination of the recyclates (e.g. plastic, PUR foams). This information would be compiled in the inventory.

5.3.3. Tier III: In-depth inventory of decaBDE use in manufacturing of products

For different uses and products the decaBDE content and use in manufacturing might not be known after the Tier II inventory. Therefore, where large uncertainty exist on the use of decaBDE and the content of decaBDE, products in the manufacturing sectors can be sampled and analysed for decaBDE in a Tier III inventory. For this assessment a pre-screening of bromine in the products can be performed (see the guidance on monitoring of POPs in products and recycling; UNEP 2021b).

In a Tier III inventory also the decaBDE content in recycled plastic and other recycled materials used in the manufacturing of products should be assessed for those plastics, polymers and textiles where a risk of decaBDE contamination exists. This would cover the industries which are using recycled plastic/polymers/materials which possibly contain decaBDE (e.g. plastic from e-waste or vehicles; flame retarded textiles applications; flame retarded PUR application).

In a Tier III inventory also the c-decaBDE mixtures used in production can be analysed for PBDE composition and for decaBDE content.

A more detailed assessment of alternatives to c-decaBDE could be conducted including an assessment or ranking of the alternatives in respect to persistent, bioaccumulative and toxic properties and other criteria.

The refined data from the Tier III monitoring and assessment should be included or update the Tables 15 and Table 16 and included in the inventory report.

5.4. Step 4: Managing and evaluating data; Step 5 inventory report

In the data evaluation **Step 4** the data compiled in the inventories need to be assessed for completeness and plausibility, possibly including a comparison with data from other countries in the region.

Data gaps may (partly) be filled by extrapolation of available statistical data. If the quality of the data is considered unsatisfactory, additional data collection (Tier II+III) or screening (Tier III) might be undertaken.

The compiled data (draft inventory) should be assessed by stakeholders and possibly by an external expert. Depending on comments further information might need to be gathered.

Another useful approach to evaluate data could be the development of a material and substance flow analysis (MFA/SFA) (Abbasi et al., 2015; Vyzinkarova and Brunner, 2013) using e.g. free software (http://www.stan2web.net/).

As last **Step 5** the compiled information and evaluated data for decaBDE used in the manufacturing would be compiled in a chapter within the inventory report. This should include:

- the methodology used in compilation of the data
- the calculations made
- assumptions made in the calculations
- all country-specific adjustments and estimates would be noted and described.
- the gaps and uncertainties of the data
- possibly further inventory tasks in a next stage (in the NIP implementation)

The data in the inventory report should serve for the NIP and action plan development and for article 15 reporting. The inventory report might contain a chapter with (preliminary) suggestions on activities for the action plan.

6. Inventory of POP-PBDEs in electrical and electronic equipment (EEE) on the market, in use/stock and related waste (WEEE)

6.1. Background

Electrical and electronic equipment (EEE) is one of the fastest growing material flows of goods as well as a large waste (WEEE) and recycling flow with related management challenges in particular in developing countries (Basel Convention Secretariat 2011a, 2011b). It is the largest stock and waste category containing c-decaBDE and c-octaBDE (listed hexa/heptaBDE) (see Chapter 2). An inventory of EEE and WEEE is an important step for addressing the challenge of managing c-decaBDE and c-octaBDE containing materials in use and at the end-of-life and support clean recycling needed for a circular WEEE recycling (World Economic Forum 2019).

Here the Stockholm Convention inventory activities and the Basel Convention inventory activities should be developed in a synergistic approach. This is ensured by applying the available guidance documents in a synergistic manner. For the development of an inventory of WEEE, a "Draft practical guidance for the development of inventories of used lead-acid batteries, waste electrical and electronic equipment and waste oils" (UNEP 2017b) has been published. Furthermore, the Basel Convention revised technical guideline on the environmentally sound management of PBDEs has been updated including decaBDE (UNEP 2018). In the development of the PBDE inventory and the assessment of PBDE in wastes, these documents should also be considered.

Inventories of EEE/WEEE have been developed to support the implementation of sustainable WEEE management systems under the Basel Convention. Among others, Thailand, Ghana, Nigeria and Tanzania have generated good examples of EEE/WEEE inventories (see Annex 3; BCRC-SEA, 2007; PACE, 2010; Magashi and Schluep, 2011; Ogungbuyi et al., 2011).

In most countries that have not conducted an EEE/WEEE inventory, the inventory of EEE/WEEE fractions containing POP-PBDEs could be seen as an important impulse and step for developing an inventory for EEE/WEEE. The amount of POP-PBDEs, mainly c-decaBDE and c-octaBDE (hexa/heptaBDE), in this sector could be calculated and reported following the steps below. The results could provide policy makers with a basis for decision-making and planning for the management and recycling/disposal of plastic in EEE/WEEE (see PBDE BAT/BEP Guidance, UNEP 2021a).

Major plastic fractions are in categories of large household appliances, small household appliances, IT equipment and consumer goods. Therefore, these uses are primarily addressed in this inventory and also in draft practical guidance for the development of inventories of WEEE (UNEP 2017b). Related major EEE categories with UNU-key and HS codes are listed in Table 17.

Table 17: Relevant product categories for the first generation EEE inventory and managing PBDEs with reference to their UNU-key and HS codes

UNU-KEY	Equipment (according to UNU-Key)	Corresponding HS Codes
0101	**Professional Heating & Ventilation**	**845110, 845130**
0104	Washing machines	845012
0106	**Household Heating & Ventilation**	**845129, 851621, 851629; 8516**
0108	Fridge or combined fridge/freezer	841810, 841821, 841822, 841829
0111	Household air conditioner	841510, 841581, 841582
0308	CRT monitors	852821, 852822, 852841, 852849
0407	CRT televisions	852812, 852813, 852873,
0303	Laptop, notebook, tablet	847130
0306	Mobile phones	851712, 851761, 851950, 852520
0309	Flat panel display for computer	852851, 852859, 853120
0408	Flat panels televisions	852872

6.2. Step 1: Planning the inventory and identifying stakeholders

This first step focuses on defining the scope of the inventory of the import, use and stocks of POP-PBDEs in EEE/WEEE and related plastic management, identifying stakeholders and companies and developing a work plan (see section 3.1).

The inventory of POP-PBDEs in EEE/WEEE is expected to address the following:

- DecaBDE containing EEE products in particular import of exempted uses (Table 1);
- Second-hand EEE imported in the inventory year and previous years during which POP-PBDEs-containing EEE/WEEE were/are imported;
- EEE stocks in use and/or stored in the possession of consumers (households, and public- and private-sector institutions and organizations);
- EEE containing POP-PBDEs entering the waste stream i.e. WEEE (synergy with the Basel Convention);
- WEEE plastics for recycling (from domestic WEEE and imported WEEE polymer fraction).

Appropriate members of the inventory task team need to be selected to conduct the inventory of this sector. Specific stakeholders for the inventory of EEE and WEEE are listed in Table 12. The core inventory team could be extended as appropriate. In developing countries, informal sectors are often involved and play a significant role in collection and recycling of WEEE and WEEE plastic.

The current chapter want to:

- Guide the inventory of PBDEs in WEEE plastic;
- Support the phase out of highly PBDE contaminated WEEE plastic fractions;
- Guide what fractions of WEEE plastic might be low impacted by PBDEs and possibly recycled.

6.3. Step 2 and 3: Choosing data collection methodology and collecting data

6.3.1. Tier I: Initial assessment

Outcome and activity of initial assessment:

- Compilation of available EEE/WEEE inventory data;
- Preliminary assessment of import of EEE possibly containing decaBDE;
- Preliminary assessment on the situation of import of second-hand EEE and WEEE;
- Assessment if any decaBDE containing EEE produced in the countries (Chapter 5) is sold on the domestic market or exported;
- Initial estimate of the scale of EEE/WEEE in use and stocks possibly containing PBDEs;
- Initial assessment which WEEE categories are not or low impacted by POP-PBDEs (see Table 26);
- Initial assessment of status of WEEE management; in particular the management of WEEE plastic.

The inventory team should contact the Basel Convention focal point to discuss the status of the EEE/WEEE inventory (available data as well as current and planned activities). The ministries of environment and ministry in charge of industry and telecommunication could also be contacted and asked for available information.

Electronics in higher quantities known for elevated PBDEs are in particular CRT TVs and CRT monitors of computers (Wäger et al., 2010). Other high risk EEE/WEEE where PBDEs are present at relevant quantities are e.g. LCD TVs or heating appliances (Hennebert et al. 2018).

Countries that have not yet established an EEE/WEEE inventory could initiate the inventory by estimating the minimum PBDE amount in CRTs and flat screen/LCD TVs in the country. This requires estimating the country's penetration rate (number of appliances per capita) in analogy to countries with similar

economic development and consumer behaviour (see Table 18), and then extrapolating from the per capita data to the target country. Table 18 shows the per capita data reported in the past. These penetration rates from 2010 are likely too high for current use and can be seen as upper estimate. Since EEE might be stored for long time, the penetration rates might still be useful.

Once the per capita data have been estimated, the POP-PBDE content in CRT casings (TVs and computer monitors), flat screens/LCD can be calculated taking into consideration the following additional data:

- Population of the respective country;
- Weight of the CRTs: **25 kg per device** (estimated average weight of a CRT monitor, either TV or PC monitor; see also Table 22);
- Polymer content of CRT casings: **30%** (estimated average, see Table 25);
- POP-PBDE content: A range of hexa/heptaBDE **0.47–1.37 kg/tonne, and 3.2 to 4.4 kg/tonne for decaBDE** for plastic used in CRT casings (estimated average; see also Table 26).

The range of the total amount of hexa/heptaBDE and decaBDE in CRT devices can be calculated as follows:

$M_{hexa/heptaBDE\ (i)}$ (CRTs) = [Number of CRTs/$capita_{Region}$] x population x 25 kg x 0.3 x [0.00047 to 0.00137]

$M_{decaBDE(i)}$ (CRTs) = [Number of CRTs/$capita_{Region}$] x population x 25 kg x 0.3 x [0.0032 to 0.0044]

Where:

$M_{PBDE(i)}$ is the amount of POP-PBDEs (i) in [kg]

(in Polymer (k) of electrical and electronic equipment (EEE) (j))

Table 18: Total and per capita amounts of CRT (TVs and personal computer (PC) monitors) in different regions and countries. The average weight of a CRT device used in this table is 25 kg

Country/Region	Total CRT units (Million)	Total weight (10^3 t)	Population (million)	CRT weight/person (kg/capita)	No. of CRTs /person (units/capita)	Source
Asian average	649	16,226	3'906	4.1	0.17	Gregory, 2009
North American average	585	14,623	529	27.6	1.11	Gregory ,2009
LAC[15] average	207	5,189	572	9.1	0.36	Gregory, 2009
Benin	0.7	17.4	8.7	2.0	0.08	Aina et al., 2011
Côte d'Ivoire	3.1	78.0	20.8	3.75	0.15	Messou et al., 2011
Ghana, 2010	4.48	112	24.2	4.6	0.19	Green Advocacy & Empa, 2011
Nigeria, 2010	26.8	670	154.7	4.33	0.17	BCCC-Nigeria et al., 2011
Colombia, 2008/9	13.7	343	46	7.46	0.3	León, 2010
Switzerland, 2008	2.2	54	7.7	7.05	0.28	BfS, 2011

6.3.2. Tier II: Inventory of POP-PBDEs in relevant EEE plastic

Expected outcomes of a Tier II inventory:

- Quantity of EEE in import containing decaBDE in particular in the exempted uses (Table 1)
- Quantity of EEE imported and in use/stock containing POP-PBDEs

[15] LAC: Latin America and the Caribbean.

- Quantity of WEEE for the inventory year and related
- Management of WEEE plastic and import and export of WEEE plastic;
- Activities on separating WEEE plastic in low-bromine an high-bromine fractions and management
- Products made from recycled WEEE plastic

While for the POP-PBDEs listed in 2009 the CRT casings (TVs and computer monitors) contain most of c-OctaBDE 50% (hexa/heptaBDE), the 2017 listed decaBDE is present in many EEE/WEEE fractions (see Table 26) and therefore a larger share of EEE/WEEE need to be assessed.

After a Party has carried out a preliminary inventory, Step 3 onwards (except the questionnaire) could be followed to summarize the results using Table 28.

The inventory can consist of the field survey using the questionnaires on EEE in use or stored at the consumer level (stocks) (Annexes 3, 4) as explained in Chapter 3. The information collected from such survey will improve preliminary inventory data reported in Table 28. The level of commitment and resources for such an inventory would be equivalent to that needed for the WEEE assessment for the Basel Convention, if a wider range of EEE/WEEE categories are included and efforts should be combined (synergy).

The use of a material flow analysis of the EEE/WEEE sector and the related substance flow of POP-PBDEs has been found useful (Abbasi et al., 2015; Morf et al., 2003; Babayemi et al. 2014; see also case study on inventory of PBDEs in EEE and WEEE) and could be considered in the development of an in-depth inventory in Tier III.

Collecting and compiling data from sectors

The aim is to establish the total amount of PBDEs in EEE and the volume of impacted WEEE plastic.

The amount of total POP-PBDEs in EEE can be calculated as:

$$M_{PBDE(i)} = M_{EEE(j)} \mathbf{x} f_{Polymer(k)} \mathbf{x} C_{PBDE(i);Polymer(k)}$$

Where:

- $M_{PBDE(i)}$ is the amount of POP-PBDEs (*i*) in [kg]
  (in Polymer (*k*) of electrical and electronic equipment (EEE) (*j*))
- $M_{EEE(j)}$ is the amount of EEE (*j*) in [in tonnes]
  (imported, stockpiled or entering the waste stream)
- $f_{Polymer(k)}$ is the total polymer fraction in [weight-%]
- $C_{PBDE(i);Polymer(k)}$ is the content of the POP-PBDEs (decaBDE and hepta/hexaBDE) (*i*) in the total polymer fraction in [kg/tonne]

Based on the formula above, the information needed is the amount of EEE/WEEE in the country, share of the relevant polymers in different EEE/WEEE categories and POP-PBDE content of those polymers. This section explains how to determine the following:

- The inventory of stocks and flows of EEE and WEEE in the country (Chapter 6.3.2);
- The estimation of the polymer fraction in relevant EEE and WEEE containing POP-PBDEs (section 6.3.2.6-B);
- The estimation of the POP-PBDEs content in WEEE and polymer fraction (section 6.3.2.6-C/D).

Information on WEEE polymers recycled and exported and the amount of WEEE polymers imported is also needed for the in-depth inventory.

An overview of the material flow of EEE, WEEE and related plastic fractions is shown in Figure 6-1.

The establishment of a material flow of EEE/WEEE and the related substance flow of POP-PBDEs has been found useful and could be considered in the development of an in-depth inventory.

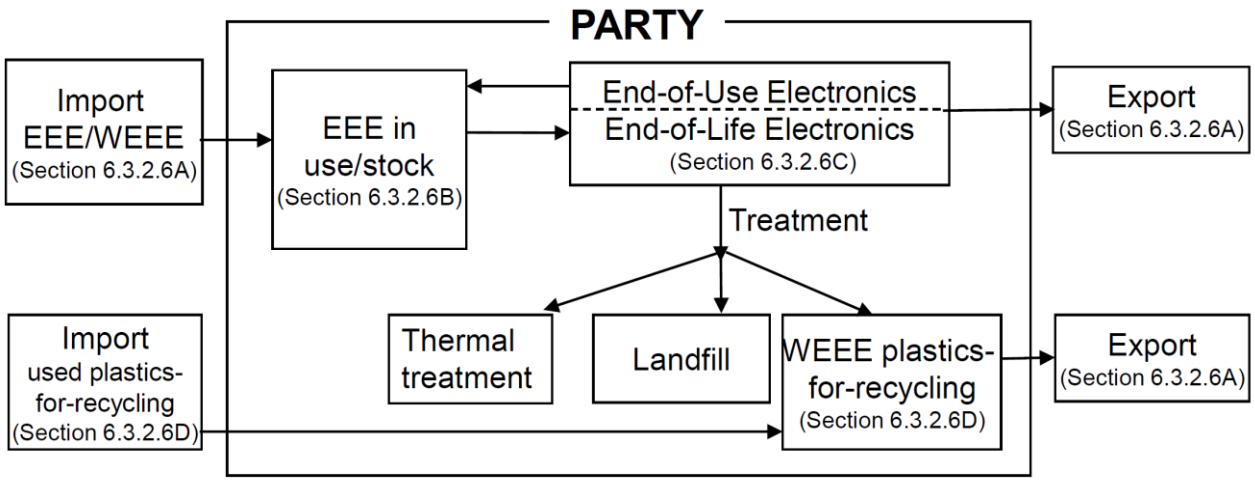


Figure 6-1: Simplified material flow of the EEE/WEEE and related plastics and the life cycle stages where POP-PBDEs are inventoried

6.3.2.1 Stocks and flows of EEE/WEEE

For the development of a final comprehensive EEE/WEEE inventory, the key EEE/WEEE categories need to be considered (see Table 9). As the EU already has categories of EEE/WEEE and information has been accumulated based on them, the EU's categories are applied in this section: category 1 "large household appliances", category 2 "small household appliances", category 3 "IT and telecommunications equipment" and category 4 "consumer equipment".[16]

Studies have shown that c-octaBDE occurs in relevant concentrations mainly in ABS casings of CRT televisions and computer monitors (Sindiku et al., 2014; Waeger et al., 2010). For the purposes of an inventory of POP-PBDEs in EEE/WEEE, the priority is categories 3 and 4 with a special focus on CRT monitors and televisions. The inventory of stocks and flows of EEE/WEEE needs to address three stages in the life cycle of EEE (as shown in the following text):

- Imports of new and second-hand EEE;
- EEE stocks (EEE in use or stored);
- EEE entering the waste stream.

Table 19: Expected presence of POP-PBDEs in WEEE categories (see Table 26)

	WEEE Category[1)]	Presence of POP-PBDEs
1	Large household appliances	Expected not present or at average concentrations clearly (i.e. more than an order of magnitude) below 0.1 wt%[2)] Heating appliances around 0.1 wt%
2	Small household appliances	Expected at average concentrations considerably below 0.1 wt%[2)]
3	IT and telecommunications equipment	Average concentrations in computer CRT monitors above 0.1 wt% and in other products below or around 0.1 wt%[2)]
4	Consumer equipment	Average concentrations in TV CRTs and LCD above 0.1 wt% and average concentrations of other consumer products below or around 0.1 wt%[2)]

[1)] According to the EU Directive 2002/96/EC of the European Parliament and of the council on waste electrical and electronic equipment (WEEE).

[2)] RoHS MCV = 0.1% (by weight) = Maximum Concentration Value according to the EU Directive 2002/95/EC of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive). Several other countries have adopted the RoHS cut-off values for EEE including China and India. Currently three provisional low POPs limits have been defined by the Basel Convention (50, 500 and 1000 mg/kg) (UNEP 2019b).

[16] 97% of the total plastic amount in EEE is used in the WEEE categories 1 – 4 (APME, 2001).

6.3.2.2 Imports and exports of new and second-hand EEE

Imports and exports of EEE can be assessed by analysing trade statistics from international databases, national statistics and trade records compiled by customs and port authorities. The most widespread available international database is the UN Comtrade Database (http://comtrade.un.org/db). The database uses different classification codes to organize commodities, of which the most common is the Harmonized Commodity Description and Coding Systems (HS). This HS system has different categories from those used in the EU WEEE Directive. The most important HS codes and UNU-KEYs relevant for the inventory of POP-PBDEs in EEE are given in Table 20 and UNU-Keys and HS codes of relevant product categories for the first generation EEE inventory and managing PBDEs also in **Table 17**.

Categories of EEE exempted for the continued use of decaBDE are listed in **Table 1** and the quantities should be noted. Companies importing or selling the equipment should be contacted to clarify on the use of decaBDE in the respective equipment.

Table 20: UN Comtrade Database HS codes, UNU-KEYs relevant for the PBDE inventory for EEE

HS Code	UNU-KEY	EU WEEE Category	Description
845130	0101	1	Ironing machines and presses including fusing presses
851660	0103	1	Electric cooking, grilling & roasting equipment
8516	0106	1	Immersion heaters; electric irons; electric instantaneous or storage water heaters; electric space heating apparatus and soil heating
8471	0301	3	Automatic data processing machines and units thereof; magnetic or optical readers, machines for transcribing data onto data media in coded form and machines for processing such data, not elsewhere specified or included.
8443	0304	3	Printing machinery used for printing by means of plates, cylinders and other printing components of heading 84.42; other printers, copying machines and facsimile machines, whether or not combined; parts and accessories thereof.
8470	0307	3	Calculating machines, reproducing and displaying machines with calculating functions; accounting machines, postage-franking machines, ticket-issuing machines and similar machines, incorporating a calculating device; cash reg.
8517	0305	3	Telephone sets, telephones for cellular networks or other wireless networks; other apparatus for the transmission or reception of voice, images or other data, including apparatus for communication in a wired or wireless network
8527	0305	4	Reception apparatus for radio-broadcasting, whether or not combined, in the same housing, with sound recording or reproducing apparatus or a clock.
8528	0404 0407 0408	3 and 4	Monitors and projectors, not incorporating television reception apparatus; reception apparatus for television, whether or not incorporating radio-broadcast receivers or sound or video recording or reproducing apparatus.
8519	0306 0403	4	Sound recording or reproducing apparatus.
8521	0404	4	Video recording or reproducing apparatus, whether or not incorporating a video tuner.
8525	0404 0406 0306	4	Transmission apparatus for radio-broadcasting or television, whether or not incorporating reception apparatus or sound recording or reproducing apparatus; television cameras, digital cameras and video camera recorders.

Trade statistics usually do not contain information about the share of second-hand articles in imports. This information is crucial, however, as POP-PBDEs are mainly expected to be contained in second-hand imports (production of c-octaBDE stopped in 2004 and c-decaBDE use reduced after 2005) and second-hand imports can comprise up to 70% of total imports in certain developing countries but are normally below (UNEP 2019).

An assessment can be done by conducting interviews with importers and port authorities. Questionnaires (found in Annexes 2) address the following key indicators:

- Type of imported products;
- Amount of imported products (e.g. in units, in tonnes, in full containers, etc.);
- The share of new vs. second-hand imports (e.g. in weight %);
- The share of CRT monitors and CRT-TVs.

If export of second-hand EEE, WEEE or plastic from WEEE recycling take place this would also be included in the inventory.

6.3.2.3 EEE in use or stored at the consumer level (stocks)

Stocks of EEE in use or stored at the consumer level can be divided into three main groups:

- Private consumers (households);
- Institutional consumers (public institutions, government, parastatals, health and educational sector);
- Corporate consumers (hotels, large businesses (industries), small business enterprises).

Since POP-PBDEs in EEE are mostly found in older appliances, and especially in CRT monitors and TVs, it is expected that the largest share of the problematic fractions can be found in the households of private consumers who tend to keep appliances longer and are also the largest buyers of second-hand EEE. Institutional consumers also often tend to keep a stock of older appliances, especially CRT monitors, either in use or in storage. Corporate consumers are less likely to hold a significant share of problematic appliances containing POP-PBDEs as they tend to exchange their ICT infrastructure rather rapidly with new appliances.

Private consumers (households)

For a first estimation, EEE in use or stored at the private consumer level can be approximated by using penetration data (measured by e.g. installed appliances per person) for specific appliances from other countries (see Table 21), which best represent the consumer patterns in the target country. To calculate the total amount of appliances in a country on a weight base, these numbers need to be multiplied by the average weight of the appliance (see Table 22) and the population of the country.

Interviews with households can be conducted (see Annex 3 for generic questionnaire that can be used). Household surveys will produce data in the format of “per household”. National statistics on the number and average size of households will be necessary to extrapolate data to the entire country, keeping in mind differences in rural and urban consumer behaviours and income classes. Therefore, household surveys could be carried out in both rural and urban areas, and among different income classes. The questionnaire will address at least the following key indicators:

- The type and amount of installed EEE in the household, with a special focus on the number of CRT monitors and CRT-TVs;
- Average life span of each individual appliance (distinguishing between how long an appliance is in use and how long it is stored before being given away/entering the waste stream, respectively);
- Size of the household (number of persons);
- Demographic location of the household (rural or urban);
- Income class of the household (classified according to the official national income classification, in order to be compatible with national statistics).

Depending on the type of information that can be retrieved, extrapolations can be made from the amount of each type of article to the amount of other articles in entire WEEE categories, and vice versa, using the sample data as summarized in Tables 21 to 24.

Table 21: Penetration rates of specific EEE in Ghana and Nigeria (appliances/person)

	Category[1)]	Ghana[2)]	Nigeria[3)]
Fridge	1	0.26	0.16
Air conditioner	1	0.09	0.12
Iron	2	0.19	0.14
Kettle	2	0.12	0.11
Personal computer	3	0.08	0.13
Mobile phone	3	0.72	0.60
TV	4	0.20	0.25
Radio/HiFi system	4	0.28	0.36

[1)] Categories according to the EU WEEE Directive 2002/96/EC: large household appliances (cat. 1), small household appliances (cat. 2), IT and telecommunications equipment (cat. 3), consumer equipment (cat. 4).

[2)] Green Advocacy and EMPA, 2011.

[3)] BCCC- Nigeria et al., 2011.

Table 22: Weight estimation of specific articles in categories 3 and 4 (adapted from Green Advocacy & EMPA, 2011)

Articles	Weight (kg)	Source
Category 3: IT and communication equipment		
CRT monitor	14.1	Laffely, 2007; Zumbuehl, 2006
LCD monitor	4.7	SWICO Recycling Guarantee, 2006; ecoinvent v2010
Desktop computer	9.9	Eugster et al., 2007
Laptop computer	3.5	SWICO Recycling Guarantee, 2006;ecoinvent v2010
Mobile phone	0.1	Estimate
Telephone	1	Huisman et al., 2008
Printer	6.5	Laffely, 2007
Photocopier	52	Furniture re-use network, 2009
Category 4: Consumer EEE		
Television (CRT)	31.6	Zumbuehl, 2006
Television (LCD)	13 (32 Inch) 39 (60 Inch)	Moreschi, 2013
Radio	2	Huisman et al., 2008
Hi-fi system	10	Huisman et al., 2008

Table 23: Share of specific WEEE categories 3 and 4 articles from the entire category stockpiled in households in Nigeria (Ogungbuyi et al., 2011)

Category	Articles	Percentage (%)
3	CRT monitor	7.5
	LCD monitor	4.5
	Desktop PC	13.3
	Laptop	10.1
	Printer	7.0
	Mobile phone	5.5
	Rest	52
	Total	100
4	CRT-TV	42.5
	Flat panel/LCD TV	14.8
	Radio	3.2
	HiFi	8.9
	Rest	30.7
	Total	100

Table 24: Weight based share of WEEE categories 1–4 in households from various countries (EMPA, 2011)

Country	WEEE-Cat. 1 (%)	WEEE-Cat. 2 (%)	WEEE-Cat. 3 (%)	WEEE-Cat. 4 (%)
EU27 average [1)]	63	10	13	14
Switzerland [2)]	66	10	24	
Nigeria [3)]	52	12	11	25

[1)] Huisman et al., 2008. [2)] Müller & Widmer, 2010. [3)] Ogungbuyi et al., 2011.

Institutional and corporate consumers

For a first estimation**,** EEE in use or stored at institutional and corporate consumers can be approximated by using exemplary data from other countries, where data are available, on the weight distribution of EEE in use or stored between private consumers and institutional/corporate consumers. Based on this data, EEE in use or stored at institutional and corporate consumers can be calculated. Figure 6-2 shows an example of this distribution from Nigeria by WEEE category and consumer type. This distribution, however, very much depends on the development status of a country and the size of the services and industrial sector. Therefore, in many cases, such a simple approximation might not be possible. Alternatively, institutional and corporate consumers could be neglected in the first inventory.

For an in-depth inventory, interviews with institutional and corporate consumers would be conducted (see Annex 4 for a generic questionnaire). The questionnaire needs to take into account different economic sectors that might feature different consumer behaviours, e.g. the banking sector might consume more ICT appliances than the producing industry. The chosen economic activities in the questionnaire could be in accordance with national statistics about employee distribution levels between the different economic activities (i.e. sectors). This will make it possible to extrapolate from the survey results to the national level. The questionnaire will address at least the following key indicators:

- The type and amount of installed EEE in the organization, with a special focus on the number of CRT monitors (and CRT-TVs);
- Average life span of each individual appliance (distinguishing between how long an appliance is in use and how long it is stored before being given away/entering the waste stream, respectively);
- Size of the organization (number of employees);
- Type of organization and main activity (institutional or corporate, economic sector).

An understanding on questionnaire use, resulting data and inventory development can be developed by studying the existing WEEE inventory reports.

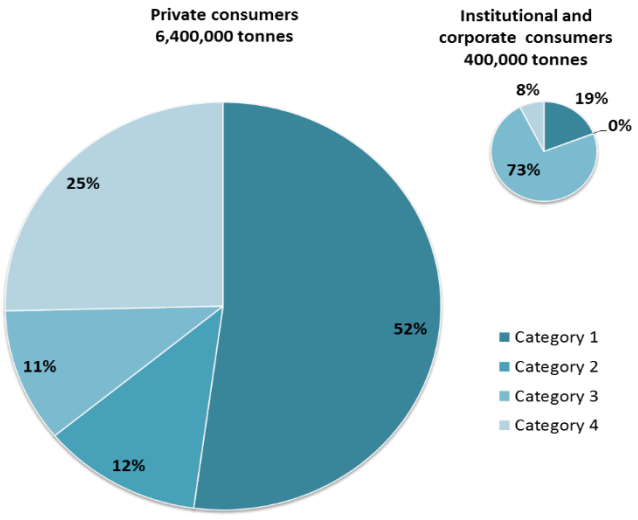


Figure 6-2: Weight distribution of EEE stockpiled by WEEE category for private and institutional/corporate consumers in Nigeria (EMPA, 2011)

6.3.2.4 EEE entering the waste stream

There are various approaches to calculating EEE articles entering the waste stream or WEEE flows, respectively (Streicher-Porte, 2006). The two key inputs for this calculation are (i) the amount of EEE stockpiled (see 4.3.1.2) by consumers and (ii) the average life span (combined time of being used and stored by consumers). These numbers need to be assessed through the consumer questionnaires as explained in the previous section. EEE entering the waste stream or WEEE generated can then be calculated using the "consumption and use" method (Bureau B&G, 1993):

WEEE generated per year = $M_{EEE(j)}^{stockpiled}$ / $ls_{EEE(j)}$

Where:

- $M_{EEE(j)}^{stockpiled}$ is the amount of EEE (*j*) stockpiled at the consumer [in tonnes]
- $ls_{EEE(j)}$ is the average life span of the specific appliance (*j*) [in years] (combined time of being used and stored at the consumer)

If further details about the final disposal and treatment process of WEEE are essential, it may be necessary to conduct field studies and hold interviews with key stakeholders of the waste sector. A questionnaire for recyclers can be found in Annex 5.

6.3.2.5 Background on total polymer fraction in relevant EEE/WEEE and PBDE content

Total polymer fraction

As discussed earlier in this chapter, relevant EEE/WEEE related to POP-PBDEs only includes (single) product types and WEEE categories having an average concentration of POP-PBDEs around or above the RoHS' MCV (Table 26). The corresponding data for the total polymer fraction are compiled in Table 25.

Table 25: Total polymer fractions in the relevant EEE/WEEE. Printed wiring boards and cables are not included (Waeger et al., 2008; EFRA 2013)

Category/Article		Total polymer fraction $f_{Polymer}$ [in % by weight]		
		Minimum	Maximum	Mean
3	ICT equipment without monitors	26%	58%	**42%**
4	Consumer equipment without monitors	21%	26%	**24%**
3	CRT monitors	13%	38%	**30%**
4	CRT-TVs	15%	38%	**30%**
4	LCD-TV (Flat screen)	30%	45%	**37%**

POP-PBDE content in the polymer fraction

To estimate the PBDE content in EEE/WEEE plastic and complete the inventory, data about their concentration in the total polymer fraction of the relevant EEE/WEEE are needed ($C_{PBDE(i);Polymer(k)}$). Due to the lack of monitoring capacity in developing countries, for this estimate PBDE impact factors from robust PBDE/BFR monitoring studies in WEEE plastic are provided to facilitate a Tier II estimate without monitoring. Data are taken from:

- The detailed study on European WEEE plastic from 2010 (Waeger et al. 2010) which might best reflect the content of EEE/WEEE in developing countries where much of WEEE from the past is still stored and management has not started or only started to some extent (Sindiku et al., 2014)
- Study on specific fraction PBDE/BFRs in WEEE plastic in France which included the separation of bromine to approx. 2000 ppm (Hennebert & Filella 2018). Data of the high bromine waste fraction is compiled in Table 27.

Table 26 provides the concentration of decaBDE and ∑hexa/heptaBDE in the total polymer fraction used in the relevant EEE. It should be noted that the provided data were derived from mixed polymer fractions from different WEEE recycling plants in Europe in 2010 (Waeger et al., 2010). The sampling procedure is

described in detail in the study.[17] Since in developing countries most EEE/WEEE has not been managed or management has recently started, the PBDE content is likely in a similar range. Therefore, with these impact factors Parties can estimate the PBDE quantities in the major EEE/WEEE fractions (following the procedure below).

Table 26: POP-PBDE (hexa/heptaBDE and decaBDE) content in total (mixed) polymers fractions of different WEEE in Europe (Waeger et al., 2010; LCD data from Hennebert & Filella 2018)

Category/Article		∑hexa/heptaBDE in plastic fractions [kg/tonne]* ($C_{hexa/heptaBDE;Polymer}$)			decaBDE in plastic fractions [kg/ tonne] ($C_{decaBDE;Polymer}$)		
		Minimum	**Maximum**	**Mean**	**Minimum**	**Maximum**	**Mean**
1	Cooling/freezing appliances; washing machines			**<0.05**			**<0.05**
1	Heating appliances			**<0.05**			**0.8**
2	Small household appliances				<0.1	0.5	**0.17**
3	ICT equipm. w/o monitors	0.027	0.22	**0.12**	0.5	1.4	**0.8**
3	CRT monitor casings	0.08	5.7	**1.37**	0.5	7.8	**3.2**
4	Consumer equipment w/o monitors (1 composite sample)	-	-	**0.08**	0.7	0.9	**0.8**
4	TV CRT monitor casings	0.03	1.9	**0.47**	0.8	7.8	**4.4**
4	Flat screens TVs (LCD)	0.008	0.010	**0.009**	1.2	4.3	**2.71**

* RoHS limit for PBDE is 1000 mg/kg or 1 kg/t. The Basel provisional low POPs contents for POP-PBDEs are 1000 mg/kg (1 kg/t) or 500 mg/kg (0.5 kg/t) or 50 mg/kg (0.050 kg/t) (UNEP 2019).

Considering the need for a (more) circular economy including WEEE (UNIDO 2017; World Economic Forum 2019), also the plastic fractions should be recycled or recovered but including phasing out PBDEs (UNEP 2021a). For many plastic fractions the bromine containing plastic need to be separated from WEEE plastic to meet the suggested POP-PBDE low POP contents of 1000 mg/kg, 500 mg/kg or 50 mg/kg (Table 26; Hennebert & Filella 2018; Swerea 2018). Plastic fractions with inherent low PBDE content are in particular large household EEE (e.g. freezing/cooling appliances, washing machines; dish washer) which might even meet the provisional low POPs content of 50 mg/kg (Table 25; Wäger et al 2010).

By separation of bromine containing plastic, a low bromine/PBDE fraction and a high bromine/PBDE fraction is generated. Data from two comprehensive studies are compiled to estimate the average PBDE content in plastic from recycling of WEEE after plastic separation (Table 27 and Table 28):

- A study on separation of PBDE/BFRs in WEEE plastic in France which included the separation of bromine to approx. 2000 mg/kg (Hennebert & Filella 2018). Data of the high bromine waste fraction is compiled in
- Table **27**.
- A study on plastic from WEEE for recycling (ABS, ABS/PS, PP/PE and PP) from 6 European countries where the bromine/BFR fraction was separated to produce low PBDE/BFR containing which meet the CENELEC Standard TS 50625-3-1 (CENELEC 2015) for bromine of <2000 mg/kg plastic; in most cases total bromine content was <1000 ppm and PBDE <200 mg/kg (**Error! Reference source not found.**; Swerea 2018);

These data can be used to estimate the level of PBDEs in WEEE plastic after bromine separation for different plastic fractions of the high bromine fractions (

[17] http://ewasteguide.info/files/Waeger_2010_Empa-WEEEForum.pdf

Table **27**) and the low bromine fractions (Table 28) if no own measured data are available but the amount of separated plastic is known.

Table 27: Mean POP-PBDEs and bromine content in high bromine plastic fraction from recycling after bromine separation (average of sampling campaign 2014 and 2015; Hennebert & Filella 2018)*

Waste plastic fraction* (high BFR after separation)	decaBDE (kg/t)	∑PBDE (2009)** (kg/t)	Bromine (kg/t)
CRTs	8.1	1.9	35.6
Small household appliances	2.8	0.69	20.3
Flat screens	5.8	0.046	45.9

*The high bromine waste plastic fraction after separation has a share of 20 to 40% of the initial plastic volume
** PBDEs listed in Annex A of the Stockholm Convention in 2009, including tetra-, penta- hexa-, and hepta-PBDEs.

Table 28: POP-PBDEs in plastic from recycling after bromine separation (Swerea 2018)*

Recycled polymers from WEEE/ASR after separation of bromine rich fraction	Average* decaBDE content (mg/kg)	Average* ΣPOP-PBDE (2009)** content (mg/kg)	Average* bromine content (mg/kg)	Share of samples above 250 mg Br/kg
ABS	77	6	696	63 % (5/8)
PS	81	<5	695	56 % (5/9)
PS / ABS	119	<5	916	80 % (4/5)
PP / PE	76	<5	795	50 % (1/2)
PP	130	<5	685	– (1/1)

*Since only 65% of samples (n'=17 out of n=26) which exceeded 250 mg/kg bromine were analysed for PBDEs (Swerea 2018) the overall average content of PBDEs and bromine in the total samples studied are lower than those listed in the table.

**PBDEs listed in Annex A of the Stockholm Convention in 2009, including tetra-, penta- hexa-, and hepta-PBDEs.

6.3.2.6 Compilation of the POP-PBDEs inventory from collected data

This section outlines how to use collected data in calculations to get the estimation for inventory of POP-PBDEs in WEEE and related plastic in a country (see Figure 6-1). Due to the differing natures (flow or stock) of the three stages (imported EEE, 6.3.2.6-A; in use/stockpiled EEE, 6.3.2.6-B; EEE entering the waste stream, 6.3.2.6-C and WEEE plastic fraction 6.3.2.6-B) in the life cycle of EEE/WEEE under consideration, the calculation approach is described for each stage.

Table 29 presents the most important numbers for the estimation/inventory. Crucial is the decaBDE and the ∑hexa/heptaBDE content in the total polymer fractions varying with the type of the EEE (Table 29).

Table 29: Total polymer fractions and c-octaBDE and decaBDE concentrations in relevant EEE categories (data from Europe; Waeger et al., 2010; Hennebert & Filella 2018)

Relevant EEE	Total polymer fraction (mean)	Σ hexa/heptaBDE content (mean) in plastics	decaBDE content (mean) in plastics
	$f_{Polymer}$ [in % by weight]	$C_{\Sigma hexa/heptaBDE;Polymer}$ 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**

Relevant EEE	Total polymer fraction (mean)	Σ hexa/heptaBDE content (mean) in plastics	decaBDE content (mean) in plastics
TV CRT monitor casings	30%	**0.47**	**4.4**
Flat screens TVs (LCD)	37%	**0.009**	**2.7**

* RoHS limit for total PBDEs is 1 kg/tonne or 0.1 wt %.

The mixed polymers in WEEE from Europe in 2010 (Table 29) might reflect the WEEE plastic content of developing countries which have not yet started with WEEE management or only are starting to process WEEE and therefore containing a relevant share of EEE manufactured before and after the stop of c-octaBDE (2004) and restriction of decaBDE (2008). This has been found for the PBDE assessment of CRTs in Nigeria where c-octaBDE and decaBDE were in the range of these impact factors (Sindiku et al., 2014).

6.3.2.6 A POP-PBDEs in imported and exported EEE

The use of decaBDE is exempted for plastic housings and parts used for heating home appliances, irons, fans, immersion heaters (see Table 1). Therefore, the import of these EEE would be assessed for the presence of decaBDE. Since other flame retardants have substituted c-decaBDE to a large extent, only a minor share of newly produced EEE contain decaBDE. Since only a share of the appliances might be treated with c-decaBDE, information on flame retardants used should be gathered from importers and retailers. **New electronics other than the exempted heating appliances (Table 1) are not considered to be flame retarded by decaBDE. However, spot assessments of other new EEE imported within the Tier III inventory can be conducted in particular those with former high decaBDE use (e.g. TVs).**

However, imported second-hand EEE and WEEE might contain PBDE levels as compiled in **Error! Reference source not found.**. Information can be gathered from customs for the respective HS codes (see Table 20). Since all c-octaBDE (hexa-/heptaBDE) use stopped 2004 and the major use of c-decaBDE has also been applied in EEE before RoHS restriction in 2008, **a major inventory activity is the assessment of import and export of second-hand electronics and import of waste plastic from electronics and related POP-PBDE content**.

In a Tier III inventory selected imported electronics might be monitored for decaBDE content (see Tier III).

Furthermore, WEEE plastic is recycled in a wide range of products resulting in PBDE (mostly decaBDE) recycled.

The amount of POP-PBDEs is calculated as follows (see also Figure 6-3):

$$M_{POP\text{-}PBDE;imported\ EEE(j)} = M_{EEE(j);imported} \times f_{EEE(j);second\text{-}hand} \times f_{Polymer} \times (C_{\sum hexa/heptaBDE;Polymer} \text{ and } C_{decaBDE;Polymer})$$

Where:

- $M_{c\text{-}octaBDE;imported\ EEE(j)}$ is the amount of POP-PBDE in imported second-hand EEE(j) in [kg]
- $M_{EEE(j);imported}$ is the amount of imported (new + second-hand) EEE(*j*) in one year [in tonnes] see section 6.3.
- $f_{EEE(j);second\text{-}hand}$ is the share of second-hand EEE(j) among the imports in [weight-%] see Table 23
- $f_{Polymer}$ is the total polymer fraction in EEE(j) in [weight-%] see section 6.3.2 and Table 29
- $C_{POP\text{-}PBDE;Polymer}$ is the content of the ∑hexa/heptaBDE and decaBDE in the total polymer fraction of EEE(j) in [kg/ tonnes] see Table 29

Consequently, the POP-PBDE contents of all relevant EEE(j) can be added up, in order to present an aggregated number for the sum of POP-PBDEs (decaBDE and hexa/heptaBDE) in imported EEE.

If import or export of WEEE plastic or export of second-hand EEE or WEEE take place this would also be noted in the inventory.

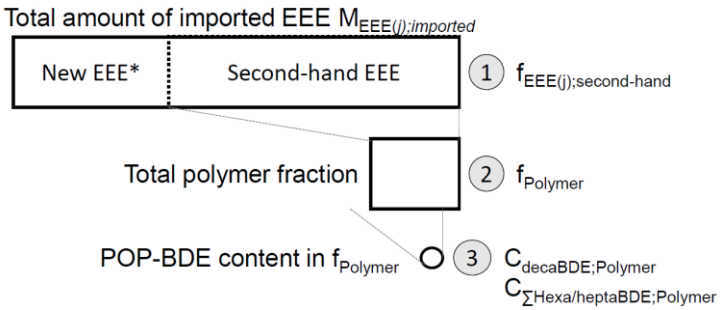


Figure 6-3: Scheme to estimate the amount of POP-PBDEs in imported EEE/WEEE **(***A minor amount of decaBDE might be imported in new equipment in exempted uses and EEE not in compliance. Both is considered low compared to second-hand import and could be assessed in Tier III inventory).

6.3.2.6 B POP-PBDEs in stocks of EEE

In contrast to the imported EEE, it is not feasible to split the EEE in use/stocks into shares of old (second-hand) EEE and new EEE. Thus, the amount of POP-PBDEs is estimated considering the whole bulk of used/stockpiled EEE (see also figure 6-4):

$$M_{POP\text{-}PBDE;EEE(j)} = M_{EEE(j);stockpiled} \times f_{Polymer} \times C_{\sum hexa/heptaBDE \text{ and } decaBDE\ Polymer}$$

Where:

- $M_{c\text{-}POP\text{-}PBDE;stockpiled\ EEE(j)}$ amount of decaBDE + hexa/heptaBDE in stockpiled EEE(j) in [kg]
- $M_{EEE(j);stockpiled}$ is the amount of stockpiled EEE(*j*) in [in tonnes] see section 4.3.1.2
- $f_{Polymer}$ is the total polymer fraction in EEE(j) in [weight-%]
  see section 4.3.2 and table 16
- $C_{POP\text{-}PBDE;Polymer}$ is the content of decaBDE and c-octaBDE in the total polymer fraction of EEE(j) in [kg/tonne] see section 4.3.3 and Table 18.

Consequently the POP-PBDE (hexa/heptaBDE, decaBDE) contents of all relevant EEE(j) can be added up, in order to present an aggregated number for the sum of POP-PBDEs in all stockpiled EEE.

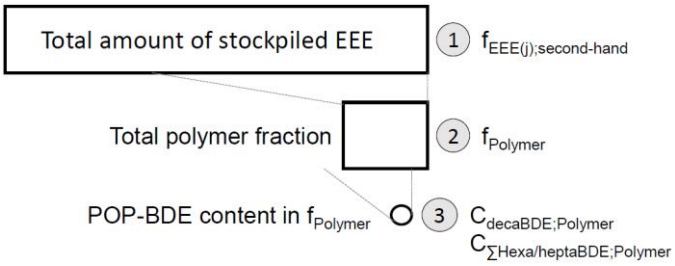


Figure 6-4: Scheme to estimate the amount of POP-PBDEs in stockpiled EEE

6.3.2.6 C POP-PBDEs in EEE entering the waste stream

The amount of POP-PBDEs in WEEE is estimated as follows (see also Figure 6-5):

$\sum hexa/heptaBDE \text{ and } decaBDE\ Polymer$

$$M_{POP\text{-}PBDE;WEEE(j)} = M_{WEEE(j)} \times f_{Polymer} \times C_{\sum hexa/heptaBDE \text{ and } decaBDE\ Polymer}$$

Where:

- $M_{c\text{-}POP\text{-}PBDE;stockpiled\ EEE(j)}$ amount of decaBDE + hexa/heptaBDE in WEEE(j) in [kg]
- $M_{WEEE(j)}$ is the amount of generated WEEE(*j*) in one year in [in tonnes]
  see section 4.3.1.3

- rest: see above

Consequently, the POP-PBDE (hexa/heptaBDE; decaBDE) contents of all relevant EEE (j) can be added up, in order to present an aggregated number for the sum of POP-PBDEs (c-octaBDE) in EEE entering the waste stream. If WEEE is exported, this fraction can be calculated separately (see figure 6-1).

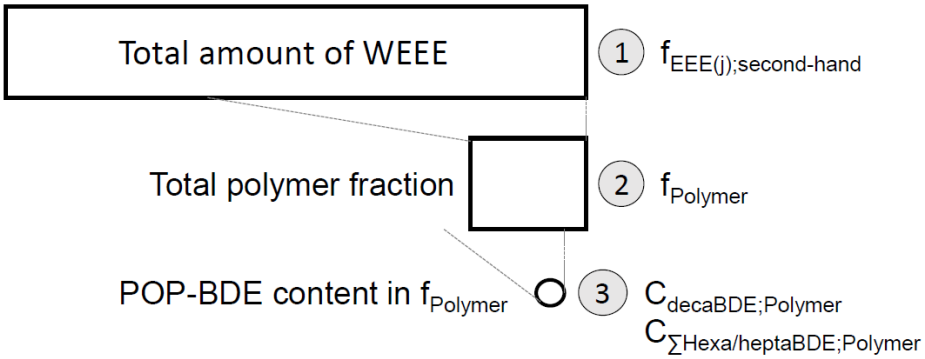


Figure 6-5: Scheme to estimate the amount of POP-PBDEs in EEE entering the waste stream (WEEE)

6.3.2.6 D PBDEs WEEE polymers - recycling and export/import

Information on further management and treatment of polymers generated from WEEE needs to be identified as such polymer fractions could be also further used/recycled or exported and may influence the successful implementation of the Stockholm Convention (see Figure 6-1). Therefore, the material flows in the end-of-life need to be considered.

Polymers generated from WEEE recycling are either:

- Separated in low bromine and high bromine fractions for further treatment and recycling (see studies with related PBDE content in
- **Table 27** and **Table 28**)
- Recycled to new products in the country;
- Thermally treated or disposed of in landfills in the country;
- Exported to other countries (e.g. for disposal or recycling).

The material flows of plastic from domestic WEEE management, treatment and recycling and of imported WEEE plastic for recycling should be monitored for their final end-of-life management or recycling. Information can be gathered from the facilities recycling WEEE. Information of import of WEEE or WEEE-polymers can be gathered from customs and importers. Facilities processing WEEE, recycling plastic or thermally recover/destroy plastic can be contacted and assessed for the WEEE plastic amounts treated.

If recycling activities of WEEE polymers take place in the country and the amount of the WEEE polymers used could be collected either from recycling plants, the facilities providing the WEEE polymers or possibly from customs. Details of sampling and analysis of WEEE polymers are described in the, *Guidance on Screening and Analysis of POPs in Articles and Products* (UNEP 2021b).

The inventory can be done by estimating the amount of total polymers from WEEE used in recycling and the respective concentration of POP-PBDEs in these polymers (similar to the approach described above or by using own measurements).

Articles made from POP-PBDE-containing materials could be labelled. It also needs to be assured that POP-PBDE-containing materials are not recycled into articles with sensitive uses (see Chapter 5 of *PBDE BAT/BEP Guidance* (UNEP 2021a)). Finally, these products need to be treated at end-of-life in an environmentally sound manner (UNEP 2018; UNEP 2021a).

The volumes of POP-PBDE containing waste being incinerated or otherwise thermally treated should be noted in the inventory report along with the technologies used for destruction. Guidance for thermal recovery and destruction of PBDE containing materials are given in the *PBDE BAT/BEP Guidance* (UNEP 2021a) and "*Revised technical guidelines on the environmentally sound management of wastes consisting*

of, containing or contaminated with hexabromodiphenyl ether and heptabromodiphenyl ether, or tetrabromodiphenyl ether and pentabromodiphenyl ether or decabromodiphenyl ether" (UNEP 2018).

The amount of POP-PBDE containing waste being landfilled should be noted in the inventory. Guidance for disposal of PBDE containing materials was given in the *PBDE BAT/BEP Guidance* (UNEP 2017b).

6.3.2.7 Compiling POP-PBDEs and plastic data of the Tier II inventory

For the final inventory, the quantity of listed hexa/heptaBDE and decaBDE should be compiled. The compilation should be separated for these homologues since the listing of decaBDE does not contain a recycling exemption while hexa/heptaBDE have an exemption for recycling if registered. Since the decaBDE is by far dominant PBDE, its presence determines recyclability of plastic fractions.

The associated polymer volumes impacted by POP-PBDEs should also be included in the table/inventory report and in the NIP for developing management considerations (action plan).

Table 30:* Estimate of quantity of decaBDE and ∑hexa/heptaBDE present in EEE, WEEE and in polymers in recycling and related plastic quantity.

Homologues	**POP-PBDEs in import for inventory year 20XX****	**POP-PBDEs in stocks for inventory year 20XX***	**POP-PBDEs entering the waste stream 20XX***	**POP-PBDEs in recycled polymers for inventory year 20XX***
Chapter	(6.3.2.6 A)	(6.3.2.6 B)	(6.3.2.6 C)	(6.3.2.6 D)
Hexa/heptaBDE				
DecaBDE				
Quantity of WEEE plastic				

*The table can be adjusted as appropriate; ** 20XX to be replaced by the year of the inventory.

6.3.3 Tier III: In-depth inventory of POP-PBDE-containing EEE/WEEE

While the PBDE impact factors selected in Tier II to estimate the presence of PBDE in the different EEE/WEEE categories (Table 29**Error! Reference source not found.**,

Table **27**, Table 28) is based on robust data sets, the PBDE content decrease over time and also depends on consumption patterns and service life of EEE in a country/region. The PBDE content in products produced from recycled plastic and imported plastic are difficult to estimate by impact factors due to the unknown source and history of such plastic. Therefore, it is useful to conduct some monitoring of PBDEs in these and other WEEE plastic on country or regional level in particular for plastic which is recycled.

Output of Tier III

- Addressing the gaps discovered in the Tier II inventory;
- Monitoring imported EEE in particular the exempted EEE uses (heating equipment) and electronics with recorded uses of decaBDE;
- Monitoring of major WEEE plastic fractions (see e.g. Wäger et al. 2010);
- Monitoring of separation of high and low bromine fraction of WEEE plastic for recycling (see e.g. Hennebert & Filella 2018;
- Table **27** and Swerea 2018;
- Table **27**, Table 28)
- Monitoring of recycled WEEE plastic used for new products (see e.g. Swerea 2018);
- Monitoring of products produced from black plastic (see e.g. Kuang et al. 2018; Puype et al. 2015; Samsonek and Puype 2013).

The PBDE levels in WEEE plastic change over time since the average production year of WEEE entering end-of-life also change with reduced share of EEE/WEEE produced before 2005 with major use of c-decaBDE and stop of c-octaBDE. Therefore, the PBDE levels in WEEE decrease over time in particular in countries with ongoing WEEE management. In developing countries often no WEEE management has been established and the entire WEEE is stockpiled (Sindiku et al. 2014). While a range of studies on PBDEs and other BFRs in WEEE plastic have been published the last decade (e.g. Wäger et al. 2010; Drage et al. 2018; Hennebert & Filella 2018), there are only a few studies from developing countries measuring PBDEs in WEEE plastic (e.g. Babayemi et al. 2014; Sindiku et al. 2014).

Monitoring of polymer products containing PBDEs or HBCD including screening and analysis is described in the Stockholm Convention guidance in a 5-step approach (UNEP 2021b). Such a monitoring could involve a pre-screening of WEEE then the information on the producer and the production year and region should be noted to get an insight into PBDE use (Sindiku et al 2014).

The data from the Tier III monitoring and assessment should be used to refine and update Tables 30 or Tables 26, 29 by own monitoring data. The inventory report should include all relevant information such as sampling and the screening and analytical methods used.

A Tier III inventory might also establish a material and substance flow analysis to best visualize and understand the stocks and flows of POP-PBDEs in EEE/WEEE. With a dynamic substance and material flow analysis and the information on the current use/stock of the respective products and the service life of the products, the products entering the waste stream can be estimated and calculated. Such dynamic substance flow analysis has been conducted for PBDEs (Morf et al. 2008; Abbasi et al. 2015).

While a screening of bromine (e.g. by XRF) is an indication for BFRs, only a smaller share of the bromine content detected in the screening stem from PBDEs (Table 31 and Table 26). In the different mixed WEEE fractions PBDE account for ca. 5 to 20% of detected bromine while other BFRs (e.g. TBBPA or DBDPE) account today for similar or even higher share of bromine (Table 31; Wäger et al. 2010; Swerea 2018; Hennebert & Filella 2018).

The upper bound POP-PBDEs content in WEEE plastic can be estimated using field measurement equipment determining the bromine content such as sliding sparks and XRF handheld equipment (see *POP-PBDEs BAT/BEP Guidance* (UNEP 2021)). This could help to identify CRTs and other EEE/WEEE plastics containing bromine/POP-PBDEs (Sindiku et al. 2014). Please note that the field screening equipment can only detect the total bromine content, and a confirmation may be required by using instrumental analysis for positive tested samples (UNEP 2021b).

Table 31: Average bromine and BFR content in WEEE plastic monitoring in the EU in 2011 (BAFU 2017)

Substance	Mean level (mg/kg)	Uncertainty
Bromine	4500	±510
DecaBDE (BDE 209)	390	±45
c-OctaBDE	120	±33
c-PentaBDE	2.4	±0.7
HBCD	14	±4.1
DecaBB	4.5	±2.7
TBBPA	630	±85
DBDPE	340	±200
BTBPE	150	±14
DDC-CO	19	±11
TTBP-TAZ	14	±4.8

6.4 Step 4: Managing and evaluating data and Step 5 inventory report

In this step the data need to be assessed for completeness and plausibility, possibly including the comparison with data from other countries in the region. Data gaps may (partly) be filled by extrapolation of available statistical data.

When a country improves the EEE/WEEE inventory and related plastic inventory over time, the data quality will become more robust and reliable and inventories can be used for planning of waste management and material recovery and recycling and control of PBDE impacted WEEE plastic . This directly supports a more circular economy for this relevant waste category.

The gathered general inventory data for EEE and WEEE could be managed in an appropriate database and sent to the governmental agency responsible for statistics. Since the data are highly valuable for the (waste) management of EEE and WEEE, they should be made available to departments responsible for waste and resource management in the country (Ministry of Environment or Industry or other responsible ministries) and to the competent authority of the Basel Convention. The data could possibly be fed into and further managed within a database of the governmental body responsible for waste and resource management.

The compiled data for this sector are included with the methodology used and the detailed calculations in the POP-PBDEs inventory report. This inventory can appear as a chapter in the overall report. Any country-specific adjustments and estimates could be noted and described.

To provide a general overview on the presence of POP-PBDE in EEE/WEEE at the national level, as well as on the amount of the impacted EEE and WEEE to be managed during the NIP implementation phase (see Figure 6-1), the information suggested to be included in the dedicated NIP chapters may include a brief summary on:

- Amount of impacted EEE and WEEE imports and exports;
- Amount of impacted EEE used and stored;
- Estimated total amount of impacted polymer fraction contained in stored and in use CRT casing of TVs and computers;
- Estimated total amount of POP-PBDEs (decaBDE and ∑hexa/heptaBDE) in use and in stored EEE;
- Amount of EEE and PBDE entering into the waste stream;
- Estimated total amount of impacted polymer volume contained in WEEE;
- Estimated total amount of POP-PBDE in WEEE;
- Information on recycling, reuse, treatment, destruction and disposal of impacted EEE/WEEE and WEEE polymers.

Further activities needed for assessing and managing this use sector would be include in the NIP.

7. Inventory of POP-PBDEs in the transport sector

7.1. Background on use and presence of PBDE in vehicles

The transport sector (cars, buses, trucks, trains, planes, and ships) is one of the large material flows of goods and ultimately becomes a large waste and recycling flow. The end-of-life management of the transport sector is a highly relevant waste category for the recovery of materials towards a more circular economy and for managing pollutants (see PBDE BAT/BEP Guidance, UNEP 2021a; Vermeulen et al. 2011).

DecaBDE has been used extensively in vehicles. In North America, a total of 380,000 t of c-decaBDE was used from 1970 to 2013, with 133,000 t (35%) used in vehicles (Abbasi et al. 2015). In Japan c-decaBDE was the main flame retardant detected in vehicles (Kajiwara et al. 2014) and automotive shredder residues (ASR).

Furthermore, before 2005 a proportion of c-pentaBDE has been used in the transport sector in the United States/North America for the treatment of flexible PUR foams (automotive seating, head rests, car ceilings, acoustic management systems, etc.) and some was used in back-coating of textiles in car seats (Table 32; Abbasi et al. 2015; Ludeka 2011; UNEP 2010 a,b; Liu et al. 2019; Leslie et al. 2013).

While the PBDEs listed in 2009 (tetra- to heptaBDE) were only produced/used in the period from approximately 1975 to 2004 (see Chapter 2), decaBDE is still produced today and received exemptions for a range of plastic (spare) parts in legacy vehicles with continued use of decaBDE (Table 2).

Cars and other vehicles (trucks and buses) are the major portion of the transport sector containing the main quantity of PBDEs of the transport sector. The focus and methodology for the inventory can therefore centre on these vehicles. However also trains, aircraft and ships contain flame retarded plastic and polymers. E.g. decaBDE has been used in unsaturated polyester (UP) resins in rail vehicles at a loading of 8.5% (Morf et al. 2003). If a country has a relevant train, aeroplane and/or ship fleet, these sectors can be included in the assessment. Furthermore, if trains, aeroplanes or ships are dismantled in a country, the amount of plastic and polymers should be inventoried and managed in an environmentally sound manner. The trend of decommissioning aircraft is growing and over the next 10 years around 11,000 aircraft retirements are expected. The COVID-19 crisis will undoubtedly accelerate many of these retirements and several operators have already announced they are bringing forward fleet retirement programs (IATA 2021). Therefore, for countries with airlines such decommissioning of aircrafts would be included in the inventory.

The decaBDE have been used in a large variety of applications in vehicles (Table 7; Table 32). The average PBDE concentration in ASR is relatively low (Table 33, 34) and rarely exceed 1000 mg/kg in the total ASR fractions. Only after separation of the polymer fractions in a few cases 1000 mg/kg decaBDE can be considerably exceeded (Table 34).

The average polymers (plastic, foams and synthetics) in cars are approximately 15% [18]. Considering an average weight of a car (1.333 t) this means that approximately 200 kg are polymers (Rouilloux & Znojek 2010). The total amount of ASR is somewhat higher (ca. 20–21%) considering glass and ceramics and some metal fines (Oekoinstitute 2018; Vermeulen et al. 2011; Sing & Lee 2015). The average decaBDE in the ASRs depends on the age of the vehicles shredded and possibly on the regions of the origin of the vehicles (Table 33). Governmental studies from Japan show that cars produced before 2000 had an average higher decaBDE content in ASR corresponding to approx. 80 g decaBDE/vehicle (Table 33). The levels decreased to approx. 120 mg/kg for cars produced after 2000 corresponding to approx. 24 g decaBDE for a Japanese passenger car. Japan stopped the use of decaBDE in 2018 and also Europe and US stopped the production and use of c-decaBDE in recent years. The global export of Israel indicate that production/export largely stopped in 2018.

High c-pentaBDE were used in vehicles in the United States (Alcock et al. 2003; Abbasi et al. 2014) and are only detected in high levels in cars from US produced before 2005 (Liu et al. 2019; Leslie et al. 2013).

[18] Please note: The polymer content and the weight of vehicles changes over time with increasing share of polymers.

Table 32: Content of decaBDE in flame retarded vehicle components

Plastic/polymers treated with c-decaBDE	Content	References
Textile (back coated)	2.2–6.2%	Drage et. al. 2018; Kajiwara et al. 2014
Flame retarded plastic	3–20%	UK HSE 2012; Sindiku et al. 2015
Floor covering	1.4%	Kajiwara et al. 2014
Adhesive layer of reflective tapes (vehicles)	1–5%	RPA 2014
Heat shrinkable tubing/products (vehicles)	10%	Danish EPA (2007)
PUR foam (treated with c-pentaBDE until 2004)	1–5%	Cambell, 2010; Ludeka 2011
Lamination to headliner fabric (c-pentaBDE)	15%	Ludeka 2011
FR2 laminates	36 g/m^2	Morf et al. 2003
Unsaturated polyester resins in rail vehicles	8.5 %	Morf et al. 2003

Three detailed studies of PBDE in vehicles have been conducted by JECC (2012), Kajiwara et al. (2014) and Liu et al. (2019) and the Japanese Ministry of Environment (2011). In total in these three studies screened 99 vehicles with XRF.

Up to now only one detailed study of PBDE in vehicles have been conducted by Kajiwara et al. (2014) in which 45 vehicles produced between 1993 and 2012 were screened with XRF. The XRF survey showed that 32 out of 515 materials/components investigated (6.2% of the total) contained more than 0.1% by weight of bromine. Major components that contain PBDEs (or other FRs), are in particular seat fabric, floor covering, and soundproof materials (Table 33). Furthermore, a few PUR foam seats, headliner, and door trim panel contained PBDEs (Table 33). The monitored floor mat, trunk sheet, heat insulation materials (engine), harness covers, and dashboards did not contain PBDEs (Liu et al. 2019, Kajiwara et al. 2014). The study focused largely on cars produced in Japan and the use of PBDEs and HBCD might differ in other regions. The only car monitored from the United States was the only car with high level of c-pentaBDE (38,000 mg/kg) in seat PUR foam (Liu et al. 2019; Table 33).

From the 515 screened samples, HBCD was only detected in 2 samples above the low POPs content of 100 mg/kg (Table 33).

Table 33: PBDE/HBCD in bromine-positive components of 45 vehicles/515 components (Kajiwara et al. 2014, Liu et al. 2019)

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

Reported concentrations of BFRs in cars, ASR, and sorted post shredder treatment fractions (PST fractions) are compiled in Table 34. DecaBDE concentrations reported in the literature for average ASR from ELV are inhomogeneous and range from 0.2 to 1,076 mg/kg. They are therefore are largely below 1000 mg/kg. However, separated fractions from ASR can contain PBDEs above 1000 mg/kg (Table 35). In particular PBDE treated components can have high decaBDE or c-pentaBDE concentration up to 128,000 mg/kg and are clearly hazardous POP waste (Table 34).

In principle, two different approaches are used for decaBDE measurements. On the one hand, XRF is used to perform a preliminary screening on selected plastic car parts/components in order to subsequently determine the PBDE/HBCD content of those parts by means of a chemical analysis (see the study of Kajiwara et al. 2014). The second approach is to carried out an analysis on the shredder fraction (Table 34). For establishing an inventory in the transport sector it is useful to calculate with an average PBDE content. However, this value is hardly calculated and only few studies are available. Liu et al. (2019) and Kajiwara (2020) calculated the POP-PBDE content per vehicle.

Based on the available data (Table 34) and for a practical inventory approach, vehicles produced before 2005 might be considered to contain 80 g POP-PBDE while vehicles produced after 2005 might be considered to contain 20 g POP-PBDE (derived from the most robust shredder studies including also some with assigned production period of the shredded cars; Table 34). For all regions decaBDE is dominating.

For US vehicles produced before 2005 a share of 50% c-pentaBDE might be assumed considering the high use of c-pentaBDE in vehicles in the United States (Alcock et al. 2003; Abbasi et al. 2014) and detected in high levels in cars from US produced before 2005 (Liu et al. 2019; Leslie et al. 2013). The formula for estimation/inventory is compiled in Section 7.3.2.1.

Table 34: Major studies on PBDE concentration in vehicles from different approaches (PBDE content in component, ASRs and related per vehicle content)

	DecaBDE	∑PBDEs 2009 (tetra-heptaBDEs)	POP-PBDEs in average car*(g)	Reference
XRF, chemical analysis (51 Cars produced from 1993–2011, Japan)	N.D.–78,000 (mg/kg) (component samples)	N.D.–52.000 (mg/kg)(component samples)	*62±21*	Liu et al. 2019, see also Kajiwara et al. 2014
XRF, chemical analysis (48 Cars produced from 1989 – 2001) and ASR (Japan)	200–618 (mg/kg) in ASR before 1996 and 39–190 (mg/kg) after 2000	N.D. –28.000 (mg/kg) (component samples)	40–124 before 1996 7.8 – 38 after 2000	JECC, 2012
Car shredder residues (Cars produced before 1996 (Japan)	406 (mg/kg)	N.D.	81.2	JAMA 2016, Japanese MoE 2011;
Car shredder residues Cars older than 1999 Japan	335 (mg/kg)	N.D.	67	JAMA 2016, Japanese MoE 2011
Car shredder residues (Cars) younger than 2000 (Japan)	120 (mg/kg)	N.D.	24	JAMA 2016, Japanese MoE 2011
50 samples by XRF, and one sample ELV grinding material in France	140 (mg/kg) (France)	N.D.	28	Swerea_IVF_AB 2018
92 component samples (XRF) and 36 waste samples (chemical analysis) from ELVs	PBDE in seat fabric 46,098 mg/kg in average, ASR 1,076 mg/kg in average	ASR 1,076 mg/kg in average (mostly c-decaBDE)	215	Choi et al., 2017
Chemical analysis of 9 fabric and 7 PUF samples from ELVs	Fabric <1000–128,000 mg/kg, PUF <1000–6,600 mg/kg	PentaBDE <1000–7,700 mg/kg,	No shredder/average given	Khaled et al.,2018
Literature review	Car parts mean value 3,245 and ASR mean 386		77 g from mean ASR	Henneberg et al. 2020
Car shredder residues (Europe, UK)	450** (mg/kg)	N.D.	90	Peacock et al. 2012
Inventory of PBDEs in vehicles in Japan	N.D.	N.D.	85 g before 1996, 26 g 2000=2011 from conc. in ASR	Kajiwara 2020

* Calculated based on approx. 200 kg light shredder residues per vehicle

**Average concentration of fluff (138 mg/kg), light plastic (118 mg/kg); heavy plastic (2163 mg/kg).

Separation of PBDE containing factions and concentrations

Due to the need to move towards a (more) circular economy (European Commission 2018; GEF 2018; UNIDO 2017), the share of non-impacted polymers from end-of-life vehicles should be recycled to the extent practical. It needs to be stressed that only certain parts in the vehicles are flame retarded (Table 2, Table 33) and most plastic and polymer components (>90%) in vehicles are not impacted by PBDEs or other BFRs (Kajiwara et al. 2014; Liu et al. 2019) and could be recycled.

The manual dismantling of vehicles and screening of bromine containing plastics and other polymers are considered impractical for the established end-of-life vehicle management with shredders in industrial

countries (Oekoinstitute 2018). Instead, the highly impacted plastic fractions and textile/fibre fractions contaminated with PBDEs might be separated by appropriate post shredder technologies (PST) (Table 35; Oekoinstitute 2018; UNEP 2021a). The light plastic fractions separated from light shredder (normally density <1.1) had reported levels between <5 and 140 mg/kg (see Table 35). The separated high density fraction from light shredder residues had levels between 800 and 2164 mg/kg PBDEs and average bromine levels above 2250 mg/kg (Table 35). In some measurements in the Netherlands also the levels in the high density fraction were low (between 1 to 5.5 mg/kg) (Table 35; Leslie et al. 2013).

Therefore, the screening of bromine in vehicles can be used for separating the bromine impacted plastic and polymers (e.g. seat fabrics, PUR foam set as, floor covering) which were easily removed. Moreover, within the XRF screening of bromine, such parts for which a recycling market exist can be assessed for bromine content and most of these parts will not contain any bromine.

In developing countries where manual separation might be practiced, the PBDE/BFR containing parts might, after separation of different plastic types, also be separated by simple density separation as practiced for WEEE plastic (Haarman 2016) or separated by bromine screening technology like XRF.

However, obstacles in recycling include the lack of market for recyclates, and the lack of cost efficient recovery infrastructures or processes (Miller et al. 2014).

Within an inventory of PBDE in the transport sector, information on end-of-life treatment and in particular on the status of separation of problematic fractions like the high density plastics and the textile fraction frequently back coated with decaBDE in particular in Asian vehicles (Choi et al. 2017; Drage et al. 2018; Kajiwara et al. 2014; Khaled et al. 2018). The PUR foam is often not treated by PBDEs but might contain PBDEs as secondary contamination from backcoating (Drage et al. 2018). However, cars from the US produced before 2005 were found to contain partly high c-pentaBDE in the PUR foams (Leslie et al. 2013; Kajiwara et al. 2014; Liu et al. 2019).

Table 35: Individual fractions from ASR after density separation

Shredder fraction from EoL vehicles	DecaBDE (mg/kg)	Bromine (mg/kg)	References
Light plastic fraction (density <1.1)	0.2–6		Leslie et al. 2013
Light plastic fraction (d<1.1)	11	202	Oekoinstitute 2018
Light plastic fraction	118		Peacock 2012
PP (d<1.1)	<5	274	Swerea 2018
PP (ELVs & WEEE; density separated)	85	613	Swerea 2018
ABS (d<1.1)	5.1	286	Swerea 2018
PS/ABS (d<1.1)	140	470	Swerea 2018
PS (ELVs & WEEE; density separated)	94	970	Swerea 2018
Medium heavy plastic fraction 1 (1.1<d<1.3)	1–5.5		Leslie et al. 2013
Heavy plastic fraction (>1.3)	810		Leslie et al. 2013
Medium heavy plastic fraction	2164		Peakock et al. 2012
Heavy plastic fraction	1357		Peakock et al. 2012
Medium heavy plastic fraction 1 (1.1<d<1.3) (n=335)		2277	Oekoinstitute 2018
Heavy plastic fraction 2 (d>1.3) (n=40)		2749	Oekoinstitute 2018
Fluff (Fibre/textile/foam) fraction	138		Peakock et al. 2012
Fluff (Fibre/textile/foam) fraction	155		Leslie et al. 2013
Fluff (Fibre/textile/foam) fraction	33	729	Oekoinstitute 2018
Heavy plastic fraction	<10–410		UBA 2020
Light plastic fraction	77–1400		UBA 2020

7.2. Step 1: Planning the inventory

This first step focuses on defining the scope of the inventory, identifying stakeholders and developing a work plan (see section 3.1). The use of decaBDE in new vehicles produced from 2017 on is considered not to contain decaBDE. Due to the exemption of decaBDE use in vehicle spare parts, also the current situation of the production of such spare parts and the stocks of spare parts should be assessed.

The inventory of POP-PBDEs in the transport sector is expected to address the following:

- Vehicles (second-hand) imported (for the inventory year and for the years with relevant vehicle imports as a base for estimating total stocks);
- Registered vehicles in use (possibly) containing decaBDE (vehicles 1970 to 2016) and c-pentaBDE (vehicles produced before 2005 particularly in US/North America);
- End-of-life vehicles in the inventory year and those having already reached end-of-life;
- Treatment and management of end-of-life vehicles;
- Amount and management of polymers from end-of-life vehicles and related PBDE contents.
- Vehicle spare parts containing decaBDE (see Table 2) – production, import, sales of exempted parts.
- Spare parts for aircraft containing decaBDE for which type approval has been applied for before December 2018 and has been received before December 2022.

If the Party has already established an inventory for the transport sector, the POP-PBDE inventory can build on these data (see below). Detailed inventories of the transport sector, however, do often not exist in developing countries. In these cases the development of the PBDE inventory could initiate the development of an inventory of the transport sector. This can support the environmentally sound waste/resource management of this large waste/resource category for the plastic/polymer fractions but also for the overall recycling of resources present in vehicles towards a (more) circular economy.

Appropriate members of the inventory task team with relevant qualifications and related experience need to be selected to conduct the inventory of this sector. Specific stakeholders for the inventory of the transport sector are listed in Table 12. It is important that the inventory task team members include key stakeholders to conduct the inventory. Additional stakeholders for data collection and as information sources could be contacted during the information gathering and evaluation steps.

7.3. Step 2: Choosing collection methodologies and step 3 collecting data

A detailed methodology for establishing an inventory in the transport sector is described in this chapter. The approach can be evaluated and tailored to the national situation. Training on conducting the inventory is usually given, often as a workshop. Feedback from the stakeholders could be considered in articulating inventory methodologies.

7.3.1 Tier I: Initial assessment

The aim of the initial assessment is to find out to which extent inventory data on the transport sector are available in the country. Readily available data on the transport sector may be gathered from national statistics, international statistics[19] and statistics of industrial associations related to the transport sector (importers of vehicles, end-of-life treatment) and ministries with relevant information.

Data to be gathered for the initial assessment include:

- Number of registered vehicles (cars, buses and trucks) in use;
- Numbers of cars produced in the country and relevant producers;

[19] For example, UN Comtrade: http://unstats.un.org/unsd/comtrade/

- Numbers of imported (and exported) vehicles including available data from:
    - International statistics on the trade of vehicles;
    - National import (and export) statistics,
- Initial assessment of vehicle spare part market (cars and aircrafts) and remanufacturing of parts possibly containing decaBDE (see Table 2).
- Numbers of vehicles having reached their end-of-life stage in the past (since ca. 1980)
    - This information could be derived from deregistration of vehicles, statistics compiled on end-of-life vehicles or by the average (estimated) lifespan.

Information should be compiled including gap assessment as base for the Tier II inventory.

7.3.2 Tier II: Basic inventory

7.3.2.1 Expected outcome of the basic inventory and PBDE estimation approach

Expected outcomes of the Tier II inventory:

- Number of registered vehicles (cars, buses and trucks) in use and on sale in the country, including:
    - Year of manufacture and on sale in the country and the age distribution of the vehicle fleet (in particular the share of vehicles older than 2005 and older than 2017 as cut-off years for use of c-pentaBDE/high use share of decaBDE and stop of use of decaBDE in vehicles);
    - Approximate percentage distribution of regions from which the vehicles were imported;
- Quantity of vehicles import containing PBDEs and likely amount and volume of plastic/polymers;
- Quantity of vehicles in use/stock containing PBDEs and likely amount of plastic/polymer;
- Quantity of end-of-life vehicles for the inventory year;
- Management of plastic and other polymers from ELVs;
- Situation of the separation of plastic/polymer fraction and recycling of plastic;
- Activities on separating WEEE plastic in low-bromine and high-bromine fractions and management;
- Available data on decaBDE and other PBDE in the country/region (see) monitoring activities;
- Products made from recycled plastic and other polymers;
- Situation and amount of disposal of plastic/polymers of vehicle and situation on thermal recovery of waste fractions from ELVs including management of the ashes;
- Export of ASRs.

In developing countries informal sectors are often involved and play a significant role in collection and recycling of ELVs. It is important to involve the informal sectors to capture their activities in the inventory of end-of-life vehicles to formulate an appropriate action plan for the NIP.

Based on global data from PBDEs in shredder residues and recalculated average of PBDEs content of individual cars (see Table 33), the POP-PBDE content is

- 80 g decaBDE for vehicles produced until 2004 for all regions; except for the US with high use of c-PentaBDE an use of 40 g decaBDE and 40 g c-PentaBDE in average car[20] can be assumed
- 20 g decaBDE for vehicles produced 2005 to 2017

[20] It is estimated that 85,000 tonnes of c-pentaBDE were used in the United States and with 36% in transport, 60% in furniture and a 4% residual in other articles (Alcock et al., 2003; UNEP, 2010b).

- 0 g decaBDE/PBDEs for vehicles produced 2017 onwards (if no exemption for decaBDE is made)

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 g decaBDE and 40 g c-PentaBDE[20] were included in average vehicles before 2005

The estimate can be adjusted for larger or smaller cars or to buses as appropriate. If own robust PBDE data are available for a country/region then these data can be used instead of the suggested PBDE estimate.

While cars produced in the 1970s contained approx. 50 kg plastic/polymers, this increased to 160 kg by 2008 and meanwhile average cars contain approx. 200 kg plastic/polymers including approx. 25 kg of synthetic textiles (Szeteiova 2008; American Chemical Council 2016). Including rubber, the average total volumes of plastic and polymers in vehicle can be roughly estimated to 200 kg/car. This estimate might be refined by considering different size of cars (see e.g. Liu et al. 2019) or the change of share of polymers over time (Rouilloux & Znojek (2010); American Chemical Council 2016).

Where larger uncertainties exist in the chosen factors (e.g. share of vehicles from 1970 to 2004 for a certain inventory sector), a possible range of values could be noted in the inventory and included in the calculation.

Tier II information gathering is done along the life cycle of PBDEs in vehicles (Figure 7-1)

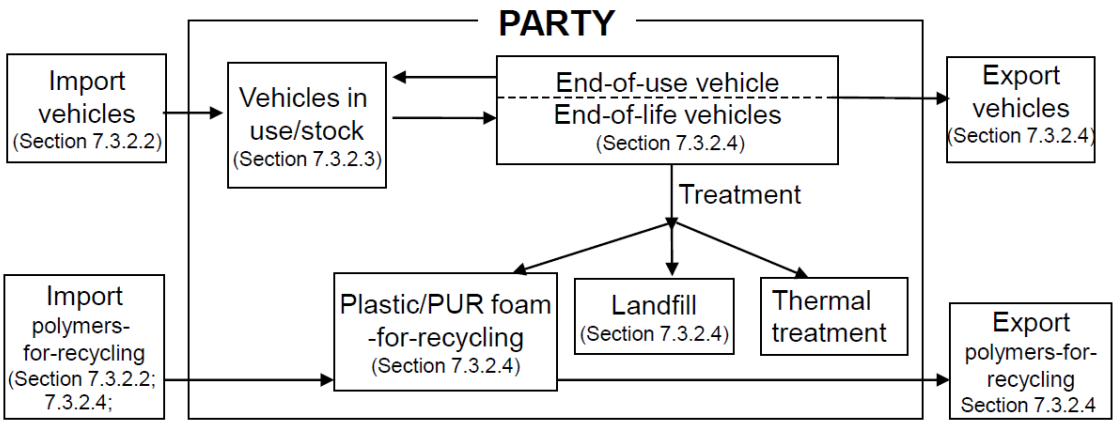


Figure 7-1: Assessing POP-PBDEs in the life cycle of PBDEs containing vehicles and related wastes

7.3.2.2 Compiling information on import and export and related PBDE amount

The data on import and export of vehicles compiled in Tier I based on international and national statistics on the trade of vehicles should be assessed and refined. The data should include an estimate of the share of imported vehicles produced before 2005 and 2005 onwards for an appropriate estimate. For an overall estimate the import/export data of vehicles over a longer period for supporting an overall historic estimate and MFA/SFA (Tier III). In many countries, restrictions exist to import vehicles older than 7 or 10 years which would exclude the import of vehicles produced before 2005 with elevated levels of PBDEs. However, in developing countries this regulation is often not implemented.

The Tier II assessment should gather following information building on Tier I assessment:

- Detailed information from customs and national statistics on cars, busses and trucks
  - National vehicle import (and export) statistics from customs and port authorities;
  - Information from importers (and exporters) or retailers.
- Detailed information from customs and national statistics on import of other transport vehicles

- Second-hand trains; trains for scrapping/recycling;
- Second-hand aeroplanes; aeroplanes for scrapping/recycling;
- Ships for ship breaking

- Detailed information on import of vehicle spare parts possibly containing decaBDE:
  - Information from importers (and exporters) or retailers of vehicle parts.
  - Information from customs and national statistics on vehicle parts
  - Information on parts for aeroplanes.

For the calculation of PBDEs in vehicles the formula in 7.3.2.1 can be used.

For the assessment of decaBDE in ships, trains and aeroplanes only the total quantity of imported ships, aeroplanes and trains would be noted. A further assessment of this transport sector is compiled below and in Tier III.

7.3.2.3 Compiling information on current vehicles in use and related PBDE stock

The Tier II assessment should gather following information on PBDEs in vehicles in the current stock/use:

- Detailed information on cars, busses and trucks currently in use and stocks
  - National registration of vehicles;
  - Information on the share of vehicles older than 2005;
  - Information on the share of regions where vehicles were imported/produced.
- Detailed information on polymers in other transport vehicles
  - Number of trains; aeroplanes, ships;
  - Related volumes of polymers in the sectors;
  - Information on the share of flame retarded plastic
- Detailed information on spare parts possibly containing decaBDE on the market/sold:
  - Information from retailers of vehicle parts.
  - Information from mechanics;
  - Information from aviation industry including information on total polymers in aeroplanes.

For the calculation of PBDEs in vehicles the formula in 7.3.2.1 can be used.

For the calculation of decaBDE in trains the estimate of Morf et al. (2003) might be used as an approximation: Plastics account for approx. 5 % of the total weight of trains. 75 % of the plastics are unsaturated polyester (UP) resins which can contain 8.5% of decaBDE (Morf et al., 2003). This would be an upper estimate since also other flame retardants can be used in UP resins.

7.3.2.4 Inventory of PBDE in end-of-life vehicles and management

The polymer fractions (both PUR foam and plastics) from ELVs are treated by disposal, recycling and/or thermal treatment.

Plastic/polymers generated from vehicle sector are either (see Figure 7-1):

- Sent to landfill and disposed (not preferred considering waste hierarchy)
- Separated in low bromine and high bromine fractions for further treatment and recycling (see Table 34; Oekoinstitute 2018)
- Recycled to articles within the country (see also *PBDE BAT/BEP Guidance* (UNEP 2021a));

- Thermally treated for destruction or energy recovery;
- Exported to other countries or imported (e.g. for disposal or recycling).

The Stockholm Convention has specific exemption for recycling of POP-PBDEs listed in 2009 but also certain low POP content limits which might restrict recycling. Therefore, it is important to estimate the amount of POP-PBDEs in recycling of the transport sector and options for the management. The recycling of PUR foam and plastic from ELVs is either undertaken by specialized companies (Vermeulen et al. 2011) or by the informal sector (Haarman 2016). While in the past most polymers from transport were disposed, more recycling of ELV plastic/polymers can be expected due to the aim for a global circular economy (GEF 2018; UNIDO 2017). The European Union already set legal recycling and recovery targets with the ELV Directive (Directive 2000/53/EC) requiring recycling a share of the plastic/polymers from ELVs (European Commission 2019; Vermeulen et al. 2011).

Such recycling operations should be assessed and quantified in the inventory process. The extent of recycling and the related information (e.g. companies, method, separation, quantity and PBDE contents) should be included in the inventory report. The technologies and approaches used by the companies should be described and compared to information in the PBDE BAT/BEP Guidance (UNEP 2021a).

The low/non PBDE-impacted polymer fractions could be further used/recycled or exported for recycling (see Figure 7-1).

The material flows of plastic from ELV treatment and of imported plastic/polymers for recycling should be monitored for their final end-of-life management and recycling. Information can be gathered from the facilities treating ELVs (scrap yards and shredder plants). If import of ELV and ELV polymers can be retrieved from customs and industries. Facilities processing plastic for recycling or for thermal treatment need to be contacted and assessed, and information on amounts and the respective activity must be recorded.

An inventory/overview of PBDEs can be established by

- estimating the amount of total polymers generated from ELVs (for the inventory year);
- the share of ELV polymers which is recycled and the products manufactured;
- the share of ELV polymers which are not recycled and the waste treatment;
- the respective concentration of POP-PBDEs in the recycled polymers.

Since the PBDE content in the polymer fractions from separation of ELV plastic/polymers have large differences (see Table 34), a detailed description on the separation and the generated fractions should be conducted possibly with PBDE analysis of selected fractions (Tier III inventory).

The plastic/polymer fractions with elevated PBDE content (Table 34) need to be treated at end-of-life in an environmentally sound manner (UNEP 2018; UNEP 2021a).

The volumes of POP-PBDE containing waste being incinerated or otherwise thermally treated should be noted in the inventory report along with the technologies used for destruction. Guidance for thermal recovery and destruction of PBDE containing materials are given in the Stockholm and Basel guidance documents (UNEP 2021a; UNEP 2018).

The amount of POP-PBDE containing waste and related disposed PBDEs being landfilled should be noted in the inventory. Guidance for disposal of PBDE containing materials is given in the *PBDE BAT/BEP Guidance* (UNEP 2017b).

The information on total ELV polymers/plastic generated and related treatment and estimated content of PBDEs over a certain period can be included (

Table **36**).

Table 36: End-of-life treatment of plastic/polymers from ELVs and estimated respective amount of PBDEs

Years can be adjusted to available data	Total amount of ELV polymers generated/ estimated PBDE content	Share of polymers recycled/estimated PBDE content	Share of polymers disposed / estimated PBDE content	Share of polymers incinerated/ estimated PBDE
2020				
2019				
2018				
2017				
2016				

7.3.2.5 Compiling plastic/polymer data in vehicles and estimating the PBDE amount (Tier II inventory)

For the final inventory, the quantity of POP-PBDEs should be compiled (Table 37). The compilation would be separated for DecaBDE and PBDEs listed in 2009 since the listing of decaBDE does not contain a recycling exemption while tetra to heptaBDE have an exemption for recycling if a Party has registered. Since the decaBDE is by far the dominant PBDE in vehicles (Table 34; Table 35), its presence determines recyclability of plastic parts and fractions considering the low POP contents (UNEP 2019b).

The associated polymer volumes impacted by PBDEs should be included in the table/inventory report and in the NIP for developing management considerations for overall environmentally sound management and destruction of the PBDE impacted fractions and recycling of the non/low impacted parts and fractions (Table 34). Other plastic additives might need to be considered for final decision on recycling of plastic and polymer fractions (Haladakis et al. 2017).

Considering the above derived simplified formula based on the data compiled for estimating PBDE in vehicles based on studies listed in Table 34 in particular the detailed monitoring studies with shredder fractions of vehicles produced before 2000 and shedder fractions of vehicles produced after 2004 (Table 34; Liu et al. 2019; Japanese MoE 2011; JECC 2012). Furthermore, considering the compatibility with the calculations with the PBDE guidance for estimating PBDEs listed in 2009 (UNEP 2015c) with stop of use of c-PentaBDE (and c-OctaBDE) in 2004, the following formula is suggested for the estimate of PBDEs in vehicles:

Total PBDEs in vehicles = Number of vehicles (produced 1970–2004) x 80 g decaBDE*/vehicle
+ number of vehicles (produced 2005–2016) x 20 g decaBDE/vehicle

* For vehicles produced in the US, it is assumed that the average POP-PBDE content is 40 g decaBDE and 40 g c-pentaBDE in vehicle produced before 2005 due to the particular use/presence of c-pentaBDE in this region (Liu et al. 2019; Alcock et al. 2003; Abbasi et al. 2014).

Furthermore, it is recommended to estimate the total plastic and polymer content in the vehicles and include it in the inventory compilation (Table 37). This is useful for the development of environmentally sound management of this large volume of plastic/polymer waste and possible consideration of extended producer responsibility considering the need to control plastic/polymer pollution globally including related POP content (UNEP 2019d; Gallo et al. 2018).

Table 37:* Estimate of quantity of decaBDE and ∑tetra-heptaBDE present in polymers in vehicles and in recycling and related plastic quantity.

Homologues	PBDE and polymer content in vehicles imported for the inventory year 20XX**	PBDE and polymer content in vehicles in use/stock for the inventory year 20XX**	PBDE and polymer content in vehicles in end of life for the inventory year 20XX**	PBDEs in recycled polymers in the inventory year 20XX**
DecaBDE				
Tetra-heptaBDE				

Quantity of total plastic/polymer				

*The table can be adjusted as appropriate; **20XX to be replaced by the year of the inventory.

7.3.3 Tier III: In-depth inventory

While the PBDE impact factors selected in Tier II to estimate the presence of PBDE in vehicles was selected from robust data sets, the PBDE content changed over time and might also depend to some extent on the region (Table 33). No monitoring of ASR is available from developing countries where still many cars from the 1970s and 1980s operate potentially containing elevated concentration of c-PentaBDE.

Output of Tier III might include:

- Addressing the gaps discovered in the Tier II inventory;
- Monitoring spare parts on the market (Table 2);
- Monitoring of PBDEs in individual vehicles (see e.g. Kajiwara et al. 2014; Liu et al. 2019);
- Monitoring of plastic and other polymers and textile covers from trains, aeroplanes and ships
- Monitoring of bromine in ASR fractions of ELV plastic for recycling (Table 35)
- Monitoring of plastic fraction produced from recycled plastic from ASR or other plastic from transport (train, aeroplane, ship) for the use in new products (see e.g. Swerea 2018).

Monitoring of polymer products containing PBDEs or HBCD including screening and analysis is described in the Stockholm Convention guidance for monitoring POPs in products in a 5 Step approach (UNEP 2021b). Such a monitoring could involve a pre-screening of insulation materials for bromine with XRF. Please note that the field screening equipment can only detect the total bromine content, and a confirmation may be required by using instrumental analysis for positive tested samples. While a screening of bromine (e.g. by XRF) is an indication for BFRs, only a smaller share of the bromine content detected in the screening stem from PBDEs (**Table 35**and 31) and therefore represents an upper bound POP-PBDEs estimate.

If samples are taken from a vehicle then the information on the type of vehicle, producer and year of production is useful for the dataset (Drage et al. 2018).

Robust measurement data can improve the database for estimates what is needed in developing countries or for transport sector like trains, airplanes and ships where hardly any data exist. Technical experts need to supervise any sampling and measurement activities. Such screening studies might be coordinated on a regional basis to minimize cost and maximize output.

A Tier III inventory might also establish a material and substance flow analysis to best visualize and understand the stocks and flows of POP-PBDEs in/from the transport sector. With a dynamic substance and material flow analysis and the information on the current use/stock of the respective products and the service life of the products, the products entering the waste stream can be estimated and calculated. Such dynamic substance flow analysis has been conducted for PBDEs (Abbasi et al. 2015).

7.4 Step 4: Managing and evaluating data and Step 5 inventory report

In this step the data are assessed for completeness and plausibility, possibly including the comparison with data from other countries in the region. Data gaps may (partly) be filled by reasonable extrapolation of available statistical data.

When a country improves the ELV inventory and related plastic/polymer inventory over time, the data quality will become more robust and reliable, and inventories can be used for planning of waste management and material recovery and recycling and the control of PBDE impacted ELV plastic/polymers. This directly supports a more circular economy for this relevant waste category. Since the largest fraction has low levels of PBDE, these POPs are not considered problematic for the overall management of ASR.

The gathered general inventory data for ELVs and related polymers could be managed in an appropriate database and sent to the governmental agency responsible for statistics. Since the data are valuable for the (waste) management of ELVs and related ASR, they should be made available to departments responsible for waste and resource management in the country (Ministry of Environment or Industry or other responsible ministries) and to the competent authority of the Basel Convention. The data could possibly be fed into and further managed within a database of the governmental body responsible for waste and resource management.

The compiled data for this sector are included in the POP-PBDE inventory report together with the methodology used and the detailed calculations.

To provide a general overview on the presence of POP-PBDE in ELVs/ASR at the national level, as well as on the amount of the impacted ELV ASR to be managed during the NIP implementation phase (see Figure 6-1), the information suggested to be included in the dedicated NIP chapters may include a brief summary on:

- Number of impacted vehicles and ELVs in imports and exports;
- Amount of polymers/plastic in vehicles and ASR;
- Estimated total amount of impacted polymer fraction;
- Estimated total amount of POP-PBDEs (decaBDE and ∑hexa/heptaBDE) in use and storage;
- Amount of ELVs entering into the waste stream;
- Estimated total amount of impacted polymer volume contained in ELVs;
- Estimated total amount of POP-PBDE in vehicles, ELVs and related ASR;
- Information on recycling, reuse, treatment, destruction and disposal of ASR and related fate of PBDEs.

Further activities needed for assessing and managing this use sector would be include in the NIP.

8. Inventory of POP-PBDEs in textiles

8.1. Background

DecaBDE has been used in a wide range of textiles that require anti-flammable characteristics (see Table 14). The use of decaBDE has been exempted for textile products that require anti-flammable characteristics except for the use in clothing and toys. The main use areas of flame retarded textiles are public occupancy spaces, high risk occupancy spaces, transport (private and public), and some military uses (See Table 14 and Table 38). DecaBDE (or other BFRs) concentration in textile depends somewhat on the type of textiles (Table 38).

For some products not the entire textile but only some textile parts might be treated as can be derived from the reported use of 2 g of DecaBDE for a specific camping tent on the European market (RPA 2014; Table 38).

The service life determines the time frame for assessing the current use/stock of decaBDE applied in textiles the last decades. The service life of treated textiles depends on the final application and also depends on the region. The service life of draperies is in average less than 10 years while the seat cover in vehicles might reach 30 years. A mattresses and related treated mattresses ticking a typical life span is around 10 years. Therefore, for some former uses the largest share of textile treated in the past 40 years might already have reached end-of-life while for some uses like textiles in vehicles a considerable share of treated textiles might still be in use e.g. as second-hand car in developing countries.

Therefore, in addition to the assessment of current used in decaBDE in textiles (see Chapter 5) also the former use and use quantities of decaBDE in textiles and related stocks should be assessed.

Other POPs used in textiles

C-pentaBDE, HBCD and SCCPs have been used as flame retardants in textiles (UNEP 2017c, 2019c). Furthermore, PFOS and PFOA and related substances were used as water repellents and PCP as biocide (UNEP 2015d, 2017d, 2017f). It is suggested to address all POPs (formerly) used in textiles (c-decaBDE, c-pentaBDE, HBCD, SCCPs, PCP PFOS and PFOA) within one inventory survey that the stakeholders are only approached once and not by different POP inventory teams.

The steps for inventory development and the tiered approach are described below in Chapter 8.2 to 8.4.

Table 38: DecaBDE concentration in some treated textile applications

c-DecaBDE application in Textiles	DecaBDE content	References
Various textiles	1.55–6.42 %	Earls (2007)
Treated tent textiles	3.8 %	Keller et al., 2014
Velour pile fabrics: 70–80 g/m^2	21–32 g/m^2	ECB (2002)
Cotton: 30–40 g/m^2	9–16 g/m^2	ECB (2002)
Flat woven (other types): 30–80 g/m^2 (40–50 g/m^2)	9–32 g/m^2	ECB (2002)
Camping tent	2 g/tent	RPA 2014

*C-PentaBDE has been used in PUR foams, intumescent paint and roller blinds/curtains

8.2. Step 1: Planning the inventory of decaBDE in textile products, use/stocks and end-of-life

This first step focuses on defining the scope of the inventory, identifying stakeholders and developing a work plan (see section 3.1).

To narrow the scope of an initial assessment, the inventory team should identify the major textile types produced (Chapter 5), textiles or products containing flame retarded textiles imported or on the consumer market, in stocks and end-of-life containing decaBDE treated used.

The inventory of decaBDE in textiles (use and stocks) is expected to address the following:

- Textiles containing decaBDE produced in the country (Chapter 5) and used in the country;

- Textiles containing decaBDE imported to the country
- Textiles imported in other products (mattress ticking; vehicles; trains);
- Professional clothing not exempted for use (uniforms of fire fighters; military; high temperature working clothes);
- Textiles containing decaBDE and c-pentaBDE (and other POPs) in use/stock;
- Status of labelling of products containing decaBDE and other POPs;
- End-of-life management of decaBDE and other POPs containing textiles (synergy with Basel Convention implementation).

Appropriate members of the inventory task team need to be selected to conduct the inventory. Specific stakeholders for the inventory of decaBDE are listed in Table 12 and should be selected according to the country situation. The NIP coordinator or task team leader can decide which stakeholders would be included in an inventory team and which stakeholders would just be contacted for an interview or with a questionnaire (Annex 6, Annex 7). The inventory task team can be extended as appropriate during the inventory process.

The inventory guidance documents of other POPs (formerly) used in textile should be consulted (UNEP 2015d, 2017c, 2019c, 2021c) and inventory activities harmonized.

8.3. Step 2 and 3: Choosing data collection methodologies and collecting data

8.3.1. Tier I: Initial assessment of decaBDE and other POPs containing textiles

Expected outputs of the initial assessment include:

- List of textiles and products containing textiles possibly imported and on market that might contain decaBDE (for vehicles see Chapter 7);
- List of textiles used in construction in the past;
- Past use of textiles requires anti-flammable characteristics in the past;
- Information on average service life of the identified textiles and product;
- Compilation of information on other POPs (formerly) used in textiles (HBCD, SCCPs, PCP, PFOS/PFOA and related compounds; UNEP 2015d, 2017c, 2019c, 2021c);
- A list of relevant large importer, retailers and suppliers of the identified textiles and products containing flame retarded textiles;
- A preliminary list of supply chain stakeholders for the individual products;
- Compilation of information as basis for Tier II assessment.

Identify the articles or products on the market and in use containing decaBDE

Desk study of existing information on textile potentially containing decaBDE imported, sold and in use and compilation of stakeholders which might have this information:

- Gathering information and data about existing past and current use of textiles with anti-flammable characteristics and products containing these textiles; by internet searches, specific industry and import/export reports, literature in scientific journals, technical reports or notes, commissioned research reports. After this initial search the national statistics (e.g. national bureau of statistics, central bank).
- Compile information on the individual textile products potentially containing decaBDE
- Compile a list of importers, retailers trading and selling these products;
- Consider the information on manufacturing of products (Chapter 5) for the assessment;
- Inform the inventory development of manufacturing of products (Chapter 5) with relevant findings from the assessment on products on the market

The information and gaps from Tier I should be compiled as basis for the Tier II inventory.

8.3.2. Tier II: Inventory of decaBDE in textiles

Expected outputs of the inventory include:

- Contact established to the retailers and supply chain and downstream users and other relevant stakeholders (e.g. customs, textile association, ministries of industry, consumer protection; Table 12) and information gathered;
- Major retailers and their supply chain, customs and other relevant stakeholders approached, and questionnaires filled out with the responses of identified companies and possibly other stakeholders (associations; related research institutes);
- Overview on domestic supply chain networks;
- Detailed information/quantity on flame retarded textiles sold and flame retardants used
- Detailed information/quantity and in used containing decaBDE and other POPs;
- Compilation of information and data on total yearly import, current use/stock of decaBDE containing textiles and products containing textiles;

- Integration of the decaBDE assessment into an overall assessment of POPs in textiles (HBCD, PentaBDE; SCCPs, PCNs and PCB in open application) used and in stocks;
- Information on chemicals alternatives and alternative materials used for decaBDE in textiles and if there is a need for exemption;
- Gaps on decaBDE presence and content in textiles identified and need for Tier III inventory elaborated;
- Additional stakeholders identified and contacted.

The assessment should cover the life cycle of textiles containing decaBDE and other POPs including:

- Synergy: with other POPs in textiles (c-pentaBDE, PFOA, PFOS, SCCP, HBCD, PCP);
- Textile containing decaBDE/other POPs imported and currently sold on the market;
- Textiles containing decaBDE/other POPs in current use/stock;
- Textiles in end-of-life containing decaBDE;
- Textiles in recycling (decaBDE/other POPs).

Collect of information and data

Following information might be gathered from customs statistics on product quantity:

- Import of textiles requiring anti-flammable characteristics;
- Import of products containing flame retarded textiles;
- Import of second-hand textiles for reuse and recycling;

Following information might be gathered from retailers and textile industry and associations:

- Sales and use of textiles containing decaBDE or other POPs in use (PFOA, SCCPs);
- Material safety data sheets for suspected products;
- Sales and use of decaBDE treated textiles in the past;
- Use/sale of flame retarded textiles in productions (furniture, transport; mattresses)
- Use/sale of flame retarded textiles and mattresses in public spaces (hospitals, prisons, hotels; fire fighters) and military (tents, tarps, protective clothing);
- Provider of services for refitting textiles with flame retardants or water
- Companies providing washing service for flame retarded textile categories
- Recycling of textiles and management of flame retarded textiles part;

Following data/information might be gathered from the waste and recycling sector:

- Amount of textile waste;
- Management of waste textiles
- Information on flame retarded textiles (e.g. military, other FR uniforms, tents);
- Data on PBDEs, HBCD, SCCPs, PFOS, PFOA and related compounds in textile waste/recycling;
- Techniques on removal of decaBDE/HBCD and other POPs containing textiles in recycling.

Comparing information on textiles containing decaBDE (and other POPs) on the market and national production and import/export data and assess if quantities match.

The gathering of information in Tier II can have in the early phase a national sensitization and information workshops on the Stockholm Convention and decaBDE use and use of other new listed industrial POPs in

the same use area (construction, textile, plastic) where information would be communicated and gathered. Details on exemptions and restrictions would be discussed.

Evaluate compiling information from Tier I and Tier II

The evaluation is intended to

- Identify gaps
- Identify actions for filling the gaps
- Formulation of further activities needed in a Tier III inventory

If more information is needed:

- Identify additional stakeholders to be contacted or other sources of use for the inventory (see Chapter 3).
- Further assessment of import and export or the textile use sectors.

Estimate the current quantity in use/stock of decaBDE in textiles

The estimate of the current use/stock of textiles containing decaBDE/pentaBDE need to consider the former use of c-decaBDE and c-pentaBDE treated textiles in the relevant use sectors (Table 14).

For a refined assessment a dynamic material and substance flow might be conducted (see Tier III).

The following equation can be used to estimate the total quantity of decaBDE in textiles (Table 39):

If the product volume of c-decaBDE containing textiles could be compiled or can be estimated, then the following equation can be used to estimate the total quantity of decaBDE present in products and stocks:

$T_{decaBDE} = PQ_{tot} \times C_{decaBDE}$

PQ_{tot}= Total quantity of textiles containing decaBDE (individually calculated for import, sold or in use/stock)

$T_{decaBDE}$= Total quantity of decaBDE in polymers

$C_{decaBDE}$= % of decaBDE in the product (see Table 38)

The summary of inventory information should be compiled in Table 39.

Assessment of end-of-life of decaBDE containing textiles

Within Tier II it is also expected that the volume of waste products containing decaBDE/pentaBDE generated is assessed and estimated and data compiled (Table 9-2). In the end-of-life evaluation, information on the recycling, reuse, treatment, destruction and disposal of decaBDE containing wastes should be gathered. Since recycling of decaBDE is not exempted according the Stockholm Convention listing, management of decaBDE containing textiles is needed that products/materials containing decaBDE does not negatively impact recycling to avoid (cross) contamination of the recyclates (new textiles or fibres). This information would be compiled in the inventory.

Table 39:* Total amount of textiles and textile containing decaBDE imported, on the market, in use/stock and in end-of-life in the inventory year.

DecaBDE** in textiles	Amount of textiles containing decaBDE** (t)	Concentration of decaBDE** in textile (Table 8-1 or own information/measurement)	Total amount of decaBDE** in textiles
DecaBDE in textiles imported			
DecaBDE in textiles in use/stock			
DecaBDE in textiles in end-of-life			
DecaBDE in textiles in recycling			

*The table can be modified as appropriate;
**Other POPs present in textiles can be integrated in the assessment/inventory (c-pentaBDE, PFOA, PFOS, SCCP, HBCD, PCP)

8.3.3. Tier III: In-depth inventory of decaBDE in textiles in imports, use and wastes/recycling

Within a Tier II inventory the current and former use of textiles containing decaBDE might not have been clarified for all uses. Therefore, monitoring can be conducted for current products on the market and products in use and in end-of-life, recycling of textiles and the products produced from recycled textiles.

Monitoring of products containing PBDEs or HBCD including screening and analysis is described in the Stockholm Convention guidance in a 5-step approach (UNEP 2021b). Such a monitoring could involve a pre-screening of textiles for bromine with XRF. If textile samples are taken from products like cars or trains or airplanes, then the information on the type of vehicle and year of production should be noted to finally get an overview on the use of decaBDE in textiles in these sectors.

The data from the Tier III monitoring and assessment should be used to refine and update Table 39. The inventory report should include all relevant information such as sampling and the screening and analytical methods used.

A Tier III inventory might also establish a material and substance flow analysis to best visualize and understand the stocks and flows of decaBDE and other POPs in textiles.

8.4. Step 4: Managing and evaluating the data; Step 5 inventory report

In the data evaluation **Step 4** the data compiled in the inventories need to be assessed for completeness and plausibility, possibly including a comparison with data from other countries.

Data gaps may (partly) be filled by extrapolation of available statistical data. If the quality of the data is unsatisfactory, additional data collection (Tier II+III) or screening (Tier III) might be undertaken.

The compiled data (draft inventory) should be assessed by stakeholders and possibly by an external expert. Depending on comments, further information might need to be gathered or the inventory can be finalized.

As last **Step 5** the compiled information and evaluated data for decaBDE use and stock in textiles would be compiled as a chapter within the inventory report. This should include:

- the methodology used in compilation of the data
- the calculations made
- assumptions made in the calculations
- all country-specific adjustments and estimates would be noted and described.
- the gaps and uncertainties of the data
- monitoring tools and approach used
- possibly further inventory tasks in a next stage (in the NIP implementation)

The data in the inventory report should serve for the NIP and action plan development and for article 15 reporting. The inventory report might contain a chapter with suggestions for an action plan.

9. Inventory of POP-PBDEs in construction

9.1. Background

DecaBDE has been used in a wide range of polymers in the construction sector including polyurethane (PUR), polyethylene, polypropylene, and PVC (see Table 40). For building insulation only, the use of decaBDE for PUR foam is exempted under the Stockholm Convention (Table 1). However, decaBDE might still be imported and used in other polymers in construction.

The service life of PUR in the LCA is considered 60 years (Spray Polyurethane Foam Alliance 2012). For other insulation polymers like polystyrene or other polymers used in construction, the service life is considered 50 years and up to a century (Li et al. 2016; Glüge et al. 2016). Therefore, the largest share insulation foams and other polymers used in the past 40 years in construction containing decaBDE are to a large extent still in use. Therefore, in addition to the assessment of current use of decaBDE in PUR foam also the former use and use quantities of decaBDE in all polymers in insulation should be assessed.

C-pentaBDE has been used in PUR foam insulation and the major use of HBCD (90%) has been used in EPS/XPS insulation foams (UNEP 2017c). These POPs should be assessed together and the PBDE inventory in buildings should be combined with the HBCD inventory (UNEP 2017c).

SCCPs is still used in a wide range of applications in buildings and construction including different uses of PVC with high plasticised content (e.g. flooring, cables, foils, wall), sealants and adhesives (UNEP 2019c).

PCNs and PCBs have been used from 1930s to 1980s in construction in particular in sealants, coatings, paints, adhesives and cables (UNEP 2017e).

PCP was a major wood preservative for buildings, stables and other constructions (UNEP 2017f; Huwe et al. 2004). Other POP pesticides such as DDT, lindane, mirex, chlordane and endosulfan was used as wood preservatives in construction.

Furthermore, also PFOA and related compounds are used in different applications in construction and in the past also PFOS and related compounds were used (Green Science Policy Institute 2021).

It is recommended to address all POPs formerly and currently used in the building and construction sector (c-decaBDE, c-pentaBDE, HBCD, SCCPs, PFOA/PFOS and related compounds, PCP, PCNs and PCB in open application) within one inventory that the stakeholders are only approached once and not by different POP inventory teams.

Inorganic pollutants such as lead in paints and asbestos which are addressed by Rotterdam Convention or SAICM are relevant pollutants in buildings and construction which might be included in such an inventory of POPs in construction considering a synergistic approach in implementation of international chemical convention frameworks.

The steps for inventory development and the tiered approach are described below in Chapter 9.2 to 9.4.

Table 40: DecaBDE concentration in polymers/plastic in construction

Uses	Content (% wt)	References
PUR foam in insulation*	4–13%	Leisewitz & Schwarz 2000
PUR foam fillers*	22%	Leisewitz & Schwarz 2000
Extruded polystyrene (XPS)	2%	Morf et al. 2003
PE insulating foam	20%	Morf et al. 2003
PE plastic sheeting PP plastic sheeting	10%	Morf et al. 2003
PVC plastic sheeting	5%	Morf et al. 2003
Roller blind and curtain*	4%	Kajiwara et al. 2013
Adhesive layer of reflective tapes	1–5%	RPA 2014
Intumescent paint*	2.5–10%	RPA 2010

*C-pentaBDE has been used in PUR foams, intumescent paint and roller blinds/curtains

9.2. Step 1: Planning the inventory of decaBDE in products, use/stocks and end-of-life

This first step focuses on defining the scope of the inventory, identifying stakeholders and developing a work plan (see section 3.1).

To narrow the scope of an initial assessment, the inventory team can identify the major types of articles or products on the consumer market and products used in the construction industries that possibly contain or contained decaBDE for further inventory activities. The inventory of decaBDE in foams and polymers in construction (use and stocks) is expected to address the following:

- PUR foam containing decaBDE produced (Chapter 5) and used in the country;
- PUR foam containing decaBDE imported to the country;
- Other insulation foams and other polymers in use/stock in the construction sector that possibly contain decaBDE;
- Insulation foams and other polymers in use/stock in the construction sector that possibly contain other POPs (HBCD, c-pentaBDE, PCNs, PCBs);
- Status of labelling of products containing decaBDE and other POPs;
- End-of-life management of decaBDE/c-pentaBDE and other POPs containing materials in the construction and demolition waste (synergy with Basel Convention implementation).

Appropriate members of the inventory task team need to be selected to conduct the inventory. Specific stakeholders for the inventory of decaBDE are listed in Table 12 and should be selected according to the country situation. The NIP coordinator or task team leader can decide which stakeholders would be included in an inventory team and which stakeholders would just be contacted for an interview or with a questionnaire (Questionnaires are in Annexes 7, 8). The inventory task team can be extended as appropriate during the inventory process.

The inventory guidance documents of other POPs present in construction should be consulted (UNEP 2017c, UNEP 2017e, UNEP 2017f, UNEP 2019c) and inventory activities harmonized in a synergistic manner.

9.3. Step 2 and 3: Choosing data collection methodologies and collecting data

9.3.1. Tier I: Initial assessment of PBDEs in polymers in construction

Expected outputs of the initial assessment include:

- List of foams and other polymers used in construction, imported and on market that might contain decaBDE;
- List of foams and other polymers used in construction in the past;
- Quantity of PUR foam and other insulation materials used in construction in the past and information on the use of decaBDE and pentaBDE in these foams;
- Compilation of foams, polymers and other materials which might contain other POPs (formerly) used in buildings and construction (HBCD, SCCPs, PCBs or PCNs from former uses; UNEP 2017c, UNEP 2017e, UNEP 2017f, UNEP 2019c).
- Preliminary information if rebonded PUR foam is used in construction in the country;
- A list of relevant large importer, retailers and suppliers of the identified materials;
- A preliminary list of supply chain stakeholders for the individual products;
- A preliminary list of major construction companies installing insulation foams and other polymers possibly containing decaBDE and other POPs;

- Information on average service life of the identified products;
- Compilation of information as basis for Tier II assessment.

Identify the articles or products on the market and in use containing decaBDE

Desk study of existing information on PUR insulation foams and other polymers in construction potentially containing decaBDE imported, sold and in use and compilation of stakeholders which might have this information:

- Gathering information and data about existing past and current use of PUR foam insulation and other polymers in construction using national bureau of statistics, data from ministry of housing, national central bank; internet searches, specific industry and import/export reports, literature in scientific journals, technical reports or notes, commissioned research reports.
- Compile information on the individual products potentially containing decaBDE
    - PUR foam on the market;
    - Other polymers used in construction (Table 40).
- Compile a list of importers, retailers trading and selling these products;
- Compile a list of major construction companies which might use insulation foams and other polymers in construction possibly containing decaBDE:
- Consider the information on manufacturing of products (Chapter 5) for the assessment
- Inform the inventory development of manufacturing of products (Chapter 5) with relevant findings from the assessment in on products on the market

The information and gaps from Tier I should be compiled as basis for Tier II inventory.

9.3.2. Tier II: Inventory of PBDEs in PUR foam and other polymers in construction

Expected outputs of the inventory include:

- Contact established to the retailers and supply chain and downstream users and other relevant stakeholders (e.g. customs, ministries) and information gathered;
- Major retailers and their supply chain, customs and other relevant stakeholders approached, and questionnaires filled out with the responses of identified companies and possibly other stakeholders (associations; related research institutes);
- Overview on domestic supply chain networks;
- Detailed information/quantity on the PUR foam imported, sold and in used containing decaBDE;
- Compilation of information and data on total yearly import, current use/stock of decaBDE containing PUR foam and other decaBDE containing polymers used in construction;
- Integration of the decaBDE assessment into an overall assessment of POPs in foams and polymers (HBCD, c-pentaBDE, SCCPs, PCNs and PCB in open application) used and in stocks in construction;
- Information on chemicals alternatives and alternative materials used for decaBDE in PUR foam and if there is a need for exemption;
- Gaps on decaBDE presence and content in PUR foams and other polymers in construction identified and need for Tier III inventory elaborated;
- Additional stakeholders identified and contacted.

The assessment should cover the life cycle of foams and other polymers in construction containing decaBDE including:

- PUR foams and other polymers containing decaBDE used in construction imported and currently sold on the market/year and total sales/use in the past;
- PUR foam and other polymers containing decaBDE in current use/stock in buildings and structures;
- Synergy: other polymers on the market and in used and stock in construction containing other POPs (HBCD, SCCPs);
- PUR foam and other polymers in end-of-life (construction & demolition waste) containing decaBDE;
- Synergy: insulation foams and other polymers in end-of-life (construction & demolition waste) containing other POPs (HBCD, SCCPs; PCNs, PCB in open application);

Collect of information and data

Following information might be gathered from customs statistics on product quantity:

- Import of PUR foam used for construction purposes;
- Import of waste PUR foam for recycling (rebond);
- Import of other polymers used in construction (see Table 40);

Following information might be gathered from retailers and industry and retailers

- Sales of PUR foam and other polymers for construction containing decaBDE (Table 40) or other POPs (HBCD, SCCPs):
- Material and safety data sheets for suspected products;
- Presence of decaBDE in the past in PUR foam and XPS foam and other polymers used in construction;
- Current and former sales of fire-retardant paints containing decaBDE (or SCCP);
- Sales of fire-retardant paints containing decaBDE (or SCCP);

Following data might be gathered from the construction sector:

- Insulation materials used and related flame retardant standards and flame retardants used;
- Material and safety data sheets for suspected products;
- Practice on removal of paints (DecaBDE containing intumescent paints; PCB or lead paints);

Following data/information might be gathered from the C&D waste sector:

- Amount of PUR foam and other foams in C&D waste;
- Data on PBDEs, HBCD, PCBs and SCCPs in C&D waste fractions;
- Management of PUR foam, XPS and other foams in C&D waste:
- Management of other polymers
- Techniques on removal of POPs and lead containing paints.

Comparing information on PUR foam containing decaBDE on the market and national production and import/export data and assess if quantities match.

The gathering of information in Tier II can have in the early phase a national sensitization and information workshops on the Stockholm Convention and decaBDE use and use of other new listed industrial POPs in

the same use area (construction, textile, plastic) where information would be communicated and gathered.

Details on exemptions and restrictions would be communicated and discussed.

Such workshops can have breakout groups on the individual sectors to be investigated further. Further stakeholder meetings can be included in a work plan targeting these sectors with a need for further investigation.

Evaluate compiling information from Tier I and Tier II

The evaluation is intended to

- Identify gaps
- Identify actions for filling the gaps
- Formulation of further activities needed in a Tier III inventory

If more information is needed:

- Identify additional stakeholders to be contacted or other sources of use for the inventory (see Chapter 3).
- Further assessment of import and export or the construction sector.

Estimate the current quantity in use/stock of decaBDE in construction and end-of-life

The estimate of the current use/stock of products containing decaBDE in construction need to consider the historic use of decaBDE treated PUR foam, XPS foam and other treated products (Table 40). As the service life of PUR foam is considered 60 years (Spray Polyurethane Foam Alliance 2012) for a first estimate of all decaBDE containing foams and polymers installed in construction the last 30 or 40 years can be considered still present. For a refined assessment a dynamic material and substance flow can be conducted (see Tier III).

The following equation can be used to estimate the total quantity of decaBDE in construction (e.g. PUR, XPS, polyethylene sheets/foil, polypropylene: Table 40):

If the total product volume of c-decaBDE containing PUR foam or other polymers in construction are known, then the following equation can be used to estimate the total quantity of decaBDE present in these products and stocks:

$$T_{decaBDE} = PQ_{tot} \times C_{decaBDE}$$

PQ_{tot}= Total quantity of PUR foam or other polymers containing decaBDE (individually calculated for import, sold or in use/stock)

$T_{decaBDE}$= Total quantity of decaBDE in polymers

$C_{decaBDE}$= % of decaBDE in the product (see Table 40)

The summary of inventory information should be compiled in Table 41.

Assessment of end-of-life of decaBDE containing polymers from construction

Within Tier II it is also expected that the volume of waste containing decaBDE/pentaBDE generated is assessed and estimated and data then compiled (Table 41). In the end-of-life evaluation, information on the recycling, reuse, treatment, destruction and disposal of decaBDE containing wastes should be gathered. Since recycling of decaBDE is not exempted according to the Stockholm Convention listing, management of PBDE containing products in end-of-life and recycling is needed that products/materials containing decaBDE do not negatively impact recycling to avoid (cross) contamination of the recyclates (PUR foam, XPS, PE, PP, EVA and others). This information would be compiled in the inventory.

Table 41:* Total amount of PUR foam and other polymers in construction containing decaBDE imported, on the market, in use/stock and in end-of-life in the inventory year.

DecaBDE in PUR foam and other polymers in construction**	Amount of polymer containing decaBDE (t)	Concentration of decaBDE in products (Table 9-1 or own information/ measurement)	Total amount of decaBDE in polymers
PUR foam imported			
PUR foam used in inventory year			
PUR foam in use/stock			
PUR foam in end-of-life			
XPS in use/stock			
XPS in end-of-life			
Polyethylene/propylene in use/stock			
Polyethylene/propylene in end-of-life			
Other products discovered*			
Other products discovered*			

*The table can be modified as appropriate; information on other products discovered in use be added

**Only PUR foam and polymers in construction (Table 9-1) containing decaBDE should be considered.

9.3.3. Tier III: In-depth inventory of decaBDE/pentaBDE in construction

Within a Tier II inventory the current and former use of decaBDE in PUR foam and other polymers in construction possibly containing decaBDE (Table 40) might not have been clarified for all products. This might include the flame retardants used in PUR foams and other polymers used in construction on the market and in particular for the products used in the past which likely contain the major total amount of decaBDE in construction. Therefore, monitoring can be conducted for current products on the market and materials in use/stock in buildings which can be sampled in the demolition and renovation of houses. If foams and other polymers from construction are recycled then the products produced from recycled materials can be monitored.

Monitoring of polymer products containing PBDEs or HBCD including screening and analysis is described in the Stockholm Convention guidance in a 5-step approach (Secretariat of the Stockholm Convention 2017b). Such a monitoring could involve a pre-screening of insulation materials for bromine with XRF. If samples are taken from renovation and from demolition, then the information on the year of installation should be noted to finally get an overview until which period decaBDE has been used e.g. in XPS and when it was substituted by HBCD and alternatives to HBCD.

The data from the Tier III monitoring and assessment should be used to refine and update Table 41 and possibly Table 40. The inventory report should include all relevant information such as sampling and the screening and analytical methods used.

A Tier III inventory might also establish a material and substance flow analysis to best visualize and understand the stocks and flows of decaBDE and other POPs in construction. With a dynamic substance and material flow analysis and the information on the current use/stock of the respective products and the service life of the products, the products entering the waste stream can be estimated and calculated. Such dynamic substance flow analysis has been conducted for HBCD in construction (Li et al. 2016) or for PBDEs (Morf et al. 2008; Abbasi et al. 2015).

9.4. Step 4: Managing and evaluating the data; Step 5 inventory report

In the data evaluation **Step 4** the data compiled in the inventories need to be assessed for completeness and plausibility, possibly including a comparison with data from other countries.

Data gaps may (partly) be filled by extrapolation of available statistical data. If the quality of the data is considered unsatisfactory, additional data collection (Tier II+III) or screening (Tier III) might be undertaken.

The compiled data (draft inventory) should be assessed by stakeholders and possibly by an external expert. Depending on comments, further information might be gathered, or the inventory can be finalized.

A material and substance flow analysis conducted on Tier III level (see e.g. Abbasi et al. 2015: Li et al. 2016; Morf et al. 2003, 2007) or a simplified MFA/SFA on Tier II level (Babayemi et al. 2016; 2018) can support an evaluation.

As last **Step 5** the compiled information and evaluated data for decaBDE use and stock in construction would be compiled as a chapter within the inventory report. This should include:

- the methodology used in compilation of the data
- the calculations made
- assumptions made in the calculations
- all country-specific adjustments and estimates would be noted and described.
- the gaps and uncertainties of the data
- monitoring tools and approach used
- possibly further inventory tasks in a next stage (in the NIP implementation)

The data in the inventory report should serve for the NIP and action plan development and for Article 15 reporting. The inventory report might contain a chapter with suggestions of activities for the action plan.

New information on decaBDE in construction should be reported to the secretariat for update of the inventory guidance.

10. POP-PBDE contaminated sites

10.1. Scope and background

In accordance with the provisions of Art. 6(1)(e) Parties shall endeavour to develop appropriate strategies for identifying sites contaminated by chemicals listed in Annex A, B or C. Therefore, creating and maintaining a public inventory of POP-PBDE-contaminated sites is the first important step for a regulatory agency in formulating a contaminated site management strategy. A contaminated site database is vital as a country develops, its population grows, land is redeveloped and land uses changes.
This chapter aims to aid developing countries with the identification of POP-contaminated sites for the inventory. In doing so, the inventory team is recommended to follow the step-by-step approach in the draft guidance on the identification and management of sites contaminated with persistent organic pollutants (UNEP 2021d), which covers systematically identifying POP-contaminated lands, assessing risk and setting priorities. The inventory needs to report information collected during the site investigation. This information includes the site profile, past and present activities, spill releases, and site owners.

Sites where e-waste or end-of-life vehicles are treated in developing countries with open burning have generated large contaminated sites (Shaw et al. 2010; Wong et al. 2007; Takahashi et al. 2017). Furthermore, landfills are the ultimate destination of many PBDE-containing materials due to their widespread application in a multitude of consumer and industrial goods (see *PBDE BAT/BEP Guidance* (UNEP 2021a); Weber et al., 2011). POP-PBDEs are released to some extent from landfill via leachate or air emissions including landfill fires (Danon-Schaffer et al., 2014; Gullett et al., 2010; Odusanya et al., 2009; Osako et al., 2004). Elevated BDE47 and BDE100 levels in humans were detected within 10 km around landfills in California (Liu et al. 2016).

The information gathered in the inventory work in Chapters 4 to 9 should be utilized for tracking potential hot spots, while also examining general and hazardous solid waste management/practice for PBDE containing waste fractions. A step-by-step guidance for the assessment of sites is given below.

10.2. Inventory approach for potential POP-PBDE-contaminated sites

10.2.1. Step 1: Planning the inventory

Information from the identified relevant sectors assessed in Chapters 4–9 should be used to identify potential POP-PBDE-contaminated sites.

A contaminated site management policy requires established e.g. “maximum permissible levels” and “levels of concern” (values that trigger action) in corresponding media. Such permissible levels are, however, hardly available as of 2019 for POP-PBDEs at the national level let alone at the international level. Only Norway has the normative values used to identify contaminated sites for POP-PBDEs. The values for soil are 0.08 mg/kg for pentaBDE (BDE-99) and hexaBDE (BDE-154), and 0.002 mg/kg for decaBDE (Aquateam, 2007; NGU, 2007). Another example is Environment Canada's *Federal Environmental Quality Guidelines (FEQGs) for PBDEs* for risk management practice that describes guidelines for water, sediment and biological tissue to protect aquatic life and mammalian and avian consumers of aquatic life from adverse effects of PBDEs (Environment Canada, 2013). The EU has developed Environmental Quality Standards (EQS) which are frequently exceeded (Eljarrata & Barcelo 2018).

A science based regulatory frame may be established for POP-PBDEs including soil, sediments and food.

Following steps can be taken to develop an inventory on PBDE contaminated/impacted areas.

Identify stakeholders

Identification of stakeholders could consider those listed in Table 12, in addition to personnel from local government such as municipal wastewater treatment plants, those responsible for disposal of biosolids, farmers, landfill owners, and the general public.

Environmental contamination from these processes and deposits can affect air, water/sediments and land. Therefore, the investigation is necessary to identify all the sectors involved, manufacturing, recycling

and storage locations, wastes being disposed, biosolids application, methods of waste disposal or treatment, and waste disposal locations and the related release (former) sectors. Potential POP-PBDE-contaminated sites are listed in Table 42. The step-by-step approach in the *Contaminated Site Toolkit* (UNIDO. 2010) can then be followed to systematically identify the POP-PBDE-contaminated sites, keep records, develop a registration system, and then perform risk assessment/prioritization on the POP-PBDE-contaminated sites.

Table 41: Potentially PBDE-contaminated sites

Sector	Activities	Facility locations	Potential other POPs/toxics
PBDE production	Production	Organobromine industry	PBDD/PBDFs; HBCD; waste from other productions
	Destruction of production waste	Sites where production waste has been destroyed	PBDD/PBDFs; HBCD;PCDD/PCDFs
	Disposal of production wastes	Landfills related to production	PBB, HBCD, PBDD/PBDF
	Former water discharge	River sediment and banks related to releases from production site	PBDD/PBDFs; other chemicals produced
Use of PBDEs in manufacturing	Production sites of PBDE-containing polymers	Production site and deposited wastes	HBCD, other additives; plastic
	Textile industry and other industries formerly using POP-PBDEs	Production site and landfill with deposited wastes, river sediment and banks related to releases	HBCD, PFOS/PFOA, SCCPs, dyes
	Oil drilling	Contaminated soil and groundwater, offshore contamination	PFOS, oil, PAHs
End-of-life treatment	Recycling area of EEE	Recycling areas and landfills with deposited wastes and ashes	PCBs, heavy metals, SCCPs, PCDD/PCDF, PBDD/PBDF
	Metal industries treating/recovering PBDE-containing materials	Production site and deposited wastes/ashes	heavy metals, PBDD/PBDF, PXDD/PXDF, PCDD/PCDF
	Deposition of PBDE-containing waste	Landfill and surrounding from leachate from POP-PBDE-containing wastes	PBDD/PBDF, plastic
	Incineration of waste containing PBDEs	Deposits of ash from incineration	PBDD/PBDF, PXDD/PXDF PCDD/PCDF, heavy metals
	Discharge of PBDEs via wastewater	Affected water and sediments; sewage sludge	
	Application sites of sewage sludge containing PBDEs	Agriculture land	

10.2.2. Steps 2 and 3: Methods for collecting and compiling data to identify potential POP-PBDEs sites

A site is generally considered contaminated by PBDEs when the concentration of one or more contaminants exceeds regulatory criteria or risk criteria for certain uses (see section 10.2.1, see Annex 9) or poses a risk to humans and/or the environment e.g. from contaminated soil (Oloruntoba et al. 2021; Weber et al. 2019). Site investigation, comprising preliminary site investigation (PSI) and detailed site investigation (DSI), provides valuable information on a site, including:

- The nature and location of contaminants with respect to the soil and groundwater table;
- Potential pathways for contaminant migration;
- The location of nearby sensitive receptors;
- Potential for direct human exposure to the contaminants;
- Potential of food and feed contamination.

Carrying out the PSI stages 1 and 2 for those locations of potential PBDE contamination listed in Table 42 is suggested for the purposes of the inventory.

The objective of PSI stage 1 is to gather sufficient information to estimate the likelihood of POP contamination that may be present at a site. Sampling relevant environmental media and investigations of subsurface conditions are not required at this stage.

PSI stage 1 includes the following activities:

- **Historical review:** review of a site's historical use and records to determine current and past activities or uses, accidents and spills, and practices and management relating to potential contamination at the site and at adjacent sites;
- **Site visits:** one or more walk-through site visits to verify the information gathered during the literature review for indicators or presence of contamination;
- **Interviews:** interviews with current or former owners, occupants, neighbours, managers, employees, and government officials who can, with reasonable attempts, be contacted about information on activities that may have caused contamination.

It should be noted, however, that while the information that is required in PSI stage 1 readily flows in developed countries, it is not always available or accessible in most developing countries. It is hoped that over time there will be a systemic and attitudinal change in the populace of developing countries. For now, site investigators will have to make do with the best information that they can collect.

PSI stage 2 would be conducted only if stage 1 indicates there is a likelihood of POP contamination at the site or if there is insufficient information to conclude that there is no potential for POP contamination. The objective of stage 2 is to confirm the presence or absence of the suspected contaminants identified in stage 1 and to obtain more information about them. To achieve this objective, site investigators must carry out the following activities:

- Development of a conceptual site model;
- Development of a sampling plan;
- Sampling of relevant environmental media laboratory or field instrumental analysis of sampled and selected environmental media for substances that may cause or threaten to cause contamination.

10.2.3. Managing/evaluating data (Step 4)

Based on the data collected, a conceptual site model (CSM) can be then developed to establish the relationship between the contaminants, exposure pathways and receptors (see Figure 10-1). The CSM, which would be developed at the very beginning of PSI stage 2, identifies the zones of the site with different contamination characteristics (i.e., whether contaminants in the soil are likely to be at the surface or at deeper levels, distributed over an entire area or in localized "hot spots"). Exposure pathways and receptors would be identified, where appropriate, for both current and future uses of the site. The CSM is based on a review of all available data gathered during stage 1, and would be continuously modified as more information becomes available during stage 2 and the detailed site investigation.

Key elements of a conceptual site model:

- Site history and setting;
- Potential contaminants of concern – contaminant properties and behaviour;
- Potential areas of environmental concern (Source Zones);
- Geology and stratigraphy;
- Regional and local;
- Overburden – sedimentary, glaciology, depositional processes;

- Bedrock – fracture networks, representative elementary volume;
- Hydrogeology and surface waters;
- Aquifers and aquitards;
- Groundwater levels and elevations;
- Hydraulic gradients and velocities;
- Boundaries;
- Plumes and pathways;
- Groundwater and vapour;
- Environmental transport and attenuation processes;
- Heterogeneity, anisotropy and scale;
- Receptors and risk.

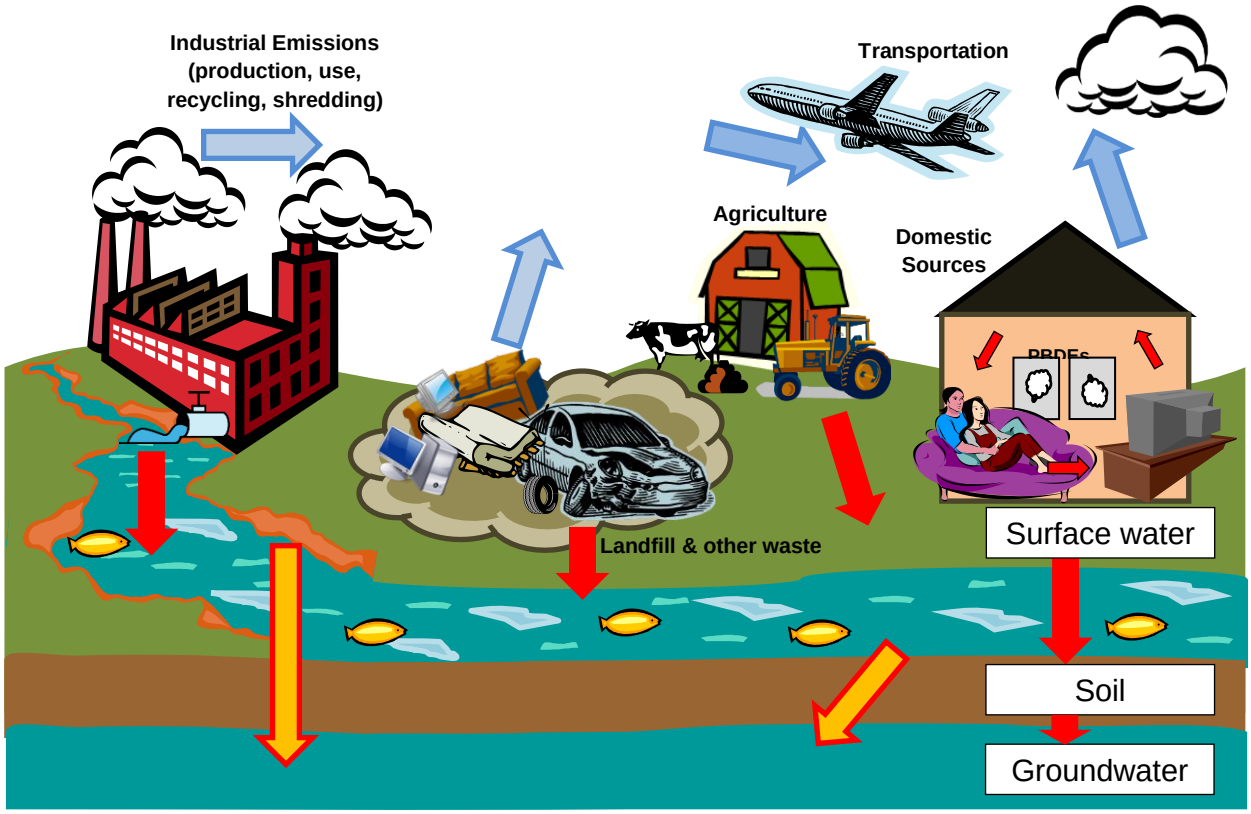


Figure 10-1: Routes of contamination migration

Clearly, the accuracy of the information gathered and analyzed during the investigation is vitally important because it forms the basis for the risk assessment phase, for making decisions on the need for, and type of, remedial action and, eventually, for the design and implementation of necessary actions.

During a site investigation, every item of information collected must be recorded properly in words, along with photographs of the site and the surrounding area, with a radius of about 50–100 m (depending on the size of the site). Reporting is essential for each stage of the investigation as site-specific information is invaluable to decision makers in their efforts to protect the environment.

It is suggested that contaminated site inventories would be established on national level. Data collection and compilation, management, and evaluation can refer to the *Contaminated Site Toolkit* (UNEP 2021d).

10.2.4. Inventory report writing and other reporting (Step 5)

Report documentation and other reporting is essential for each stage of the investigation as site-specific information is invaluable to decision-makers in their efforts to protect human health and the environment and to understand the related risks.

Relevant findings would be included in the inventory report, the NIP and the national contaminated sites database. Further activities needed for assessing and possibly securing or cleaning of contaminated sites would be included in the NIP.

Information which might be compiled for individual (relevant) contaminated sites would be included in the inventory report and in the national contaminate site database.

The PSI stage 1 report would identify potential contamination:

- Potential source of contamination;
- Potential contaminants of concern;
- Areas of potential environmental concern (potential lateral extent, vertical extent and media).

If for (selected) sites a PSI stage 2 assessment has been conducted, a report would identify contamination and potential contamination including:

- Source of contamination;
- Contaminants of concern (i.e. types of POPs);
- Areas of environmental concern (potential lateral extent, vertical extent, media);
- Recommendations for action.

For further information on reporting, refer to the *Contaminated Site Toolkit*.

The inventory of contaminated sites could include:

- Types and quantities of PBDEs and PBDE-containing materials disposed;
- Other pollutants at the site;
- The names and addresses of entities responsible for disposal of PBDE-containing materials; The names and addresses of entities responsible for disposal of other pollutants at the site;
- Details of the treatment of waste before disposal;
- Records of site contamination;
- Details of the clean-up process (if any) once a site has been registered as being contaminated;
- Information on the monitoring of contaminated sites;
- Records of on-going monitoring and research.

As mentioned above, a contaminated site management policy requires established “maximum permissible levels” and “levels of concern” (values that trigger action) in corresponding media such as e.g. soil, sediment or water. Such permissible levels are, however, not established for PBDEs. Therefore, for the time being, PBDE levels at contaminated sites might be compared to EQS of the EU or Environmental Quality Guidelines (FEQGs) of Canada (Annex 9a) or to background and other contaminated sites levels reported in literature. For further assessment of exposure risk and possible needed securing or remediation activities such “maximum permissible levels” and “levels of concern” would need to be defined. For this toxicological information and information on risk management on PBDEs would be consulted (e.g. example in Annex 9b).

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Annex 1. List of E-waste inventories from developing countries

In several developing countries EEE/WEEE inventories according to the "EMPA" methodology have been conducted (see table below). The related reports are also available on the internet online (selected under http://ewasteguide.info/ewaste/case-studies)

Country	Year	Focus[1)]	Programme	References
Benin	2010/11	Categories 1-4	Basel Convention	Aina et al. 2011
Burkina Faso	2010/11	Categories 1-4	PACE	PACE 2011
Côte d'Ivoire	2010/11	Categories 1-4	Basel Convention	Messou et al. 2011
Ghana	2010/11	Categories 1-4	Basel Convention	Amoyaw-Osei et al. 2011
Nigeria	2010/11	Categories 1-4	Basel Convention	Ogungbuyi et al. 2011
Tanzania	2010	Category 3 & 4	UNIDO	Magashi et al. 2011
Uganda	2008	Category 3 & 4	UNIDO	Wasswa and Schluep 2008
South Africa	2008	Categories 1-4	Swiss e-waste programme	Finlay and Liechti 2008
Morocco	2008	Category 3 & 4	Hewlett Packard	Laissaoui and Rochat 2009
Chile	2007	Category 3	Swiss e-waste programme	Steubing 2007; Steubing et al. 2010
Colombia	2008	Category 3 & 4	Swiss e-waste programme	Ott 2008
Brazil	2009	Categories 1-4	Swiss e-waste programme	Rocha 2009
Kenya	2008	Category 3 & 4	Hewlett Packard	Waema and Mureithi 2008

[1)] Category 1: Large household appliances, Category 2: small household appliances, Category 3: IT and telecommunications equipment, Category 4: consumer equipment

Annex 2. Questionnaire for EEE importers

Date:	Location:	Interviewer:

Interview introduction
I am …….. (name interviewer) coming from …. **We are collecting data on e-waste generation and management in order to ….** **Can we ask you some questions about e-waste? / Thank you for participating in our survey**

General information about company		
☐ **Import and/or** ☐ **Production of electrical and electronic equipment (EEE)**		
Name of company		
Address / City		
Number of employees		
Year of foundation		
Name and function of contact person		
Telephone		
E-mail		
Main activity		
To which economic se	☐ **Collection** ☐ **Dismantling/Recycling** ☐ **Refurbishment** ☐ **other:**	
Is your institution ISO 14001 certified? *(ISO 14001 is an international certification for an environmental management system)*		☐ **YES** ☐ **NO**

Introducing question
(Introduction & introductory question, answers will not be evaluated. First question should ideally be answered with yes in order to set up a positive atmosphere for the interview to be held.) **Do you know what e-waste or waste of electrical and electronic equipment (EEE)/ waste of electrical and electronic equipment (WEEE) is?** *(describe to interviewed person what EEE)/WEEE is, if necessary….)*

1. Questions about awareness and behaviour			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
1.1	**Are you aware about the environmental hazards caused by discarded EEE**	☐ **YES** ☐ **NO**	
1.2	**Are you aware that some EEE parts may be profitably recycled?**	☐ **YES** ☐ **NO**	
1.3	**Are you aware that some hazardous fractions in EEE need a special treatment in order to be safely disposed of?**	☐ **YES** ☐ **NO**	

2. Imported / produced electric and electronic equipment (EEE)

2.1 EEE-products

a) Which EEE-products does your company import / produce?

b) How many units per year of each product does your company sell?

c) Which percentage of your imported products are second-hand products? (please tick)

d) What is the (estimated) national market share in % of your company for each product?

e) According to your experience, what's the average life span of each product?
*(**from the purchase** by the consumer **to the disposal** by the consumer)*

a) *Product*	*b)* *units/year*	*c)* *% second hand*	*d)* *market share %*	*e)* *ø life span (years)*
*If PCs or TVs are imported/ produced, **ask for the LCD-CRT ratio** of the monitors!*				

2.2 Distribution of products / customers	
Product	**Who are the (main) customers for each product?**
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐Direct sale to corporate users ☐others:
	☐Wholesaler ☐Retail ☐Direct sale to private users (households) ☐Direct sale to public institutions ☐Direct sale to corporate users ☐others:

3. General questions			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
3.1	**Is the principle "Extended Producer Responsibility" (EPR) known in your company?**	☐ **YES** ☐ **NO**	**if yes: could you describe it shortly?**
3.2	**Is your company working on a formal basis or is it an informal company?** ☐ **formal** ☐ **informal**		
3.3	**Is your company member of any association or body of importers and/or producers of electrical and electronic equipment (EEE)?**	☐ **YES** ☐ **NO**	**if yes: name of body/association?**
3.4	**Is your company member of any association or body which is in charge of a proper e-waste management (collection and recycling)?**	☐ **YES** ☐ **NO**	**if yes: name of body/association?**
3.5	**Please describe your company's strategy to collect and recycle the e-waste generated by its customers?**		
3.6	**From your point of view, what are the main obstacles for a proper e-waste treatment?**		
3.7	**What should be done to facilitate e-waste management (to your company)?**		
3.8	**Would you be willing to pay for a service/organisation which collects and treats the e-waste generated by your customers?** **YES** ☐ **NO** ☐		

	If yes: at what conditions? *(e.g. pickup service, guarantuee of proper disposal, reliability, etc.)*

3.9	**General remarks**

Annex 3. Questionnaire for households (EEE)

Date:	Location:	Interviewer:

Interview introduction
I am …….. (name of interviewer) coming from ….
We are collecting data on e-waste generation and management in order to ….
Can we ask you some questions about e-waste? / Thank you for participating in our survey

Interviewed person	
Name (female/male)	
Suburb	
City & State	☐ **urban area** ☐ **rural area**
Telephone	
E-mail	

0. Introducing question
(Introduction & introductory question, answers will not be evaluated. First question should ideally be answered with yes in order to set up a positive atmosphere for the interview to be held.)
Do you know what electrical and electronic equipment (EEE) or waste of electrical and electronic equipment (WEEE) is?
(describe to interviewed person what e-waste is, if necessary….)

1. Questions about awareness and behaviour		
1.1	**Are you aware that some hazardous fractions in e-waste need a special treatment in order to be safely disposed of?**	☐ **YES** ☐ **NO**

1.2	**Do waste collectors come and pick up waste at your door?** **Do they pick up e-waste too?**	☐ **YES,everything** ☐ **YES, but no e-waste** ☐ **NO**

1.3	**a) Is the current e-waste collection convenient to you?** **b) What could be improved?**	a) ☐ **YES** ☐ **NO**	b)

2. Number (#) of electrical and electronic equipment in the household
How many appliances of each electric and electronic product do you have in your household (in use and stored)?

Large household appliances (category 1)	
Product	*#*
Fridges*	
Air conditioners*	
Washing machines*	
Freezers	
Clothes dryers	
Electric heaters	
Dish washers	
Grillers	
Electric/Gas stoves	
(Steam-)Ovens	
Electric hot plate	

Small household appliances (category 2)	
Product	*#*
Irons*	
Kettles*	
Blenders*	
Microwaves*	
Hair dryers	
Mixers	
Fans	
Vacuum cleaners	
Carpet sweepers	
Toasters	
Popcorn makers	
Rice cooker	
Water dispenser	
Cables	
Extension boxes (?)	
Soldering iron	

Electric lawn-mowers	
(Alarm) Clocks	

IT and telecommunications equipment (category 3)	
Product	*#*
PCs* (central unit)	
CRT monitors*	
LCD monitors*	
Laptops*	
Mobile phones*	
Phones	
Printers	
Copy machines	
Scanners	
Fax machines	
Modems	

Consumer equipment (category 4)	
Product	*#*
TVs (CRT)*	
TVs (flat panel)*	
Radios*	
Stereos*	
DVD players	
VCR players (video-cassette recorder)	
MP3-players	

Cameras	
Game consoles	

Other _____ _____	
Product	*#*

3. Tracer products
3.1 Life span of the tracer product
a) From the <u>moment you buy</u> the product <u>until the moment you dispose it or give it away</u>: How many years do you have the product in your household, approximately? ***b) For how many years do you use the product?*** ***c) After its usage, for how many years do you store the product in your household?*** *note: adding up answer b) and c) should equal answer a) → b) + c) = a)*

Cat.	*Product*	*a)*	*b)*	*c)*
		[in years]		
1	Fridge			
1	Air conditioner			
1	Washing machines			
1				
1				
2	Iron			
2	Kettle			
2	Blender			
2	Microwave			
2				
2				
3	PC (central unit)			
3	CRT monitor			
3	LCD monitor			
3	Laptop			
3	Mobile phone			
3				
3				

Cat.	*Product*	*a)*	*b)*	*c)*
		[in years]		
4	TV (CRT)			
4	TV (flat panel)			
4	Radio			
4	Stereo			

4				
4				
5	Light bulb			
5	Fluorescent tube			
	….			

Annex 4. Questionnaire for corporate and institutional consumers

Date:	Location:	Interviewer:

Interview introduction
I am …….. (name interviewer) coming from ….
We are collecting data on e-waste generation and management in order to ….
Can we ask you some questions about e-waste? / Thank you for participating in our survey

General information about organization	
Name of organization	
Type of organization	☐ public authority ☐ educational organization ☐ private company ☐ NGO ☐ other: ……
Address / City	
Number of employees	
Name and function of contact person	
Telephone	
E-mail	
Main activity	
For <u>private companies</u>: Economic activity of the company	☐ Mining/Manufacture of industrial products ☐ Bank/Insurance ☐ Sales ☐ Telecommunication ☐ Tourism ☐ Other services ☐ other:
Is your organization ISO 14001 certified? *(ISO 14001 is an international environmental certification)*	☐ YES ☐ NO

Introducing question
(Introduction & introductory question, answers will not be evaluated. First question should ideally be answered with yes in order to set up a positive atmosphere for the interview to be held.) **Do you know what electrical and electronic equipment (EEE) or waste of electrical and electronic equipment (WEEE) is?** *(describe to interviewed person what e-waste is, if necessary….)*

1. Questions about awareness and behaviour			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
1.1	**Are you aware about the environmental hazards caused by discarded electronic equipment?**	☐ YES ☐ NO	
1.2	**Are you aware that some electronic parts may be profitably recycled?**	☐ YES ☐ NO	
1.3	**Are you aware that some hazardous fractions in e-waste need a special treatment in order to be safely disposed of?**	☐ YES ☐ NO	
1.4	**Does your organization have a policy or strategy for the management of e-waste?**	☐ YES ☐ NO	
1.5	**Does your organization keep inventories of the electric and electronic equipment discards / stores?**	☐ YES ☐ NO	

2. Number (#) of electrical and electronic equipment in the organization
a) How many appliances of each product do you totally have in your organization (in use and stored)? b) How many of them are not in use (stored)?

IT and telecommunications equipment (category 3)		
Product	*a) total*	*b) not in use*
PCs* (central unit)		
CRT monitors*		
LCD monitors*		
Laptops*		
Mobile phones*		
Landline phones*		
Printers*		
Copy machines*		
Scanners		
Fax machines		
Modems		

Large household appliances (category 1)		
Product	*a) total*	*b) not in use*
Fridges*		
Air conditioners*		

Small household appliances (category 2)		
Product	*a) total*	*b) not in use*
Kettles		
Microwaves		
Fans		
Water dispenser		

Consumer equipment (category 4)		
Product	*a) total*	*b) not in use*
TVs (CRT)*		
TVs (flat panel)*		
Radios*		
Video projector		
DVD players		
Cameras		

Lighting equipment (category 5)		
Product	*a) total*	*b) not in use*
Light bulbs		
Fluorescent tubes		
Long life light bulbs (energy saving)		
Rechargeable lamps		

Other _____ _____		
Product	*a) total*	*b) not in use*

3. Tracer products
3.1 Life span of the tracer product
a) From the <u>moment the product is bought until the moment it is disposed of or given away</u>: How many years* does your organisation *have the product, approximately? ***b) For how many years is the product in use?*** ***c) After its usage, for how many years is the product usually stored in your organisation?*** *note: adding up answer b) and c) should equal answer a) → b) + c) = a)*

Cat.	*Product*	*a)*	*b)*	*c)*
		[in years]		
3	PC (central unit)			
3	CRT monitor			
3	LCD monitor			
3	Laptop			
3	Mobile phone			
3	Phone			
3	Printer			
3	Copy machine			
3				
Cat.	*Product*	*a)*	*b)*	*c)*
		[in years]		
1	Fridge			
1	Air conditioner			
4	TV (CRT)			
4	TV (flat panel)			
4	Radio			

3.2 Detailed information about tracer products				
Category	*Product*	**Where does your organization buy its products?** *(e.g. supermarket, second-hand market, friends, etc.)*	**How many new appliances does your organization buy per year?**	**How many years does your organization store a product before its disposal?**
	In general			
3	PC (central unit)			
3	CRT monitor			
3	LCD monitor			
3	Laptop			
3	Mobile phone			
3	Phone			
3	Printer			
3	Copy machine			
1	Fridge			
1	Air conditioner			
4	TV (CRT)			
4	TV (flat panel)			
4	Radio			

3.3Disposal of tracer product (please tick)

What does your company do with the electrical and electronic equipment which is not of use anymore?

Category	*Product*	Sell to a second-hand dealer	Give or sell to a scrap dealer	Dispose with general waste	Hand over to an e-waste collection	Sell via tender offer	Sell/hand over to employees	Sell to individuals	Donate	Other
	In general									

3	PC (central unit)									
3	CRT monitor									
3	LCD monitor									
3	Laptop									
3	Mobile phone									
3	Phone									
3	Printer									
3	Copy machine									
1	Fridge									
1	Air conditioner									
4	TV (CRT)									
4	TV (flat panel)									
4	Radio									

4. General questions			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
4.1	**Are you aware of what happens to the equipment you have discarded?**	☐ **YES** ☐ **NO**	
4.2	**From your point of view, what are the main obstacles for a proper e-waste treatment?** *(e.g costs, lack of infrastructure and/or policy within your company, lack of legislation, absence of recycling solutions, absence of collection system, etc.)*		
4.3	**What should be done to facilitate e-waste management (to your organization)?**		
4.4	**Would you be willing to pay for your equipment to be collected and treated?**	☐ **YES** ☐ **NO**	**If yes: at what conditions?** *(e.g. pickup service, guarantuee of proper disposal, etc.)*
4.5	**Is your organisation working on a formal basis or is it an informal organisation?** ☐ **formal** ☐ **informal**		
4.6	**General remarks**		

Interview closure
Thank you for participating in this survey • *The interviewer could also provide information about <u>when & where</u> the results of the survey will be available (if this is the case)*

Annex 5. Questionnaire for WEEE recyclers

Date:	Location:	Interviewer:

Interview introduction
I am …….. (name interviewer) coming from ….
We are collecting data on e-waste generation and management in order to ….
Can we ask you some questions about e-waste? / Thank you for participating in our survey

General information about company		
Name of company		
Address / City		
Number of employees		
Year of foundation		
Name and function of contact person		
Telephone		
E-mail		
Main activity		
Which e-waste activities does the company carry out?	☐ **Collection** ☐ **Dismantling/Recycling** ☐ **Refurbishment** ☐ **other:**	
Is your companyISO 14001 certified? *(ISO 14001 is an international certification for an environmental management system)*	☐ **YES** ☐ **NO**	

Introducing question
(Introduction & introductory question, answers will not be evaluated. First question should ideally be answered with yes in order to set up a positive atmosphere for the interview to be held.)
Do you know what e-waste or waste of electrical and electronic equipment is?
(describe to interviewed person what e-waste is, if necessary….)

1. Questions about awareness and behaviour			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
1.1	**Are you aware about the environmental hazards caused by discarded electrical and electronic equipment?**	☐ **YES** ☐ **NO**	
1.2	**Are you aware that some hazardous fractions in e-waste need a special treatment in order to be safely disposed of?**	☐ **YES** ☐ **NO**	**if yes: which ones?**

2. Collection of (waste) electrical and electronic equipment		
	Question	*Answer*
2.1	**By which strategies and channel does your company collect e-waste?** *Which stakeholders are involved? Responsibilities? etc.*	
2.2	**In terms of amounts, which one is the most important strategy/channel?**	

2.3	**Do you cooperate with other companies/authorities for collection purposes?**	☐ **YES** ☐ **NO**	**if yes: which ones? can you provide any details?**

2.4	**Which company transports the materials during collection?**	

2.5	**What are the main obstacles for a proper e-waste collection?**	

3. Recycling / treatment of waste electric and electronic equipment (WEEE)
3.1 WEEE products that are treated
Which electrical and electronic products does your company (collect and) treat? How many units or kg per month of each product does your company actually treat? (throughput) How many units or kg per month of each product could your company treat? (treatment capacity) Does your company pay or charge the treatment of the respective product? Or does it accept the product for free? If yes: how much does your company pay per unit or kg of each product? (price, on average)

a) Product	*b) actual throughput (indicate unit)*	*c) capacity (indicate unit)*	*d) pay / charge*	*e) price (indicate unit)*
*Note: don't forget to **write down the units** of the indicated numbers!*				
General (all products)			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ fee	
			☐ pay ☐ charge ☐ fee	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	
			☐ pay ☐ charge ☐ free	

3.2 Material fractions arising from WEEE

a) Which material fractions arise from your company's recycling activities?

What does your company do with each material fraction? (treatment/destination)

Passing on the respective fraction to a further treatment, disposal, refining, etc.: is this associated with an income or with costs for your company, or does this happen for free? (please tick)

In case of income / costs: could you indicate an average price you get / pay

a) *Material fraction*	***b)*** *Treatment / destination (e.g. indicate company, market, type of treatment etc.)*	***c)*** *income/costs*	***d)*** *price (indicate unit)*
*Note: don't forget to **write down the units** of the indicated numbers!*			
		☐ income ☐ costs ☐ free	
		☐ income ☐ costs ☐ free	
		☐ income ☐ costs ☐ free	
		☐ income ☐ costs ☐ free	
		☐ income ☐ costs ☐ free	
		☐ income ☐ costs ☐ free	
		☐ income ☐ costs ☐ free	
		☐ income ☐ costs ☐ free	
		☐ income ☐ costs ☐ free	
		☐ income ☐ costs ☐ free	

General questions about recycling/treatment of e-waste		
3.3	**Which processes does your company carry out?** ☐ **Sorting of products** ☐ **Manual dismantling** ☐ **Shredding** ☐ **Separation of (shredded) fractions** ☐ **Cable stripping/granulation** ☐ **Burning (e.g. cables, cases)** ☐ **Leaching (e.g. printed wiring boards)** ☐ **other:**	

3.4	**How many workers are engaged in the recycling operation?**	

3.5	**What environmental measures does your company undertake to prevent the release of hazardous substances?**	

3.6	**Which measures undertakes the company to prevent health damages to the workers?**	

4. Refurbishment of (waste) electric and electronic equipment			
4.1 (W)EEE products that are refurbished			
b) Which electrical and electronic products are refurbished in your company? c) How many units are refurbished per month? (throughput) d) What is the average purchase price you pay for a product your refurbish? e) What is the average sales price you get for your refurbished product?			
a) *Product*	***b)*** *actual throughput (indicate unit)*	***c)*** *purchase price (indicate unit)*	***d)*** *sales price (indicate unit)*
*Note: don't forget to **write down the units** of the indicated numbers!*			

General (all products)			

General questions about refurbishment		
	Question	*Answer*
4.2	**Where does the company get the appliances that are apt for refurbishment?**	

4.3	**By which channels does your company sell the refurbished products?**	
4.4	**What is done with parts or products which cannot be used for refurbishment?**	

4.5	**How many workers are engaged in the refurbishment operation?**	

5. General questions			
	Question	*Answer*	*Enhance the replies with comments, suggestions, details, etc.*
5.1	**Apart from e-waste, which other materials is your company working with?**	*e.g. scrap metals, paper, plastic, etc.*	
5.2	**Is your company working on a formal basis or is it an informal company?** ☐**formal** ☐**informal**		
5.3	**Is your company member of any association or body of recyclers?**	☐ **YES** ☐ **NO**	**if yes: name of body/association?**
5.4	**Does your company cooperate with other companies or authorities in order to collect and recycle e-waste?**	☐ **YES** ☐ **NO**	**if yes: name? can you provide details?**
5.5	**From your point of view, what are the main obstacles for a proper e-waste <u>treatment</u>?**		
5.6	**What should be done to facilitate e-waste treatment (to your company)?**		
5.7	**Are you satisfied with the current financing of e-waste management?** ☐ **YES** ☐**NO**		
	If no: what should be improved? *(e.g. fee, regulation, corporate responsibility (EPR), etc.)*		

5.8	**General remarks:**

Interview closure
• Thank you for participating in this survey • The interviewer could also provide information about <u>when and where</u> the results of the survey will be available (if this is the case)

Annex 6. Questionnaire for compiling information on the production and import/export of c-decaBDE

Persistent organic pollutants (POPs) are toxic chemicals that adversely affect human health and the environment. They persist for long periods of time in the environment and can accumulate in the food chain and finally contaminate people. The Stockholm Convention is a global treaty which supports the phase out of POPs. In 2017 decabrominated diphenyl ether (commercial decaBDE; BDE209) was listed as POPs in Annex A, with specific exemptions.

The use of decaBDE is exempted in the following uses in following products[1]:

- Textile products that require anti-flammable characteristics, excluding clothing and toys
- Heating home appliances, irons, fans, immersion heaters.
- Polyurethane foam for building insulation
- Parts for use in vehicles specified in paragraph 2 of Part IX of Annex A[1] of the Stockholm Convention
- Aircraft for which type approval has been applied for before December 2018 and has been received before December 2022 and spare parts for those aircraft.

The use of decaBDE has been exempted in the Stockholm Convention in these products but will need to be phased out after a certain period.

Therefore the government is assessing production, import, sales and use of products containing decaBDE.

The following survey has been developed to gather relevant information that will support these activities. Please fill in the/those section(s) below which is/are relevant for your activity domain.

Name of establishment Registration number	
Address	
Name of respondent	
Position	
Telephone/Mobile	
Email	
Signature/date	

This questionnaire is divided in 4 sections

- **Section A: General**
- **Section B: Producer of c-decaBDE**
- **Section C: Import of decaBDE**
- **Section D: Export of decaBDE**
- **Section E: Waste management and recycling**

Please fill in the section(s) below which are relevant for your activity domain (manufacturer/importer/user/recycler/waste manager etc.).

[1] SC-8/10: Listing of decaBDE; chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.8-SC-8-10.English.pdf

Section A: General

1. **Do you produce □ or import □ or trade/sell □ and/or import □ c-decaBDE?**

2. **Are you aware that decaBDE is listed as POPs in the Stockholm Convention and will be restricted with the option of continued use after exemptions have been registered by the government? Your action?**

□ Yes

□ No

□ We have stopped the production □ the import □ of decaBDE in _____year

□ We are planning to stop the production □ the import □ of c-decaBDE in____month/year

□ We plan to continue production □ the import □ of c-decaBDE and will ask for exemption.

Section B: Production of c-decaBDE

3. **Since when do you produce c-decaBDE?**

_____

_____

Section BII: Production quantity of c-decaBDE

4. **Please fill the table below on the quantities of c-decaBDE and related decaBDE**

Year	c-decaBDE produced (t/a)	decaBDE content (%); other PBDEs (%)
2020 (estimate)		
2019 (estimate)		
2018		
2016		
2015		

Section C: Export of decaBDE

5. Please fill the table below on the quantities of exported decaBDE

Year	c-decaBDE exported (t/a;)	DecaBDE content (%); other PBDEs (%)
2020 (estimate)		
2019 (estimate)		
2018		
2016		
2015		

Section D: Importation of DecaBDE

6. a) Please fill the table below on the quantities of imported decaBDE

Year	c-decaBDE imported (t/a;)	DecaBDE content (%); other PBDEs (%)
2020 (estimate)		
2019 (estimate)		
2018		
2016		
2015		

Section E: Waste management from decaBDE production

7. **Please elaborate on the waste management of waste from production and use.**

   a. **What wastes are generated from decaBDE production and how are they managed?**

   b. **Do you contribute to the end of life management and treatment of decaBDE you sold? How?**

8. **Have you ever conducted an environmental audit? If yes, please elaborate more (date, internal, external, consultancy firm….)**

9. **Do you have ISO 14001? Yes___ No___ Or a similar certificate_____**

Annex 7. Questionnaire for compiling information on the use of decaBDE in manufacturing in exempted products and the import of decaBDE containing products

Persistent organic pollutants (POPs) are toxic chemicals that adversely affect human health and the environment. They persist for long periods of time in the environment and can accumulate in the food chain and finally contaminate people. The Stockholm Convention is a global treaty which supports the phase out of POPs. In 2017 decabrominated diphenyl ether (commercial decaBDE; BDE209) was listed as POPs in Annex A, with specific exemptions.

The use of decaBDE is exempted in the following uses in following products[1]:

- Textile products that require anti-flammable characteristics, excluding clothing and toys
- Heating home appliances, irons, fans, immersion heaters.
- Polyurethane foam for building insulation
- Parts for use in vehicles specified in paragraph 2 of Part IX of Annex A[1] of the Stockholm Convention
- Aircraft for which type approval has been applied for before December 2018 and has been received before December 2022 and spare parts for those aircraft.

The use of decaBDE has been exempted in the Stockholm Convention in these products but will need to be phased out after a certain period.

Therefore the government is assessing production, import, sales and use of products containing decaBDE.

The following survey has been developed to gather relevant information that will support these activities. Please fill in the/those section(s) below which is/are relevant for your activity domain.

Name of establishment Registration number	
Address	
Name of respondent	
Position	
Telephone/Mobile	
Email	
Signature/date	

What is your main business?

a) Importer/wholesaler b) Importer/distributor

c) Manufacturer d) Other trading/selling □ Please describe _____

This questionnaire is divided in 5 sections:

- **Section A: General**
- **Section B: DecaBDE containing articles produced in the country**
- **Section C: Imported products containing decaBDE**
- **Section D: Alternatives to decaBDE**
- **Section E: Waste management and recycling**

Please fill in the section(s) below which is/are relevant for your activity domain (manufacturer/importer/user/recycler/waste manager etc.).

[1] SC-8/10: Listing of decaBDE; chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.8-SC-8-10.English.pdf

Section A: General

1 Are you aware that decabromodiphenyl ether (decaBDE) is listed as POPs and becomes restricted?

- ☐ Yes
- ☐ No
- ☐ We have stopped the use of **decaBDE** in _____Year
- ☐ We are planning to stop the use of **decaBDE** in _____Year
- ☐ We plan to continue use of **decaBDE** and will ask for use exemption_____

Section B: Articles produced in the country containing decaBDE

2 Do you produce ☐ or import ☐ or use ☐ articles containing decaBDE which could contain decaBDE under the specific exemptions granted under Stockholm Convention?

- ☐ Textile products that require anti-flammable characteristics, excluding clothing and toys. Please specify_____
- ☐ Additives in plastic housings and parts used for heating home appliances, irons, fans, immersion heaters. Please specify_____
- ☐ Polyurethane foam for building insulation. Please specify_____

3 Do you use decaBDE in the manufacturing of production process

Contain decaBDE

Yes ☐ No ☐ Don't know ☐

4 Please provide details on the articles you produce containing decaBDE

_____

_____

_____

_____

If you use commercial decaBDE in manufacturing of products then please specify and detail the type of products and quantities:

Type of product, trade name	% of decaBDE in the article	Country/company of origin of decaBDE if imported (and HS Code)	Company/Source of decaBDE if locally purchased (and contact)	Use of the article	Year	Quantity produced / sold (tonnes)
					2017	
					2018	
					2019	
					2020 (estimate)	
					2017	
					2018	
					2019	
					2020 (estimate)	
					2018	
					2019	
					2020	

*Please feel free to provide more information on separate sheet

5 Do you have stockpiles of products treated with or containing decaBDE

Type of products	Quantity	Content of decaBDE (wt %) (if available)	Storage conditions	Location

6 Supplier of the commercial products you produce or import containing decaBDE

Name of company	Product	Contact information

Remarks

_____

_____

_____

_____

_____

7 What other flame retardants do you use in production?

_____

_____

_____

Section C: Imported articles

8 Please fill the table below on the quantities of imported decaBDE or articles containing decaBDE

Year	Total quantity/type of decaBDE imported or imported articles containing decaBDE per year (tonnes)	% of decaBDE in article	Total quantity sold/used locally (tonnes)	Total quantity exported (tonnes)
2020 (estimate)				
2019 (estimate)				
2018				
2017				

Section D: Alternatives to decaBDE in production

9 Are you aware of any alternatives to decaBDE in production?

- ☐ No
- ☐ Yes. Please list known alternatives_____
- ☐ Are you using alternatives? Please list_____

10 Are you interested and willing to switch to an alternative to decaBDE (please keep in mind that decaBDE will have to be phased out over time)?

- ☐ Yes
- ☐ No, not at the moment. If no, then please elaborate more on the reasons:

Economic Reasons

Technical Reasons

Other Reasons

11 What are your requirements/needs to switch to an alternative to decaBDE?

Section E: Waste management and recycling

12 Do you use recycled materials that contain decaBDE for your production?

- ☐ Yes, if yes please go to question number 13
- ☐ No, if no please go to question number 18

13 In which products do you use recycled materials that contain decaBDE? (please list)

_____

14 Do you mix materials from recycling with virgin materials (what %)?

_____

15 What are the sources of materials for recycling?

- ☐ From your premises, what %: _____
- ☐ Collection from the local market, what %: _____
- ☐ Others (e.g. import) _____

16 What are additives/flame retardants of concern in the recycling of materials (please list)

_____

_____

17 What is the quantity of articles produced from recycled materials*?

Total quantity of rubber produced from recycled rubber per year*	
Year	Quantity (tonnes and/or quantity units**)
2015	
2016	
2017	
2018	
2019	
2020	

*details can be compiled in a separate sheet/table
**like number of articles etc.

18 Please elaborate more on your internal waste management procedure regarding the waste in production.

a) Waste materials stockpiles

b) Waste materials sold:

Locally:

Exported:

c) Waste materials reused in the same company

19 Please elaborate on the waste management of end-of-life products containing decaBDE.

a) Do you take back wastes potentially containing decaBDE? What type of treatment* is applied?

Type of waste/products	Waste treatment* (company/location)

***(e.g. recycling, disposal to landfill; incineration, export, unknown)**

b) How is waste electric and electronic equipment (WEEE) managed?

c) How are waste flame-retarded textile products managed?

d) How is polyurethane foam for building insulation managed when it becomes waste?

e) How are end-of-life vehicles (ELV) managed?

20 How is the end-of-life treatment of other product and waste categories (please describe for individual product/waste category)?

21 Have you ever conducted an environmental audit? If yes, please elaborate more (date, internal, external, consultancy firm….)

Annex 8. Questionnaire for compiling information on products containing decaBDE in import, retail or sale

Persistent organic pollutants (POPs) are toxic chemicals that adversely affect human health and the environment. They persist for long periods of time in the environment and can accumulate in the food chain and finally contaminate people. The Stockholm Convention is a global treaty which supports the phase out of POPs. In 2017 decabrominated diphenyl ether (decaBDE; BDE209) was listed as POPs in Annex A, with specific exemptions.

The use of decaBDE is exempted in the following uses in following products[1]:

- Textile products that require anti-flammable characteristics, excluding clothing and toys
- Heating home appliances, irons, fans, immersion heaters.
- Polyurethane foam for building insulation
- Parts for use in vehicles specified in paragraph 2 of Part IX of Annex A of the Stockholm Convention[1]
- Aircraft for which type approval has been applied for before December 2018 and has been received before December 2022 and spare parts for those aircraft.

The use of decaBDE has been exempted in the Stockholm Convention in these products but will need to be phased out after a certain period.

Therefore, the government is assessing production, import, sales and use of products containing decaBDE.

The following survey has been developed to gather relevant information that will support these activities. Please fill in the/those section(s) below which is/are relevant for your activity domain.

Name of establishment Registration number	
Address	
Name of respondent	
Position	
Telephone/Mobile	
Email	
Signature/date	

1. What is your main business:

a) Importer/wholesaler ☐

b) Importer/distributor ☐

c) Retailer ☐

e) Other trading/selling ☐ Please describe_____

[1] SC-8/10: Listing of decaBDE; chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP.8-SC-8-10.English.pdf

2. Do you import or sell any of the following products?

- ☐ Textile products that require anti-flammable characteristics, excluding clothing and toys. Please specify_____
- ☐ Additives in plastic housings and parts used for heating home appliances, irons, fans, immersion heaters. Please specify_____
- ☐ Polyurethane foam for building insulation. Please specify_____
- ☐ Spare parts for use in legacy vehicles. Please specify_____

3. To your knowledge do any of the products/articles you sell contain decaBDE?

Contain decaBDE

Yes ☐ No ☐ Don't know ☐

If yes, please specify and detail the type of products:

Type of product	decaBDE content (wt %) (if available)	Trade name	Sale per year

4. Do you take back wastes potentially containing decaBDE? What type of treatment* is applied?

Type of waste/products	Waste treatment* (company/location)

***(e.g. recycling, disposal to landfill; incineration, export, unknown)**

5. Do you have stockpiles of products treated with or containing decaBDE?

Type of products	Quantity	Content of decaBDE (wt %) (if available)	Storage conditions	Location

6. Supplier of the commercial products you sell or import containing decaBDE

Name of company	Product	Contact information

7. Remarks

Annex 9. Environmental Quality Guidelines for PBDEs and risk criteria for certain uses

Annex 9a. Federal Environmental Quality Guidelines for PBDEs in Canada

Environment Canadian developed Federal Environmental Quality Guidelines for PBDEs (Environment Canada 2013; Table A-2)

Table A-2. Federal Environmental Quality Guidelines for PBDEs (Environment Canada 2013)

Homologue/ Formulation*	Congener	Water (ng/L)	Fish Tissue (ng/g ww)	Sediment** (ng/g dw)	Wildlife Diet† (ng/g ww food)	Bird Eggs(ng/g ww)
TriBDE	total	46	120	44	–	–
TetraBDE	total	24	88	39	44	–
PentaBDE	total	0.2	1	0.4	13 (bird)	29
	BDE-99	4	1	0.4	3	–
	BDE-100	0.2	1	0.4	–	–
HexaBDE	total	120	420	440	4	–
HeptaBDE	total	17‡	–	–	64	–
OctaBDE	total	17‡‖	–	6700‖	63‖	–
NonaBDE	total	–	–	–	78	–
DecaBDE	total	–	–	19‖§	9	–

*FEQG for TriBDE, TetraBDE, HexaBDE, HeptaBDE, NonaBDE and DecaBDE are based on data for BDE-28, BDE-47, BDE-153, BDE-183, BDE-206, and BDE-209 respectively unless otherwise noted

**Values normalized to 1% organic carbon

†Applies to mammalian wildlife unless otherwise noted

‡Values based on a mixture of HeptaBDE and OctaBDE

‖Values adopted from Screening Assessment Report (Environment Canada, 2006). Sediment values from the SAR appear different here because they have been normalized to 1% organic carbon

§Based on a mixture of DecaBDE with some NonaBDE

Annex 9b. Health derived limits for PBDEs in soil

POP contamination in soil can result in human exposure in particular via livestock and mouthing of children (Moya and Philips 2014; Weber et al. 2018, 2019). Therefore, these exposure pathways are key to determine limits for POPs in soils. Chicken/egg are one of the most sensitive exposure pathways from soils to humans due to the high consumption of soil by chicken and the high transfer rates for POPs to egg and meat (Weber et al. 2018, 2019). For human uptake of hazardous substances, the US ATSDR has derived Minimal Risk Levels (MRLs) (ATSDR, 2020). MRLs are derived for acute (1–14 days), intermediate (>14–364 days), and chronic (≥365 days) exposure durations. The MRLs are estimates, which are intended to serve as screening levels to identify contaminants and potential health effects that may be of concern at hazardous waste sites (ATSDR, 2020).

For the lower brominated PBDEs (tetraBDE, pentaBDE, hexaBDE and heptaBDE) the MRL for acute oral exposure is 60 ng per kg body weight per day and for intermediate oral exposure the MRL is 3 ng/kg/day (ATSDR, 2020). No MRL has been derived yet for chronic PBDE exposure (Oloruntoba et al. 2021). For free range chickens, the take up ∑7PBDE by soil ingestion (20 g soil per day), the soil ∑7PBDE concentration must be less than 8.6 ng/g that children stay below the MRL considering the uptake via eggs (Oloruntoba et al 2021). Therefore the 8.6 ng/g ∑7PBDE in soil would be a soil limit for the toxic lower brominated PBDEs (∑7PBDE) and for intermediate exposure duration (>14–364 days), derived to protect children for PBDE intake via a free-range egg per day. It was concluded that this is only a first approximation and the soil limit of 8.6 ng Σ7PBDE/g is an upper limit, because in real life there are also other exposure paths and exposure can last for more than 365 days (chronic exposure) (Oloruntoba et al. 2021).

Furthermore, Oloruntoba et al. (2021) stressed that polybrominated dibenzo-*p*-dioxins and dibenzofurans (PBDD/Fs) are co-contaminants in PBDEs, and PBDD/F concentrations are increasing in sun-exposed e-waste plastic and during thermal processes like WEEE smouldering or dumpsite fires (Sindiku et al., 2015; Weber and Kuch, 2003). Extreme high levels of PBDD/Fs and PCDD/Fs have recently been detected in a chicken egg in e-waste burning sites in Ghana (Petrlik et al., 2019). Therefore, these and other pollutants will need to be included in an appropriate risk assessment of soils containing PBDEs (Oloruntoba et al. 2021).